MIS Quarterly

RESEARCH ARTICLE

VALUING INFORMATION TECHNOLOGY RELATED INTANGIBLE ASSETS[1]

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In this article, we assess the value of information technology related intangible assets and then use data on business practices and management capabilities to understand how this value is distributed across firms. Using a panel of 127 firms over the period 2003–2006, we replicate and extend the finding from Brynjolfsson, Hitt, and Yang (2002) that $1 of computer hardware is correlated with more than $10 of market value. We account for the "missing $9" by broadening the definition of IT to include capitalized software, and then include all purchased and internally developed software, other internal IT services, IT consulting, and IT-related training (whether or not it is capitalized by the firm). In addition, we use data on IT-related business practices in order to analyze the distribution of IT-related intangibles within the sample. Our results suggest that the "invisible" IT not accounted for on balance sheets is being priced into the market value of firms. We also estimate that there is a 45% to 76% premium in market value for the firms with the highest organizational IT capabilities (based on separate measures of human resource practices, management practices, internal IT use, external IT use, and Internet capabilities), as compared to those with the lowest organizational IT capabilities. Our results thus suggest that contributions of IT to value depend heavily on other factors, and are not a rising tide that lifts all boats.

Keywords: IT value, market value, IT-related intangibles, IT capabilities, intangible assets, R&D value, brand value

Introduction

A company's intangible assets—especially those related to information technology—are not well captured on corporate balance sheets. The vast majority of intangible spending is expensed; that is, not treated as investments that build assets on the balance sheet (Lev 2000, p. 91). One rare exception is goodwill,[2] while the other notable exception is a small portion of software development costs.[3] Thus, any spending on busi

[1]Vijay Gurbaxani was the accepting senior editor for this paper. Ram Gopal served as the associate editor.

[2]When one company buys another, the acquirer adds the net assets of the target to its balance sheet. The additional value of what the acquirer paid over and above the net assets of the target is then added as goodwill to the acquirer's balance sheet. Goodwill, thus, does not include intangibles created outside of mergers and acquisitions. Lev (2000) notes other rare cases of balance sheet intangibles, such as movie rights and commissions paid for life insurance and mortgages.

[3]Software spending in the *application* development stage of a project (including designing, coding, installing, or testing) can be capitalized. However, any spending in the *preliminary* stage of a software project is expensed,

ness process reengineering, such as mapping business processes or reconfiguring the work force, must be treated as an expense (Ernst & Young 1998). Yet, it is precisely this restructuring of the firm that forms a significant component of technology investments.

While IT accounts for about 30% of all business investment,[4] publicly available data on firm-level IT investment and IT practices are severely lacking. For example, the most recent free and publicly available IT spending data set was last published in 1997.[5] In a well-known study, Brynjolfsson, Hitt, and Yang (2002) (hereafter BHY 2002) found that $1 of computer hardware is correlated with more than $10 of market value, suggesting that there are at least $9 of unmeasured IT-related intangible assets for every $1 of measured hardware. However, the lack of available data on IT-related intangibles has hampered efforts to understand the nature of this relationship between IT and business value.

In this paper, we set out to find the "missing $9" with a market value approach based on IT-related spending and practices data. Our hypothesis is that while IT-related intangible assets are often absent from the balance sheet, they are reflected in a company's market value. Consider three traditional bellwether components of the Dow Jones Industrial Average: Caterpillar, 3M, and Home Depot. In Figure 1, we illustrate the sizable differences between each of their market values and their balance sheet assets.

Specifically, we argue that while important complements to IT investment—like changes in business processes—may be intangible, they are not unmeasurable when the right data and methods are applied (Brynjolfsson and Hitt 2005). Our analysis relies on a balanced panel of annual data from 127 firms over the period 2003–2006, which provides us with broader and more recent IT spending estimates compared to data used in BHY 2002 (which relied on 1987–1997 data from *Computer Intelligence*). We then use a separate data set on IT competencies to analyze whether IT-related intangible assets are evenly distributed among firms or concentrated in leading firms.

Applying econometric methods, we find that IT intangibles are a significant driver of market value even though they are "invisible" on the balance sheet. The work presented below is the first we are aware of that replicates the original BHY 2002 finding that at least $10 of market value is associated with every $1 of hardware assets. This is the case even though we use (1) different source data that measure IT spending,[6] (2) a different panel of firms, and (3) a different time period.

While BHY 2002 theorized a missing $9 of IT intangibles for every $1 of hardware, their data set was limited to hardware data. In this work, we are able to directly account for the missing piece of intangible IT by including capitalized software in a market value estimating equation, as well as all purchased and internally developed software, other internal IT services, IT consulting, and IT-related training, whether or not this spending is actually capitalized by the firm. We find that $1 of this broadest measure of IT assets is closely correlated with $1 of market value, the equilibrium value predicted by economic theory (Hall 2000, 2001).[7] Our results demonstrate that the invisible IT not accounted for on the balance sheet is being priced into the market value of firms, suggesting that IT assets defined by accounting standards capture only a fraction of the business value of IT.[8]

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which might include hiring consultants to evaluate the need for the software in the first place. The same is true for spending in the *post-implementation* stage, which includes training, maintenance, or support. Even when it comes to software that is ready to use off-the-shelf (known as prepackaged software in National Income and Product Accounts), the Bureau of Economic Analysis (Moylan 2001, p. 3) noted: "Although in theory prepackaged software purchases with a useful life of at least one year should be capitalized, most are treated as an expense."

[4]Source: Bureau of Economic Analysis, National Income and Products Accounts Table 5.3.5. "Private Fixed Investment by Type." This is the sum of information processing equipment (line 10) and software (line 17) divided by total nonresidential fixed investment (line 2).

[5]The data was published as part of the *InformationWeek* 500, an annual ranking of the 500 firms that are most innovative users of IT. Since 1998, this annual ranking has not included IT spending. As of 2014, the list has been shortened and renamed the *InformationWeek* Elite 100.

[6]BHY 2002 used IT data from Computer Intelligence Infocorp (CII), whereas this research uses data from the SeeIT Survey (described in further detail below).

[7]The equilibrium value predicted by economic theory is that $1 of any asset should be valued by the market at roughly $1. BHY 2002 also found that that $1 of non-IT physical assets and $1 of financial assets were each correlated with roughly $1 of market value. We find this as well. Interestingly, we find that $1 of research and development (R&D) and $1 of brand assets are each associated with significantly more than $1 of market value.

[8]*Statement of Position (SOP) 98-1*, "Accounting for the Costs of Computer Software Developed or Obtained for Internal Use" was developed by the American Institute of Certified Public Accountants (AICPA). *Emerging Issues Task Force (EITF) 97-13*, "Accounting for Costs Incurred in Connection with a Consulting Contract or an Internal Project that Combines Business Process Reengineering and Information Technology Transformation" was developed by the Financial Accounting Standards Board (FASB). These documents constitute a set of guidelines that firms use in determining whether spending on IT and business process reengineering projects can be expensed or capitalized, depending on the type of spending and the stage of the project.

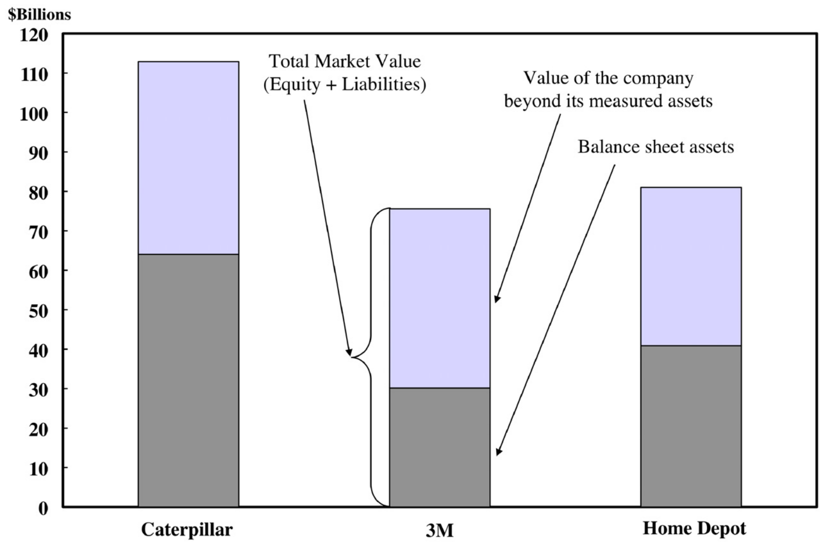

Figure 1. The Value of Three Components of the Dow Jones Industrial Average as Compared to Their Balance Sheet Assets (Data from December 31, 2010)

Beyond quantifying the size of IT intangibles, our research examines how these intangibles are distributed within our sample. We do so by relying on a measurement of organizational IT capabilities (ITC) used in Aral and Weill (2007). ITC is based on how management capability and human resource capability facilitate or inhibit IT investment, how IT is used in internal communications and with suppliers, and the company's Internet capabilities. We assign firms grades of "A" through "F" based on their ITC scores, and analyze the relationship between these categories and firms' corresponding market value.[9] We find that firms with the highest ITC (in the top 5% of the sample) have a 45% to 76% greater market value than the firms with the lowest ITC (in the bottom 5% of the sample), indicating that IT-related intangible assets are far from being commodities. Rather, they can be a significant value differentiator between firms.

The remainder of our paper is organized as follows: the next section reviews the relevant literature, and is followed by our conceptual framework and econometric model. We then describe the data used in this study, present our results, and conclude with a summary of findings and implications for future research.

[9]Using various categories allows for more flexibility in the association between ITC and market value over assuming a monotonic relationship, especially for very high or low values of ITC.

Literature

While the most visible assets of a modern corporation may be its structures, equipment, and other physical property, for many firms the most valuable assets are intangible. These include intellectual property like patents and copyrights, brand capital whether created by advertising or word of mouth, business processes and methods, and even the organization of the firm and allocation of decision rights. More formally, our definition of intangible assets is that used by Lev (2000, p. 5):

> Assets are claims to future benefits, such as the rents generated by commercial property, interest payments derived from a bond, and cash flows from a production facility. An intangible asset is a claim to future benefits that does not have a physical or financial (a stock or a bond) embodiment. A patent, a brand, and a unique organizational structure (for example, an Internet-based supply chain) that generate cost savings are intangible assets.

Research on the economics of IT has established that computer hardware investments are typically accompanied by substantial software, organizational, and process investments, and that productivity of IT investments is much higher when these complementary investments are also made.[10] These are

[10]For a lengthy discussion and review, see Brynjolfsson and Saunders (2010).

the sorts of intangible investments we seek to more carefully measure and analyze in this paper.

According to recent estimates by the Bureau of Economic Analysis, U.S. businesses hold more than $2.3 trillion worth of intellectual property assets,[11] and invest a further $600 billion in such assets each year.[12] Nakamura (2001), using a wider definition of intangibles, analyzed economy-wide spending data on R&D, software, and advertising, as well as aggregate data on labor inputs and corporate operating margins, and estimated that intangible assets in U.S. corporations could total as much as $5 trillion. Corrado et al. (2009), using different methods but an even broader metric that includes organizational capital, found almost $4 trillion in intangible assets in the U.S. economy. While such aggregate estimates are noteworthy, there is a paucity of data at the firm level. We seek to contribute to the literature using a combination of firm-level intangible asset data and market value equations.

Our research complements and extends other empirical work that uses financial markets to value IT and other intangible assets. Anderson et al. (2003) used estimating equations relating the market value of the firm to its book value, earnings, R&D, and Y2K spending. They found that $1 of Y2K spending was correlated with an average of $30 to $40 of market value (with one of their estimates being as high as $62 of market value). Their interpretation was that the high values for Y2K spending were likely due to complementary investments in organizational assets as well as improvements to the supply chain as a whole. While this is the most plausible and intuitive explanation, they did not have the data to empirically demonstrate the value of IT-related intangibles. Our study uses IT practice and capabilities data alongside intangible IT spending data to quantify the value of IT-related intangibles and examine how they are distributed in the sample.

While existing studies have examined the relationship of IT, organizational design, and market value, our work more directly measures and quantifies the IT-related intangible assets (or IT intangibles for short) through an estimating equation. For instance, Lev and Radhakrishnan (2005) used the firm's sales, general, and administrative expenses (SG&A) as a proxy for organizational capital[13] in a sample of publicly traded companies. They found that this measure of organizational capital was significant in explaining a firm's sales, and that it was also highly correlated with the firm's spending on IT. Their organizational capital and IT measures together explained market value beyond traditional measures such as book value and growth potential. Their results, while quite powerful, relied purely on spending data.[14] However, our work builds on their findings as we use organizational practice data as well as specific IT intangibles spending data to estimate IT-related organizational capital.

Our study uses a panel of data that spans multiple industries across time, which enables us to control for more confounding factors than would be possible in a single cross section. For example, Rai et al. (2006) constructed a model to relate IT infrastructure to better supply chain management capabilities and improved performance. While they presented a potentially more sophisticated measure of IT capabilities, their data were a one-time cross section of firms that allowed them to focus only on the manufacturing and retail sectors. In addition, the performance measures in their work were subjective; while their sample contained 110 firms, they could obtain objective performance measures from *Compustat* for only 57 of them. A second study relying on a single cross section of firms was conducted by Subramani (2004), who used a detailed questionnaire of IT usage in 131 firms to gauge the benefits of using supply chain management systems. The firms in that survey were supplier firms to a single large retailer in Canada. In contrast to these studies, we use a longitudinal panel and are able to include a lagged value of market value in an effort to control for unobserved factors that could contribute to higher market value.

In addition to quantifying IT-related intangibles, our findings support the observation that IT investments are significantly riskier than non-IT investments (Dewan et al. 2007). IT capabilities are neither easy to create nor copy because they involve a *system* of practices. While copying any one piece might be straightforward, an organizational system as a whole is very difficult to duplicate (Brynjolfsson and Milgrom 2012; Brynjolfsson et al. 1997; Milgrom and Roberts 1990, 1995; Porter 1996). Our finding that the highest ITC firms are correlated with 45% to 76% more value than the lowest ITC firms fits with this framework. The rewards are higher for firms that have built an interlocking system of complementary IT capabilities because such investments involved significant risk: many changes to the workplace often need to be made, and the interaction effects of any new practices with existing practices can be difficult to anticipate.

By incorporating estimated values of R&D and brand directly in a market value equation, our analysis complements other

[11]Consisting of software, research and development, and entertainment, literary, and artistic originals. See BEA Fixed Assets Table 2.1, line 77.

[12]See BEA NIPA Table 5.3.5, "Private Fixed Investment by Type," line 16.

[13]We use the term *organizational capital* to be consistent with the literature, which often uses *capital* and *assets* interchangeably.

[14]Based on the *InformationWeek* 500 annual list of IT spending published until 1997.

approaches in the literature that value such intangibles using discounted *ex post* future returns and production functions. Hand (2003), using a net present value (NPV) profitability model, found that the NPV of R&D and brand is significantly positive and that the firms that were the largest spenders on R&D and advertising were the ones with the highest returns on those assets. Lev (2004) noted that companies with the greatest amount of R&D assets had the highest risk-adjusted returns between 1983 and 2000, implying that "R&D-intensive companies were systematically underpriced by the market" (p. 110). Barth et al. (1998) found that brand value estimates are a significant and positive predictor of share prices and future returns. Using a production function framework, Seethamraju (2003) estimated the value of trademarks, and found that these estimated values are reflected in share prices. These four studies demonstrate that despite their virtual absence from the balance sheet, R&D and advertising are highly valuable investments. Using the market value equation framework outlined within the next section, our analysis is another lens through which to quantify the value of these intangibles.

Conceptual Framework

We begin with the simple, yet elegant, principle that the total value of financial claims on the firm should be equal to the sum of the firm's physical, financial, and intangible assets (Baily 1981; Hall 2000, 2001).

While one can measure the total number of dollars spent on coding software, running experiments, or keyword advertising, how this *spending* translates into intangible asset *value* is often difficult to quantify. We argue that financial markets provide an important way to value intangible assets beyond the balance sheet and other input metrics such as spending. We model the value of financial claims against the firm, *MV*, as the sum of each of its *n* assets, A_i (based on the model in BHY 2002, pp. 150-151):

$$MV = \sum_{i=1}^{n} A_i \qquad (1)$$

In other words,

> If all assets can be documented and no adjustment costs are incurred in making them fully productive, buying a firm is equivalent to buying a collection of separate assets. Thus the market value of a firm is simply equal to the current stock of its capital assets (*ibid*, p. 151).

For example, while Procter and Gamble (P&G) was worth more than \$237 billion at the end of June 2012,[15] the company listed just \$132 billion in assets on its balance sheet. While we can measure physical assets for publicly traded companies because of the accounting regulations that require their inclusion on disclosed balance sheets, measuring their intangible assets poses significant challenges: with the exception of goodwill or other purchased intangibles, they are virtually invisible on financial statements.

One of the key contributions of this work is to construct several types of intangible assets and directly measure their values in an empirical estimation of (1). We do not assume that the residual of the firm's market value above and beyond the firm's book value is due entirely to intangibles. Continuing with the P&G example, we do not begin with the assumption that the other \$105 billion of its market value is simply equal to the sum of its intangible assets. Rather, in our approach, we estimate how much each type of asset—physical, financial, or intangible—contributes to the entire \$237 billion of the company's market value.

We begin with the null hypothesis that \$1 of an asset should contribute \$1 to a firm's market value. To test this hypothesis, we construct three types of intangible assets and include them in a market value equation: IT intangibles, advertising, and R&D. We also add physical and financial assets to this equation, and then estimate the relationships between all asset types and market value.

We control for factors such as industry and year in an estimation of (1). In any given year, the market value of two firms that operate in different industries will differ because of unobserved differences due to barriers to entry, regulation, or competition, for example. There may also be time-varying unobserved factors, such as excessive optimism or pessimism on the part of investors, that necessitate controlling for year in an estimation of (1).

Econometric Model

In order to relate the market value of the firm to its various assets, we use the following estimation equation:

$$\begin{aligned} MV_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 F_{it} + \beta_3 IT_{it} + \\ \beta_4 R_{it} + \beta_5 B_{it} + controls + \varepsilon_{it} \end{aligned} \qquad (2)$$

[15]As the sum of equity plus total liabilities. Alternatively, it was worth \$198 billion using the sum of equity plus debt.

The value of all financial claims on the firm (equity plus liabilities) is placed on the left-hand side of equation (2) and is denoted by *MV*. Subscripts *i* and *t* represent firm *i* in year *t*. We use various categories of assets on the right side of the equation. The first category is physical, non-IT assets (also described as ordinary assets in the literature), represented by *K*. This category includes all non-IT equipment and structures. Next, we have other assets, *F*, which represents total balance sheet assets minus ordinary assets. Included in *F* are inventories, receivables, cash, and other accounting assets, such as goodwill.

The next term is *IT*, which represents IT assets. We use three different measures of IT in our analysis. The first measure includes purchased hardware only, the second measure includes capitalized hardware and software, and the third and broadest measure of IT includes all hardware and software, internal IT services, IT consulting, and IT-related training. In our broader measures of IT, we combine both tangible (such as hardware) and intangible (such as software and services) assets, rather than attempting to value each asset type separately.[16]

The term *R* represents R&D assets, and *B* represents brand assets. We include controls for year and industry, as well as a dummy variable for firms that do not report R&D, and a dummy variable for firms that do not report advertising.[17] We scale all dummy variables to control for firm size by multiplying each of them by the firm's total balance sheet assets.[18]

Given that our data are in panel form, we estimate equation (2) using generalized least squares (GLS) to address potential serial correlation of the error terms and heteroskedasticity. As one of our objectives is to estimate the distribution of IT intangible assets among the sample firms, we do not use fixed effects or first differences, as this would overcorrect for the effects we are looking to measure.[19] In addition, as the time period of our panel is relatively short, if we use fixed effects or first differences, any measurement error in the slowly changing right-hand side variables could significantly bias the coefficients downward (Griliches and Hausman 1986).

To estimate the value of $1 of ordinary assets, *K*, we use net property, plant, and equipment (PP&E) as listed on the balance sheet, and subtract IT assets that would be included in *K* to avoid double-counting.[20] We use the unadjusted value of other assets, *F*, as listed on the balance sheet, and we assume this approximates a current-cost measure. To measure *IT*, *R*, and *B*, we use the perpetual inventory method (PIM) to construct assets based on depreciation rates and price deflators from the Bureau of Economic Analysis (BEA) where possible.[21]

Our null hypothesis is as follows: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 1$. If any of these coefficients are greater than 1, then it means that firms, on average, are reaping greater benefit from their assets than the replacement costs of those assets. However, this does not mean that there is a "free lunch" in the market, especially when it comes to intangibles. Rather, there are potential adjustment costs and omitted variables to consider (BHY 2002). In particular, BHY 2002 found that $1 of computer hardware assets was correlated with more than $10 of market value, and reasoned that this was due to omitted IT

[16] Lev (2000, p. 7) remarked on how difficult this would be to do:

> the demarcation lines between intangible assets and other forms of capital are often blurry. Intangibles are frequently embedded in physical assets (for example, the technology and knowledge contained in an airplane) and in labor (the tacit knowledge of employees), leading to considerable interaction between tangible and intangible assets in creation of value.

[17] Since spending on R&D and advertising is required to be disclosed where it is material to the firm, we assume a value of 0 for firms that do not report it.

[18] This allows for a more realistic interpretation of the dummy variables. The effects of industry or year on market value are much more likely to be related to the size of the firm than to simply be a constant dollar amount across all firm sizes.

[19] One of the principle assumptions in random effects estimation is that the firm effect is uncorrelated with all of the explanatory variables. However, as Hall et al. (2005, p. 26) note, this assumption would be inappropriate in estimating the value of R&D:

> R&D tends to change slowly over time, a firm's R&D intensity is highly correlated with its individual effect; in fact, it is an important component of what creates differences across firms, so removing these effects would entail an overcorrection.

This is likely true of IT intangibles and advertising as well.

[20] Although net PP&E is listed in historical-cost dollars (based on the year the asset was purchased) rather than a true replacement or current-cost (how much it could cost to purchase the asset in that year), converting this value into a current-cost measure is challenging because firms are not required to disaggregate their investment by type (such as equipment or structures). Converting historical-cost PP&E into a current-cost measure would entail a number of assumptions about the mix of investment, and since measuring such physical assets is not the main focus of this work, we follow the prevailing practice in the IS literature to leave net PP&E as reported by the firm as is (e.g., see Brynjolfsson and Hitt 2003; BHY 2002). Nevertheless, we do attempt such an adjustment as a robustness check, as detailed in the results section.

[21] In the absence of published data from the BEA (such as the depreciation rate for advertising), we use values based on the prevailing practice in the literature.

intangible assets. When the authors included an interaction term comprised of organizational practices plus hardware in their estimating equations, the coefficient on hardware alone fell significantly, suggesting up to $9 of related assets correlated with each dollar of hardware assets. In this paper, we seek to measure the missing $9 by using data on IT intangible spending in an estimating equation for market value.

However, cost-based measures may not be enough to quantify the value of intangible assets. If two firms spend $20 million each on an enterprise resource planning (ERP) system, it is reasonable to expect that the value of each system is going to be firm specific. For example, P&G adopted an approach to a technology-driven and highly coordinated supply chain that involved careful attention to more than just the technology. As director of customer services and logistics for P&G in North America, Lamar Johnson noted:

> Our approach in the 1980s was not completely software driven…we developed our attitude way before there were computers on everybody's desk or an Internet. All technology does is facilitate these practices; it is not what creates them. It's the culture and work process that drives them (Stankevich 2003, p. 43).

A number of recent papers have shown that complementary business practices are necessary to get the full value from IT (Bartel et al. 2007; Bloom et al. 2012; Bresnahan et al. 2002; Brynjolfsson and Hitt 2003; Brynjolfsson et al. 2002; Crespi et al. 2007; Dedrick et al. 2003; McKinsey Global Institute 2001; Pilat 2004). Moreover, research has shown that such practices do not work as effectively on an individual basis as they do within a cohesive system (Athey and Stern 1998; Brynjolfsson et al. 1997; Milgrom and Roberts 1990, 1995).[22]

Thus, to examine the distribution of IT intangibles, we construct a variable to capture management capabilities and organizational IT practices. This variable is based on a measure called organizational IT capabilities from Aral and Weill (2007). It is constructed from five components, which quantify how management capability and human resource capability facilitate or inhibit IT investment, how IT is used in internal communications and with suppliers, and the company's Internet capabilities. We examine whether the value from IT-related intangibles is evenly distributed across firms within the sample, or whether most of the value is concentrated in firms with high ITC. Moreover, given the complementarities one might expect from investments in IT hardware, software, and services alongside workplace practices and skills, we interact ITC with measures of IT.

We construct ITC as a standardized variable (mean 0, variance 1). We then create dummy variables based on the firm's ITC score, akin to academic letter grades of "A" through "F".[23] If a firm's ITC is in the bottom 5% of the sample, then ITC_F = 1. Otherwise, it is equal to 0. If ITC is between the 5th and 15th percentiles, then ITC_D = 1. Otherwise, it is 0. The variable ITC_B = 1 if ITC is between the 85th and 95th percentiles, 0 otherwise, and ITC_A = 1 if ITC is in the top 5% of the sample, and 0 otherwise. The baseline group of ITC_C firms is in the middle 70% of the distribution, between the 15th and 85th percentiles.[24] Using this set of dummy variables, we construct the following estimating equation:

$$\begin{aligned} MV_{it} = {} & \beta_0 + \beta_1 K_{it} + \beta_2 F_{it} + \beta_3 IT_{it} + \beta_4 R_{it} \\ & + \beta_5 B_{it} + \beta_6 EMP_{it} * ICT\_F_i \\ & + \beta_7 EMP_{it} * ITC\_D_i + \beta_8 EMP_{it} * ICT\_B_i \\ & + \beta_9 EMP_{it} * ICT\_A_i + \beta_{10} IT_{it} * ICT\_F_i \\ & + \beta_{11} IT_{it} * ICT\_D_i + \beta_{12} IT_{iy} * ICT\_B_i \\ & + \beta_{13} IT_{it} * ICT\_A_i + controls + \varepsilon_{it} \end{aligned} \tag{3}$$

For the baseline group of ITC_C firms (whose dummy is omitted), the total contribution of IT assets to market value is $\beta_3 \cdot IT$ dollars. For an ITC_F firm, the total contribution of IT assets to market value would be $(\beta_3 + \beta_{10}) \cdot IT + \beta_6 \cdot EMP$ dollars. For an ITC_A firm, the contribution of IT assets to market value would be $(\beta_3 + \beta_{13}) \cdot IT + \beta_9 \cdot EMP$ dollars. The null hypothesis underlying this estimating equation is that the eight coefficients β_6 through β_{13} are equal to zero.

Data

Sample Construction

Our data set consists of 508 firm-year observations from 2003 through 2006, based on a balanced panel of 127 publicly traded U.S. firms across a broad range of industries. We construct our sample by starting with the firms that participated in the Social and Economic Explorations of IT (SeeIT) survey, a project based at the MIT Sloan School to poll com-

[22]See Brynjolfsson and Saunders (2010, Chapter 4) for a review of key papers in the area of IT and complementarities.

[23]We use five categories: A, B, C, D, and F, as there is no academic letter grade of E.

[24]Given that ITC is a standardized variable, the middle 70% of the distribution is within approximately one standard deviation of the mean.

panies about IT spending and technology usage covering data from 2005 through 2006.[25] We match the publicly traded firms from the survey to *Compustat Industrial Annual*, and eliminate firms without data for market value, total assets, employment, or PP&E. We drop a small handful of firms with implausibly high IT asset estimates, as compared to PP&E from *Compustat*.[26] In addition, we drop companies incorporated outside the United States, in order to eliminate confounding effects from firms subject to different tax laws, markets, cultures, and regulations.

Furthermore, we exclude IT producers, financial firms, and natural resource firms such as mining and oil companies. As compared to firms in the rest of the economy, IT producers face different input prices for computer hardware and software since such firms use the IT they produce themselves (BHY 2002).[27] Thus, we drop firms with primary industry codes in computer and electronic product manufacturing (NAICS 334), software publishing (NAICS 5112), data processing, hosting, and related services (NAICS 518), and computer system design and related services (NAICS 5415). We exclude financial corporations (NAICS 52) as their balance sheets are fundamentally different than those of other firms in the economy.[28] Mining and oil firms (NAICS 21 and 324) hold significant assets whose market values fluctuate with the potentially volatile market price of their underlying commodities, yet such changes are not reflected in the book value of assets on the balance sheet. Because of the large potential changes to the left-side variable (market value) from such swings in input costs or assets, without resultant changes to the right-side variables, we exclude these firms.[29]

[25]Described further in Appendix A.

[26]This occurs when our estimate for capitalized IT assets is larger than all of PP&E, implying that ordinary (non-IT) assets are negative.

[27]In addition, IT producers face different accounting rules when it comes to capitalizing software. If software is developed internally and is only used by the firm itself, *Statement of Position 98-1* from the AICPA applies. If the software will also be sold to other customers, then *Statement 86* from the Financial Accounting Standards Board (FASB) applies.

[28]Financial firms have high levels of "other" assets that may affect our estimate for the coefficient of *F*. Government sources such as the Federal Reserve's *Flow of Funds* and the BEA's *Integrated Macroeconomic Accounts for the United States* separate financial firms from the rest of the economy. A number of papers that examine intangible assets and Tobin's *q* (the ratio of market value to total assets) dropped financial firms from their analyses (Berger and Ofek 1995; Hall 2000, 2001; McGahan and Porter 1999, 2003).

[29]Such firms are often based on a single commodity input factor, magnifying the effect of such price swings.

To create a balanced panel, we keep firms that have complete data in every year from 2003 through 2006. All of the firm-level data is constructed on a fiscal year-end basis. The summary statistics of the sample can be found in Table 1.

Variable Construction and Data Sources

Market Value

We define market value as the sum of all financial claims on the firm at the end of each fiscal year, as shown in equation (4):

$$MV = PSTK + (PRCC\_F * CSHO) + LT \qquad (4)$$

MV, or market value, is the sum of three variables. The first is the value of preferred stock (*Compustat* mnemonic PSTK), the second is the price of common stock at the end of the fiscal year, (PRCC_F) times the number of outstanding shares of common stock (CSHO), and the third variable is total liabilities (LT).

IT Assets: Three Measures

The firm-level IT spending data is summarized in Table 2. On average, each firm in our sample spent $229.8 million per year on IT, of which $29.6 million, or 12.9%, was on hardware. We convert this annual IT spending into three different measures of IT assets, progressively broadening the definition each time:

1. **Purchased Hardware:** This is the measure from BHY 2002, which uses hardware owned by the firm (regardless of the extent to which the firm capitalizes hardware).

2. **Capitalized Hardware and Software**: This is an estimate of the IT assets that would be included on the balance sheet of the company. This measure does not include uncapitalized purchases of hardware that would have been in the first measure, *Purchased Hardware*.

3. **All IT**: Our broadest measure of IT assets is derived from virtually all IT spending by the firm—hardware, purchased and internally developed software, other internal IT services, external IT services (such as consulting), and IT-related training—whether or not the firm capitalizes or expenses such spending.[30]

[30]We omit leased hardware and software, which is a relatively small component of IT spending.

Table 1. Variable Means for Sample, 2003-2006 ($Millions)

	Mean	Standard Deviation	Minimum	Maximum*
Market Value	31,422.1	60,251.6	295.7	354,347.9
IT Assets				
Purchased Hardware	52.8	109.1	.3	622.8
Capitalized Hardware and Software	156.5	278.9	1.2	1,517.0
Purchased Hardware, All Software, Other Internal IT Assets, IT Consulting, IT-Related Training	505.9	970.7	5.0	5,411.7
Ordinary Assets	5,455.5	11,746.6	2.6	72,539.3
Other Assets	12,965.4	38,239.4	53.3	245,509.5
R&D Assets	2,583.5	7,574.8	0	44,004.9
Brand Assets	331.9	956.0	0	5,891.8
Employment (000s)	58.4	77.0	.4	465.0

Note: Total of 508 observations.
*To avoid disclosure, we list the maximum as the average of the 10 largest observations.

Table 2. Average IT Spending per Firm, 2003-2006 ($Millions)

	Mean	Standard Deviation	Minimum	Maximum*
Hardware	29.6	57.5	.2	327.0
Prepackaged Software	33.9	61.1	.3	326.4
External IT Services (e.g., business process consulting, integration services)	41.1	73.2	.3	388.5
Internal IT Services (e.g., custom software, design, maintenance, administration)	114.1	198.2	.9	1,073.9
IT-Related Training	11.1	18.5	.03	95.4
Total IT Spending	**229.8**	**401.8**	**1.9**	**2,168.1**

Note: Total of 508 observations.
*To avoid disclosure, we list the maximum as the average of the 10 largest observations.

In Figure 2, we illustrate IT spending and assets for the 2003–2006 sample. We estimate that our first and narrowest measure of IT assets, *Purchased Hardware*, averaged $52.9 million per firm during the sample period.[31] The same firms averaged $156.9 million of *Capitalized Hardware and Software*, our second and broader measure of IT. Finally, the sample firms averaged $505.9 million of IT assets based on our third and broadest measure, *All IT*. In Appendix A, we elaborate further on how IT spending is converted into each IT asset measure.

[31]Consisting of $39.9 million of hardware that is capitalized, and $13.0 million that is not capitalized.

Hardware

To construct firm-level hardware assets, we begin with total annual hardware spending as reported by the firm. We convert each of these flows into a constant-dollar (2005) measure using the investment price deflator for computers and peripherals from the BEA.[32] As is the practice of the BEA, we assume spending occurred halfway through the year.[33] We use the BEA rate of depreciation for computers and periph-

[32]Bureau of Economic Analysis, National Income and Products Accounts Table 5.3.4 "Price Indexes for Private Fixed Investment by Type," line 11.

[33]We make this assumption for all subsequent asset calculations.

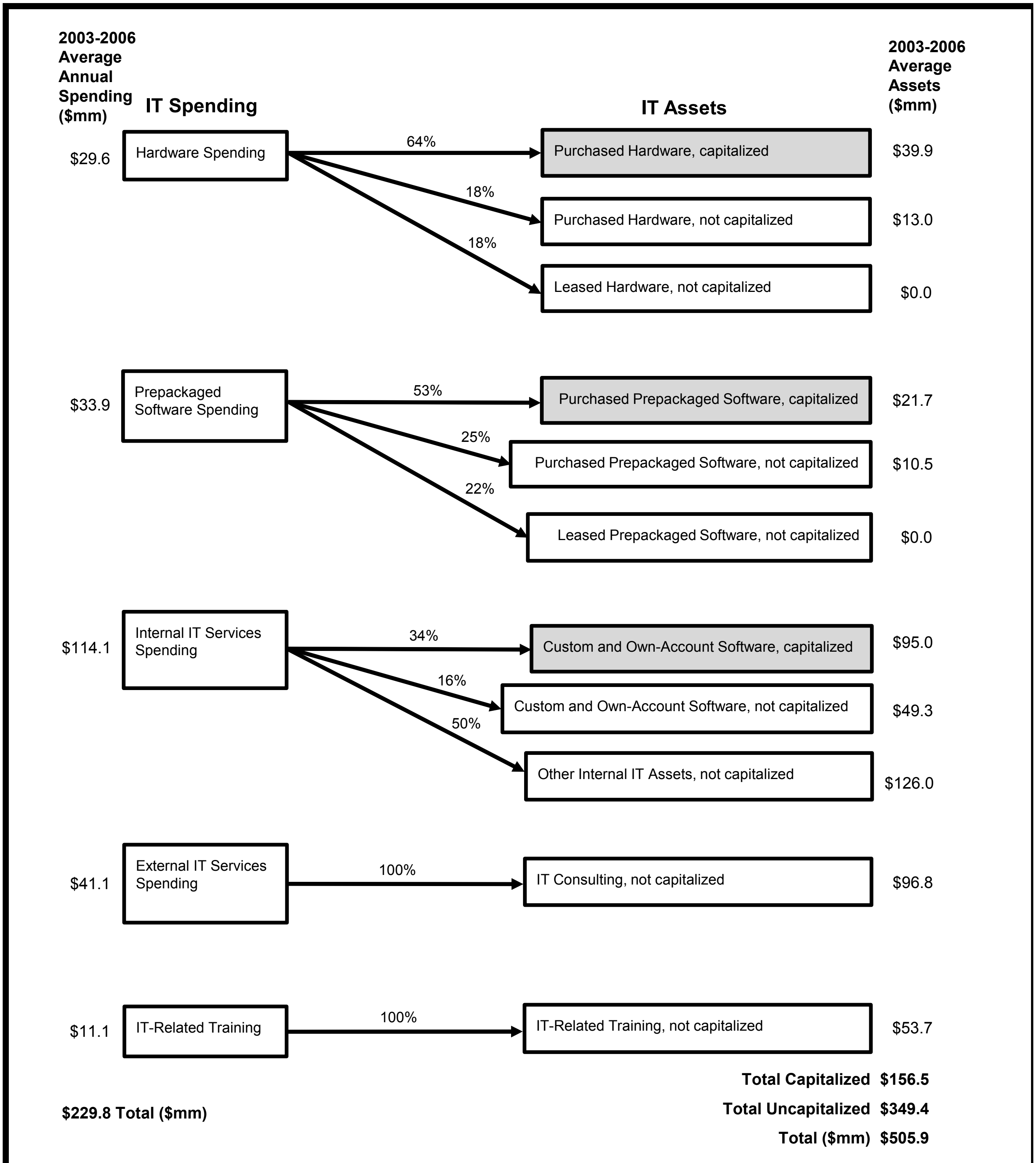

Figure 2. Converting IT Spending into IT Assets

erals, which is approximately 33 percent.[34] Each year's constant-dollar estimate is then converted back into a current-dollar, or replacement cost measure, using the appropriate price deflator for computers and peripherals.[35] Our spending data cover the period of 2003–2006, and thus we impute earlier values of hardware spending to generate estimates of hardware assets. We start with the firm's reported hardware spending in 2003, and apply the industry-level growth rate of investment in computers and peripherals from the BEA to estimate the historical values of firm-level hardware spending.[36]

Prepackaged Software

Similar to hardware, we convert all prepackaged software spending by the firm into a constant-dollar measure by using the BEA depreciation rate of 55% per year as well as the appropriate investment price deflators.[37] We use the BEA growth rate of investment in prepackaged software at the industry level to impute earlier firm-level spending estimates prior to 2003.[38] Finally, our annual prepackaged software asset estimates are then converted from constant dollars into current dollars by using the appropriate price deflators.[39]

Custom and Own-Account Software

In contrast to prepackaged software that is ready to use off-the-shelf, custom software is "tailored to the specifications of a business enterprise or government unit" (BEA 2000, p. 3). Own-account software is "in-house expenditures for new or significantly-enhanced software created by business enterprises or government units for their own use" (BEA 2000, p. 4). As the SeeIT survey does not ask for further breakdown of spending beyond "Internal IT Services," and the BEA price deflators and depreciation rates of 33% per year are the same for both custom and own-account software, we aggregate these two types of software assets in our estimates.[40] We use the BEA growth rate of investment in custom software at the industry level to impute earlier firm-level spending estimates prior to 2003.

In its calculations of IT assets, the BEA estimates that 50% of programmer and system analyst time is spent on new software development (BEA 2000, p. 5). Thus, we allocate 50% of internal IT services spending toward *Custom and Own-Account Software* assets, and the other 50% toward *Other Internal IT* assets. While a 50% split is the prevailing practice of the BEA, the agency acknowledges that this ratio is an approximation (BEA 2000, p. 5). Thus, as a robustness check, we derive results using other ratios in order to examine the sensitivity of our analyses to this assumption.

Other Internal IT Assets

The 50% of internal IT services spending that is not allocated toward *Custom and Own-Account Software* assets is allocated toward *Other Internal IT* assets. This includes spending on activities such as design, maintenance, or administration of IT. There are no published price deflators or depreciation rates available from the BEA for this type of spending. Thus, as a price deflator, we use the BEA gross output deflator for

[34]The BEA does not publish a depreciation rate for computers and peripherals. Rather, it publishes depreciation schedules for the various subcomponents of hardware, such as mainframes, printers, terminals and displays, tape drives, and storage devices (see BEA [2003], M-30, available at http://www.bea.gov/national/FA2004/index.asp). Thus, we impute an aggregated depreciation rate for computers and peripherals based on combining BEA Fixed Assets Tables 2.1, 2.4, and 2.7. While the rate derived varies slightly from year to year, it is very close to 33% (ranging from 33% to 35% during the sample period by our estimates). Our calculations are available upon request.

[35]We compute an end-of-year price deflator based on BEA Fixed Assets Tables 2.1 and 2.2, as end-of-year price indexes for computers and peripherals are not published and they vary slightly from the published mid-year investment price deflators (as the BEA assumes investment is made in the middle of the year).

[36]The BEA does not publish a chain-type quantity index for computers and peripherals. Thus, we aggregated the various subcomponents of hardware from the nonresidential detailed estimates of the BEA, available at http://www.bea.gov/national/FA2004/Details/Index.html. We then create a Fisher chain-type quantity index for computers and peripherals extending back to 1998. Since our asset estimates for IT rely more on imputation for 2003 and 2004 than for 2005 and 2006, as a robustness check we later run estimates based only on 2005 and 2006 asset values.

[37]BEA depreciation rates for various types of equipment and software are available at http://www.bea.gov/national/FA2004/Tablecandtext.pdf. The investment price deflator for prepackaged software is available from the nonresidential detailed estimates of investment (chain-type quantity index), available at http://www.bea.gov/national/FA2004/Details/Index.html.

[38]We use the chain-type quantity index of investment for prepackaged software, available at http://www.bea.gov/national/FA2004/Details/Index.html.

[39]For all asset calculations that follow, we (1) use appropriate price deflators to convert nominal, current-dollar flows into constant-dollar flows; (2) use the appropriate depreciation rates to create estimates of assets in constant dollars; and (3) convert each year's assets in constant dollars into current-dollar assets using the appropriate price deflators.

[40]See depreciation rates for each at http://www.bea.gov/national/FA2004/Tablecandtext.pdf. The investment price deflators for custom and own-account software are from the nonresidential detailed estimates of investment (chain-type quantity index), available at http://www.bea.gov/national/FA2004/Details/Index.html.

NAICS 541512, computer systems design services. To impute historical spending at the firm level before 2003, we use the industry-level growth rate of investment in custom software, applied to the 2003 firm-level value of spending on *Other Internal IT* assets. We use the depreciation rate for firm-specific resources found in Corrado et al. (2005, 2009), which amounts to about 37.5% per firm in our sample.[41]

IT Consulting

Spending on external IT services, which includes business process consulting and integration services, is converted into an *IT Consulting* asset. We use an approximate 37.5% depreciation rate and the gross output deflator for NAICS 541512 (the same as for *Other Internal IT* assets) to convert current-dollar annual spending as reported by the firm into constant-dollar measures. To impute firm-level spending in years before 2003, we use the industry-level growth rate of investment in custom software, applied to the 2003 firm-level value of spending on *IT Consulting*. As part of our extended analyses, we also report results with *IT Consulting* assets depreciated by a rate of either 15% or 60%.

IT-Related Training

We use the annual spending reported by the firm for IT-related training and convert it to an *IT-Related Training* asset. We use an approximate 37.5% depreciation rate and the gross output deflator for NAICS 541512 (the same as for *Other Internal IT* assets and *IT Consulting*) to convert current-dollar spending into annual asset measures. To impute firm-level spending in years before 2003, we use the industry-level growth rate of investment in custom software, applied to the 2003 firm-level value of spending on IT-related training. As part of our extended analyses, we also report results with *IT-Related Training* assets depreciated by a rate of either 15% or 60%.

IT Capabilities (ITC)

ITC is based on the work of Aral and Weill (2007). It is the sum of five components, which include management capabilities, human resource capabilities, IT usage in internal and external communications, and Internet capabilities.[42] We list the components and summary statistics of ITC in Table 3, and the distribution of ITC (from ITC_A through ITC_F) in Table 4.

Each of the five components of ITC is constructed from the sum of several questions, which are measured on a 1 to 5 scale within the 2005 and 2006 SeeIT surveys. To reduce measurement error, we average the answers from both years and give each firm a single value for each component in the sample period. We standardize each of the five component sums to mean 0, variance 1 variables. We then add those five standardized components, and restandardize the resultant sum to create the final mean 0, variance 1 variable that represents ITC.

Research and Development (R&D) Assets

We begin with annual R&D spending as reported by the firm (*Compustat* mnemonic XRD) as far back as 1983 (or the first year reported by the firm), and apply BEA price deflators and depreciation rates to estimate R&D assets.[43] The R&D depreciation rate for firms in transportation and warehousing industries (NAICS 48-49) is 18%. In the chemicals industry (NAICS 325), the R&D depreciation rate is 11%, and for all other firms it is 15%.[44] Approximately half of the firms in our sample report nonzero values of R&D, and as firms are required to report R&D spending if it exceeds 1% of sales (Zhao 2002, p. 156), we assume a value of zero R&D spending for firms that do not report R&D. We create a dummy variable equal to 1 for any firms with no R&D assets in our estimating equations. For firms that report R&D generally but have some values missing, we impute the missing values by taking the ratio of R&D to sales for the trailing or leading five years and applying it to the value of sales in the year(s) of missing R&D. In accordance with accounting standards, R&D spending is entirely expensed by firms.

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[41]The formula for depreciation of firm-specific resources in Corrado et al. (2005, 2009) is the average of the depreciation rates of R&D and advertising. Since we use a 15% depreciation rate for R&D for most firms and a 60% depreciation rate for advertising, this averages to a depreciation rate of about 37.5%. As an alternative to this baseline assumption, we also consider depreciation rates for *Other Internal IT* assets ranging from 15% to 60% in our analyses.

[42]We do not have enough response data to create the sixth component from Aral and Weill, which measured the degree of digitization in purchases and sales. The formulation of ITC is based on case studies of two manufacturing firms, two financial services firms, and 7-Eleven Japan. See Aral and Weill (pp. 767-770) for further details.

[43]Although we use the perpetual inventory method and not a strict service life, after 20 years of 15% depreciation per year, the value of each dollar invested in R&D would have deteriorated by more than 96%.

[44]The BEA rate for R&D depreciation in the Computers and Electronics industry is 16.5%, but we do not consider IT producers in our sample.

Table 3. Components of IT Capabilities (ITC)

ITC is the standardized sum (mean 0, standard deviation 1) of the five factors below.		
Please rate whether the following factors at your company facilitate or inhibit the ability to make new information technology investments on a scale from 1 to 5, with 1 being "inhibits significantly," 3 being "no effect," and 5 being "facilitates significantly."		
HR Capabilities	**Average**	**Std. Dev.**
Technical skills of existing IT staff	4.56	.50
Business skills of existing IT staff	4.52	.50
Ability to hire competent IT staff	2.53	1.18
Skills of end-users	3.54	.57
Management Capability		
Business unit involvement in IT projects	2.60	1.14
Senior management support	2.55	1.14
Please rate how important the following methods are for *(internal communications, communications with suppliers*) in your company on a scale from 1 to 5, with 1 being "not at all important," 3 being "moderately important," and 5 being "extremely important."		
Internal Communications		
Email	4.53	.50
Mobile electronic mail (e.g., BlackBerry)	4.49	.50
Instant messaging	3.62	.60
Company Intranet	3.54	.55
Wireless (including phone and pager)	4.44	.50
Communications with Suppliers		
Email	4.54	.50
Mobile electronic mail (e.g., BlackBerry)	4.56	.50
Instant messaging	3.50	.50
Internet	3.59	.49
Wireless (including phone and pager)	4.44	.50
Please identify to what extent your company uses Internet technology to perform each of the tasks on a scale from 1 (no use of the Internet) to 5 (fully automated via the Internet).		
Internet Capability		
Sales force management	4.55	.50
Employee performance measurement	3.08	.88
Training	3.09	.83
Post-sales customer support	3.01	.85

Table 4. Distribution of Capabilities (ITC)

Category	Meaning	Number of Observations
ITC_A	95^{th} percentile and above	24
ITC_B	85^{th}-95^{th} percentile	52
ITC_C	15^{th}-85^{th} percentile	356
ITC_D	5^{th}-15^{th} percentile	52
ITC_F	5^{th} percentile and below	24
Total		**508**

Brand Assets

To construct brand assets, we begin with advertising spending as reported by the firm (*Compustat* mnemonic XAD). Approximately 50% of the firms in our sample report advertising expenditures. For firms that do not report advertising, we use a database maintained by Kantar Media called *Ad$pender*, which estimates advertising spending for approximately 95% of the firms covered by *Compustat.* For any remaining firms without *Compustat* or *Ad$pender* advertising spending data, we assume a value of zero for advertising. To convert flows of advertising spending into brand assets, we start with annual advertising spending as far back as 1995 (or the first year reported by the firm), and use a 60% annual depreciation rate (following Corrado et al. 2005, 2009) with a price deflator based on the Producer Price Index (PPI) for advertising agencies. In accordance with accounting standards, all advertising expenditures are entirely expensed by firms. We also create a dummy variable equal to 1 for any firms with no brand assets in our estimating equations.

Ordinary Assets

Ordinary assets (i.e., physical, non-IT assets) are equal to the *Compustat* measure of net property, plant, and equipment (*Compustat* mnemonic PPENT), minus our estimate for capitalized IT.[45] Net PP&E as reported by the firm is in historical-cost dollars rather than current-cost dollars. While current-cost estimates would be more desirable in our market value estimations, in the absence of disaggregated investment data by type (such as equipment and structures), we leave PPENT as is.[46]

Other Assets

We define other assets as total balance sheet assets (*Compustat* mnemonic AT) minus net PP&E. Other assets include inventories, financial assets such as accounts receivable, cash, other liquid assets, and any balance sheet intangibles such as goodwill.

[45]We use the BEA definition of physical assets, which is equipment plus structures. The Bureau of Labor Statistics has a different definition of assets, which includes inventories and undeveloped land. To be fully consistent across the source data for depreciation rates, price deflators, and investment growth, we use the BEA as the definitive source for all data in this paper where possible. Further detail for the BLS definition of assets can be found in BLS (1983, Appendix C).

[46]As a robustness check, we adjust net PP&E as reported by the firm to a current-cost estimate by assuming the firm invests in equipment and structures at the industry rate. The industry-level estimates of current- and historical-cost assets are found in BEA Fixed Assets Tables 3.1ES and 3.3ES. Our alternative calculations are available upon request.

Sector Controls

We create sector dummy variables, and in order to have at least 20 observations in each sector, we aggregate similar NAICS sectors. We list our sector classifications in Table 5.

Results

Summary

Using our 2003–2006 data set, we first replicate the BHY 2002 finding that $1 of computer hardware is correlated with about $10 of market value. We then account for the missing $9 of value by broadening the definition of IT assets to capture virtually all IT spending, whether the firm treats this spending as capitalized or expensed. One dollar of the broadest measure of IT assets is correlated with close to its theoretical value of $1 of market value.

However, our results suggest that this value is not spread evenly throughout the sample. Rather, it is positively correlated with firms that possess the highest IT capabilities, such as the ITC_A firms. The estimated difference in market value between ITC_A and ITC_F firms is striking: holding all physical as well as intangible assets of the firm constant, we estimate an average difference in market value of 52% between the ITC_A and the ITC_F firms. This finding is robust to alternative specifications and assumptions, and our point estimates of the difference in market value range from 45% to 76%. The estimated premium of ITC_A firms is consistent with the observations that IT investments are riskier than ordinary investments (Dewan et al. 2007), or that those firms with the highest IT capabilities simply execute better than their peers, perhaps reflecting better management. Thus, the evidence suggests that the market generously rewards the firms with the highest IT capabilities.

In addition, we estimate that $1 of R&D and $1 of brand assets are each correlated with slightly more than $1 of market value, further suggesting the importance of intangible assets in differentiating firms. While the coefficients for R&D and brand are significantly greater than 1 in virtually all specifications, the coefficient for brand is measured with larger standard errors. More research is necessary to quantify the strength of brand, determine how

Table 5. Sector Dummy Variables

Sector Dummy Variables	NAICS Codes	Observations
1. Agriculture, Utilities, Construction	11, 22, 23	40
2. Nondurable Process Manufacturing: Paper Products; Chemical Products	322, 325	104
3. Other Nondurable Manufacturing: Food, Beverage and Tobacco Products; Textile Mills and Textile Product Mills; Apparel and Leather and Allied Products; Printing and Related Support Activities; Plastics and Rubber Products	311-316, 323, 326	28
4. Durable Manufacturing, High-Tech: Electrical Equipment, Appliances and Components; Motor Vehicles, Bodies and Trailers, and Parts; and Other Transportation Equipment	335, 336	40
5. Durable Manufacturing, Non High-Tech: Wood Products; Nonmetallic Mineral Products; Primary Metals; Fabricated Metal Products; Machinery; Furniture and Related Products; Miscellaneous Manufacturing	321, 327, 331, 332, 333, 337, 339	80
6. Wholesale and Retail Trade	44-45	68
7. Transportation and Warehousing	48-49	32
8. Information	51	24
9. Real Estate and Rental and Leasing, Professional, Scientific and Legal Services; Management of Companies and Enterprises; Administrative and Support services, Waste Management and Remediation Services	53, 54, 55, 56	32
10. Educational Services; Health Care and Social Assistance	61, 62	24
11. Arts, Entertainment and Recreation; Accommodation and Food Services; Other Services except Government	71, 72, 81	36
	Total	**508**

it varies between firms, and identify the correct industry-specific depreciation rates.

Sample Validation

Because we use the *replacement* cost of computers (the cost to replace a firm's stock of computers in the dollars of that year), and not the *historical* cost of computers (the cost of computers in the year in which they were purchased), in theory the market value of $1 of replacement-cost computers should not differ from year to year. This approach allows us to compare our results directly to BHY 2002. From 1987 (the first year of the BHY 2002 data set) through 2006 (the last year of our data set), the replacement cost of hardware held by businesses in the United States grew 215%, from $76 billion to more than $161 billion (Figure 3). This barely outpaced the Consumer Price Index (CPI), which grew 175% during the same period. However, the story is very different when we take into account the quality changes to computing over this time: U.S. businesses held 32 times as much computing power at the end of 2006 as they did in 1987.[47] Even though 20 years of technological change have produced computers of remarkably different quality, the equilibrium market value of $1 of new 1987 computers in 1987 should not be different than the market value of $1 of new 2006 computers in 2006.

We find that the ratio of intangible IT spending to hardware spending in our sample is similar to that of the economy as a whole during the sample period. In our sample, we estimate $6.76 in intangible IT spending for every $1 of hardware spending from 2003 to 2006 (Table 2).[48] Within the U.S. economy from 2003 to 2006, for every $1 of hardware investment, businesses spent $6.13 in software, internal IT services, and external IT services (including training). Intangible in-

[47]Source: Bureau of Economic Analysis, Fixed Assets Table 2.2. "Chain-Type Quantity Indexes for Net Stock of Private Fixed Assets, Equipment and Software, and Structures by Type," line 5. The value of the quantity index was 3.507 in 1987, and 113.598 in 2006 (with 2005 as the base year, equal to 100).

[48]This is calculated as all IT spending ($229.8 million), minus hardware ($29.6 million), divided by hardware ($29.6 million), which is $6.76.

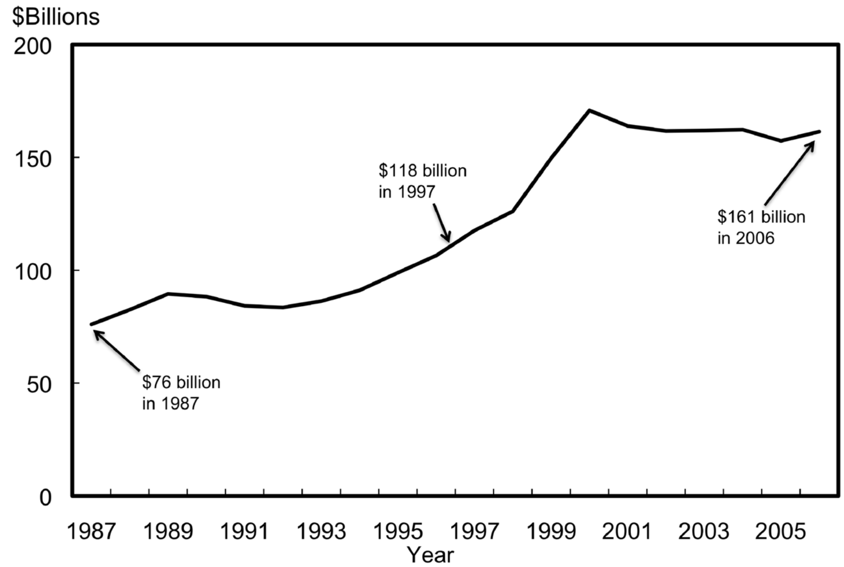

Figure 3. Computer Hardware Owned by Businesses in the United States, 1987–2006 (Source: BEA Fixed Assets Table 2.1, "Current-Cost Net Stock of Private Fixed Assets, Equipment and Software, and Structures by Type," line 5)

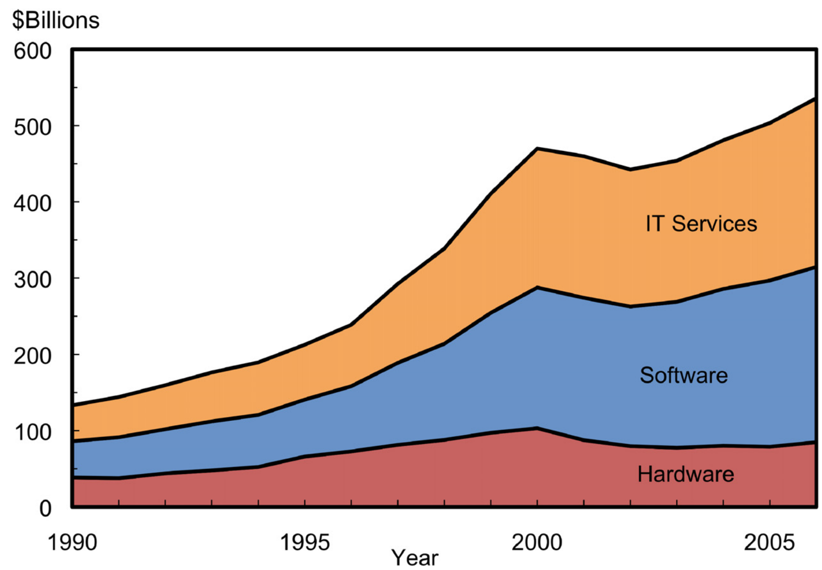

Figure 4. IT Spending by Businesses in the United States, 1990–2006 (Source: BEA NIPA Table 5.3.5, "Private Fixed Investment by Type," and authors' calculations from the Census Bureau's *Service Annual Survey*)

vestments in IT have grown significantly in the United States over the period 1990–2006, from $95 billion in 1990 to more than $450 billion in 2006 (shown in Figure 4).[49]

Market Value as a Function of IT Assets

In Table 6, we illustrate market value estimation of equation (2) for our three different measures of IT, moving from the narrowest measure of IT assets (purchased hardware) to the broadest definition (all IT). Column 1 is an attempt to replicate the results of BHY 2002. One dollar of computer assets, defined as hardware only, is correlated with more than $10 of market value, significantly above the theoretical value of $1. In contrast, $1 of "ordinary" and "other" assets is correlated with close to $1 of market value.[50] BHY 2002 did not maintain that $1 of hardware itself is worth more than $10, and neither do we. Our hypothesis is that hardware is correlated with unmeasured IT intangibles. Adding R&D and brand assets reduces the coefficient for IT in column 2, which is what one would expect if there is a positive synergy between IT and R&D (Bardhan et al. 2013) or IT and product variety (Gao and Hitt 2012).[51]

Although $1 of hardware is associated with more than $10 of market value, $1 of IT defined more broadly as all capitalized IT (both capitalized hardware and software) is associated with approximately $7 of market value (Table 6, column 3). When we include measures of R&D and brand assets, $1 of capitalized IT is associated with about $5 of market value (column 4). We then relax the assumption that the firm capitalizes hardware and software at the industry average.[52] Instead, we use a hypothetical upper bound on capitalized IT by assuming the firm capitalizes *all* purchases and payroll for hardware and software.[53] Even in such a case, $1 of this definition of IT is correlated with more than $3 of market value (column 5), suggesting that there are still complementary intangible IT assets that are unaccounted for.

We then use our broadest definition of IT, which includes IT services and training that were not included in narrower measures. In these specifications, $1 of IT is correlated with close to $1 of market value, its theoretical value (Table 6, columns 6 and 7).[54] Our interpretation is that by progressively broadening the definition of IT to include previously unmeasured intangibles, we are better capturing IT assets. We examine the robustness of this result by using different assumptions and measures of the dependent and independent variables, as seen in Table 7.

Robustness of Market Value Results

Alternative Dependent Variables

We begin by using two different definitions of market value. In the first case (Table 7, column 2), we adjust the face value of long-term debt (*Compustat* mnemonic DLTT) to reflect the additional premium (or discount) of the market value of bonds to the face value of bonds. For data to adjust long-term debt, we start with the *Mergent Fixed Income Securities Database*, with data on approximately 180,000 corporate bond issues. We extract the unique CUSIP identifier and issue information for each bond. We match this information to the *Trade Reporting and Compliance Engine (TRACE)* database, a product of the Financial Industry Regulatory Authority (FINRA). The TRACE database represents more than 99% of U.S. cor-

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[49]Source: Hardware is from BEA NIPA Table 5.3.5, "Private Fixed Investment by Type," line 11. Software is from the same BEA table, line 17, and consists of the sum of prepackaged, custom, and own-account investment. IT services are the sum of internal IT services and external IT services. For internal IT services, we use an amount equal to investment in own-account software because the BEA allocates 50% of all internal IT spending for own-account software. Thus, we include the other 50% of all internal IT spending here. Spending on external IT services is from the *Service Annual Survey*. From 1998 to 2006, we use revenue in NAICS industry 5415 (computer systems design and related services) minus 541511 (custom computer programming services), as NAICS 541511 is allocated for custom software and thus is already counted. For 1990–1997, we use the revenue from SIC industries 7373, 7376, and 7379 as this most closely matches the definitions of NAICS industry 5415 excluding 541511. However, this is not an exact match. Thus, we further adjust the SIC estimates to match the NAICS definitions by multiplying the SIC estimates from 1990 to 1997 by the 1998 ratio of NAICS to SIC revenue in these industries (1998 being the only year in which data under both NAICS and SIC is available). We begin with 1990, the first year with data available for SIC codes 7373, 7376, and 7379 in the *Service Annual Survey*.

[50] Our results from OLS estimation (not shown here) are also similar to BHY 2002, and are qualitatively similar to our GLS results. One dollar of computer assets is correlated with more than $10 of market value, and $1 of "ordinary" and "other" assets are each correlated with close to $1 of market value. When we broaden the definition of IT, we estimate coefficients closer to 1. One dollar of R&D and advertising are each associated with significantly more than $1 of market value, and we estimate a 68% difference in market value between ITC_A and ITC_F firms.

[51]BHY 2002 used the ratios of current-year R&D to sales and advertising to sales as controls. Using these ratios instead of R&D and advertising assets in column 2 results in a higher IT hardware coefficient closer to the result from column 1.

[52]Based on the *Annual Capital Expenditure Survey* (ACES) data. See appendix A for more detail.

[53]We do not have a specification for capitalized IT if the firm capitalizes 0% of IT spending, as that variable would be zero.

[54]Recall our conceptual framework: each dollar's worth of an asset—if properly measured—should be correlated with about $1 of market value.

Table 6. Market Value as a Function of the Assets of the Firm, 2003–2006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Information Technology (*IT*) – Hardware only Purchased Hardware (BHY 2002 measure)	11.31 (3.51)	8.75 (3.89)					
Information Technology (*IT*) – Capitalized only Capitalized Hardware, Capitalized Software			7.19 (1.39)	5.68 (1.52)	3.61 (1.01)		
Information Technology (*IT*) – All Hardware, All Software, Other Internal IT Assets, IT Consulting, IT-Related Training						1.53 (.41)	1.15 (.46)
Ordinary Assets (*K*)	1.20 (.08)	1.48 (.14)	1.22 (.08)	1.48 (.14)	1.48 (.14)	1.20 (.08)	1.48 (.14)
Other Assets (*F*)	1.12 (.09)	1.80 (.18)	1.09 (.10)	1.81 (.17)	1.81 (.18)	1.12 (.09)	1.80 (.18)
R&D (*R*)		1.65 (.23)		1.65 (.23)	1.64 (.23)		1.63 (.23)
Brand (*B*)		2.57 (1.45)		2.48 (1.38)	2.53 (1.41)		2.49 (1.44)
Number of Observations	508	508	508	508	508	508	508
Assumptions	Firm capitalized all purchased hardware only	Firm capitalized all purchased hardware only	Firm capitalized industry average of purchases and payroll for hardware & software	Firm capitalized industry average of purchases and payroll for hardware & software	Firm capitalized 100% of purchases and payroll for hardware & software	Virtually all IT spending included in IT assets (except leased hardware & software)	Virtually all IT spending included in IT assets (except leased hardware & software)

Note: All regressions are GLS, with correction for heteroskedasticity and serial correlation. Controls for sector, year, no R&D, and no advertising are included (where each control is multiplied by total balance sheet assets).

Table 7. Market Value as a Function of the Assets of the Firm with Additional Specifications, 2003–2006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Information Technology (*IT*) – All Hardware, All Software, Other Internal IT Assets, IT Consulting, IT-Related Training	1.15 (.46)	.86 (.44)	1.12 (.49)	1.15 (.47)	.93 (.47)	1.37 (.44)	.73 (.28)	1.68 (.62)	.75 (.37)	1.15 (.44)
Ordinary Assets (*K*)	1.48 (.14)	1.35 (.19)	1.25 (.20)	.72 (.11)	1.49 (.14)	1.47 (.14)	1.49 (.14)	1.48 (.14)	1.12 (.14)	1.45 (.13)
Other Assets (*F*)	1.80 (.18)	1.81 (.20)	1.76 (.24)	1.39 (.19)	1.81 (.18)	1.80 (.18)	1.79 (.18)	1.81 (.18)	1.85 (.17)	1.73 (.17)
R&D (*R*)	1.63 (.23)	1.94 (.22)	1.05 (.27)	1.68 (.24)	1.63 (.23)	1.64 (.23)	1.61 (.24)	1.66 (.23)	1.02 (.22)	1.47 (.24)
Brand (*B*)	2.49 (1.44)	3.39 (1.44)	1.20 (1.40)	2.62 (1.51)	2.49 (1.44)	2.49 (1.44)	2.47 (1.47)	2.52 (1.42)	.33 (1.13)	2.24 (1.39)
Lagged MV									.28 (.04)	
(HQ in High-Tech Spillover Area = 1) * Total Assets										.25 (.09)
Number of Observations	508	508	508	508	508	508	508	508	508	508
Assumptions	Baseline result (From Table 6, column 7)	Market value adjusted for market value of bonds	Market value = equity + debt	Ordinary assets estimated at current-cost instead of historical-cost	0% of internal IT services spending for custom & own-account software	100% of internal IT services spending for custom & own-account software	IT consulting, IT training, and other internal IT assets at 15% depreciation	IT consulting, IT training, and other internal IT assets at 60% depreciation	Lagged market value included	Headquarters located in high-tech metropolitan area

Note: All regressions are GLS, with correction for heteroskedasticity and serial correlation. Controls for sector, year, no R&D, and no advertising are included (where each control is multiplied by total balance sheet assets).

porate bond market activity for 30,000 issuers. From January 2003 through December 2006, the database contains more than 18 million trades. For each bond, we keep the last recorded price for the end of the fiscal year. We aggregate the face and market values of all outstanding bonds for each company, and match them to our sample. Finally, we take the ratio of the aggregate market value of a company's outstanding bonds to their aggregate face value, and multiply it by the face value of the company's long-term debt.

Our main definition of market value—equity plus liabilities—is consistent with the sum of all financial claims to the firm (Hall 2000, 2001). However, in column 3, we use an alternative definition of the market value of the firm consistent with the empirical corporate finance literature: equity plus long-term and short-term debt.[55]

We note that with either alternative market value definition, our results do not change substantially. In column 2, the coefficient on IT drops somewhat, while the coefficients of R&D and brand in column 3 fall closer to 1.

Assumptions for Ordinary Assets

We then use current-cost estimates of ordinary assets instead of historical-cost (or book-value) estimates in column 4. We use BEA data on current-cost assets by industry[56] and divide this by the historical-cost estimates of assets by industry,[57] and then multiply this ratio by the historical-cost estimate of net PP&E for the firm (*Compustat* mnemonic PPENT). In this estimation, while other coefficients remain the same, the coefficient for ordinary assets falls below 1. To the extent that firms invest in different physical assets that differ from the industry average, this leads to measurement error, biasing the coefficient toward zero (Griliches and Hausman 1986).

Assumptions about Internal IT Services Spending

Our baseline assumption for internal IT services spending by the firm was that 50% was for own-account and custom software, and the remaining 50% was for other internal IT assets such as design, maintenance, and administration. In columns 5 and 6, we relax this assumption: In column 5, we assume that 0% of internal IT services spending is for own-account and custom software, while all of it is on other internal IT assets. In column 6, we assume the opposite is true, wherein 100% of internal IT services spending is toward own-account and custom software, and 0% is on other internal IT assets. It is worth noting that these upper and lower bound assumptions change the coefficient on IT assets only somewhat.

Depreciation Rates for IT Consulting, Training, and Other Internal IT Assets

Instead of our baseline depreciation rate of 37.5% for IT consulting, IT training, and other internal IT assets, we use 15% as an alternative assumption in column 7, and 60% in column 8.[58] The coefficient on IT assets is 0.73 with a 15% depreciation rate, and 1.68 with a 60% depreciation rate. While the coefficient on IT is closest to 1 with our baseline estimate of 37.5%, neither estimates from column 7 nor column 8 are significantly different from 1.

Lagged Market Value

We include market value lagged by one year to capture time-varying unobserved firm effects in column 9. The coefficient on lagged market value is positive and significant, indicating that unobserved qualities of the firm, such as management quality, are serially correlated over time. The coefficient on IT is reduced to 0.75, although it is not significantly different from 1.[59]

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[55]Thus, the mnemonics are *PSTK* + (*PRCC_F* * *CSHO*) + *DLTT* + *DLCC*. See Berger and Ofek (1995), Lang and Stulz (1994), and Villalonga (2004a, 2004b).

[56]See BEA Fixed Assets Table 3.1ES. An ideal calculation would start with a firm-level series of investment in each of equipment and structures, apply the appropriate deflators and depreciation rates to each series, and then add them together. However, firms are not required to record disaggregated investment by type, and thus we assume that the firm invests in a physical asset mix at the same rate as its industry.

[57]See BEA Fixed Assets Table 3.3ES.

[58]We do not vary the depreciation rates for hardware, prepackaged software, or own-account and custom software in our additional specifications because these rates are published by the BEA, the most authoritative source available for macroeconomic data.

[59]Interestingly, the coefficient on brand is reduced to 0.33 and is not significantly different from zero, suggesting that advertising spending has weak explanatory power once previous market value is controlled for. The effects of powerful, long-lasting, and valuable brands are correlated with firm value but are not fully captured by advertising spending measures alone. A source of future work lies in capturing brand strength more directly.

Accounting for Potential Spillovers

It has been well demonstrated that technological change leads to positive spillovers that extend beyond firm boundaries (Cheng and Nault 2007; David 1990; Tambe and Hitt 2014). If firms with high levels of IT assets were predominately located in areas of abundant high-tech spillovers, the IT variable could be, in effect, taking credit for such spillovers. To test whether this might be the case, we create a dummy variable equal to 1 if the firm is headquartered in an area that is well known for high-tech spillovers.[60] Approximately 20% of our sample (96 observations) is headquartered in such an area. Column 10 is a specification that includes this dummy variable multiplied by total balance sheet assets, to scale for firm size and to achieve consistency with other dummy variables. While the coefficient on this dummy variable is positive and significant, the remaining coefficients are almost exactly the same as our baseline estimate in column 1.

Market Value Results with IT Capabilities (ITC)

Although $1 of our broadest measure of IT is correlated with close to $1 of market value on average, our results suggest that high ITC firms account for a disproportionate share of this value. In Table 8, column 1, we include the ITC_A through ITC_F dummy variables multiplied by firm employment.[61] Our point estimate is that ITC_A firms are each worth an extra $119,810 more per employee than an ITC_C firm. Note that these interaction effects decrease monotonically from ITC_A firms through ITC_F firms (although we do not estimate a statistically significant difference in value between ITC_C and ITC_D firms). This is consistent with a dose-response relationship and increases our confidence in our interpretation. Using the specification in column 2, where ITC_A through ITC_F are multiplied instead by IT assets, we also find striking differences in value. Every $1 of IT assets is worth $14.63 more in an ITC_A firm than an ITC_F firm. Again, the effects decrease monotonically for each ITC group. Our point estimates imply that an ITC_A firm with the sample average amount of IT assets ($505.9 million) is correlated with $7.4 billion more in market value than an ITC_C firm,[62] while an ITC_F firm with the sample average amount of IT assets is correlated with $2.6 billion *less* in market value than an ITC_C firm.[63] This makes the difference between an average ITC_A and ITC_F firm equal to about $10 billion in market value, significant at the 1% level and very large in a practical sense—amounting to about one-third of the average firm's market value in the sample.

Robustness of Market Value Results with ITC

In Table 9, we illustrate our baseline result, along with a set of results based on alternative assumptions, from estimating equation (3). In Table 10, we then compare the percentage differences in market value between ITC_A, ITC_B, ITC_D, and ITC_F firms with ITC_C firms based on the findings from Table 9. Note that in the baseline result in column 1, the estimated difference in market value between ITC_A firms and ITC_F firms is 53%. Our market value results with ITC are robust to a variety of different conditions, including different definitions of market value and ordinary assets, different assumptions about how internal IT services are converted into IT intangible assets, and usage of alternative depreciation rates. Furthermore, the results are robust to specifications that include lagged market value and high-tech spillovers.[64] The effects of ITC on market value change monotonically within each specification, with differences in value between ITC_A and ITC_F firms ranging from 45% to 76%. The contribution of IT to market value appears to be concentrated in a relatively small number of firms with very high IT capabilities, and firms with the lowest IT capabilities are correlated with large discounts in market value compared to their more IT-enabled competitors. As a result, firms with average or below average IT capabilities are not deriving maximum value from their IT assets.

Measurement Error and its Impact on the Results

Although it is necessary to consider measurement error given the inherent difficulty of quantifying intangible assets, we do not see it as a source of serious concern that would change the

[60]We use the 10 cities listed in *Wired* Magazine's "10 Top Tech Towns": Austin, Boston, Los Angeles, New York City, Orlando, Pittsburgh, Raleigh-Durham, the San Francisco Bay Area, Seattle, and Washington, DC. The list is available at http://www.wired.com/wired/archive/15.01/geekcities.html. We use the greater metropolitan area for each city. This is defined by the Office of Management and Budget (OMB) as the metropolitan statistical area (MSA), and is also used by the U.S. Census Bureau. For the San Francisco Bay area and Raleigh-Durham, we use a slightly broader definition, called the combined statistical area (CSA), which aggregates nearby MSAs together based on commuting patterns.

[61]We scale variables ITC_A through ITC_F by employment to account for firm size. As these variables are based on workplace practices, we scale them by total employees rather than total assets.

[62]14.63 * 505.9 = $7.4 billion.

[63](-5.21 * 505.9) = -$2.6 billion.

[64]Note that average IT asset levels change from columns 5 through 8 because of the alternative assumptions used to construct them.

Table 8. Market Value as a Function of the Assets of the Firm and ITC

	(1)	(2)
Information Technology (*IT*) – All Hardware, All Software, Other Internal Assets, IT Consulting, IT-Related Training	.67 (.36)	.71 (.36)
Ordinary Assets (*K*)	1.58 (.13)	1.51 (.13)
Other Assets (*F*)	1.94 (.17)	1.91 (.16)
R&D (*R*)	1.56 (.22)	1.58 (.23)
Brand (*B*)	3.24 (1.26)	3.58 (1.34)
ITC_A * IT		14.63 (5.09)
ITC_B * IT		9.77 (1.94)
ITC_D * IT		-.75 (1.67)
ITC_F * IT		-5.21 (3.93)
ITC_A * Employment	119.81 (57.26)	
ITC_B * Employment	78.11 (15.10)	
ITC_D * Employment	-4.66 (22.44)	
ITC_F * Employment	-171.89 (49.62)	
Number of Observations	508	508

Note: All regressions are GLS, with correction for heteroskedasticity and serial correlation. Controls for sector, year, no R&D, and no advertising are included (where each control is multiplied by total balance sheet assets). Employment levels are reported in thousands.

interpretation of our results. First, the simplest interpretations of measurement error would likely bias the coefficient estimates downward (Griliches and Hausman 1986), so in the case of R&D and brand, in which we obtain positive and significant coefficient estimates greater than 1, we may in fact be underestimating the true contribution of these intangible assets to market value.

Next, we consider ITC. While reducing ITC to a single construct risks oversimplification, if it were subject to serious measurement error, it would be very unlikely that dummy variables ITC_A through ITC_F would explain market value *in order*. While there are potentially more sophisticated models of IT capabilities cited in the literature, such papers generally do not have (1) coverage of firms across multiple industries, and (2) repeated observations of the same firm over time.

We then consider whether there was significant measurement error in the IT asset estimates. Such error would likely bias any coefficient estimates on IT assets downward, and possibly produce the same set of qualitative results as illustrated in Table 6, wherein the broader the definition of IT assets, the smaller the coefficient of IT. While we cannot rule this out altogether, we do not consider this to be a likely possibility that explains the bulk of our results. First, our firm-level survey results measuring intangible IT spending within sample firms are in line with economy-wide spending on IT intangibles (as discussed above and shown in Figure 4). This consistency makes it less likely that firm-level estimates of IT

Table 9. Market Value as a Function of the Assets of the Firm and ITC: Alternative Specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Information Technology (*IT*) – All Hardware, All Software, Other Internal IT Assets, IT Consulting, IT-Related Training	.55 (.35)	.35 (.35)	.37 (.40)	.59 (.36)	.37 (.37)	.87 (.35)	.35 (.21)	.84 (.48)	.29 (.33)	.68 (.35)
Ordinary Assets (*K*)	1.56 (.12)	1.45 (.16)	1.30 (.19)	.80 (.09)	1.56 (.12)	1.55 (.13)	1.57 (.12)	1.56 (.12)	1.25 (.13)	1.57 (.14)
Other Assets (*F*)	1.91 (.16)	1.84 (.17)	1.80 (.22)	1.58 (.18)	1.91 (.16)	1.93 (.16)	1.90 (.16)	1.91 (.16)	1.88 (.15)	1.79 (.17)
R&D (*R*)	1.53 (.22)	1.92 (.20)	.95 (.26)	1.58 (.23)	1.55 (.22)	1.49 (.23)	1.54 (.22)	1.52 (.22)	.98 (.23)	1.12 (.25)
Brand (*B*)	3.42 (1.25)	3.26 (1.20)	1.71 (1.40)	3.80 (1.34)	3.50 (1.24)	2.87 (1.37)	3.41 (1.26)	3.45 (1.25)	1.39 (1.14)	2.88 (1.34)
ITC_A * IT	17.53 (5.34)	16.59 (4.53)	23.73 (6.15)	18.55 (5.91)	19.50 (5.60)	17.15 (5.60)	9.69 (3.46)	27.33 (7.96)	14.44 (4.60)	20.12 (6.37)
ITC_B * IT	2.33 (2.17)	.83 (2.18)	5.06 (2.01)	2.97 (2.23)	-2.81 (2.68)	3.15 (3.21)	1.89 (1.34)	3.05 (2.91)	1.69 (1.93)	3.08 (2.15)
ITC_D * IT	-.62 (1.68)	-.40 (1.68)	-.31 (1.97)	-.86 (1.77)	-.76 (1.70)	-.71 (1.69)	-.39 (1.00)	-.87 (2.26)	-.70 (1.39)	-.52 (2.10)
ITC_F * IT	-.53 (3.83)	.68 (3.35)	4.11 (4.86)	2.39 (3.43)	-.56 (3.78)	-.86 (4.16)	-.64 (2.41)	-.76 (5.37)	.75 (3.41)	.25 (4.25)
ITC_A * Employment	-44.66 (30.67)	-42.37 (27.93)	-26.15 (30.45)	-45.67 (35.76)	-68.60 (38.80)	-40.63 (33.78)	-31.83 (40.27)	-65.25 (41.09)	-17.18 (22.32)	-51.94 (31.17)
ITC_B * Employment	66.03 (17.29)	74.69 (18.90)	47.68 (11.14)	61.91 (16.53)	79.96 (19.56)	58.91 (16.69)	63.54 (16.95)	66.11 (17.07)	50.00 (15.43)	63.33 (12.19)
ITC_D * Employment	-4.31 (22.40)	-17.97 (22.38)	7.14 (23.34)	8.97 (24.55)	-4.11 (21.81)	8.37 (13.23)	-3.87 (22.56)	-4.17 (22.35)	5.31 (20.10)	-5.61 (24.68)
ITC_F * Employment	-170.35 (58.14)	-205.79 (63.31)	-174.56 (76.28)	-271.45 (63.13)	-174.74 (56.66)	-132.59 (62.53)	-158.87 (58.94)	-167.75 (57.94)	-139.42 (52.09)	-176.85 (63.01)
Lagged FV									.23 (.04)	
(HQ in High-Tech Spillover Area = 1) * Total Assets										.27 (.10)
Number of Observations	508	508	508	508	508	508	508	508	508	508
Assumptions	Baseline result	Market value adjusted for value of bonds	Market value = equity + debt	Ordinary assets estimated at current-cost instead of historical-cost	0% of internal IT services spending for custom & own-account software	100% of internal IT services spending for custom & own-account software	IT consulting, IT training, and other internal IT assets at 15% depre-ciation	IT consulting, IT training, and other internal IT assets at 60% depre-ciation	Lagged market value included	Head-quarters located in high-tech metropoli-tan area

Note: All regressions are GLS, with correction for heteroskedasticity and serial correlation. Controls for sector, year, no R&D, and no advertising are included (where each control is multiplied by total balance sheet assets). Empowerment levels are reported in thousands.

Table 10. Relative Valuation of ITC_A, ITC_B, ITC_D, and ITC_F to ITC_C Firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Percent above/below an ITC_C firm										
ITC_A	20%	35%	33%	21%	43%	21%	20%	20%	20%	23%
ITC_B	16%	15%	17%	16%	11%	16%	17%	16%	12%	17%
ITC_C	—	—	—	—	—	—	—	—	—	—
ITC_D	-2%	-4%	1%	0%	-2%	0%	-2%	-2%	0%	-2%
ITC_F	-33%	-37%	-26%	-47%	-33%	-26%	-31%	-32%	-25%	-32%
Avg. IT asset ($mms)	505.9	505.9	505.9	505.9	487.6	524.1	848.7	368.8	505.9	505.9
Avg. employment (000s)	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4
Assumptions	Baseline result	Market value adjusted for value of bonds	Market value = equity + debt	Ordinary assets estimated at current-cost instead of historical-cost	0% of internal IT services spending for custom & own-account software	100% of internal IT services spending for custom & own-account software	IT consulting, IT training, and other internal IT assets at 15% depre-ciation	IT consulting, IT training, and other internal IT assets at 60% depre-ciation	Lagged market value included	Head-quarters located in high-tech metropolita n area

Note: Percentages are based on the specifications in Table 9. Note that average IT asset levels change from columns 5 through 8 because of the alternative assumptions used to construct them.

assets (as constructed from intangible IT spending) greatly differ from their true values. Second, if our firm-level estimates of IT assets were subject to significant measurement error, it would be very unlikely that our IT asset variable could explain market value in order when interacted with variables ITC_A through ITC_F in Tables 8 and 9.

We rerun the results from Tables 8 and 9 based on a subset of the data from 2003 to 2004,[65] which tests the robustness of imputing pre-2003 data[66] as well as the assumption that ITC is quasi-fixed.[67] The results based on the 2003–2004 subset are very similar to those based on the 2003–2006 sample. In addition, we reran the specifications without brand and R&D asset variables, and similar results were obtained for all of the IT-related intangible variables.

Table 11 displays the correlation matrix of our sample. Neither ordinary assets nor other assets are correlated with our measures of IT, which suggests that the high valuations for IT are not being driven by a correlation between IT and ordinary or other assets.

Limitations of the Intangible Assets Data

While our results are robust to a number of different assumptions, there are limitations to our intangibles data. First, the R&D and brand variables are constructed based on respective spending on each of those assets. As a result of this limitation, it is beyond the scope of this work to compare the relative importance of R&D, brand, or IT based solely on the coefficients from the estimating equations. For example, although the coefficient of brand is higher than that of the broadest measure of IT, this could be the result of missing brand-related intangibles (in the same way that the coefficient of hardware was quite high until more IT-related intangibles

[65]Not shown for brevity. Results available upon request.

[66]The 2003 and 2004 IT asset estimates rely more on imputation than do the same estimates from 2005 and 2006, as our IT spending data runs from 2003 to 2006.

[67]Since our organizational IT and management practice data were measured in 2005 and 2006, analyzing the results based on 2003 and 2004 tests the robustness of our assumption that ITC is quasi-fixed and thus is applicable to those years as well. As BHY (2002, p. 146) note, many organizational practices are embedded in a firm's culture and thus are slow-changing. Therefore, a firm's ITC in 2003 and 2004 should be closely correlated with its ITC in 2005 and 2006. In a sense, one can think of the 2005–2006 values as proxies for the 2003–2004 values, albeit noisy ones. Moreover, since we are using categories (ITC_A through ITC_F) rather than exact values of ITC, our results are more robust against measurement error within the ITC variable. Since ITC as constructed (spreading the 2005–2006 average across all four years) is a strong predictor of market value from 2003 to 2006, it would be very unlikely that the 2005 and 2006 values for ITC are radically different than the 2003 and 2004 values. If there were no relationship between the 2003-2004 values of ITC and the 2005-2006 values, then ITC would not be a reliable predictor of market value from 2003 to 2006.

Table 11. Correlation Table for Variables in Sample

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Market Value	1.00															
2	IT Hardware	.10**	1.00														
3	Capitalized IT	.10**	.96***	1.00													
4	Broadest IT	.10**	.98***	.98***	1.00												
5	Ord. Assets	.83***	.04	.03	.04	1.00											
6	Other Assets	.91***	.07	.05	.08*	.82***	1.00										
7	R&D	.84***	.03	.03	.04	.60***	.78***	1.00									
8	Advertising	.82***	.02	.02	.03	.61***	.75***	.76***	1.00								
9	No R&D	-.23***	-.09**	-.06	-.10**	-.04	-.19***	-.36***	-.18***	1.00							
10	No Advertising	-.08*	-.03*	-.01*	-.01	-.07	-.06	-.03	-.09**	-.03	1.00						
11	ITC	.02	.02	.03	.02	-.09**	-.01	-.04	-.04	.07*	.04	1.00					
12	ITC_A	.02	-.03	-.01	-.02	-.02	-.02	.07	-.06	-.01	.09**	.41***	1.00				
13	ITC_B	-.04	.05	.06	.04	-.08*	-.05	-.07	-.06	-.04	-.09**	.42***	-.08	1.00			
14	ITC_C	.00	.04	.03	.04	-.02	.01	-.09*	.04	.16***	.11**	.08*	-.34***	-.52***	1.00		
15	ITC_D	.05	-.07*	-.07*	-.07	.09**	.07*	.14***	.04	-.20***	-.09**	-.49***	-.08	-.11***	-.52***	1.00	
16	ITC_F	-.03	-.03	-.03	-.03	.04	-.04	.02**	-.01	-.01	-.06	-.47***	-.05	-.08*	-.34***	-.08*	1.00

Note: Total of 508 observations for all variables.
***p < .01, **p < .05, *p < .10

were included in the estimating equation). Rather, our analyses suggest the necessity of determining and capturing more fine-grained measures of intangible assets in an effort to better demonstrate and explain market value as derived from IT-related intangible assets. Due to our sample size, there is not enough of an overlap to make a meaningful comparison between ITC in this work and *ORG* from BHY 2002. However, we do not see this as a significant impediment to these research findings, as *ORG* was based primarily on management and organization-related variables and ITC is based more on specific IT-related capabilities of firms.

Conclusion

In this work, we set out to answer the following questions: First, can we quantify the value of IT-related intangible assets, most of which are invisible on corporate balance sheets? Second, can we use data on IT-related business practices and management capabilities to analyze whether this value is evenly distributed across firms or concentrated in leading firms? Using a panel of 127 firms over the period 2003–2006, we create comprehensive asset measures based on IT-related intangible spending at the firm level. We build on the framework by BHY 2002 and, using our newly constructed data set, replicate their finding that $1 of computer hardware is correlated with more than $10 of market value. Using our expanded definition of IT, which includes hardware, software that is both purchased and developed internally, other internal IT services, IT consulting, and IT-related training, we account for the missing $9 by directly estimating the value of a broader set of IT assets in a market value equation.

Furthermore, our results suggest that IT is not a rising tide that lifts all boats. Instead, differences in management and organizational IT capabilities (e.g., management practices, HR practices, internal IT use, external IT use, and Internet capabilities) largely account for the value of IT intangibles. Firms with the highest IT capabilities (ITC) have significantly higher market value compared to firms with the lowest IT capabilities. Holding all tangible and intangible assets of the firm fixed, we estimate that the firms in the highest ITC category have 45% to 76% greater market value than the firms in the lowest ITC category. Our results suggest that the previously invisible IT intangibles not accounted for on the balance sheet are being priced into the market value of firms, providing further evidence that assets constructed in accordance with accounting standards such as SOP 98-1 or EITF 97-13 measure only a fraction of the business value of IT.

Gaps of this magnitude among otherwise similar firms are indicative of comparable gaps in management understanding and execution. Documenting and quantifying this set of relationships among IT, management practices, and market value is not only a step toward understanding the growing importance of IT-related intangibles, but also a crucial step toward better management, and ultimately greater returns on investment in IT for firms across the economy.

Acknowledgments

SAP supplied generous funding for this research. Lorin Hitt, Paul Hofmann, Jason Yotopoulos, and the participants of the Workshop on Information Systems and Economics all provided excellent suggestions and guidance. We are thankful to the participants and review team of the 2010 International Conference on Information Systems, where this work won the Best Conference Paper award. We are also grateful to Vijay Gurbaxani, senior editor, as well as the associate editor and two anonymous reviewers for their helpful feedback on this article. We thank Peter Weill and Stephanie Woerner at the MIT Center for Information Systems Research for their help in supplying us with the data set from the Social and Economic Implications of Information Technology (SeeIT) project, funded by NSF Grant IIS-0085725. Emily Dietrich and Stefanus Soegiarto provided valuable research assistance. All errors are, of course, our own.

References

Anderson, M. C., Banker, R. D., and Ravindran, S. 2003. "The New Productivity Paradox," *Communications of the ACM* (46:3), pp. 91-94.

Aral, S., and Weill, P. 2007. "IT Assets, Organizational Capabilities, and Firm Performance: How Resource Allocations and Organizational Differences Explain Performance Variation," *Organization Science* (18:5), pp. 763-780.

Athey, S., and Stern, S. 1998. "An Empirical Framework for Testing Theories About Complementarity in Organizational Design," Working Paper 6600, National Bureau of Economic Research.

Baily, M. N. 1981. "Productivity and the Services of Capital and Labor," *Brookings Papers on Economic Activity* (1981:1), pp. 1-65.

Bardhan, I., Krishnan, V., and Lin, S. 2013. "Business Value of Information Technology: Testing the Interaction Effect of IT and R&D on Tobin's Q," *Information Systems Research* (24:4), pp. 1147-1161.

Bartel, A., Ichniowski, C., and Shaw, K. 2007. "How Does Information Technology Affect Productivity? Plant-Level Comparisons of Product Innovation, Process Improvement, and Worker Skills," *Quarterly Journal of Economics* (122:4), pp. 1721-1758.

Barth, M. E., Clement, M. B., Foster, G., and Kaznik, R. 1998. "Brand Values and Capital Market Valuation," *Review of Accounting Studies* (3:1-2), pp. 41-68.

BEA. 2000. "Recognition of Business and Government Expenditures for Software as Investment: Methodology and Quantitative Impacts, 1959-98," Bureau of Economic Research, Washington, DC.

BEA. 2001. "Estimation of Software in the U.S. National Accounts: New Developments," Bureau of Economic Research, Washington, DC (available at http://www.bea.gov/papers/pdf/USSoftware.pdf).

BEA. 2003. *Fixed Assets and Consumer Durable Goods in the United States, 1925-97*, Washington, DC: U.S. Government Printing Office, Bureau of Economic Research.

Berger, P. G., and Ofek, E. 1995. "Diversification's Effect on Firm Value," *Journal of Financial Economics* (37:1), pp. 39-65.

Bloom, N., Sadun, R., and Van Reenen, J. 2012. "Americans Do IT Better: US Multinationals and the Productivity Miracle," *American Economic* Review (102:1), pp. 167-201.

BLS. 1983. *Trends in Multifactor Productivity, 1948-81*, Bulletin of the United States Bureau of Labor Statistics (2178), Washington, DC.

Bresnahan, T. F., Brynjolfsson E., and Hitt, L. M. 2002. "Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence," *Quarterly Journal of Economics* (117:1), pp. 339-376.

Brynjolfsson, E., and Hitt, L. M. 2003. "Computing Productivity: Firm-Level Evidence," *Review of Economics and Statistics* (85:4), pp.793-808.

Brynjolfsson, E., and Hitt, L. M. 2005. "Intangible but Not Unmeasurable: Some Thoughts on the Measurement and Magnitude of Intangible Assets," Remarks for Chapter 12 in *Measuring Capital in the New Economy*, C. Corrado, J. Haltiwanger, and D. Sichel (eds.), Chicago: University of Chicago Press/National Bureau of Economic Research Studies in Income and Wealth, pp. 557-576.

Brynjolfsson, E., Hitt, L. M., and Yang, S. 2002. "Intangible Assets: Computers and Organizational Capital," *Brookings Papers on Economic Activity* (2002:1), pp. 137-181.

Brynjolfsson, E., and Milgrom, P. 2012. "Complementarity in Organizations" in *The Handbook of Organizational Economics*, R. Gibbons and J. Roberts (eds.), Princeton, NJ: Princeton University Press, pp. 11-56.

Brynjolfsson, E., Renshaw, A. A., and Van Alstyne, M. 1997. "The Matrix of Change," *Sloan Management Review* (38:2), pp. 37-54.

Brynjolfsson, E., and Saunders, A. 2010. *Wired for Innovation: How Information Technology is Reshaping the Economy,* Cambridge, MA: MIT Press.

Cheng, Z. J., and Nault, B. R. 2007. "Industry Level Supplier-Driven IT Spillovers," *Management Science* (53:8), pp. 1199-1216.

Corrado, C., Hulten, C., and Sichel, D. 2005. "Measuring Capital and Technology: An Expanded Framework," in *Measuring Capital in the New Economy*, C. Corrado, J. Haltiwanger, and D. Sichel (eds.), Chicago: University of Chicago Press/National

Bureau of Economic Research Studies in Income and Wealth, pp. 11-46.

Corrado, C., Hulten, C., and Sichel, D. 2009. "Intangible Capital and Economic Growth," *Review of Income and Wealth* (55:3), pp. 661-685.

Crespi, G., Criscuolo, C., and Haskel, J. 2007. "Information Technology, Organisational Change, and Productivity Growth: Evidence from UK Firms," Discussion Paper No. 783, Centre for Economic Performance, London School of Economics.

David, P. A. 1990. "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox," *The American Economic Review* (80:2), pp. 355-361.

Dedrick, J., Gurbaxani, V., and Kraemer, K. L. 2003. "Information Technology and Economic Performance: A Critical Review of the Empirical Evidence," *ACM Computing Surveys* (35:1), pp. 1-28.

Dewan, S., Shi, C., and Gurbaxani, V. 2007. "Investigating the Risk–Return Relationship of Information Technology Investment: Firm-Level Empirical Analysis," *Management Science* (53:12), pp. 1829-1842.

Ernst & Young. 1998. *Accounting for the Costs of Computer Software Developed or Obtained for Internal Use: Statement of Position 98-1*, Assurance & Advisory Business Services, November.

Gao, G., and Hitt, L. 2012. "Information Technology and Trademarks: Implications for Product Variety," *Management Science* (58:6), pp. 1211-1226.

Griliches, Z., and Hausman, J. A. 1986. "Errors in Variables in Panel Data," *Journal of Econometrics* (31:1), pp. 93-118.

Hall, B. H., Jaffe, A., and Trajtenberg, M. 2005. "Market Value and Patent Citations," *The Rand Journal of Economics* (36:1), pp. 16-38.

Hall, R. E. 2000. "E-Capital: The Link Between the Stock Market and the Labor Market in the 1990s," *Brookings Papers on Economic Activity* (2000:2), pp. 73-118.

Hall, R. E. 2001. "The Stock Market and Capital Accumulation," *The American Economic Review* (91:5), pp. 1185-1202.

Hand, J. R. M. 2003. "The Increasing Returns-to-Scale of Intangibles," in *Intangible Assets: Values, Measures and Risks*, J. Hand and B. Lev (eds.), New York: Oxford University Press, pp. 303-331.

Lang, L. H. P., and Stulz, R. M. 1994. "Tobin's *q*, Corporate Diversification, and Firm Performance," *Journal of Political Economy* (102:6), pp. 1248-1280.

Lev, B. 2000. *Intangibles: Management, Measurement, and Reporting*, Washington, DC: Brookings Institute Press.

Lev, B. 2004. "Sharpening the Intangibles Edge," *Harvard Business Review* (82:6), pp. 109-116.

Lev, B., and Radhakrishnan, S. 2005. "Valuation of Organizational Capital," in *Measuring Capital in the New Economy*, C. Corrado, J. Haltiwanger, and D. Sichel (eds.), Chicago: University of Chicago Press/National Bureau of Economic Research Studies in Income and Wealth, pp. 73-110.

McGahan, A. M., and Porter, M. E. 1999. "The Persistence of Shocks to Profitability," *The Review of Economics and Statistics* (81:1), pp. 143-153.

McGahan, A. M., and Porter, M. E. 2003. "The Emergence and Sustainability of Abnormal Profits," *Strategic Organization* (1:1), pp. 79-108.

McKinsey Global Institute. 2001. *US Productivity Growth 1995-2000: Understanding the Contribution of IT Relative to Other Factors* (available at http://www.mckinsey.com).

Milgrom, P., and Roberts, J. 1990. "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *The American Economic Review* (80:3), pp. 511-528.

Milgrom P., and Roberts, J. 1995. "Complementarities and Fit: Strategy, Structure and Organizational Change in Manufacturing," *Journal of Accounting and Economics* (19:2-3), pp. 179-208.

Nakamura, L. 2001. "What is the US Gross Investment in Intangibles? (At Least) One Trillion Dollars a Year!," Working Paper No. 01-15, Federal Reserve Bank of Philadelphia.

Pilat, D. 2004. "The ICT Productivity Paradox: Insights from Micro Data," *OECD Economic Studies* (38:1), pp. 37-65.

Porter, M. E. 1996. "What Is Strategy?," *Harvard Business Review* (74:6), pp. 61-78.

Rai, A., Patnayakuni, R., and Seth, N. 2006. "Firm Performance Impacts of Digitally Enabled Supply Chain Integration Capabilities," *MIS Quarterly* (30:2), pp. 225-246.

Seethamraju, C. 2003. "The Value Relevance of Trademarks," in *Intangible Assets: Values, Measures and Risks*, J. Hand and B. Lev (eds.), New York: Oxford University Press, pp. 228-247.

Stankevich, D. 2003. "The Human Link in Supply Chain Technology," *Retail Merchandiser* (43:2), pp. 43-45.

Subramani, M. 2004. "How Do Suppliers Benefit from Information Technology Use in Supply Chain Relationships?," *MIS Quarterly* (28:1), pp. 45-73.

Tambe, P., and Hitt, L. M. 2014. "Job Hopping, Knowledge Spillovers, and Regional Returns to Information Technology Investments," *Management Science* (60:2), pp. 338-355.

Villalonga, B. 2004a. "Diversification Discount or Premium? New Evidence from the Business Information Tracking Series," *Journal of Finance* (59:2), pp. 479-506.

Villalonga, B. 2004b. "Does Diversification Cause the Diversification Discount?," *Financial Management* (33:2), pp. 5-27.

Zhao, R. 2002. "Relative Value Relevance of R&D Reporting: An International Comparison," *Journal of International Financial Management and Accounting* (13:2), pp. 153-174.

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Appendix A

Variable Construction

SeeIT Survey Detail

The IT spending and practice data is from the SeeIT survey. The data covers IT spending from 2003 to 2006, and IT practices in 2005 and 2006. Approximately 600 companies participated in the survey, and about half of them were publicly traded. The survey was conducted by telephone in 2005 and 2006 with a single point of contact in each company. The majority of respondents were CIOs, those in IT finance functions, or those in IT project management functions. The IT spending questions covered hardware, prepackaged software, external IT services (e.g., business process consulting and integration services), internal IT services (e.g., custom software, design, maintenance, and administration), and IT-related training.

Methodology of Converting IT Spending into IT Assets

To allocate IT spending into the three measures of IT assets (purchased hardware, capitalized hardware and software, and all IT), we begin by estimating the percentage of IT spending that is leased or purchased in each category of Table 2. We then estimate how purchases or payroll are either capitalized or expensed by the firm. In the absence of direct data from the firms themselves (as publicly traded firms are not required to list capitalized IT as a separate item on their balance sheets), we use an industry-level census survey, called the *Annual Capital Expenditure Survey* (ACES). The ACES contains the *Information and Communication Technology Supplement*, which details hardware and software spending in each of the 20 major two-digit NAICS sectors by leases or by purchases and payroll. The survey also divides purchases and payroll data into either capitalized or expensed spending by sector.

Therefore, we assume that firm spending on IT is allocated as leases or purchases and payroll at the sector average rate, and that any purchases and payroll would also be capitalized at the sector average rate. We list the summary statistics for hardware and software capitalization and leases for our sample in Table A1. Analysis of the sample demonstrated that an average of 82.2% of hardware spending was for purchases (while the remainder was leased) and, overall, an average of 64.0% of hardware spending was capitalized (which ranged from 51.2% to 84.7% among sectors). An average of 53.1% of software spending was capitalized, and this value ranged from 24.5% to 68.7% among sectors within our sample.

Below, we elaborate further on how IT assets are divided into each of our three measures of IT.

Hardware

To account for hardware assets in our three measures of IT, we divide each year's hardware spending by the firm into three categories as illustrated in Figure 2: capitalized purchases (which average 64% of IT spending), uncapitalized purchases (which average 18%), and leases (which comprise the other 18%). We do not convert spending on hardware leases into hardware assets.

Hardware assets that are considered within our first measure of IT assets (the BHY 2002 measure of purchased hardware) average $52.9 million per firm. Hardware assets that are included in the second measure, capitalized IT, average $39.9 million per firm. In the third and broadest measure of all IT, hardware assets average $52.9 million per firm.

Prepackaged Software

We use the industry-level capitalization ratios from the ACES data to divide prepackaged software spending into three categories: capitalized purchases (which average 53% of spending), uncapitalized purchases (which average 25%), and leases (which comprise the other 22%). Prepackaged software assets included in the second measure of IT assets, capitalized IT, average $21.7 million per firm. In the third and broadest measure of all IT, prepackaged software assets average $32.2 million per firm. We do not convert spending on prepackaged software leases in our prepackaged software asset estimates.

Custom and Own-Account Software

Spending on internal IT services as detailed in the SeeIT survey covered activities such as custom software, design, maintenance, and administration. We divide this spending into *Custom Software*, *Own-Account Software*, and *Other Internal IT* assets (see Figure 2). Half of all annual spending is assumed to be on *Custom and Own-Account Software*, and the other half is assumed to be on *Other Internal IT* assets (BEA 2000, p. 5).

We divide the internal IT services spending that is allocated toward *Custom and Own-Account Software* assets into capitalized and uncapitalized categories according to the industry-level ratios from the ACES. As illustrated in Figure 2, we assume that 34% of internal IT services spending is capitalized, while the remainder is expensed.

On average, firms in our sample have $95.0 million per year of *Custom and Own-Account Software* assets included in our second measure of capitalized IT, and average $144.3 million of *Custom and Own-Account Software* included in our third and broadest measure of all IT.

Other Internal IT Assets

Spending in this area is assumed to be entirely expensed. Firms in our sample average about $126.0 million per year of *Other Internal IT* assets, and this asset category is only included in the third and broadest measure of all IT.

IT Consulting

We assume the firm fully expenses any spending on external IT services,[68] and thus *IT Consulting* assets, which average $96.3 million per year in our sample, are included only in the third and broadest measure of all IT.

IT-Related Training

We assume that firms fully expense spending on *IT-Related Training* in accordance with SOP 98-1, and thus, any *IT-Related Training* assets are included only in the third and broadest measure of all IT. These assets average $53.7 million per year in the sample.

Table A1. Capitalization Ratios of Hardware and Software Spending for 2003-2006 Sample

Spending Type	Mean	Standard Deviation	Minimum	Maximum
Hardware purchases and leases	100.0%	—	—	—
Purchases, capitalized	64.0%	10.0%	51.2%	84.7%
Purchases, not capitalized	18.2%	6.2%	5.4%	30.0%
Leases, not capitalized	17.8%	5.3%	5.4%	26.0%
Software purchases, payroll, and licensing	100.0%	—	—	—
Purchases and payroll, capitalized	53.1%	8.8%	24.5%	68.7%
Purchases and payroll, not capitalized	24.8%	8.3%	12.0%	59.2%
Leases, not capitalized	22.1%	3.9%	11.6%	34.9%

[68]While it is clear from SOP 98-1 that all business process consulting is to be expensed, it is possible that some integration services that are part of the application stage of software development could be capitalized. In the absence of more detailed data on (1) the extent of external IT services spending that included integration services, and (2) the extent to which any such services were in the application stage of software development, we assume all such spending is entirely expensed by the firm.