An Asset Approach to Information Value

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Introduction

Can we measure the value and output of information, such as hard-to-replicate business processes, culture, human capital, organizational practices, and other firm-specific knowledge? Our research seeks to do just that. We maintain that these practices are intangible assets that, in combination, provide significant value to firms and are often missing in traditional productivity and financial analyses. Although these assets are naturally difficult to measure, we utilize a novel approach by combining and reconciling production functions and market value equations. In the first phase of our research, we use computer assets as an observed proxy for IT-related intangible assets (such as the business process redesign that accompanies large scale technology investment) and test the hypothesis that we can value such intangibles based on a multiple of the computer assets in the firm. Using annual data from 175 firms from 2003-2006, we estimate that the value of IT-related intangibles is approximately 10-12 times that of hardware. This calculation uses various specifications of both market value and production function regressions. This leads us to an estimate that U.S. corporations held \$1.4-\$1.7 trillion of IT-related intangibles from 2003-2006.

Our study's main contribution is to introduce a unified framework to examine whether flows of capital services from production functions are consistent with the underlying asset values that we estimate from market value equations. As a baseline, we begin with non-IT (ordinary) capital, and then use this framework to examine computer capital. We then further analyze our results for computer capital by explicitly incorporating the flows of capital services from IT-related intangible capital, and consider whether these flows correspond to the value placed on these assets in the securities markets. To our knowledge, there are no previous studies that use this strategy to quantify the value or returns to IT-related intangible capital. Brynjolfsson, Hitt, and Yang (2002) used market value equations to demonstrate that computers were worth significantly more than their replacement value, and that this value was accounted for by a set of complementary business and human resource practices. However, whether this additional value is \$10, \$30, or \$3 to \$1 is an unresolved question that we are attempting to answer in this research.

The recent time period of our data updates the landmark IT and productivity studies that used datasets from 10-20 years ago. Most IT and productivity studies have been carried out at the industry level since data at that level of analysis is much easier to find. Reliable, firm-level data for IT is quite difficult to find. Ours is one of the first "post-bubble" studies to examine the value of IT assets, by using a balanced panel of 175 publicly traded companies from 2003-2006.

There have been other recent attempts to quantify the size of intangible assets in the U.S. economy using aggregate data. Corrado, Hulten, and Sichel (2005, 2006) estimate that annual business investment in intangibles not included in the government's official definition of investment could be about \$1 trillion per year. This uncounted amount is about the same size as the official estimates of annual business investment. Another scholar, Nakamura, in a 2001 paper estimates that the stock of intangibles in the U.S. economy could be as high as \$5 trillion.

We seek to contribute to this literature with firm-level estimates based on a combination of production functions and market value equations.

In our first set of results, we do not measure these intangibles directly. Rather, our analysis suggests that there would be significant asset mispricing if we focused only on measured assets and did not incorporate the value of IT-related intangibles. We demonstrate that there is a significant difference between the behavior of computer capital and that of ordinary capital in market value and production functions. As a baseline, we find that $1 of ordinary capital is valued on average at about $1 by the market, and that the capital service flows from ordinary capital are in line with their predicted values from neoclassical economic theory. Yet, we find that applying the same analysis to computer capital is inadequate on two counts. First, using the same neoclassical assumptions, we see dazzling returns to computers in a production function, and significantly higher market values for computers in a market value equation. Second, if we assume investors have bid up the price of computers for these returns, and the returns come *solely* from computers and not from intangibles, it appears that investors are bidding far too much. Explicitly incorporating the IT-related intangible assets in our model gives us a reasonable explanation for both our market value and production function results. In the next phase of our research, we plan to measure these intangibles more directly using survey questions.

Data and Econometric Model

Our dataset of 700 observations consists of a balanced panel of 175 publicly traded companies using annual data from 2003 through 2006. The firm-level data comes from two sources. The first source is the Social and Economic Explorations of IT (SeeIT) survey, a two-year effort that polled firms about IT spending, assets, and technology usage. A survey respondent was typically the CIO, CTO, or IT budget analyst, and all respondents had intimate knowledge of their firm's IT resources and practices. The remainder of the firm-level data, such as market value, capital stock, sales, and expenses, comes from *Compustat Industrial Annual*, a database with financial information about every publicly traded company in the United States.

We formulate two estimating equations, the first based on output, and the second based on market value. The estimation of the production function is based on a standard Cobb-Douglas production function:

$$\ln Q_{it} = \beta_0 + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln C_{it} + controls + \varepsilon_{it} \qquad (1)$$

The variable Q_{it} is value added for firm *i* in year *t* in constant (2000) dollars. *L* represents total compensation of employees, *K* represents ordinary capital, and *C* represents computer capital. We include controls for year, industry, advertising, and research and development (R&D).

Similar to Brynjolfsson, Hitt, and Yang (2002), we use an estimating equation for market value:

$$V_{it} = \gamma_0 + \gamma_1 \ln F_{it} + \gamma_2 \ln K_{it} + \gamma_3 \ln C_{it} + controls + \varepsilon_{it} \qquad (2)$$

The value of all financial claims on the firm – equity plus liabilities – is placed on the left side of the regression and is represented by *V*. All assets that appear on a firm's balance sheet are accounted for on the right side of the regression. *F* represents financial and other assets, which include receivables, cash, and other accounting assets such as goodwill. *C*, *K*, and the controls are the same as in (1).

Our null hypothesis is that the marginal flows of capital services that we estimate in the production function are going to be equal to the marginal cost of capital. For example, in (1), holding other factors fixed, a 10% increase in ordinary capital *K* would increase value added by approximately $0.10 * \beta_2 * Q$. The cost of 10% more capital would be the rental price of that capital, which we represent as r_K, multiplied by the amount of additional capital stock, 0.10*K*. From 2003-2006, the average rental price of ordinary capital was about 12%, a figure that takes into account depreciation, taxes, and the average cost of capital. Put algebraically, our H_0 is that $\beta_3 Q = r_C C$ and $\beta_2 Q = r_K K$. The alternative hypothesis is that the marginal products and costs of capital are not equal to each other.

In the market value equation (2), our null hypothesis is that a dollar of an asset on the right side would be associated with a dollar of market value on the left side. That is, H_0 : $\gamma_1 = \gamma_2 = \gamma_3 = 1$.

According to the Bureau of Labor Statistics (BLS), the input share of computers in the private business sector from 2003-2006 was 1.04%. That is, $r_C C / Q$ was equal to 0.0104. Thus, if we estimate (1) and find that β_3 is greater than 0.0104, then computers would be more productive than our null hypothesis would predict.

Many production function regressions have estimated β_3 as greater than 0.010 (Brynjolfsson and Hitt 2003, Stiroh 2004). If computers are much more productive than the Bureau of Labor Statistics (BLS) would indicate, we would expect this capital to be bid up in the securities markets. The market value estimates in Brynjolfsson, Hitt, and Yang (2002) demonstrated that one dollar of computer capital was bid up to a value of 10 dollars or more in the financial markets. In the case of computers, we might expect

$$\beta_3 Q = r_C \gamma_3 C \qquad (3)$$

With (3), we can test the hypothesis that the market has bid up the capital to zero rents.

As an alternative to (3), let us suppose that, for every dollar that a firm spends on technology, it spends *x* dollars on business process redesign. We then explore whether we can infer the value and output of intangibles based on the quantity of observable computers. Let $I = xC$ where *I* represents intangible capital. Then, based on the properties of logs in equation (1), the output attributable to computers will represent the flows of capital services from both the observed hardware and the unobserved intangibles. Algebraically, this is:

$$\beta_3 Q = r_C C + r_I (xC) \tag{4}$$

We are left with two unknowns, r_I, the rental price of intangible capital, and *x*, the multiple of IT-intangible capital to hardware. If we estimate one value, we can rearrange (4) and infer the other value.

1. Using the market value equation (2), for example, we can posit *x* as equal to $(\gamma_3 - 1)$ and infer r_I.
2. Or, we estimate r_I by hypothesizing that the rental price of the blended IT system of hardware plus intangibles, r_{C+I} , is equal to the rental price of ordinary capital, r_K (and that $r_I < r_{C+I} < r_C$)

$$\begin{aligned} \beta_3 Q &= r_{C+I}(C+I) \\ &= r_K (C+I) \end{aligned}$$

For the ratio of *I*/*C*, of intangibles to computer assets, this reduces to:

$$\frac{I}{C} = \frac{\beta_3 Q}{r_K C} - 1 \tag{5}$$

Results

Using a pooled OLS regression, with controls for year, industry, advertising, and R&D, our main results for (2) are as following (with Huber-White robust standard errors clustered by firm in parentheses). Values are in millions of dollars.

$$\underset{}{\widehat{V}} = \underset{(1683)}{2013} + \underset{(0.02)}{1.05}\ln F + \underset{(0.08)}{1.02}\ln K + \underset{(5.86)}{10.91}\ln C + controls$$

$$n = 700, R^2 = .98$$

The point estimates above indicate that a dollar of financial assets is correlated with \$1.05 of market value, and a dollar of ordinary capital is associated with \$1.02 of market value. These estimates are incredibly close to their theoretical values, especially when considering our small sample size. However, a dollar of computer capital is correlated with \$10.91 of value. While the standard error for computers is significantly higher than the standard errors for the other kinds of capital, the 90% confidence interval is [\$1.22, \$20.61].

Is the additional value attributed to computers in line with its output contribution? We display our OLS results of estimating (1):

$$\ln \widehat{Q} = \underset{(0.268)}{0.114} + \underset{(0.028)}{0.742}\ln L + \underset{(0.021)}{0.243}\ln K + \underset{(0.0114)}{0.0337}\ln C + controls$$

$$n = 700, R^2 = .97$$

We estimate the output elasticity of computer capital to be .0337, well above the null hypothesis that the output elasticity of computer capital would be .0104. The 95% confidence interval for our estimate is [.0113, .0562], so we can reject the null that flows of capital services from computer capital are at their neoclassical values.

We now connect these results together, beginning with ordinary capital. According to our production function estimate, increasing the capital stock by 10% would yield an approximate increase of 0.10*0.243 to value added, or about 2.43%. In our sample, the annual aggregate value added for the 175 firms averaged $1,104 billion, so increasing $1,104 billion by 2.43% is approximately $26.8 billion. That is on the output side. We now evaluate the cost side. The average annual aggregate capital stock for the sample was $2,483 billion, and 10% of that is $248 billion. Putting output and cost together, increasing the capital stock by 10%, or $248 billion, yields a gross return of $26.8 billion. That's a 10.8% return. However, the average rental price of capital in our sample was 12%. This is the neoclassical return we would expect the capital stock to generate. Our point estimate on the net rents on capital is thus 10.8% minus 12%, or -1.2%. Our 95% confidence interval for the output elasticity of ordinary capital is [.2017, .2838] and includes zero rents (using the bottom estimate of .2017 yields a -3.0% rent, while the top estimate of .2838 yields a rent of 0.7%).

In analyzing computer capital, we are challenged by two sets of abnormal results. First, the returns to computer capital appear well above their rental prices. Increasing computer capital by 10% would add 0.10*0.0337*1109 to value added, or about $3.8 billion. Since the average annual aggregate capital stock of computers for the sample was $24.0 billion, then an increase of 10% would cost $2.4 billion. If a $2.4 billion investment yields $3.8 billion in gross returns, that is a remarkable 153%. According to the BLS, the rental price of computers is about 51% per year. This is much higher than ordinary capital, because computers depreciate so quickly (about 30% per year). So the return appears to be a 103% rent above the 51% neoclassical return.

The high output elasticity of computer capital that we observe is consistent with the literature. Stiroh's (2004) meta-analysis provides an estimate of the output elasticity of computers to be .046. Brynjolfsson and Hitt (2003) estimate a computer elasticity of .0483 with their primary data set. Brynjolfsson, Hitt, and Yang (2002) report an elasticity of computer capital of .045.

We now compare the market value of computers in relation to their output, using the framework in equation (3). Suppose that the BLS is systematically underestimating the rental prices for computers, and that the market is bidding up the price of computer capital to zero (or near-zero) net returns. Recall that according to our production function estimate, a 10% increase in our sample's computer capital resulted in an increase of $3.8 billion value added per year. If the market is bidding $10.91 per $1 of computer capital inside these firms, then we multiply the 10% increase in computer capital ($2.4 billion) by 10.91, which would yield $26.1 billion. Paying $26.1 billion for $3.8 billion of capital service flows is a 14% gross return. For computers, that is a very low return since the rental price of computers is 51% per year – implying a net negative return of 36% per year!

This scenario of very negative returns occurs if we focus *solely* on computers as the explanation of higher value and productivity. If instead we use equation (5) and substitute $\beta_3 = 0.0337$, $Q = 1109$, $r_K = 0.12$, and $C = 24.0$, then $I / C = 11.97$. This is not very different than our market value estimates. Remarkably, only production function data is used to calculate this value – and no data from the market value equation is used at all. Thus, a multiple of about 12 to 1 is what we would call one estimate of the value of IT-related intangibles. This is implied by the production function if we posit that the rental price of capital for the system of $C + I$ is the same as ordinary capital *K*.

Our financial valuation and production functions complement each other. If we relied solely on the market value equations themselves, we would produce a useful update of Brynjolfsson, Hitt and Yang (2002) whose data is from 1987-1997, but we would have no way to tell whether the asset prices we observe for computers and their related intangible complements are reasonable. Moreover, if we focused solely on production functions in order to estimate the size of IT-related intangible assets, we would have no other confirmation of how reasonable this estimate is.

Further Study

In the next phase of our research, we plan to use additional survey data from the SeeIT survey to better match the value of intangibles to the output they generate. In our initial results, we did not measure these intangibles directly. Rather they were measured indirectly based on the premise that computer investment and intangibles are highly correlated. By using organizational practice data, we can more directly match the value of IT-related intangibles to output. In addition to organizational practices, we will also use the SeeIT survey to incorporate more comprehensive IT spending data (such as software, services, and IT labor) and add more controls to our earlier specifications. This will allow us to better isolate the value of intangibles and rule out other explanations that might have been driving our earlier results.

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