

A New Approach to the Valuation of Intangible Capital

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Abstract

Intangible capital can be thought of as the distinctive way in which firms generate value from a given set of inputs. This perspective naturally leads to an interpretation of intangible capital as the difference between the value of installed and uninstalled inputs. Hence, intangible capital is an adjustment cost, not a separate factor of production. In equilibrium, the adjustment cost is equal to the marginal product of intangible capital. Based on this approach, I highlight the role of two types of intangibles: intellectual property, which is associated with spending on R&D and advertising, and organizational capital, which is associated (at least narrowly) with spending on information technology. Estimates using firm-level panel data suggest that organizational capital has a gross marginal product of about 70 percent annually, while intellectual property earns a return that's less than its marginal cost. Furthermore, I show that estimates from misspecified empirical models — which don't control for unobserved heterogeneity and simultaneity, and don't allow for the possibility that the stock market mismeasures the value of intangible-intensive companies — are upward-biased.

Baruch Lev has been instrumental in shaping my thinking about intangible assets. I thank him for his guidance and for providing me with the dataset on IT investment that he and Suresh Radhakrishnan put together. Special thanks go to Suresh for cheerfully answering my queries. I am also indebted to Stephen Bond, whose collaboration lays the foundation for this research. Daniel Cooper provided research assistance. The editors, CRIW conference participants, and Darrel Cohen provided helpful comments and suggestions. The data on earnings expectations are provided by I/B/E/S International Inc. The views presented are solely mine and do not necessarily represent those of the Federal Reserve Board or its staff.

1 Introduction

Almost without exception, there are no direct measures of the value generated by intangible capital. Indirect measures have evolved to fill the void. For example, Sweden's Skandia developed indicators of its intellectual capital for its annual report.¹ However, in the absence of wider disclosure about expenditures on intangibles, researchers have relied on equity markets to infer the value of intangibles.

The equity market approach to valuing intangibles is attractive because of its simplicity. If the equity market reveals the intrinsic value of the firm, then the value of intangible assets must be the residual after subtracting the value of tangible assets from the market value. For example, the market value of Enron was \$80 billion in March 2001 and its tangible assets were worth approximately \$12 billion. Using the equity market approach, the value of Enron's intangibles was \$68 billion (\$80 billion - \$12 billion = \$68 billion), or so the argument goes. Recent revelations indicate rather too persuasively that the value of Enron's intangibles was, in fact, considerably overstated by the stock market.

It may be unfair to blame the equity market for failing to anticipate Enron's collapse, although it must be noted that market participants ignored publicly available evidence about Enron's shaky foundation.² Taking a broader perspective, the collapse of the NASDAQ 100 index also calls into question the equity market approach. To take one of dozens of possible examples, we might legitimately wonder "what happened to

¹In 1995, Skandia first released a supplement to its financial statement that quantified the company's efforts to build intellectual capital using indicators like the number of employees with college degrees and the share of new products in revenue. In its current annual report, however, Skandia does not report such items.

²For example, in a March 2001 article for *Fortune*, Bethany McLean asked the question "How exactly does Enron make its money?" and proceeded to give a chilling answer.

Yahoo!'s intangibles?" Using the equity market approach, two years ago Yahoo!'s intangibles were worth upwards of \$100 billion. Now they are worth less than a tenth of that number. Of course, these changes do not necessarily pose a problem for the equity market approach. Yahoo!'s market capitalization could reflect changes in expected profits or expected returns or both. But the Yahoo! example does illustrate a potential pitfall from using the equity market approach. If asset prices don't reflect fundamentals, then the value of intangible capital is overstated by the size of the mismeasurement.

More generally, the equity market approach to valuing intangibles is a catch-22: there can be no valuation of intangibles without information about them, but there can be no information about intangibles without valuation of them. For the equity market to work efficiently, investors must have information about intangibles. But, investors do not have the information because intangibles are so difficult to value. This circular reasoning calls into question the almost fetishistic adherence to strongly efficient markets that is the basic assumption underlying the equity market approach. How can the value of the firm as revealed by equity markets be equal to the intrinsic value of the firm — defined as the present discounted value of cash flows — when so little is known by market participants about the value of intangibles?

There can be only limited progress in understanding the role of intangibles if researchers continue to discount the possibility that the stock market fails to reveal everywhere and always the exact expected value of intangibles. As a first task, I present a model in which the value of intangibles can be estimated whether or not the stock market is strongly efficient. As a consequence, I establish the conditions under which the equity market can be used to infer the value of intangibles. The basic requirement is intuitive: the stock market cannot mismeasure the intrinsic value of intangible-intensive

companies by more than it mismeasures the intrinsic value of tangible-intensive companies. Replacing intangible-intensive and tangible-intensive in the preceding sentence with 'new economy' and 'old economy' underlines how suspect this condition is. It amounts to a conviction that the stock market mismeasures the value of the Yahoo!s of the world by less than it mismeasures the value of, say, the Union Pacific Railroads of the world.

As an alternative to using the stock market to infer the value of intangibles, I rely on analysts' profit forecasts. IBES has collected data on profit forecasts for a large sample of companies since 1982. The analysts report long-term forecasts, out to a five-year horizon. If intangibles are expected to contribute materially to the bottom line over that horizon, then their value is reflected by analysts' forecasts. Of course, such forecasts are not a panacea. After all, the majority of analysts did not anticipate Enron's collapse. But analysts, perhaps unlike the marginal investor, are well-informed about the companies and industries they are paid to follow. Next to company management, analysts are most likely to know that, for example, a new supply chain management system at Dell increases intangible capital and, as a result, generates additional profits.

I use analysts' forecasts to construct estimates of the discounted value of expected future profits. I use this estimate instead of the equity value of the firm in the empirical model I develop. Combined with a dataset that distinguishes among tangible capital, information technology (IT), and intellectual property (IP), I estimate whether \$1 of IT and of IP capital are associated with extraordinary expected profits. If they are, it will bolster the assertions of those who argue that intangibles generate huge returns or are a marker for other unobservable investments. If not, it will provide a sobering check on

new economy enthusiasts and further underline the danger of using the stock market to value hard-to-measure investments.

2 The Valuation of Intangible Capital

2.1 Intangible Capital: An Instrumental Definition

I distinguish between two types of intangibles, intellectual property and organizational capital. Broadly defined, IP includes patents, trademarks, copyrights, brand names, secret formulas and so on. For my purposes, I define organizational capital as business models, designs, and routines that create value from information technology. Without a doubt, organizational capital is a broader concept than this definition suggests. For example, innovative compensation policies and effective training programs are surely part of a broader definition of organizational capital. Indeed, the systematic focus on creating organizational capital can be traced to Fredrick Winslow Taylor and his intellectual forebearers. I adopt a definition based on IT not because IT is qualitatively different from any other technology that aids organizational efficiency, but because it is so preeminent nowadays.

The primary reason for my dichotomous taxonomy is instrumental; it suits my empirical model and the data. In terms of the data, companies report expenditures on R&D and advertising, which create what I have defined as intellectual property. These expenditures can be capitalized to create the IP capital stock. It may seem like such a stock is essentially arbitrary — there is little guidance, for example, about how R&D and advertising depreciate — but it should be recognized that the stock of property,

plant, and equipment is a similarly unpalatable concept, even though researchers have become sufficiently inured of it.³

At a practical level, it's important to distinguish between intellectual property and organizational capital because the data show that IP cannot be increasing substantially in importance. Nakamura (1999) reports that advertising as a proportion of nonfinancial corporate gross domestic profit grew from 3.9 percent in the period 1980-89 to 4.1 percent in 1990-97. The comparable figures for R&D are 2.3 percent in 1980-89 and 2.9 percent in 1990-97. Moreover, careful research on the value of R&D and advertising suggests that these expenditures earn somewhat less than normal rates of return (see, e.g., Hall 1993). Hence, if we suspect that intangibles generate extraordinary value, organizational capital must be the driver.

So what exactly is organizational capital? As a purely mechanical matter, organizational capital is the adjustment cost from IT investment, defined as the difference between the value of installed and uninstalled IT.⁴ Suppose a company purchases database software — and it is worthwhile to keep in mind that software is tangible capital in U.S. company and national accounts. The software by itself does not generate any value. At a minimum, the software has to be combined with a database and, perhaps, a sales force to create value. Organizational capital defines how the database is used and, consequently, creates value from the software investment.

A specific example illustrates the definition. Dell's value depends on a unique organizational design which sells build-to-order computers direct to customers. There's

³Indeed, the accounting for physical assets in financial statements may be about as deficient as the accounting for IP. Physical assets are capitalized at historical costs and are depreciated in ways that may be poor approximations to the service flow. Perpetual inventory capital stocks constructed from such data may also be only loose approximations to the service flow of capital.

⁴This rather narrow definition based on IT adjustment costs is motivated by a broader interpretation of organizational capital in terms of adjustment costs, as in, for example, Prescott and Visscher (1980).

little difference between Dell's and Compaq's tangible capital stock since both companies assemble computers. The reason any given piece of tangible capital is more valuable when it is installed at Dell has to do with Dell's unique organizational capital embodied in its business model and routines. Compaq cannot replicate Dell's tangible capital stock and become another "Dell." That's because organizational capital is not a factor input itself. Instead, organizational capital is a distinct way of combining the usual factors of production.

Organizational capital, as I have defined it, is by its very nature inexorably linked with IT. It may be embedded in tangible assets like computers and software, and in workers (as with computer programmers' ideas), leading to considerable interaction between tangible and intangible assets in the creation of value. When there are such interactions, the valuation of intangibles on a standalone basis becomes impossible.⁵ But in the model in the next section, the values are connected. This is because organizational capital is whatever makes installed capital more valuable than uninstalled capital. The same goes for intellectual property.

2.2 Theoretical Model

In each period, the firm chooses investment in each type of capital good: $\mathbf{I}_t = (I_{1t}, \dots, I_{Nt})$, where j indexes the N different types of capital goods and t indexes time.⁶ This is equivalent to choosing a sequence of capital stocks $\mathbf{K}_t = (K_{1t}, \dots, K_{Nt})$, given \mathbf{K}_{t-1} , to

⁵This is the view espoused by Lev (2001).

⁶The firm index i is suppressed to economize on notation except when it clarifies the variables that vary by firm.

maximize V_t , the cum-dividend value of the firm, defined as:

$$V_t = E_t \left\{ \sum_{s=t}^{\infty} \beta_s^t \Pi(\mathbf{K}_s, \mathbf{I}_s, \epsilon_s) \right\}, \quad (1)$$

where E_t is the expectations operator conditional on the set of information available at the beginning of period t ; β_s^t discounts net revenue in period s back to time t ; Π is the revenue function net of factor payments, which includes the productivity shock ϵ_s as an argument. Π is linear homogeneous in (K_s, I_s) and the capital goods are the only quasi-fixed factors — or, equivalently, that variable factors have been maximized out of Π . For convenience in presenting the model, I assume that there are no taxes and the firm issues no debt and has no current assets, although these considerations are incorporated in the empirical work.

The firm maximizes equation (1) subject to the series of constraints:

$$K_{j,t+s} = (1 - \delta_j)K_{j,t+s-1} + I_{j,t+s} \quad s \geq 0 \quad (2)$$

where δ_j is the rate of economic depreciation for capital good j . In this formulation, investment is subject to adjustment costs but becomes productive immediately. Furthermore, current profits are assumed to be known, so that both prices and the productivity shock in period t are known to the firm when choosing I_{jt} . Other formulations — such as one where there is a production and/or a decision lag — are possible but this is the most parsimonious specification.

Let the multipliers associated with the constraints in equation (2) be $\lambda_{j,t+s}$. Then the first-order conditions for maximizing equation (1) subject to equation (2) are

$$-\left(\frac{\partial \Pi_t}{\partial I_{jt}}\right) = \lambda_{jt} \quad \forall j = 1, \dots, N \quad (3)$$

and

$$\begin{aligned} \lambda_{jt} &= \left(\frac{\partial \Pi_t}{\partial K_{jt}}\right) + (1 - \delta_j) \beta_{t+1}^t E_t [\lambda_{j,t+1}] \quad \forall j = 1, \dots, N \\ &= E_t \left[\sum_{s=0}^{\infty} \beta_{t+s}^t (1 - \delta_j)^s \left(\frac{\partial \Pi_{t+s}}{\partial K_{j,t+s}}\right) \right]. \end{aligned} \quad (4)$$

Combining equations (3) and (4) and using the linear homogeneity of $\Pi(\mathbf{K}_t, \mathbf{I}_t, \epsilon_t)$,

$$\begin{aligned} \sum_{j=1}^3 \lambda_{jt} (1 - \delta_j) K_{j,t-1} + \epsilon_t &= \Pi_t + \beta_{t+1}^t E_t \left[\sum_{j=1}^3 \lambda_{j,t+1} (1 - \delta_j) K_{jt} \right] \\ &= E_t \left[\sum_{s=0}^{\infty} \beta_{t+s}^t \Pi_{t+s} \right] \\ &= V_t. \end{aligned}$$

Assuming that $N = 3$, the value of the firm can be expressed as the sum of the installed values of the beginning-of-period capital stocks, which according to equation (2) are equal to the difference between the current capital stock and current investment,

$$V_t = \lambda_K (K_t - I_t) + \lambda_{KIT} (KIT_t - IT_t) + \lambda_{KIP} (KIP_t - IP_t) + \epsilon_t \quad (5)$$

where investment in tangible capital (excluding IT), in information technology, and in intellectual property are I , IT , and IP ; the capital stock (excluding IT) is denoted by K , and the IT and IP capital stocks are distinguish by appending IT and IP .

According to equation (3), the multipliers on each capital stock are equal to the price of capital including adjustment costs. In equilibrium, this marginal cost of an additional unit of capital is equal to its net marginal product, defined by the Euler equation (4). Interpreting these multipliers in terms of organizational capital and intellectual property is straightforward since the intangibles are themselves the multipliers. This interpretation also clarifies why intangibles are not another factor of production that can be purchased, like a computer or a college graduate. Intangibles are, by their very nature, firm-specific.

Let's return to the Dell example to explain why. Dell isn't more valuable than Compaq because it has more tangible capital, IT, or IP. (Indeed, a naive comparison of the companies' balance sheets might suggest that Compaq is the stronger company.) Dell is more valuable than Compaq because Dell's build-to-order business model — embodied in λ_{KIT} and, perhaps, to a lesser extent in λ_{KIP} — creates more profit per unit of capital.

If we knew more about the characteristics of intangible capital, it would be possible to write down sensible expressions for the functional forms of the marginal product and marginal cost of an additional unit of IT and IP capital.⁷ In the absence of such expressions, we can estimate the multipliers directly using equation (5). A regrettable drawback of this approach is that the estimated multipliers are assumed to be constant, albeit after controlling for the unobservable productivity shock which contains a firm-specific effect, a time-specific effect, and an idiosyncratic component. To the extent

⁷Cummins and Violante (2002) make some progress on this front using a general equilibrium model in which adjustment costs depend explicitly on the cost of training workers so that they can upgrade to the frontier vintage of capital.

that the multipliers are not constant, the estimates will be averages of the multipliers.⁸ Certainly, then, caution should be exercised in interpreting the coefficients as structural parameters.

3 Estimation of the Empirical Valuation Equation

To estimate the empirical valuation equation (5), two primary issues have to be confronted:

- The value of the firm is unobservable.

What I have called the equity market approach assumes either that the stock market value of the firm, V^E , equals the intrinsic value of the firm, V , or that any market mismeasurement is orthogonal to the firms' current capital stocks and investments. Since such a condition is at least suspect, I propose an alternative that arguably rests on firmer footing.

- The productivity shock ϵ — think of a new product or process — is unobservable to the econometrician and it affects both the value of the firm and its investment policy.

As a result, the coefficients in the empirical specification cannot be estimated with OLS or variants (GLS, Within-Groups, and so on). Instead, I use the system-GMM estimator proposed by Blundell and Bond (1998, 2000). They show that the system-GMM estimator performs well when there are fixed effects and the

⁸Cross-sectional estimation does not sidestep this problem completely since the estimates would still be averages across firms. Moreover, such a half-way approach is inadvisable since it doesn't control for firm- and time-specific effects.

endogenous variables have near unit roots, as is true of all three of the capital stocks.

I deal with each issue in turn.

3.1 Unobservable Value of the Firm

The most widely-used proxy for the intrinsic value of the firm is its stock market value. According to one view of the stock market, this makes good sense since share prices reflect the present discounted value of expected future distributions from the firm to its shareholders. If this is the case, there are two possible explanations for share price movements: changes in expected future profitability that support future dividend payments, or changes in expected returns. Hence, share prices of intangible-intensive companies may have been rising until 2000 on advance news of unprecedented profit growth (see, e.g., Hall 2001). Another possibility consistent with this view is that investors decided that the stock market was much less risky than they previously thought. For example, Siegel (1999)'s seminal book argues that the safest long-term investment vehicle has been stocks, not bonds. Accordingly, investors may have realized that they were irrationally fearful of stocks. Now requiring a lower expected return in a world in which stocks are not really all that risky, rational investors bid up stock prices. In other words, the equity premium was too high in the past but it's just right now.⁹

Another view of the stock market cautions that share prices may sometimes have a life of their own, away from the intrinsic level represented by the present discounted

⁹McGrattan and Prescott (2000) use this argument to conclude that "it is troubling that economic theory failed so miserably to account for historical asset values and returns while, at the same time, it does so well in accounting for current observations." The "current observations" in their study date from the beginning of 2000, so apparently we are back in a world in which the economic theory needs some work (see also Kiley 2000).

value of future distributions. The theoretical possibility that share prices deviate from their intrinsic value because of a rational bubble has long been recognized.¹⁰ Outside of this particular paradigm, there is an abundance of models in which share prices are influenced by noise traders, fads or other psychological factors. While we cannot explain the disconnect between asset prices and their intrinsic values, simple observation of the behavior of — to name just two examples in addition to the ones already discussed — tulip prices in 1634-37 and Japanese share prices in 1989, suggests that such behavior is difficult to dismiss on empirical grounds. In which case, the recent stock market boom and at least partial bust may be another example of such anomalies. Indeed, Shiller (2000) argues that investors have not rationally learned that the stock market is less risky than they previously thought. Rather, he details a whole host of reasons why investors are irrationally exuberant.

It is important to highlight the key distinction between these two different views of the stock market. In the first, market efficiency is treated as a maintained hypothesis. In the second, market *inefficiency* is treated as a maintained hypothesis. To illustrate the implications of this, suppose we pick a stream of expected profits. The first theory tells us what the (possibly time-varying) discount rate (i.e., the return) must be in order to justify the observed stock price. The second theory tells us that there is some reason outside the basic model — bubbles, noise traders, fads, or the like — why the stock price differs from its intrinsic value. It's very difficult to determine which of these explanations is preferable because they both rely on unobservable factors to explain the very same data. To have any degree of confidence in either explanation, one must

¹⁰A rational bubble occurs when the expected discounted future price does not converge to zero in the limit. There are both theoretical and empirical arguments that can be used to rule out rational bubbles (see, e.g., Campbell, Lo, and MacKinlay 1997, chapter 7). Hence, rational bubbles are unlikely to offer a persuasive explanation for financial market behavior.

exploit the testable implications of the dynamic stochastic structure of the unobservable factors. To do so I set out a model based on joint research with Stephen Bond (2000, 2002).

Suppose the stock market reveals the intrinsic value of the firm with some error, so that

$$V_t^E = V_t + \mu_t, \quad (6)$$

where μ_t is the measurement error in the equity valuation V_t^E , regarded as a measure of the intrinsic value V_t . Substituting V_t^E for V_t in equation (5) then gives the empirical valuation equation when there are noisy share prices:

$$V_t^E = \lambda_K(K_t - I_t) + \lambda_{KIT}(KIT_t - IT_t) + \lambda_{KIP}(KIP_t - IP_t) + (\mu_t + \epsilon_t). \quad (7)$$

Ignoring the difficulties presented by the unobservable productivity shock, which are considered in the following section, the model's dependent variable is measured with error. The folk wisdom is that measurement error of this type biases the standard errors but not the coefficient estimates (see, e.g., Hausman 1991). However, this is untrue when the measurement error is correlated with the explanatory variables, as would be the case if the stock market tends to do a poorer job measuring the value of intangible-intensive companies than tangible-intensive companies. In that case, it seems likely that $\hat{\lambda}_{KIT}^{OLS}$ and $\hat{\lambda}_{KIP}^{OLS}$ would be upward-biased, leading to an overstatement of the value of intangible capital.¹¹ Identification requires construction of an alternative estimate of V_t .

¹¹In the multivariate case, it is not possible to sign the bias based on a priori reasoning.

As an alternative to using the stock market to infer the value of intangibles, I rely on analysts' profit forecasts. Intangible assets create value only to the extent that they are expected to generate profits in the future. Professional analysts are paid to forecast the future profits of the firms they track — and leading analysts are paid very well indeed for performing this role. Thus we can ask whether analysts are forecasting profit growth in line with the intangible asset growth that seems to be implied by stock market valuations. Though the popular press regularly lambastes analysts for being too optimistic, the answer is 'no'.¹² After introducing the data in the next section, I show that analysts' forecasts of future profits are unbiased and informative, at least for my sample.

Combining these forecasts with a simple assumption about the discount rates β_{t+s}^t , I construct an alternative estimate of the present value of current and future net revenues as

$$\hat{V}_t = E_t \left(\Pi_t + \beta_{t+1}^t \Pi_{t+1} + \dots + \beta_{t+s}^t \Pi_{t+s} \right). \quad (8)$$

I then use this estimate in place of the firm's stock market valuation. Clearly the estimate \hat{V}_t will also measure the firm's intrinsic value, V_t , with some error v . The potential sources of measurement error include truncating the series after a finite number of future periods, using an incorrect discount rate, and the fact that analysts forecast net

¹²Of course, armed with a time-varying, firm-specific discount rate, one can equate any stream of profit forecasts to the observed stock price at every observation; without additional restrictions there are, in fact, an infinite number of paths of time-varying discount rates that can equate the two. The key point is that extreme assumptions would be required to obtain the V^E 's in the sample from the analysts' forecasts of future profits. Share prices appear to be high not only in relation to current profits, but also in relation to the best available forecasts of likely future profits.

profits rather than net revenues. The resulting empirical valuation equation is:

$$\hat{V}_t = \lambda_K(K_t - I_t) + \lambda_{KIT}(KIT_t - IT_t) + \lambda_{KIP}(KIP_t - IP_t) + (v_t + \epsilon_t). \quad (9)$$

As discussed in the following section, identification will depend on whether the measurement error v is uncorrelated with suitably lagged values of instruments, for example, capital stocks. This seems plausible since the current measurement error from using analysts' forecasts is unlikely to be correlated with lags of the capital stock. Ultimately, however, this is an empirical question that will be investigated using tests of overidentifying restrictions.

3.2 Unobservable Productivity Shock

Despite some important differences, the empirical valuation equations resemble production functions. In particular, the unobservable productivity shock consists of a firm-specific, a time-specific, and an idiosyncratic component. This similarity is unfortunate because, as Griliches and Mairesse (1999) say, "In empirical practice, the application of panel methods to micro-data have produced rather unsatisfactory results." Hall and Mairesse (1996, 1997) show that attempts to control for unobserved heterogeneity and simultaneity — both likely sources of bias in the OLS results — have produced implausible estimates. In particular, the application of GMM estimators, which take first differences to eliminate unobservable firm-specific effects and use lagged instruments to correct for simultaneity in the first-differenced equations, has produced especially unsatisfactory results.

Bond and Blundell (1998, 2000) show why. The problems are related to the weak correlation between the regressors and the lagged levels of the instruments. This results in weak instruments in the context of the first-differenced GMM estimator. Bond and Blundell show that these biases can be dramatically reduced by incorporating more informative moment conditions that are valid under quite reasonable conditions. Essentially, their approach is to use lagged first-differences as instruments for equations in levels, in addition to the usual lagged levels as instruments for equations in first-differences. The result is the so-called system-GMM estimator, which I use as the preferred estimator. This is implemented using DPD98 for GAUSS (Arellano and Bond 1998).¹³

There are two types of diagnostic tests for the empirical models. First, I report the p -value of the test proposed by Arellano and Bond (1991) to detect first- and second-order serial correlation in the residuals. The statistics, which have a standard normal distribution under the null, test for nonzero elements on the second off-diagonal of the estimated serial covariance matrix. Second, I report the p -value of the Sargan statistic (also known as Hansen's J -statistic), which tests the joint null hypothesis that the model is correctly specified and that the instruments are valid.¹⁴

3.3 A digression on what can be learned from misspecified empirical valuation models

Brynjolfsson and his collaborators — see, e.g., Brynjolfsson, Hitt, and Yang (2000) — have argued that estimating a properly specified empirical model does not allow the

¹³In all specifications, time effects are captured by including year dummies in the estimated specifications.

¹⁴Formally, the Sargan statistic is a test that the overidentifying restrictions are asymptotically distributed $\chi^2_{(n-p)}$, where n is the number of instruments and p is the number of parameters.

econometrician to identify the value of intangible capital. They estimate a specification similar to the one in equation (7) using OLS and variants, finding coefficients on IT capital of around 10. According to their interpretation, the stock market doesn't literally value \$1 of IT capital at \$10, Rather, the estimate of 10 is a "marker" for related intangibles that generate \$9 in value.

The model I have presented shows that the value of intangible capital cannot be inferred from a misspecified empirical model in which some measure of intangible capital is an omitted variable. Nevertheless, for the sake of comparison, consider for notational simplicity a case in which the firm has only IT capital and there is some unmeasured intangible capital, called KIC . The Brynjolfsson et al. argument says that the coefficient estimate on IT capital in a valuation equation, call it β_{KIT} , can be used to measure the omitted effect of intangible capital.

As a straightforward analysis of omitted variable bias reveals, this is incorrect. In terms of a large sample result,

$$p \lim b_{KIT} = \beta_{KIT} + \beta_{KIC}\beta_{KIC,KIT},$$

where β_{KIC} is the marginal effect of the omitted intangible capital on value — what we would like to know — and $\beta_{KIC,KIT}$ is the coefficient estimate from a hypothetical regression of the omitted intangible KIC on IT capital: $\beta_{KIC,KIT} = \text{COV}(KIC, KIT)/\text{VAR}(KIT)$. To learn anything about β_{KIC} , assumptions have to be made about both β_{KIT} and $\beta_{KIC,KIT}$. It may be reasonable to suppose that β_{KIT} is about unity. But what is reasonable for $\beta_{KIC,KIT}$? We might figure that \$1 of IT capital is associated with more than \$1 of omitted intangible capital, which means that $\beta_{KIC,KIT} > 1$. Hence, the coefficient estimate we are interested in, β_{KIC} , could well be around unity if $\beta_{KIC,KIT}$ is large enough

so that $\beta_{KIT} + \beta_{KIC}\beta_{KIC,KIT} \approx 10$.¹⁵ In any event, such speculation rests on assumptions about relationships we know little about. That's what motivates the estimation of a model which is robust to measurement error in proxies for firms' intrinsic value, and to unobserved heterogeneity and simultaneity.

4 Data

4.1 Sources and definitions

The limiting factor in terms of the data is the availability of information about IT outlays. For IT expenditures I use a data set compiled by Lev and Radhakrishnan from *Information Week*, which is in turn based on surveys by the Gartner Group. The total sample is an unbalanced panel of firms that appeared in the *Information Week* 500 list between 1991 and 1997 and for which Compustat and IBES data are available.

The variables used in the empirical analysis are defined as follows:

- V^E is the sum of the market value of common equity (defined as the number of common shares outstanding multiplied by the end-of-fiscal-year common stock price) and the market value of preferred stock (defined as the firm's preferred dividend payout divided by S&P's preferred dividend yield obtained from Citibase).
- \hat{V} is the present value of analysts' profit forecasts. Let NI_{it} and $NI_{i,t+1}$ denote firm i 's expected profits in periods t and $t + 1$ formed using beginning-of-period

¹⁵As a purely empirical matter, Brynjolfsson et al.'s interpretation of the coefficient estimate on IT capital is quite puzzling. When a variable that measures organizational intangibles is added to the regressions, β_{KIT} is unaffected. If the additional variable better measures intangibles, then the coefficient estimate β_{KIT} has to be affected since it's a "marker" for intangibles. Since it's unaffected, the variable that's supposed to measure organizational capital must be uninformative, or β_{KIT} is biased for another reason, such as the stock market mismeasurement that I've highlighted.

information (i.e., period $t - 1$ information). Let EGR_{it} denote firm i 's expected growth rate of profits in the following periods formed using beginning-of-period information. Notice, I date the stock market valuation of the firm, V^E , at time $t - 1$ so the market information set contains these forecasts. We calculate the implied level of profits for periods after $t + 1$ by growing out the average of NI_{it} and $NI_{i,t+1}$ at the rate EGR_{it} . Let this average be ANI_{it} .¹⁶

The resulting discounted sequence of profits defines \hat{V}_{it} :

$$\begin{aligned}\hat{V}_{it} = & NI_{it} + \beta_t NI_{i,t+1} + \beta_t^2 (1 + EGR_{it}) ANI_{it} + \beta_t^3 (1 + EGR_{it})^2 ANI_{it} \\ & + \beta_t^4 (1 + EGR_{it})^3 ANI_{it} + \beta_t^5 \frac{(1 + EGR_{it})^3 ANI_{it}}{\bar{r} - \bar{g}}\end{aligned}$$

The constant discount factor reflects a static expectation of the nominal interest rate over this five year horizon; that is I use the 30-year Treasury bond interest rate in year t (plus a fixed 8 percent risk premium as suggested by Brealey and Myers (1996) among others).

- D_t is the book value of debt which is the sum of short- and long-term obligations.
- C_t is net current assets, essentially cash-on-hand.
- I and K are capital expenditures and the current cost net stock of property, plant, and equipment (both excluding IT). The current cost stock is constructed with the

¹⁶In principle, the horizon for calculating \hat{V} should be infinity. However, the analysts estimate EGR over a horizon of five years. Thus, in order to match the horizon for which there is information, I set the forecast horizon to five years. I then do a terminal value correction to account for the firm's value beyond year five. The correction assumes that the growth rate for earnings beyond this five year horizon is equal to that for the economy. Specifically, the last year of expected earnings is turned into a growth perpetuity by dividing it by $(\bar{r} - \bar{g})$; where I assume that \bar{r} is the mean nominal interest rate for the sample period as a whole (about 15 percent, which includes a constant 8 % risk premium) and \bar{g} is the mean nominal growth rate of the economy for the sample period as a whole (about 6 percent).

perpetual inventory method using an industry-level rate of economic depreciation constructed from Hulten and Wykoff (1981).

- *IT* and *KIT* are IT expenditures and the current cost net stock of IT. The current cost stock is constructed with the perpetual inventory method using a depreciation rate consistent with annual economic depreciation of 40 percent.
- *IP* and *KIP* are IP expenditures and the current cost net stock of IP. IP expenditures is the sum of R&D and advertising. The current cost stock is constructed with the perpetual inventory method using a depreciation rate consistent with annual economic depreciation of 25 percent.

The sample used for estimation includes all firms with at least four consecutive years of complete data. Four years of data are required to allow for first-differencing and the use of lagged variables as instruments. The determination whether the firm satisfies the four-year requirement is done after deleting observations. Several observations from the *Information Week* survey were deleted because they looked like recording or reporting errors. Also, a few observations were deleted because $\hat{V} < 0$.

Table 1 describes details about the sample. The first two rows define the different proxies for the intrinsic value of the firm. Notice that debt is added and net current assets is subtracted to make the total value of the firm. At both the mean and median values, the V^E -based value is about 70 percent greater than the \hat{V} -based value. The second interesting feature of the data is that the mean stock and flow of IP is greater than the comparable figures for IT. This is perhaps a bit surprising given that there are so many firms that report no IP spending at all.

4.2 Analysts' forecasts are informative

To lay the foundation for using the analyst-based proxy for the intrinsic value of the firm, I compare the analysts' forecasts of long-term growth, EGR_{it} , with realizations of growth over a three-year horizon, AGR_{it} . As a first-cut, compare the mean growth rates for the companies in the sample. The analysts expected profits to grow at an annual rate of 11.3 percent. Over a three-year horizon, profits actually grew at a touch smaller annual rate of 11 percent.

Figure 1 presents a more detailed comparison of actual and expected profit growth. The OLS regression line, which passes through the main cloud of observations, has a slope of 0.74.¹⁷ As the regression results reported in the lower right-hand corner show, the standard error of the slope coefficient estimate is 0.15, small enough so that zero can be strongly rejected but large enough so that unity cannot be rejected. Hence, the null hypothesis that expected profit growth is an unbiased forecast of actual profit growth cannot be rejected.¹⁸ This conclusion is bolstered by examining the intercept term, which is statistically insignificant from zero. If the intercept is suppressed, the slope coefficient increases further to 0.94.

Taking a step back, three features of the data are apparent. First, analysts don't forecast negative long-term growth. That's sensible, since such forecasts would be equivalent to saying that the company is essentially worthless. Second, analysts are loath to forecast very high long-term growth rates. That's sensible too. Very few companies generate profit growth in excess of 30 percent, and it's hard to identify ex ante those that may. Finally, actual profit growth is highly variable. Some companies do

¹⁷Extreme observations have been left out of the figure in order to maintain a 1:1 aspect ratio. These observations are, however, included in fitting the regression.

¹⁸In a related context, Keane and Runkle (1998) show that rational expectations of analysts' forecasts cannot be rejected.

grow at very fast rates or suffer large retrenchments. Nevertheless, what's obvious is that analysts' forecasts are reasonable and well-informed about companies' future prospects. The fact that analysts cannot perfectly predict the future does not reduce the utility of their forecasts. A lot can happen to a company over a three year period; much, if not most of which, cannot be anticipated. That analysts do as well as they do is remarkable.

5 Empirical Results

The empirical results are laid out in two stages. In Table 2, I present OLS estimates of the empirical valuation equations in levels and within groups. After establishing that these results are consistent with the sort of bias I've described, I present in Table 3 the results from two GMM estimators. First, I present a standard estimator that first-differences the empirical equations and uses lagged capital stocks as instrumental variables. For reasons described in section 3.2, the coefficient estimates are likely to be downward-biased in this case. Second, I present results from the system-GMM estimator. The diagnostic statistics indicate that system-GMM is well-behaved and the results themselves are quite sensible.

The first column of Table 1 is comparable to Brynjolfsson and his collaborators' levels specifications. Notice that these researchers failed to subtract net current assets from the total value of the firm. As a result, the total value of the firm is overstated, sometimes considerably — think of Microsoft, which has billions of dollars of cash sitting on its balance sheet. Nevertheless, using a different dataset (containing different firms during a different time period), different techniques for constructing the capital stocks, and different controls, I reproduce a very large coefficient estimate on IT capital.

According to a first pass at the data, IT capital is associated with about \$5 of unmeasured intangibles and IP capital is associated with about \$1 of unmeasured intangibles. These findings are little changed in column 2, in which \hat{V} replaces V^E . However, the estimates on IT capital are cut in half in columns 3 and 4 — in which net current assets are included in the total value of the firm — underlining the importance of defining the total value of the firm correctly.

The within-groups estimates of the value of IT and IP capital in columns 5 and 6 are all negative. This is unsurprising since the capital stocks are highly persistent. While unit root tests are useless for short panels, the (unreported) AR(1) coefficient estimates from regressions of the current capital stocks on their first lags are all greater than 0.96. In such situations, the received wisdom from the literature on production function estimation says that we should expect downward bias within groups.¹⁹

The levels OLS results do not control for endogeneity and simultaneity and the within-groups do not control for simultaneity. That simultaneity must be important is made obvious by expressing the beginning-of-period capital stock in terms of $K_t - I_t$, $KIT_t - IT_t$, and $KIP_t - IP_t$. That unobserved heterogeneity is also important is easy to motivate since the firm-specific effect is surely correlated with contemporaneous investments. To deal with simultaneity and eliminate the firm-specific effect, I first-difference the empirical valuation equations and estimate with GMM, using lagged levels of the capital stocks as instruments. These results are in columns 1 and 2 of Table 3.

¹⁹In fact, it is not unusual for production function estimates of the capital share to go from 0.3 in levels to negative values for within-groups. The magnitude of the bias in Table 1 may seem surprisingly large by comparison, but keep in mind that production functions are estimated in logs which invalidates a direct comparison.

Taking a look first at the Sargan test, the p -value indicates that the instruments are not rejected. That doesn't mean, however, that they are informative. Indeed, in unreported results, I confirm that weak instruments cannot be rejected using the partial R^2 or first-stage F -statistic as criteria. If the instruments used in the first-differenced equations are weak, then the results should be biased in the direction of within-groups.²⁰ Indeed, a comparison of columns 1 and 2 to columns 5 and 6 of Table 2 shows that the first-differenced estimates are biased toward the within-groups estimates.

To address this concern, I use the system-GMM estimator in columns 3 and 4. The Sargan test indicates that the model using V^E is rejected while the one using \hat{V} is not. This suggests that the instruments are correlated with the market's mismeasurement of companies' intrinsic values but not with the analysts' mismeasurement of the same. Why might that be? As I have argued, intangibles are difficult to value. If, say, the lagged change in the stock of intangibles is correlated with the amount by which the market misses the firm's intrinsic value, then the system-GMM estimator will tend to be rejected. By contrast, for reasons I've detailed, there's less reason to worry that analysts' forecast errors are correlated with the lagged change in the stock of intangibles.

Therefore, my preferred estimates are the results in column 4. All three coefficient estimates are statistically significant from zero, but the standard errors are large enough so that unity cannot be rejected. Nevertheless, taking the point estimates at face value is revealing. Consider the coefficient estimate on IT capital — about 1.7 — and recall that this is equal to one plus the marginal product of IT capital (λ_{KIT} from equation (4)). As Cummins and Violante (2002) show, one way to interpret the

²⁰As Bond and Blundell (2000) show, the first-differenced GMM estimator coincides with a 2SLS estimator when the fixed effects are removed with the orthogonal deviations transformation and the same moment conditions are used. OLS transformed to orthogonal deviations coincides with within groups, and weak instruments will bias 2SLS in the direction of OLS. Hence, weak instruments will bias this particular 2SLS estimator (which coincides with first-differenced GMM) in the direction of within groups.

economic depreciation rate is in terms of adjustment costs. Hence, gross marginal product of about 70 percent annually would cover the rapid depreciation of IT capital and allow the firm to earn a competitive return on its investment.

The coefficient on IP capital is less than unity — consistent with earlier findings — perhaps indicating that firms don't reap the full benefits of their IP investment. Finally, the estimate on tangible capital (excluding IT) is just greater than unity. This is consistent with lower rates of return on these types of capital and with recent studies in which estimated adjustment costs are quite modest in size.

6 Conclusion

The dramatic rise of the stock market in the 1990s led many observers to conclude that intangible capital was an increasingly important contributor to companies' bottom lines, at least in expectation. Such expectations have not been borne out recently, to say the least. What then are we supposed to conclude about the value of intangible capital?

From a methodological standpoint, one possible conclusion is that it was folly to tie the valuation of the companies' important intangibles to the vagaries of the stock market. Such an approach makes intangible capital a now-you-see-it, now-you-don't type of capital. My approach offers a different perspective both about how intangibles might be valued and what intangibles are.

In the model I present, intangible capital is a distinctive way of organizing the usual factor inputs, not an input itself. This captures the idea that companies with similar factors of production — say, college-educated workers using computers — can have very different values. Moreover, this approach shows that companies cannot simply

replicate the success of other companies by buying some intangibles. Since intangibles are the difference between the value of installed and uninstalled (non-intangible) capital, they cannot be purchased like a college graduate or a computer.

While the recent collapse of intangible-intensive companies' stock prices is not necessarily inconsistent with the assumption that the equity market reveals companies' intrinsic value, it certainly seems reasonable to use an empirical model that admits that possibility. Using such a model in conjunction with an estimator that controls for unobserved heterogeneity and simultaneity yields some very plausible estimates. Firms' organizational capital is very valuable — its marginal product is about 70 percent annually — and firms' may well have trouble appropriating the returns to their intellectual property since its marginal product is estimated to be somewhat less than its marginal cost.

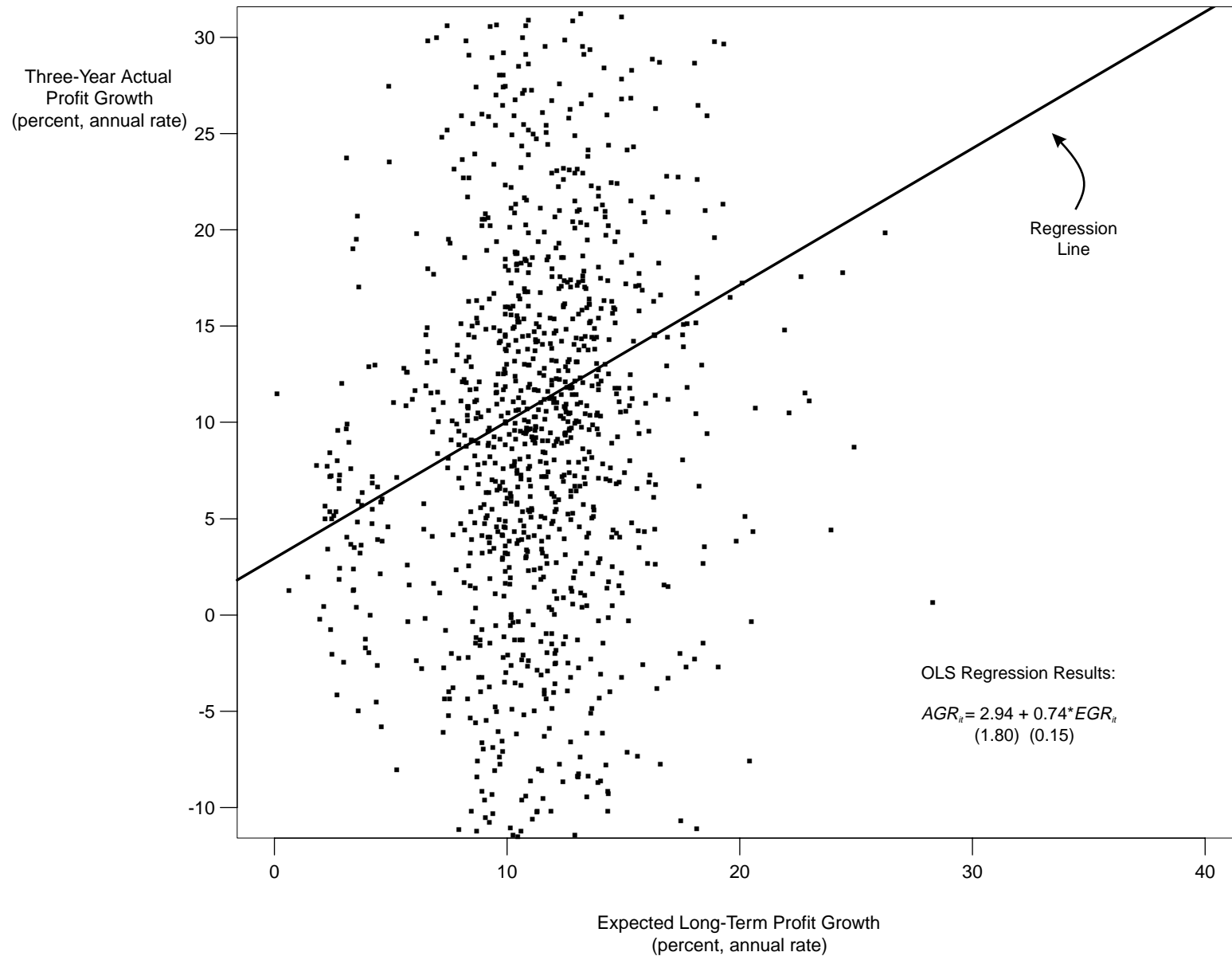
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Figure 1
Actual Profit Growth and Expected Long-Term Profit Growth, 1992-1997



**Table 1: Descriptive Statistics for Variables Used in Empirical Analysis
(Millions of Current-Dollars)**

Variable	mean	standard deviation	first quartile	median	third quartile
$V^E + D - C$	13,533	26,700	2,457	5,287	13,123
$\hat{V} + D - C$	8,175	18,120	1,251	3,047	8,036
K	5,822	10,107	734	2,051	6,453
KIT	784	1,688	118	285	681
KIP	1,421	3,573	0	221	1,018
I	773	1,686	109	301	733
IT	251	520	40.0	91.5	232
IP	395	1,057	0	51.7	256.0

The sample contains firms with at least four years of complete data. The number of firms in this sample is 253, for a total of 1,503 observations, and the sample period is 1991-1997.

Table 2: OLS Estimates of the Valuation Equations

	LEVELS				WITHIN-GROUPS	
	Dependent Variable				Dependent Variable	
	$V_t^E + D_t$	$\hat{V}_t + D_t$	$V_t^E + D_t - C_t$	$\hat{V}_t + D_t - C_t$	$V_t^E + D_t - C_t$	$\hat{V}_t + D_t - C_t$
	(1)	(2)	(3)	(4)	(5)	(6)
$K_t - I_t$	0.644 (0.239)	0.433 (0.181)	0.837 (0.225)	0.626 (0.158)	1.15 (0.642)	0.499 (0.312)
$KIT_t - IT_t$	6.19 (2.56)	5.36 (2.42)	3.17 (1.99)	2.35 (1.75)	-6.12 (3.08)	-6.05 (3.05)
$KIP_t - IP_t$	1.99 (0.848)	1.42 (0.573)	2.36 (0.803)	1.79 (0.499)	-3.71 (2.41)	-3.52 (1.71)
DIAGNOSTIC TESTS (p -VALUES)						
First-Order Serial Correlation	0.058	0.060	0.136	0.124	0.859	0.741
Second-Order Serial Correlation	0.079	0.081	0.168	0.161	0.312	0.451

Year dummies are included (but not reported) in all specifications. Robust standard errors on coefficients are in parentheses.

The sample contains firms with at least four years of complete data. The number of firms in this sample is 253, for a total of 1250 observations, and the estimation period is 1992-1997.

The tests for serial correlation in the residuals is asymptotically distributed as $N(0,1)$ under the null of no serial correlation.

Table 3: GMM Estimates of the Valuation Equations

	FIRST-DIFFERENCES		SYSTEM	
	Dependent Variable		Dependent Variable	
	$V_t^E + D_t - C_t$	$\hat{V}_t + D_t - C_t$	$V_t^E + D_t - C_t$	$\hat{V}_t + D_t - C_t$
	(1)	(2)	(3)	(4)
$K_t - I_t$	2.31 (1.83)	0.540 (0.760)	1.86 (0.134)	1.01 (0.119)
$KIT_t - IT_t$	-4.52 (12.6)	-10.6 (5.58)	0.855 (0.686)	1.69 (0.529)
$KIP_t - IP_t$	-9.10 (11.7)	-3.61 (4.59)	0.396 (0.317)	0.910 (0.265)
DIAGNOSTIC TESTS (p -VALUES)				
First-Order Serial Correlation	0.990	0.788	0.461	0.564
Second-Order Serial Correlation	0.317	0.560	0.597	0.705
Sargan Test	0.131	0.424	0.002	0.260

Year dummies are included (but not reported) in all specifications. Robust standard errors on coefficients are in parentheses.

The sample contains firms with at least four years of complete data. The number of firms in this sample is 253, for a total of 1250 observations, and the estimation period is 1992-1997.

In the first-differences estimator, the instrumental variables are the levels of the period $t - 3$ and $t - 4$ capital stocks. In the system estimator, the valuation equation in first-differences is estimated jointly with the valuation equation in levels. The instrumental variables for the first-differenced equation are the levels of the period $t - 3$ and $t - 4$ capital stocks. The instrumental variables for levels equation are the first-differences of the period $t - 2$ capital stocks. Year dummy variables are also included as instruments in all specifications.

The tests for serial correlation in the residuals is asymptotically distributed as $N(0,1)$ under the null of no serial correlation. The test of the overidentifying restrictions, called a Sargan test, is asymptotically distributed as $\chi^2_{(n-p)}$, where n is the number of instruments and p is the number of parameters.