

Association for Information Systems AIS Electronic Library (AISeL)

ICIS 2010 Proceedings

International Conference on Information Systems
(ICIS)

2010

VALUING IT-RELATED INTANGIBLE CAPITAL

Adam Saunders

University of Pennsylvania, adam.saunders@sauder.ubc.ca

Follow this and additional works at: http://aisel.aisnet.org/icis2010_submissions

Recommended Citation

Saunders, Adam, "VALUING IT-RELATED INTANGIBLE CAPITAL" (2010). *ICIS 2010 Proceedings*. 243.
http://aisel.aisnet.org/icis2010_submissions/243

This material is brought to you by the International Conference on Information Systems (ICIS) at AIS Electronic Library (AISeL). It has been accepted for inclusion in ICIS 2010 Proceedings by an authorized administrator of AIS Electronic Library (AISeL). For more information, please contact elibrary@aisnet.org.

VALUING IT-RELATED INTANGIBLE CAPITAL

Completed Research Paper

Adam Saunders

The Wharton School, University of Pennsylvania

561 Jon M. Huntsman Hall

3730 Walnut St.

Philadelphia, PA 19104

asaund@wharton.upenn.edu

Abstract

As part of an effort to examine the value of intangible assets in the firm, our study is the first to create IT-related intangible asset stocks from firm-level survey data. We also use data on IT-related business practices in order to understand the distribution of IT-related intangibles, and we create asset stocks to value research and development (R&D) and brand. Using a panel of 130 firms over the period 2003-2006, we find that intangible assets are correlated with significantly higher market values beyond their cost-based measures. Moreover, we estimate that there is a 30-55% premium in market value for the firms with the highest organizational IT capabilities (based on a measure of HR practices, management practices, internal IT use, external IT use, and Internet use) as compared to those with the lowest organizational IT capabilities.

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

Introduction

This paper seeks to quantify the value of information technology (IT)-related intangible capital. Although intangible assets are naturally difficult to measure, we utilize a novel approach to doing so by using a market value estimation of a firm's various intangible assets. Our study is the first to create asset stocks based on IT-related intangible spending at the firm level. We also use data on IT-related business practices and management capabilities to analyze where this value is distributed among firms. As part of a broader effort to value intangible assets of the firm, we use market value estimation of research and development (R&D) and brand as well.

Using a balanced panel of annual data of 130 firms from 2003-2006, our results suggest that IT-related intangibles are a significant driver of market value. We recreate the Brynjolfsson, Hitt and Yang (2002) finding that \$1 dollar of computer hardware is correlated with more than \$10 of market value, suggesting at least \$9 of unmeasured intangible assets. We then account for the "other \$9" by broadening the definition of IT to include software, and then all IT-intangible spending. The value of \$1 of the broadest measure of IT is correlated with close to \$1 of market value, its theoretical value. Moreover, we demonstrate that these intangibles are not spread evenly across firms. By replicating an organizational IT capabilities (ITC) variable from Aral and Weill (2007), we estimate that firms with high ITC (1.5 standard deviations and above the mean) are associated with 30-55% greater market value than the firms with low ITC (lower than 1.5 standard deviations below the mean). This effect works in order – high ITC firms are correlated with significantly more value than average ITC firms, which in turn are correlated with significantly more value than low ITC firms. We also find that one dollar of R&D and brand is associated with significantly more than one dollar of value in a market value equation.

The motivation behind our research is that a company's intangible assets are not well captured in government statistics or corporate balance sheets. The Bureau of Economic Analysis (BEA), responsible for publishing the Gross Domestic Product and most other measures of the economy, estimates that U.S. corporations held \$13.1 trillion in equipment and structures at the end of 2008.¹ However, it does not estimate the value of intangible assets, such as organizational knowhow, human capital, and brands that are an important source of value for companies today.² The value of intangibles is not only missing from government sources; it is also largely absent in corporate balance sheets. Current accounting standards dictate that virtually no intangible investment can be capitalized, that is, treated as an investment and recorded on the balance sheet. One of the few exceptions to this rule is purchased goodwill. 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. Purchased goodwill, thus, does not include intangibles created outside of mergers and acquisitions. Consider Google, undoubtedly built on a sea of intangible assets and valued at more than \$160 billion.³ The company lists a total of just \$40 billion of assets on its balance sheet, \$5 billion of which is goodwill. Why is Google valued at \$120 billion more than the sum of its assets? Our hypothesis is that while intangibles are mostly invisible on the balance sheet, they are reflected in the market value of companies today.

Recent studies have attempted to quantify the size of intangible assets in the U.S. economy using aggregate data and have found vast amounts of uncounted capital. Corrado, Hulten, and Sichel (2005, 2009) estimate that annual business investment in intangibles not included in the U.S. government's official definition of investment could be \$1 trillion per year. This uncounted amount is about the same size as the official estimates of annual business investment. They also estimate that the stock of uncounted intangible assets held by business is \$3.6 trillion. Nakamura (2001) uses aggregated data on expenditures on intangibles, labor inputs, and corporate operating margins, and estimates that corporate intangible assets in the U.S. economy could be as high as \$5 trillion. We seek to contribute to this literature by providing more precise estimates based on firm-level market value equations.

¹ Source: BEA Fixed Assets Table 4.1. "Current-Cost Net Stock of Private Nonresidential Fixed Assets by Industry Group and Legal Form of Organization", Line 13.

² We note however that the BEA has begun publishing a parallel set of unofficial GDP statistics that treat R&D as an investment rather than as an expense. The BEA plans to fully incorporate R&D as an investment in the core GDP statistics by 2013 (Aizcorbe et al, 2009).

³ As of August 2010.

Our main contribution is to be the first to quantify the value of IT-related intangible capital and demonstrate that this value is correlated with firms with more intensive IT practices (e.g. internal IT use, external IT use, and Internet use) and superior management and HR capabilities. Our 2003-2006 dataset provides us with broader and more recent IT estimates than can be found in currently published research by Brynjolfsson, Hitt and Yang (2002) that relies on *Computer Intelligence* data from 1987-1997. In this paper, we build on their framework, that used market value equations to demonstrate that \$1 of computer hardware was associated with more than \$10 of value, and that this value was accounted for by a set of complementary human resource practices. While IT-related intangible assets were the most plausible explanation for the “other \$9” of value, their data was limited to hardware only. With our expanded definition of IT-related intangibles that measure software, internal IT services, external IT services, and IT-related training, we estimate these values – the “other \$9” – directly in a market value equation.

Our study complements and extends recent empirical work that uses financial markets to value IT and intangible capital. Anderson, Banker and Ravindran (2003) use market value equations relating the firm to its book value, earnings, R&D, and Y2K spending and find that the value of a dollar of Y2K spending is correlated with an average of 30-40 dollars of market value (with one estimate being as high as 62 dollars of market value). Their interpretation is 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 this. Our study uses IT practice and capabilities data directly with intangible IT spending to analyze the size of this intangible value and how it is distributed.

While existing studies have examined the relationship of IT, organizational capital and market value, ours is the first to directly measure and quantify the IT-intangibles in an estimating equation. For instance, Lev and Radhakrishnan (2005) use the firm’s sales, general, and administrative (SG&A) expenses as a proxy for organizational capital in a sample of publicly traded companies. They find this measure of organizational capital is significant in explaining a firm’s sales, and that this measure is also highly correlated with the firm’s spending on IT. Together, they explain market value beyond traditional measures such as book value and growth potential. Their results, while quite powerful, rely purely on spending data, and our work builds on their findings as we use organizational practice data as well as specific IT-intangibles spending to estimate IT-related organizational capital.

We see our findings as complementary to the observation that IT investments are significantly riskier than non-IT investments (Dewan, Shi and Gurbaxani, 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 difficult to duplicate (Brynjolfsson, Renshaw and Van Alstyne 1997; Milgrom and Roberts 1990, 1995; Porter 1996). Our finding that the highest ITC firms are correlated with 30-55% more value than the low ITC firms fits perfectly in this framework. The rewards are higher for the firms that have built an interlocking system of complementary IT capabilities because these investments involved significant risk.

Our paper uses estimated values of R&D and brand directly in a market value equation, complementing other approaches in the literature that value these intangibles using event studies, production functions, and discounted *ex-post* future returns. Hand (2003), using a net present value (NPV) profitability model, finds that the NPV of R&D and brand is significantly positive and that the firms that were the largest spenders in R&D and advertising were the ones with the highest returns to those assets. Lev (2004) notes that the companies with the highest amounts of R&D capital had the highest risk-adjusted returns between 1983 and 2000, implying that “R&D-intensive companies were systematically underpriced by the market,” (Lev 2004, p.110). Barth et al. (1998) finds that brand value estimates are a significant and positive predictor of share prices and future returns. Using a production function framework, Seethamraju (2003) estimates the value of trademarks, and finds this estimated value is reflected in share prices. These approaches demonstrate that despite their absence from the balance sheet, R&D and advertising are highly valuable investments and are subject to increasing returns to scale. Using the market value equation framework, our paper is another lens to quantify the value of these intangibles.

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

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 assets (Baily, 1981; Hall 2000, 2001). Our underlying assumption is that financial markets provide an important way to value intangible assets beyond the balance sheet and other input metrics. We model the value of financial claims against the firm, MV , as the sum of each of its n assets, A (based on the model in Brynjolfsson, Hitt and Yang 2002, pp.150-151):

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

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*).

As noted earlier, while Google is valued at approximately \$160 billion, the company lists \$40 billion in total assets on its balance sheet, of which only \$5 billion is intangible. While we can measure physical assets for publicly traded companies because of the accounting regulations that require their inclusion in balance sheets, measuring intangible assets poses significant challenges: With the exception of goodwill, they are virtually invisible on corporate balance sheets.

One of the key contributions of this paper is to be the first to create several types of intangible asset stocks and measure them directly in an empirical estimation of (1). That is, rather than *assume* that the residual of the firm's market value above and beyond the firm's book value is due entirely to intangibles, we construct measures for each intangible asset to estimate directly. Put another way, we don't begin with the assumption that the other \$120 billion of Google's market value is the sum of its intangible assets. Rather, in our approach, we estimate how much each type of asset – physical, financial, and intangible – contributes to the entire \$160 billion.

Our null hypothesis is that a dollar's worth of an asset should contribute to one dollar of market value. To test this, we construct three types of intangible asset stocks based on aggregated historical spending to include in the market value equation: IT-intangibles, advertising, and R&D. In the absence of these assets from the corporate balance sheet, we estimate the relationship of our constructed measures and market value.

Even with an ideal dataset that could accurately measure both the tangible and intangible assets of the firm, we would need to control for factors such as industry and year in an estimation of (1). In any given year, the market value of two firms with identical quantities of assets that operate in different industries will differ because of differences in industry growth rates, or regulation, for example. There are also time-varying unobserved factors, such as excessive optimism or pessimism on the part of investors, that necessitates controlling for year in an estimation of (1).

Econometric Model

To relate the market value of the firm to its various assets, we use the following estimating equation:

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

The value of all financial claims on the firm (equity plus liabilities) are placed on the left-hand side and are represented by MV . (Subscripts i and t represent firm i in year t .) We list various categories of assets on the right side of the equation. The first is physical, non-IT (ordinary) capital, K . This includes non-IT equipment, structures, land, and inventories. Next is financial assets, F , which represents total balance assets minus physical capital. This includes receivables, cash, and other accounting assets such as goodwill. The next term is IT , which represents information technology assets. We will use three different measures of IT in our analysis. The first measure includes purchased hardware only, the second includes capitalized hardware and software, and the third, broadest measure of IT includes all hardware and software, internal IT services, external IT services, and IT-related training. The term R represents R&D assets, and B represents advertising spending converted into an asset. We include controls for year and industry, as well as dummy variables for firms that have zero R&D or firms for which we impute advertising expenditures.

Given that our data is in panel form, we estimate equation (2) using Generalized Least Squares (GLS) to correct for potential serial correlation of the error terms and heteroskedasticity. Since one of our goals is estimating the distribution of IT-intangible capital between the firms in sample, we do not use fixed effects or first-differencing as this would sweep away the effects we are looking to measure. 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, Jaffe and Trajtenberg (2005) 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,” (p.26). This can well apply to IT-intangible spending as well. In addition, since the time period in our panel is relatively short, if we use fixed effects or first differencing with Ordinary Least Squares (OLS), any measurement error in the slowly changing right-hand side variables is going to significantly bias the coefficients downward (Griliches and Hausman, 1986).

To estimate the value of a dollar of ordinary capital, K , we adjust net property, plant and equipment (PP&E), listed in net historical-cost dollars (based on the year the asset was purchased) into a replacement cost, or current-cost measure (how much it would cost to purchase the asset in that year). We use the unadjusted value of financial assets listed on the balance sheet and assume this approximates a current-cost measure. To measure IT , R , and B , we use the perpetual inventory method (PIM) to aggregate historical spending and create asset stock values based on depreciation rates and price deflators from the BEA or BLS. If none exist (such as depreciation rates for advertising), we use reasonable values based on the prevailing practice in the literature.

Our null hypothesis is $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 1$. If any of these coefficients are greater than 1, then it means that firms, on average, are reaping greater value than the replacement costs of those assets. This does not mean that there is a “free lunch” in the markets, especially when it comes to intangible assets. If intangible assets carry more risk, it is reasonable to test $\beta_3, \beta_4, \beta_5 = 1$ against the alternative hypothesis that they are greater than 1. This extra value could represent a market premium as compensation for the additional risk in those assets.

Another reason the coefficient can be above 1 is because of omitted variable bias. Brynjolfsson, Hitt and Yang (2002) found \$1 dollar of computer hardware was correlated with more than \$10 of market value. They reasoned that this was due to omitted IT-intangible capital. When they included a measure of organizational practices interacted with hardware, the coefficient on hardware alone fell significantly. With three different measures of IT ranging from hardware only to a broad measure encompassing all IT spending on intangibles, we have direct data to measure the “other \$9” in an estimating equation.

When it comes to intangible assets, cost-based measures may not be enough to describe their value. That is, if two manufacturing firms spend \$20 million on bulldozers, it is reasonable to expect that the inherent replacement *value* of this equipment is not firm specific. Yet this reasoning does not apply well to intangibles. If two firms spend \$20 million on an Enterprise Resource Planning (ERP) system, it is reasonable to expect that the value of that system *is* going to be firm specific. A number of recent papers have shown that complementary business practices are necessary to get the full value from IT (Bartel, Ichniowski, and Shaw 2007; Bloom, Sadun and Van Reenen, 2007; Bresnahan, Brynjolfsson and Hitt 2002; Brynjolfsson and Hitt 2003; Brynjolfsson, Hitt and Yang, 2002; Crespi, Criscuolo and Haskel 2007; Dedrick, Gurbaxani, and Kraemer, 2003; McKinsey Global Institute, 2001, Pilat 2004).

To examine the distribution of IT-intangibles, we construct a variable to capture management capabilities and organizational IT practices. This is based on the measure created by Aral and Weill (2007) they termed organizational IT capabilities (ITC). We use this variable to test whether most of the value from IT-related intangibles is concentrated in the firms with high ITC.

We construct ITC as a standardized (mean 0, variance 1) variable. We then create four dummy variables based on the firm’s ITC score. If ITC is less than 1.5 standard deviations from the sample mean, then $ITC_F = 1$, otherwise, it is equal to 0. If ITC is between -1.5 and -0.5 standard deviations from the sample mean, $ITC_D = 1$, otherwise it is 0. The variable $ITC_B = 1$ if ITC is 0.5 to 1.5 standard deviations above the sample mean, 0 otherwise, and $ITC_A = 1$ if ITC is greater than 1.5 standard deviations from the sample mean, and 0 otherwise. The baseline group is composed of firms for which ITC is between -0.5 and 0.5 standard deviations from the sample mean, which we call ITC_C . (One can think of the F, D, C, B and A levels of ITC similar to an academic letter-grade system). Using this set of dummy variables, we construct the following estimating equation:

$$MV_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 F_{it} + \beta_3 IT_{it} + \beta_4 R_{it} + \beta_5 B_{it} + \beta_6 ITC_F + \beta_7 ITC_D + \beta_8 ITC_B + \beta_9 ITC_A + \beta_{10} IT_{it} * ITC_F + \beta_{11} IT_{it} * ITC_D + \beta_{12} IT_{it} * ITC_B + \beta_{13} IT_{it} * ITC_A + controls + \varepsilon_{it} \quad (3)$$

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

Data

Our data consists of a balanced panel of 130 publicly traded U.S. companies, representing a broad cross-section of industries. With annual data from 2003-2006, we have a total of 520 observations. We construct our sample by starting with firms that are publicly traded and participated in the Social and Economic Explorations of IT (SeeIT) survey, a two year effort by the MIT Sloan School to poll companies about IT spending and technology usage. We match those firms to *Compustat*, and eliminate firms with missing market value, total assets, or ordinary capital. We drop a small handful of firms with implausibly high computer hardware estimates (as compared to their measures of property, plant and equipment in *Compustat*).⁴ We also eliminate companies headquartered outside the United States, to eliminate confounding effects coming from companies subject to different tax laws, markets, culture or regulation. 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. We display the sample summary statistics in Table 1.

	Mean	Std. Deviation	Minimum	Maximum*
1. Market Value	31,095.0	59,672.7	295.7	353,935.7
2. IT Capital – purchased hardware	45.0	88.4	0.2	493.0
3. IT Capital – capitalized hardware and software	202.9	354.6	1.4	1,869.0
4. IT Capital – all capitalized and uncapitalized hardware, software, plus services, training, and leases converted to asset stocks.	562.8	1,080.8	4.6	6,285.3
5. Ordinary Capital (when IT defined as line 3 or line 4)	9,511.2	18,769.3	3.9	110,629.6
6. Other Assets	11,617.9	35,193.2	26.4	229,411.8
7. R&D Capital	2,529.2	7,495.2	0	44,004.9
8. Brand Capital	337.1	946.4	0	5,891.8

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

We also exclude IT-producers, financial, mining, and oil companies. IT-producers face different input prices for computer hardware and software than the rest of the economy (since such firms use the IT they produce themselves). We drop firms with primary industry codes in Computers and Semiconductors (NAICS 334); Software publishing (NAICS 5112); Information and Data Processing Services (NAICS 514) and Computer System Design and Related Services (NAICS 5415). We also exclude financial corporations (NAICS 52) because they are fundamentally different from other firms in the economy, and have such high levels of financial assets that it may affect our estimate for the coefficient of *F*. Mining and oil companies (NAICS 21, 324) hold significant assets that fluctuate with the market price of the underlying commodities, yet such changes are not reflected on the book value of assets

⁴ Such as when the estimate for hardware is greater than all of property, plant and equipment, or when our estimate for hardware is greater than all of equipment (meaning that non-IT equipment would be zero or negative).

on the balance sheet. Because of the large potential changes to the left-side variable (market value) without resultant changes to the right-side variables, we exclude such firms.

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):

$$MV = PSTK + (PRCC_F * CSHO) + LT + DLTT \left(\frac{\text{market_value_of_bonds}}{\text{face_value_of_bonds}} - 1 \right) \quad (4)$$

MV, or market value, is the sum of four separate terms. The first is preferred stock (*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 is total liabilities (*LT*). The last term is an adjustment to the face value of debt (*DLTT*), which reflects the additional premium (or discount) of the market value of bonds to the face value of bonds. If the market value of bonds is equal to the face value, this term is equal to 0.

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 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 percent of U.S. corporate bond market activity of 30,000 issuers. From January 2003 through December 2006, the database contained more than 18 million trades. For each bond, we keep the last recorded price for the close of the fiscal year. We aggregate the face and market values of all outstanding bonds for each company, and match this to our sample. Finally, we use the ratio of the market value to the face value of a company's outstanding bonds and apply it to the face value of the company's long-term debt.

IT Capital

The IT spending and practice data comes from the SeeIT survey. The survey was conducted using telephone interviews in 2005 and 2006 with a single point of contact in each company. The data covers spending from 2003-2006, and IT practices in 2005 and 2006. Approximately 600 companies participated in the survey and about half of them were publicly traded. The majority of respondents were CIOs, in IT finance functions, or in IT project management functions. The questions included the amount of computer capital in the firm, as well as annual spending on hardware, prepackaged software, external IT services (e.g., business process consulting, integration services), internal IT services (e.g. writing software, design, maintenance, and administration), and IT-related training. (The IT practice questions are used to construct an IT capabilities variable as described in Table 5.)

The firm-level IT spending data is summarized in Table 2.

Table 2. Average IT Spending per Firm, 2003-2006 (\$Millions)				
	Mean	Standard Deviation	Minimum	Maximum*
1. Hardware	32.4	61.9	0.2	343.5
2. Prepackaged Software	37.1	66.9	0.3	370.2
3. External IT Services (e.g., custom software, business process consulting, integration services)	47.0	89.5	0.3	503.5
4. Internal IT Services (e.g., own-account software, design, maintenance, administration)	129.2	236.6	0.9	1,337.5
5. IT-related Training	12.8	23.6	0.03	131.1
Total IT Spending	258.5	469.3	1.9	2,627.7

On average, each firm in our sample spends \$258.5 million per year on IT, of which \$32.4 million, or about 12.5% is for hardware. We convert this spending into three different measures of IT assets in our analysis, moving from narrow to broad:

- 1. Purchased Hardware:** This replicates the measure from Brynjolfsson, Hitt and Yang (2002), who use hardware owned by the firm (whether or not it is capitalized).
- 2. Capitalized Hardware and Software:** This represents what would be on the balance sheet of the company. (Note this does not include the uncapitalized purchases of hardware that were in the first measure.)
- 3. All IT:** Our broadest measure of IT is capitalized, uncapitalized purchases, and leases of hardware and software, as well as spending on other internal IT services, external IT services, and training that we convert into asset stocks.

To create the three measures, we estimate what percentage of IT spending in each category of Table 2 is capitalized. We use an industry-level Census survey to estimate the extent that firms capitalize IT.⁵ The *Annual Capital Expenditure Survey* (ACES) contains the *Information and Communication Technology Supplement*, categorizing hardware and software spending into capitalized and uncapitalized amounts for each of the 20 major NAICS sectors.

We match the industry-level capitalization ratios to our firm-level data and list the summary statistics in Table 3. In our sample, firms capitalized an average of 64.0% of their hardware spending from 2003-2006, and this ranged from 51.2% to 84.7%. For software, while an average of 53.1% of software spending was capitalized, it ranged between 26.5% and 68.7%.

Spending Type	Mean	Standard Deviation	Minimum	Maximum
1. Hardware purchases and leases	100.0%	---	---	---
2. Purchases, capitalized	64.0%	10.0%	51.2%	84.7%
3. Purchases, not capitalized	18.2%	6.2%	5.4%	30.0%
4. Leases, not capitalized	17.8%	5.2%	5.4%	26.0%
5. Software purchases, payroll, and licensing	100.0%	---	---	---
6. Purchases and payroll, capitalized	53.1%	8.7%	26.5%	68.7%
7. Purchases and payroll, not capitalized	24.9%	8.1%	12.0%	56.8%
8. Leases, not capitalized	22.0%	3.9%	11.6%	34.9%

In Table 4, we list our estimates of IT assets for the sample in 2003-2006. For instance, the average firm held \$34.2 million in purchased, capitalized hardware. We also estimate that the average firm held another \$10.8 million in purchased hardware that was not capitalized. This is not listed separately in Table 4, rather we list the total of all uncapitalized hardware (\$21.5 million) of which we estimate \$10.8 million is purchased and \$10.7 million is leased. Therefore, our first measure of IT, purchased hardware, averaged \$45.0 million (\$34.2 + \$10.8 million) per firm during the sample period. Our second measure of IT, capitalized hardware and software, averaged \$202.9 million per firm. Our third and broadest measure of IT (which includes IT services and training) averaged \$562.9 million per firm.

⁵ We use an industry-level survey because we cannot observe firm decisions to capitalize IT in each year.

Table 4. Average IT Stocks by Firm for 2003-2006 Sample (\$millions)				
Asset	Capitalized	Not Capitalized	Total	Average Depreciation Rate
1. Hardware	34.2	21.5	55.7	30.8%
2. Prepackaged Software	28.8	27.2	56.0	40.6%
3. Custom Software	28.6	16.5	45.1	28.2%
4. Own-Account Software	111.3	63.1	174.4	27.2%
5. External IT Services (other than software design, e.g., business process consulting, integration services)	0	69.0	69.0	37.2%
6. Internal IT Services (other than software design, e.g. maintenance and administration)	0	135.0	135.0	37.2%
7. Training	0	27.8	27.8	37.2%
Total	202.9	360.0	562.9	

To construct each of the IT assets listed in Table 4, we used the following methods:

Hardware

We begin with total hardware spending as reported by the firm (Table 2, Line 1).⁶ This is an unadjusted figure from the year in which the hardware was purchased. We convert each of these flows into a constant-dollar (2000) measure using the industry-specific price deflator for computers and peripherals from the BLS. We divide each year's spending into three categories, using the industry-level data from the ACES: Capitalized purchases (Table 3, line 2), uncapitalized purchases (line 3) and leases (line 4). We use a three-year service life for hardware and assume these investments are made halfway through the year (as is the practice of the BEA and BLS). For example, the stock of hardware in constant dollars at the end of 2006 is the sum of each constant-dollar flow from 2004, 2005, and 2006, depreciated at an average of 30.8% per year.⁷ The constant-dollar asset stock measure is then converted back into a current-dollar, or replacement cost measure, using the price deflator for computers and peripherals in 2006. This is repeated to get current-dollar estimates from 2003-2006.

Because we use three years of flow data to calculate each year's worth of computer assets, and our spending data covers 2003-2006, the 2003 and 2004 asset stocks include imputed flow data (from 2001 and 2002). To impute this earlier hardware spending, we start with the firm's reported spending in 2003, and apply the BLS industry-level growth rate of hardware from 2001 and 2002 to create historical values of hardware spending.

⁶ Although the SeeIT survey asked firms to report their stock of hardware, we create stocks from firm spending rather than use reported hardware stocks because we are concerned whether the asset stock measures reported by the firm truly reflect the *replacement* cost and not the *historical* cost. To be consistent between firms and with the other asset stocks we calculate, we concluded it was more reliable to use reported spending totals from the years in which the assets were purchased and apply appropriate price deflators and depreciation rates to create the asset stocks.

⁷ The rate of depreciation for computers and peripherals from the BLS is also industry-specific and depends on the composition of hardware in each industry.

Prepackaged Software

Similar to hardware, we convert all flow data reported as prepackaged software by the firm into a constant dollar measure, and use price deflators and depreciation rates from the BLS. We use the industry-level capitalization ratios from the ACES data to divide the spending into capitalized purchases, uncapitalized purchases, and leases. We also use a three-year service life. We impute the 2001 and 2002 spending on prepackaged software from the 2003 reported spending and the 2001 and 2002 industry-level growth rates of prepackaged software investment from the BLS. The constant-dollar estimates are then converted back into current-dollar estimates using the BLS price deflator for prepackaged software.⁸

Custom software

As opposed to prepackaged software, which 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). It includes expenses for programs as well as payments to freelance programmers or outside organizations to develop the software.

We begin with the firm’s reported spending on External IT services and allocate it to create two asset stocks: custom software, and miscellaneous External IT services. To identify how to allocate this spending, we use the *Service Annual Survey* conducted by the Census Bureau. We proxy for the industry providing all External IT services as NAICS industry 5415, Computer System Design and Related Services. Revenue from this industry was \$188.3 billion in 2006. The industry we proxy as custom software is NAICS 541511, Custom Computer Programming Services, and is a subset of NAICS 5415. Revenue in NAICS 541511 was \$64.3 billion in 2006. Thus, our estimated ratio of custom software spending to all External IT services spending was roughly 34% (64.3/188.3) in 2006. We do this calculation in other years and find this ratio to be steady from 2003-2006.

The 34% of External IT services spending that is allocated to custom software is further divided into capitalized and uncapitalized portions. We use BLS depreciation rates and price deflators for custom software, and use a five-year service life. We impute firm-level spending for 1999-2002 from the BLS industry-level growth rates of custom software, applied to the 2003 firm-level value of custom software investment.

Own-Account Software

The definition of 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). We begin with the firm’s reported spending on Internal IT services and allocate 50% of this to own-account software and the other 50% towards maintenance and administration, as is the current practice of the BEA (BEA 2000). The 50% that is not part of own-account software is allocated to an asset stock we call miscellaneous Internal IT services and is described further detail below.

For the part that is own-account software, we divide this into capitalized and uncapitalized portions according to the industry-level ratios in the ACES data. We use the depreciation rates and price deflators from the BLS, and use a 5-year service life. We impute firm-level spending for 1999-2002 from the BLS industry-level growth rates of own-account software, applied to the 2003 firm-level value of own-account software investment.

Miscellaneous External IT Services

This asset stock is created from the 66% of External IT Services spending that is not allocated to custom software, which includes activities such as business process consulting and integration services. This asset stock is treated as uncapitalized. There are no price deflators or depreciation rates for this capital available from the BLS, thus we use the closest available substitutes. We use a 37.2% annual rate depreciation, which is the average of R&D and advertising (following the methodology for firm-specific resources in Corrado, Hulten, and Sichel 2005, 2009). The price deflator we use is the BEA gross output deflator for NAICS 541512, Computer Systems Design Services. We

⁸ For all asset stock calculations below, we do the following: 1) Use appropriate price deflators to convert nominal flows into constant dollar flows; 2) Use the appropriate depreciation rates and service lives to create constant dollar asset stocks; and 3) Convert each year’s constant-dollar asset stocks into current-dollar asset stocks using that year’s price deflator.

use a 5-year service life, and impute firm-level spending for 1999-2002 from the BLS industry-level growth rates of custom software, applied to the 2003 firm-level value of miscellaneous External IT services spending.

Miscellaneous Internal IT Services

This asset stock is created from the 50% of Internal IT Services spending that is not allocated to own-account software, which includes activities such as maintenance and administration. This asset stock is treated as uncapitalized. We use the same depreciation rate as we do for Miscellaneous External IT Services (37.2%), and also use the gross output deflator for NAICS 541512. We use a 5-year service life, and impute firm-level spending for 1999-2002 from the BLS industry-level growth rates of own-account software, applied to the 2003 firm-level value of miscellaneous Internal IT services spending.

Training

We use the spending reported by the firm for IT-related training and convert it to an uncapitalized asset stock. We use the same depreciation rate (37.2%) as we do for the other intangible asset stocks we created (Miscellaneous Internal Services and Miscellaneous External IT Services), and the same gross output deflator (NAICS 541512) to convert the flows into constant-dollar measures. We also use a 5-year service life, and impute firm-level spending for 1999-2002 from the BLS industry-level growth rates of custom software, applied to the 2003 firm-level value of IT training.

Research and development (R&D) capital

We begin with R&D as reported by the firm (*Compustat* mnemonic XRD) and apply BEA price deflators and depreciation rates to create an R&D asset stock. The R&D depreciation rate for firms in Transportation and Warehousing (NAICS 48-49) is 18%, for Chemicals (NAICS 325) it is 11%, and for all other firms it is 15%.⁹ We use a 20-year service life for R&D. Approximately half the firms in our sample report nonzero values of R&D. Since U.S. firms are required to report R&D spending if it exceeds 1% of sales (Zhao 2002), we assume zero R&D spending for firms that do not report R&D. We create a dummy variable equal to one if a firm does not report R&D and use it in all of our estimating equations. For firms that generally report R&D, but have some values missing, we impute the missing values by taking the R&D/sales ratio for the trailing or leading five years and applying it to the sales in the year(s) of missing R&D. By current accounting practice, no R&D spending is capitalized.

Brand capital

We start with advertising spending data reported by the firm (*Compustat* mnemonic XAD) where possible. Approximately 50 percent of firms in our sample report advertising expenditures. Advertising costs are typically disclosed in financial reports when material, and so we are reasonably confident that this covers the firms that spend significant amounts on advertising. However, for the firms that do not report advertising, we use a database maintained by Kantar Media called *AdSpender*, that reports estimated advertising costs for 95% of firms covered by *Compustat*. For the handful of firms (less than 10 in our sample) that we could not get data from either source, we use industry-level advertising to sales ratios from *Schonfeld & Associates*. We construct the asset stock of advertising using a 60% depreciation rate (following Corrado, Hulten and Sichel 2005, 2009). We use the producer price index (PPI) for advertising agencies as a price deflator and use an 8-year service life. By current accounting practice, advertising is not capitalized.

Ordinary capital

We define ordinary capital as equipment, structures, land and inventories minus capitalized IT (which is either hardware only, or hardware and software depending on the estimating equation).¹⁰ In *Compustat*, this is net

⁹ The BEA rate for R&D depreciation in the computers and electronics industry is 16.5%, but we do not use IT-producing firms in our sample.

¹⁰ This is to be consistent with the BLS definition of capital. The BLS has a fifth category, rental residential capital, which only applies to the Real Estate industry (NAICS 531). Further detail can be found in BLS (1983, Appendix C).

property, plant and equipment (mnemonic PPENT) plus inventories (mnemonic INVT), minus our measure of capitalized IT. We disaggregate the net historical cost, or book value measure of property, plant, and equipment into current-cost measures of non-IT equipment, structures, and land for each firm. This adjustment was made in an attempt to keep all assets in the estimating equations in current-cost, rather than historical-cost values.¹¹

Other assets

We define other assets as total balance sheet assets (*Compustat* mnemonic AT) minus net property, plant and equipment (PPENT) and inventory (INVT). This includes financial assets such as accounts receivable, cash, other liquid assets, and any other accounting assets intangibles on the balance sheet.

IT Capabilities (ITC)

The ITC variable is based on Aral and Weill (2007). It is the sum of five components, which comprise management capability, human resource capability, IT usage in communications internally and externally, and Internet usage.¹² Each component is constructed from the sum of several questions on a 1-5 scale that were in the 2005 and 2006 SeeIT surveys.¹³ To reduce measurement error, we average both measures and give each firm a single value for the sample period. We standardize each of the five component sums to mean 0, variance 1 variables. We then add those five components, and restandardize that sum to create the mean 0, variance 1 variable we call ITC. We list the components and summary statistics of ITC in Table 5, and the distribution of ITC (from ITC_F through ITC_A) in Table 6.

Table 5. Components of IT Capabilities (ITC)		
	Average	Std. Deviation
ITC	0	1
<i>Questions on a 1-5 scale, with 5 being "most important", "facilitates significantly", or "most use"</i>		
<i>HR Capabilities</i>		
Technical skills of existing IT staff	4.57	0.50
Business skills of existing IT staff	4.53	0.50
Ability to hire competent IT staff	2.53	1.18
Skills of end-users	3.55	0.57
<i>Management Capability</i>		
Business Unit involvement in IT projects	2.60	1.14
Senior Management Support	2.56	1.16
<i>Internal IT Use</i>		

¹¹ At the end of 2006, the current-cost value of structures held by businesses was \$6,910.5 billion, whereas the net historical cost, or book value of these same structures was \$3,522.9 billion. Source: BEA Fixed Assets Table 4.1, "Current-Cost Net Stock of Private Nonresidential Fixed Assets by Industry Group and Legal Form of Organization," Line 15, and BEA Fixed Assets Table 4.3, "Historical-Cost Net Stock of Private Nonresidential Fixed Assets by Industry Group and Legal Form of Organization", Line 15.

¹² We do not have enough response data to create the sixth component in Aral and Weill (2007), which measures the degree of digitization in purchase and sales.

¹³ A much more detailed description of the questions can be found in Aral and Weill (2007).

Email	4.53	0.50
Mobile Electronic Mail (e.g., BlackBerry)	4.48	0.50
Instant Messaging	3.63	0.59
Company Intranet	3.55	0.55
Wireless (including phone and pager)	4.44	0.50
<i>Supplier IT Use</i>		
Email	4.54	0.50
Mobile Electronic Mail (e.g., BlackBerry)	4.56	0.50
Instant Messaging	3.50	0.50
Internet	3.60	0.49
Wireless (including phone and pager)	4.44	0.50
<i>Internet Capability</i>		
Sales force management	4.54	0.50
Employee performance measurement	3.10	0.89
Training	3.11	0.84
Post-sales customer support	3.00	0.86

Table 6. Distribution of Capabilities (ITC)		
Category	Meaning	Number of Observations
ITC_A	ITC > 1.5	20
ITC_B	0.5 < ITC <= 1.5	152
ITC_C	-0.5 < ITC <=0.5	196
ITC_D	-1.5 < ITC <= -0.5	108
ITC_F	ITC < -1.5	44
Total		520

Results

Our results are as follows: With our 2003-2006 dataset, we are able to recreate the Brynjolfsson, Hitt and Yang (2002) finding that \$1 dollar of computer hardware is correlated with more than \$10 of value. We then account for the “other \$9” by broadening the definition of IT to include software, and then all IT intangible spending. The value of \$1 of the broadest measure of IT is correlated with close to \$1, its theoretical value. However, our results suggest that this value is not spread evenly throughout the sample. Rather, it is positively correlated with the firms with the highest capabilities (such as the ITC_A firms) and is negatively correlated with the firms without such capabilities (such as the ITC_F firms). The difference in market value between these groups is striking: Holding fixed all physical as well as intangible assets of the firm, we estimate a 30-55% value premium to the ITC_A firms over the ITC_F firms. This finding holds up to alternative specifications as well as several robustness checks. The estimated premium of being an ITC_A firm is consistent with the observation that IT investments are riskier than ordinary investments (Dewan, Shi, and Gurbaxani, 2003) and thus, the firms that do IT well are rewarded handsomely by the market. We also estimate \$1 of R&D and brand capital is correlated with more than \$1 of value, whereas we do not find the same premiums to physical or financial capital. This further suggests that intangible assets, rather than physical assets, are what differentiate firms.

Because the market value equations use the *replacement* cost of computers (the cost to replace the stock of computers in the dollars of that year), and not *historical* cost (the cost of the computers in the year in which they were purchased), the market value of \$1 of replacement-cost computers, in theory, should be no different from year to year. This will allow us to compare our results directly to Brynjolfsson, Hitt and Yang (2002). From 1987-2006, the stock of hardware held by businesses in the United States grew 215%, from \$76 billion to more than \$161 billion (Figure 2). However, this barely outpaced the Consumer Price Index (CPI), which grew 175% during the same period. The story is very different when we take into account the quality changes to computing: U.S. businesses held 32 times as much computing power at the end of 2006 as they did in 1987.¹⁴ However, even though 20 years of technical change have produced computers of stunningly different quality, the market value of \$1 of new 1987 computers in 1987 should be no different than the market value of \$1 of new 2006 computers in 2006.

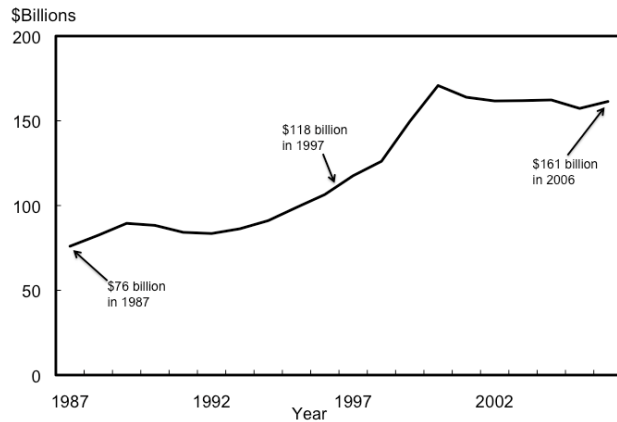


Figure 2. Computer Hardware Owned by Businesses in the United States, 1987-2006. Source: BEA Fixed Assets Table 2.1, “Current-Cost Net Stock of Private Fixed Assets, Equipment and Software, and Structures by Type,” Line 5.

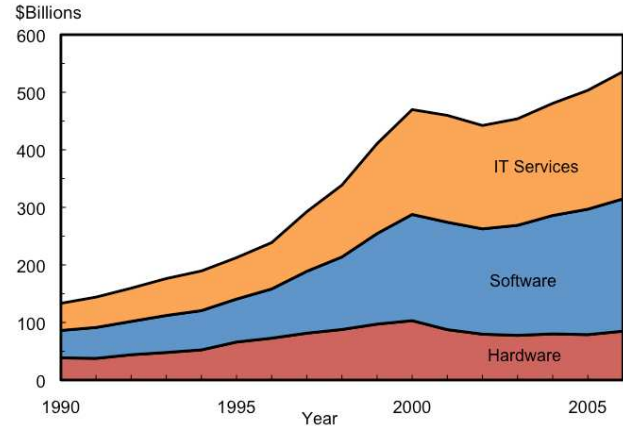


Figure 3. IT Spending by Businesses in the United States, 1990-2006. Sources: BEA NIPA Table 5.3.5, “Private Fixed Investment by Type,” and author’s calculations from the Census Bureau’s *Service Annual Survey*.

When we examine investments in IT made by businesses in the United States, 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. In our sample, we compute \$6.98 in intangible IT for every \$1 of hardware spending from 2003-2006 (Table 2). For the U.S. economy in 2003-2006, for every \$1 dollar of hardware investment, businesses spent \$6.13 in software, internal IT services and external IT services (including training). Intangible investments in IT have grown significantly in the United States from 1990-2006, from \$95 billion in 1990 to more than \$450 billion in 2006 (shown in Figure 3).¹⁵

¹⁴ 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).

¹⁵ Source: Hardware and Software (prepackaged, custom, and own-account) investment from BEA NIPA Table 5.3.5, “Private Fixed Investment by Type,” Lines 11 and 12. IT services consist of Internal IT services and External IT services. IT training is included in IT services. Since the BEA allocates 50% of all Internal IT spending for own-account software, we create a category for Internal IT Services as equal to spending on own-account software. Spending on External IT services from the *Service Annual Survey*. From 1998-2006, we use revenue in NAICS industry 5415 (Computer Systems Design and Related Services) minus 541511 (Custom Computer Programming Services), since NAICS 541511 is allocated for custom software. For 1990-1997, we use the revenue from SIC industries 7373, 7376, and 7379 as this most closely matches the industries from NAICS 5415 excluding 541511. We further adjust the SIC estimates to match the NAICS definitions by multiplying the SIC estimates by the ratio of the NAICS to SIC revenue in these industries in 1998, the only year in which data in both formats is available. We begin with 1990, the first year with data available from SIC codes 7373, 7376, and 7379 in the *Service Annual Survey*.

In Table 7, we use market value estimation of equation (2) for all three of our measures of IT, moving from the narrowest measure (purchased hardware) to including all IT-related intangibles. Column 1 is an attempt to replicate the results from Brynjolfsson, Hitt and Yang (2002). We see that one dollar of computer capital, defined as hardware only, is correlated with about \$11 of value, significantly above its theoretical value of \$1. In contrast, a dollar of ordinary capital and other assets are correlated with close to \$1. These results are similar to the results in Brynjolfsson, Hitt and Yang (2002, p.160).¹⁶ They did not maintain that that hardware itself is worth more than \$10, (and neither do we), but that this hardware is correlated with unmeasured intangibles. We examine this hypothesis in Columns 3-6.

Although \$1 of hardware is associated with about \$11 of value, \$1 dollar of IT defined as capitalized hardware and software is associated with approximately \$3-\$4 of value, as shown in Columns 3 and 4. One dollar of the broadest definition of IT (in Columns 5-6) is correlated with close to \$1 of value. In fact, we cannot reject the hypothesis that \$1 of the broadest definition of IT assets is correlated with \$1 of value. As for the other intangible assets we measure, R&D and brand, we find \$1 of each asset is correlated with significantly more than \$1 in value.

	(1)	(2)	(3)	(4)	(5)	(6)
Information Technology (<i>IT</i>) = Hardware	11.44 (3.08)	10.96 (3.28)				
Information Technology (<i>IT</i>) = Hardware, Capitalized Software			4.59 (1.05)	3.40 (0.94)		
Information Technology (<i>IT</i>) = Hardware, Capitalized Software, Other Intangibles					1.16 (0.33)	0.89 (0.29)
Ordinary Capital (<i>K</i>)	1.02 (0.05)	0.87 (0.05)	1.01 (0.06)	0.86 (0.05)	1.03 (0.07)	0.87 (0.05)
Other Assets (<i>F</i>)	1.14 (0.05)	1.02 (0.06)	1.15 (0.05)	1.04 (0.06)	1.14 (0.05)	1.03 (0.06)
R&D (<i>R</i>)		1.43 (0.27)		1.46 (0.26)		1.44 (0.27)
Brand (<i>B</i>)		7.88 (1.58)		8.01 (1.55)		7.92 (1.58)
Number of Observations	520	520	520	520	520	520

Note: All regressions are GLS, with correction for heteroskedasticity and serial correlation. Sector and year dummies are included, as well as dummies for no R&D and whether advertising was imputed.

Although \$1 of our broadest measure of IT is correlated with close to \$1 of value *on average*, our results suggest that high ITC firms account for a disproportionate share of the value IT-intangibles. In Table 8, Column 3, we estimate that holding all assets fixed, the difference in value between the ITC_A and the ITC_F firms is 3,998 – (-4,924) million, or \$8.9 billion. We estimate the difference in value between the ITC_F firms and the ITC_B firms is about \$7.6 billion. The same is true when using capitalized IT in Column 1. These differences are statistically significant at the 1% level, and are practically significant as well. Since the average market value of the firms in our sample is \$31.1 billion, an \$8.9 billion difference is almost a 30% premium in market value for the companies with the highest IT capabilities over the companies with the lowest IT capabilities.

¹⁶ Our results from OLS estimation (not shown here) are also similar to Brynjolfsson, Hitt and Yang (2002) and are qualitatively similar to our GLS results. One dollar of computer capital is correlated with more than \$10 of value, and a dollar of ordinary capital and other assets are each correlated with close to \$1 of value. When we broaden the definition of IT, we estimate coefficients closer to 1. One dollar of advertising and R&D are associated with significantly more than \$1 of value, and ITC can predict significant differences in market value.

Table 8. Financial Value as a Function of the Assets of the Firm and ITC, 2003-2006				
	(1)	(2)	(3)	(4)
Information Technology (<i>IT</i>) = Hardware, Capitalized Software	2.84 (0.94)	-0.60 (2.02)		
Information Technology (<i>IT</i>) = Hardware, Capitalized Software, Other Intangibles			0.74 (0.27)	0.01 (0.70)
Ordinary Capital (<i>K</i>)	0.94 (0.07)	0.89 (0.06)	0.93 (0.06)	0.90 (0.06)
Other Assets (<i>F</i>)	0.99 (0.06)	1.01 (0.06)	1.00 (0.06)	1.02 (0.06)
R&D (<i>R</i>)	1.77 (0.29)	1.44 (0.27)	1.79 (0.28)	1.47 (0.27)
Brand (<i>B</i>)	5.97 (1.64)	6.97 (1.63)	6.14 (1.61)	6.68 (1.63)
ITC < -1.5 (ITC_F = 1)	-5,066 (2,022)	-8,486 (2,304)	-4,924 (1,976)	-8,300 (2,333)
-1.5 < ITC < -0.5 (ITC_D = 1)	-1,281 (901)	-2,450 (959)	-1,273 (868)	-2,129 (952)
0.5 < ITC < 1.5 (ITC_B = 1)	2,372 (790)	-1,062 (919)	2,650 (761)	-652 (922)
ITC > 1.5 (ITC_A = 1)	3,951 (2,304)	-2,831 (1,730)	3,998 (2,257)	-2,570 (1,752)
IT*ITC_F		14.93 (8.08)		5.55 (3.24)
IT*ITC_D		3.42 (2.29)		0.76 (0.76)
IT*ITC_B		15.95 (3.69)		5.50 (1.36)
IT*ITC_A		71.01 (18.45)		25.81 (6.90)
Number of Observations	520	520	520	520

Note: All regressions are GLS, with correction for heteroskedasticity and serial correlation. Sector and year dummies are included, as well as dummies for no R&D and whether advertising was imputed.

Our results suggest that organizational IT practices are highly complementary to investments in IT. That is, \$1 dollar of IT capital in an ITC_A firm is correlated with significantly higher value than \$1 of IT capital in an ITC_C or ITC_F firm. This is shown in Table 8, Column 4, with the full set of interaction terms for IT and ITC. For an ITC_A firm with the sample average of the broadest measure of IT assets (\$562.9 million), the total estimated effect of IT on market value is $(25.81+0.01)*562.9 - 2,570$ million, equal to \$12.0 billion. However, for an ITC_F firm with the same amount of IT, the total estimated effect of IT on market value is $(5.55+0.01)*562.9 - 8,300$ million, equal to -\$5.2 billion. In other words, each dollar of IT is correlated with *negative* nine dollars in market value. The difference between these two groups is \$17.2 billion, significant at the 1% level, and very large in a practical sense – amounting to more than 55% of the average market value of the firms in the sample. The estimated difference between the top and bottom performers is similarly striking if we use capitalized IT instead (Column 2).

There isn't just a significant difference in value that can be explained by the extreme ends of the distribution of ITC. We also estimate significant differences in value between the average (ITC_C) firms and the ITC_A and ITC_F firms. In Table 8, Column 4, \$562.9 million of the broadest measure of IT in the ITC_C firms is estimated to be valued at 0.01×562.9 , or \$5.6 million, and this is not statistically different from 0. However, this is \$5.2 billion more than that ITC_F firms, and \$12.0 billion less than the ITC_A firms. Both of these differences are statistically significant at the 1% level.

In the analyses in Tables 7 and 8, we reject the null hypothesis that the coefficients of R&D and brand are equal to 1 against the alternative that they are greater than 1 at the 5% level of significance. We were surprised by the large value for brand, and upon further analysis, found a single, large consumer products company drove a substantial part of this value. If we drop this company from the sample and rerun the analyses in Tables 7 and 8 (not shown), we find that the coefficients of the other variables remain virtually unchanged but the coefficient for brand drops to below 5 in Table 7, and is approximately 3 in Table 8. This suggests that when it comes to brand, certain industries (such as consumer products) are disproportionately important. This observation fits with our findings that most of the IT-intangibles appear to be concentrated in a small number of firms. The same is likely true for R&D and brand.

It is unlikely that measurement error is responsible for our results. If anything, measurement error in the IT hardware, R&D, or brand variables would strengthen our conclusions, as measurement error in these variables would bias the coefficients downwards (Griliches and Hausman, 1986). Measurement error would also not explain why our ITC variable works in order in explaining differences in market value. We also reran all specifications without advertising and R&D altogether, and all the same results for IT hold. We further examine whether our results hold if we drop values from 2003 and 2004. The 2003 and 2004 IT asset stocks rely more on imputation than the 2005 and 2006 values of IT (because our IT spending data runs from 2003-2006). As well, since our organizational IT and management practice data was measured in 2005 and 2006, by dropping 2003 and 2004 we can examine whether our assumption that ITC is quasi-fixed and thus applicable to 2003 and 2004 is acceptable. Our main results still hold based only on 2005 and 2006 values for each firm.

Conclusion

Using a panel of 130 firms over the period 2003-2006, our study is the first to create comprehensive asset stocks based on IT-related intangible spending at the firm level. We build upon the framework by Brynjolfsson, Hitt and Yang (2002) who found that \$1 of computer hardware was correlated more than \$10 of market value, and that this value was accounted for by a set of complementary human resource practices. With our expanded definition of IT, that includes both purchased and internally developed software, internal IT services, external IT services, and IT-related training, we estimate these values – the “other \$9” – directly in a market value equation.

Our results suggest that IT is not a “rising tide that lifts all boats.” By using survey data that takes account of management and organizational IT capabilities (e.g., HR practices, management practices, internal IT use, external IT use, and Internet use), we find that these capabilities can help account for the value of IT intangibles. Firms with the highest IT capabilities (ITC) are correlated with significantly higher market value than the firms with the lowest IT capabilities. Holding fixed all tangible and intangible assets of the firm, we estimate that the firms in the highest ITC group have 30-55% greater market value than the firms in the lowest ITC group. We actually estimate that for every \$1 of our broadest measure of IT, firms in the lowest ITC group realize a *loss* of \$9 of market value.

Our study also uses market valuation techniques to value research and development (R&D) and brand as part of a broader effort to examine the value of intangible assets in the firm. Based on our results that R&D and brand are correlated with significantly higher market value, further research is warranted on which industries and firms drive most of this value. The results suggest that what will differentiate firms in the 21st century will be how they manage their intangible assets.

Acknowledgements

SAP supplied generous funding for this research. Erik Brynjolfsson, Lorin Hitt, Paul Hofmann, Jason Yotopoulos, the associate editor of ICIS 2010 and two anonymous referees all provided excellent suggestions and guidance. Stephanie Woerner was very helpful in supplying the dataset from the Social and Economic Implications of Information Technology (SeeIT) project, funded by NSF Grant IIS-0085725.

References

- Aizcorbe, A. M., Moylan, C. E., and Robbins, C. A. 2009. "Toward Better Measurement of Innovation and Intangibles," *Survey of Current Business* (89:1), January, pp. 10-23.
- Anderson, M.C., Banker, R.D., and Ravindran, S. 2003. "The New Productivity Paradox," *Communications of the ACM* (46:3), March, 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), September-October, pp. 763-780.
- Baily, M.N. 1981. "Productivity and the Services of Capital and Labor," *Brookings Papers on Economic Activity* (1981:1), pp. 1-65.
- 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), November, 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), March, pp. 41-68.
- Bloom, N., Sadun, R., and Van Reenen, J. 2007. "Americans Do I.T. Better: US Multinationals and the Productivity Miracle," *NBER Working Paper* 13085, May.
- 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), February, pp. 339-376.
- Brynjolfsson, E., and Hitt, L. M. 2003. "Computing Productivity: Firm-Level Evidence," *Review of Economics and Statistics* (85:4), November, pp.793-808.
- 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., McAfee, A., Sorell, A., and Zhu, F. 2009. "Scale without Mass: Business Process Replication and Industry Dynamics," Working paper, MIT.
- Brynjolfsson, E., Renshaw, A.A., and Van Alstyne, M. 1997. "The Matrix of Change," *Sloan Management Review* (38:2), Winter, pp. 37-54.
- Bureau of Economic Analysis. 2000. Recognition of Business and Government Expenditures for Software as Investment: Methodology and Quantitative Impacts, 1959-98," Washington, DC. May.
- Bureau of Economic Analysis. 2003. *Fixed Assets and Consumer Durable Goods in the United States, 1925-97*, Washington, DC: U.S. Government Printing Office.
- Bureau of Economic Analysis. 2000. "Recognition of Business and Government Expenditures for Software as Investment: Methodology and Quantitative Impacts, 1959-98," Available from <http://www.bea.gov>.
- Bureau of Labor Statistics. 1983. *Trends in Multifactor Productivity, 1948-81*, BLS Bulletin 2178.
- 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, pp. 11-46.
- Corrado, C., Hulten, C., and Sichel, D. 2009. "Intangible Capital and Economic Growth," *Review of Income and Wealth* (55:3), September, pp. 661-685.
- Crespi, G., Criscuolo, C., and Haskel, J. 2007. "Information Technology, Organisational Change, and Productivity Growth: Evidence from UK Firms," *CEP Discussion Paper No. 783*, March.
- David, P.A. 1990. "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox," *The American Economic Review* (80:2), May, 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), March, pp. 1-28.
- Gu, F., and Lev, B. 2002. "Intangible Assets: Measurement, Drivers, Usefulness," Working Paper, Stern School of Business, New York University.
- Hall, B.H., Jaffe, A., and Trajtenberg, M. 2005. "Market Value and Patent Citations," *The Rand Journal of Economics* (36:1), Spring, 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), December, 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.
- Kaplan, R.S., and Sandino, T. 2001. "Accounting for Computer Software Development Costs," Harvard Business School Note 102-034.
- Lev, B. 2004. "Sharpening the Intangibles Edge," *Harvard Business Review* (82:6), June, 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, pp. 73-110.
- McKinsey Global Institute. 2001. *U.S. Productivity Growth 1995-2000: Understanding the Contribution of IT Relative to Other Factors*. Available at <http://www.mckinsey.com>.
- Mead, C.I. 2007. "R&D Depreciation Rates in the 2007 R&D Satellite Account," Bureau of Economic Analysis/National Science Foundation 2007 R&D Satellite Background Paper, November.
- Milgrom, P., and Roberts, J. 1990. "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *The American Economic Review* (80:3), June, 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), March-May, pp. 179-208.
- Nakamura, L. 2001. "What is the U.S. Gross Investment in Intangibles? (At least) One Trillion Dollars a Year!" *Working Paper No. 01-15, Federal Reserve Bank of Philadelphia*. October.
- Oliner, S.D., Sichel, D.E., and Stiroh, K.J. 2007. "Explaining a Productive Decade," *Brookings Papers on Economic Activity* (2007:1), pp. 81-152.
- 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), November-December, pp. 61-78.
- 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.
- Tambe, P. and Hitt, L.M. 2010. "Job Hopping, Knowledge Spillovers, and Regional Returns to Information Technology Investments." SSRN Working Paper, March. Available at SSRN: <http://ssrn.com/abstract=1302637>
- Zhao, R. 2002. "Relative Value Relevance of R&D Reporting: An International Comparison," *Journal of International Financial Management and Accounting* (13:2), Summer, pp. 153-174.