Profitability and Stock Returns in Production-Based Asset Pricing with Decreasing Returns to Scale *

Ronald J. Balvers
DeGroote School of Business
McMaster University
Email: balvers@mcmaster.ca

Li Gu
Division of Banking Supervision and Regulation
Federal Reserve Board
Email: li.gu@frb.gov

Dayong Huang
Bryan School of Business and Economics
University of North Carolina at Greensboro
Email: d_huang@uncg.edu

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Abstract

In a production-based asset pricing model with decreasing returns to scale following Brock (1982) stock returns at the firm level no longer identically equal investment returns but, instead, are determined by a measure of gross profitability, the book-to-market ratio, and the change in future profitability prospects. Firm decisions of capital investment and utilization both negatively predict profitability and future returns. Book-to-market ratios positively forecast returns as is typical, but with specific predicted exceptions. These implications are confirmed empirically and the production-based model with decreasing returns predicts costs of equity capital better than traditional asset pricing models.

JEL Classification: G12.

Keywords: Profitability; Stock returns; Production-based asset pricing; Investment returns; Capacity utilization; Decreasing returns to scale

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1. Introduction

We modify the investment-based asset pricing approach of Cochrane (1991, 1996) by building directly on the formulation of Brock (1982) which models capital accumulation on a time-to-build assumption rather than adjustment costs and assumes decreasing returns to scale instead of constant returns. The assumption of decreasing returns allows us to highlight the role of profitability on equity returns and substantially modifies Cochrane's investment-based approach because unlevered stock returns no longer equal investment returns. Investment returns still explain stock returns but only partially: we derive that stock returns are a weighted average of average investment returns (including a profitability markup) and the rate of change in the value of intangible assets, with weights related to the book-to-market ratio. A significant implication of this result is that it captures theoretically the dual aspects of value documented empirically by Novy-Marx (2013): profitability and the book-to-market ratio have separate positive effects on required stock returns.[1]

Allowing decreasing returns to scale also lets us move away from the convex adjustment costs formulation that has dominated investment-based asset pricing research. While convex

[1] These outcomes may suggest the naïve perspective that the best way to invest is by purchasing "cheap" (high book-to-market) stocks in "good" (high profit rate) companies. However, predictability of stock returns arises here in an efficient market. The positive return impact of book-to-market ratios is a result of tangible asset values being more sensitive than intangible asset values to mean-reverting productivity shocks, and the positive effect of profitability on returns stems from firms becoming more profitable as a reward for having chosen the riskier production route (as in Berk, Green, and Naik, 1999).

adjustment costs are analytically convenient and are helpful in allowing the model to numerically replicate asset price variability and investment dynamics (Jermann, 1998, and Zhang, 2005), they are hard to rationalize as a uniform vital source of economic dynamics. Hall (2004) argues that convex adjustment costs of investment are too small to explain large fluctuations in stock prices. Abel and Eberly (2011) show that a model without adjustment costs can explain both the low sensitivity of investment to the book-to-market ratio and the higher sensitivity of investment to operating profit, which are hard to explain with convex adjustment costs. And the survey by Caballero (1999) makes it clear that investment choices are influenced by convex adjustment costs in some firm-level environments, but by non-convex adjustment costs in others. Convex adjustment costs thus may provide a confounding basis for understanding differences in firm-level investment returns, even if adequate at the aggregate level.[2] The recent work of Bloom (2009), Lin and Zhang (2013), and Belo, Bazdresch and Lin (2013) considers both non-convex and convex adjustment costs in investment and makes progress in replicating firm-level investment dynamics. It, however, relies heavily on numerical methods.

On the other hand, our productivity-based formulation maintains the important strengths of the investment-based formulation.[3] Firms in effect choose the riskiness of their operations,

[2] The adjustment cost assumption has been popular in part because it can account for more variability in investment returns and accordingly higher asset price volatility. In our time-to-build framework, however, profitability factors unrelated to investment returns also affect stock prices and these may be highly variable, especially since we interpret the productivity shocks that drive profitability more broadly than total factor productivity. It is not our intent here to calibrate a general equilibrium model to explain the size of the equity premium or match the volatility of asset prices. Remaining outside the confines of the standard real business cycle model, and avoiding explanations that rely on time-series variation in risk premia, we see no a priori reason that our model would have trouble explaining asset price volatility.

[3] To streamline terminology we propose to refer to Brock's (1982) contribution as *productivity*-based asset pricing and to Cochrane's (1991) contribution as *investment*-based asset pricing. Both are special cases of *production*-based

and observed internal decisions provide a real and current signal as to management's information and intended level of risk exposure. A firm's chosen characteristics provide a timely and accurate measure of risk sensitivities perceived by insiders. As Lin and Zhang (2013) emphasize, it is the promise of investment-based, and more generally production-based asset pricing, to identify the links between production decisions and risk exposure such as to provide estimates of costs of capital that are more precise than those derived from the traditional consumption-based approach. The consumption perspective requires that risk loadings be estimated from past time series of returns with or without ad-hoc conditioning variables; the production perspective determines the structural variables that drive the risk loadings. Lin and Zhang (2013) argue that the production-based view may well turn out to provide superior estimates of costs of capital, with the potential of a paradigm shift in asset pricing.

Several recent papers also relate profitability and stock returns, using elements of the Brock approach. Li, Livdan, and Zhang (2009) present a hybrid of Brock's productivity-based approach and Cochrane's investment-based approach by allowing both decreasing returns to

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asset pricing which focuses on the production side rather than the traditional consumption side to derive implications for asset returns. Production-based asset pricing as broadly interpreted builds on the theoretical work of Brock (1982), Cox, Ingersoll, and Ross (1985), and Berk, Green, and Naik (1999) and has been applied to explain and predict stock returns by Balvers, Cosimano, and McDonald (1990), Hsu (2006), Balvers and Huang (2007), Booth et al. (2008), Lioui and Poncet (2008), Kogan and Papanikolaou (2012, 2013), and others. Brock (1982) assumes production under a decreasing-returns-to-scale technology with time to build and an array of productivity shocks driving firm decisions. Stock returns here depend on production decisions that interact with the firm's exposure to the various productivity shocks. Cochrane (1991) and Restoy and Rockinger (1994), building on the q-theory of Tobin (1969) and Hayashi (1982), show that stock returns are identical to investment returns in an environment with constant returns to scale and convex adjustment costs, thus summarizing the production attributes relevant for determining stock returns as simply the determinants of investment returns. This investment-based approach to asset pricing has stimulated a growing body of empirical work by Cochrane (1996), Gomes, Kogan, and Zhang (2003), Carlson, Fisher, and Giammarino (2004), Zhang (2005), Xing (2008), Liu, Whited and Zhang (2009), Li and Zhang (2010), Hou, Xue, and Zhang (2012), Lin and Zhang (2013), and others.

scale and convex adjustment costs. Although they succeed in explaining external financing anomalies, they additionally contend that stock returns and profitability (equal to cash flows in their model) are inversely related. This is counter factual in light of Novy-Marx's (2013) findings and reverses the result we obtain in the pure Brock framework. Since the results are largely numerical it is challenging to identify the exact mechanism, but Li et al. (2009) argue along the lines of the pure investment-based approach that higher profitability facilitates investment, and that, in turn, higher investment implies lower investment returns and stock returns. Empirically, Li et al. support this prediction by identifying a positive interaction effect between profit (cash flows) and investment, which affects returns in addition to the investment link by itself. However, they do not control for the effect of profitability by itself which likely accounts for the discrepancy between their findings and those of Novy-Marx.

The work of Kogan and Papanikolaou (2012, 2013) may be viewed as a structural version of the Brock approach with two types of productivity shocks. By adding a second, investment-specific, productivity shock to traditional approaches (such as Jermann, 1998, Boldrin, Christiano, and Fisher, 2000, and Balvers and Huang, 2007), they generate additional implications and avoid relying on the Solow residual to operationalize productivity shocks. Their model produces a positive link between returns and both book-to-market ratios and profitability: higher growth options imply more exposure to investment-specific technology shocks that mitigate market risk, causing lower average stock returns; and higher profitability implies riskier tangible assets and more exposure to total factor productivity shocks, causing higher average stock returns. By explaining the dual dimensions of value and by avoiding the empirical use of Solow residuals, Kogan and Papanikolaou attain some of the key objectives of our paper. However, our paper offers a substantially different perspective: illustrating alternate economic mechanisms and correlations, producing distinct new testable implications, generating cost of capital predictions without requiring time series estimation of factor betas, and providing a simple model with closed-form solutions for profitability rates, book-to-market ratios, investment returns, stock prices and stock returns.

We add a utilization decision to the Brock model to generate a richer decision environment that is more revealing about the information available to management.[4] Investment takes time to become productive, but adjusting utilization is instantaneously productive. Both decisions convey important, distinct clues about the firm's sensitivity to risk. Risk arises as a result of persistent productivity shocks which we interpret not in the narrow sense of technology shocks but, as in Novy-Marx (2013), more broadly as profitability shocks affecting individual firms through exogenous changes in, for instance, total factor productivity, market conditions, competitiveness, the macro environment, and input costs.

The model generates closed-form solutions for stock returns, profitability, book-to-market ratios, investment, and the utilization rate that provide new testable implications. First, in addition to the standard implication that investment as a signal of future productivity affects expected stock returns, utilization as a signal of perceived current productivity also affects expected returns. Both are inversely related to expected profitability and expected stock returns.

[4] There are investment-based asset pricing papers that also provide a richer decision environment. In particular, Chen and Zhang (2011) explicitly consider employment as an additional input factor affecting investment returns and hence future stock returns. They look at aggregate inputs only. Employment, furthermore, has the drawback of being very heterogeneous. It is important to distinguish between hours worked per person and the number of persons employed; distinguish between skilled and unskilled; and consider the impact of labor hoarding. In contrast, capacity utilization, as we capture it by electricity usage, is a more homogeneous measure of activity.

Second, a higher current book-to-market ratio *normally* (i.e., unconditionally) indicates higher future returns, the standard value effect, because the higher book-to-market ratio implies more weight on the tangible value component, which has higher average returns, and less weight on the intangible value component, which has lower average returns.[5] But, *in specific instances* – whenever intangible asset returns are expected to exceed tangible asset returns – the model implies that the book-to-market effect does not hold and is, in fact, reversed as we confirm empirically.

The implied impact of investment and utilization on future stock returns is tested using the Manufacturing Industry Database, made available by the National Bureau of Economic Research and the Center of Economic Studies (NBER-CES), in combination with COMPUSTAT. The Manufacturing Industry Database provides industry-level historical data for 459 industries on the stock of physical capital, spending on electricity, and productivity. This database has not been applied extensively in this context (Booth et al. 2008 is the exception) but is well suited for our purposes. Electricity usage per unit of capital provides a desirable proxy for the utilization rate that appears to be a more reliable indicator of the intensity of usage of the firm's production capacity than reported utilization rates. We merge industry-level electricity expenditure deflated by the price index for electricity per unit of capital with the COMPUSTAT

[5] Technically, we show that the risk-adjusted returns on tangible capital must follow a submartingale process, while the risk-adjusted returns on intangible capital must follow a supermartingale process.

firms by SIC code and assume that COMPUSTAT firms in the same industry have similar utilization rates.[6]

The empirical results support the model predictions. We find that both the investment-to-capital ratio and the utilization rate have significant negative forecast power for returns.[7] In addition, the book-to-market ratio has the expected positive return effect for the average firm, but as predicted explicitly, is reversed in cases for which returns on intangible assets are expected to exceed returns on tangible assets. We further find that prediction of the cost of capital from our production-based model works significantly better than prediction of the cost of capital based on the CAPM or the Fama-French three-factor model.

2. Production, Profitability, and Expected Stock Returns

We present first an equilibrium model along the lines of Brock (1982), Cox, Ingersoll, and Ross (1985), and Berk, Green, and Naik (1999), that allows prediction of the required return on the equity of a particular firm from market conditions and firm characteristics, utilizing a production-side perspective. The model makes explicit the impact of decreasing returns, and the associated capital investment and utilization decisions, on expected returns and profitability. The

[6] Burnside, Eichenbaum, and Rebelo (1995) originally used electricity usage as a proxy for capacity utilization. Da and Yun (2010) employ electricity consumption in the asset pricing context. They approach this issue from a consumption-based asset pricing perspective, viewing electricity consumption as a high-frequency alternative measuring consumption in real time.

[7] The evidence that investment is negatively related to future returns is consistent with, for example, Cochrane (1991, 1996), Titman, Wei and Xie (2004), Zhang (2005), and Xing (2008).

impact is time-varying and suggests predictability of realized stock returns based on prior profitability, value, utilization and investment information.

Firm decisions with capital, capital services, and decreasing returns

Consider a representative firm maximizing the expected net present value to shareholders with respect to its production and investment choices in each period. The maximized value of the firm V is determined as the present value of dividends to the shareholders:

$$V(\theta_t, K_t) = \underset{U_t, I_t}{Max} \left(D_t + E_t[m_{t+1}\, V(\theta_{t+1}, K_{t+1})]\right), \tag{1}$$

which is the standard Bellman Equation of dynamic programming. The dividends paid by the firm in each period t are denoted by D_t. The productivity variable θ_t and the available capital stock K_t are the state variables which are jointly sufficient for determining firm value.[8] The aggregate stochastic discount factor is given as m_{t+1}, and $E_t(\cdot)$ carries the subscript t to indicate that expectations are conditional on all currently available information.

The maximum value of the firm $V_t \equiv V(\theta_t, K_t)$ is the equity value of the firm before dividends: $V_t = P_t + D_t$, with $P_t = E_t[m_{t+1}\, V(\theta_{t+1}, K_{t+1})]$ the *ex-dividend* equity value of the firm. Given the definition of the stock return, $r_{t+1}^S = (D_{t+1} + P_{t+1} - P_t)/P_t$, equation (1) can be rewritten as $1 = E_t[m_{t+1}(1 + r_{t+1}^S)]$, reflecting the fact that risk- and dividend-adjusted stock prices follow a

[8] It is clear from the specification in equations (1) - (4) that, indeed, the productivity variable θ_t and the available capital stock K_t are sufficient state variables for the value of the firm

martingale process so that pricing the equity value of the firm according to equation (1) rules out arbitrage opportunities.

We assume that net operating income, Y_t, is determined by a simple power function of the firm's current physical capital stock, K_t, the choice of the utilization of its currently available capital stock, U_t, and by the exogenous current level of productivity, θ_t: $Y_t = \theta_t^{1-\alpha} U_t^{\alpha} K_t^{\beta}$.[9] Dividends D_t are then given as:

$$D_t = \theta_t^{1-\alpha} U_t^{\alpha} K_t^{\beta} - q\, I_t, \qquad (2)$$

with I_t the current level of capital investment and q the relative price of an investment good. For later use we define $u_t = U_t / K_t$ as the fraction of the capital stock chosen to be utilized for current production, and $i_t = I_t / K_t$ as the current level of investment per unit of capital that will contribute to next period's capital stock.

Productivity θ_t here is to be interpreted quite generally. It is a conflation of technology shocks and other disembodied productivity shocks together with miscellaneous exogenous factors that affect the profitability of the firm, such as changes in the competitive environment, and input costs (see, e.g., Novy-Marx, 2013, for a similar characterization of productivity). Following Brock (1982) we may view θ_t as a vector containing a multitude of systematic productivity shocks. We choose not to do so formally to keep the notation simple and because

[9] The exponent on the productivity level in the production function is similar to that in Cooper (2006). Abel and Eberly (2011, equation 3) show that this specification naturally arises given our interpretation of Y_t as revenue net of labor cost.

this generalization would add few new insights given our focus. However, we note that a multi-productivity-factor version would be easy to deal with in our production-based approach while making it difficult to apply the CAPM.

The interpretation of Y_t as operating income means that we have implicitly accounted for the impact of labor and additional inputs on production and costs, which are only represented by the exogenous influence of wages and other input costs on income, captured by the productivity level θ_t. Capital is viewed as productive even if not in use, so we take $\beta > 0$. The reason is that excess capacity on average, while not continuously in use during a period, nevertheless allows for better maneuverability, increased flexibility, and a frictionless way of dealing with peak load scenarios and fluctuating demand. We also set $\alpha > 0$ and assume decreasing returns to scale so that $\alpha + \beta < 1$. In this we follow Brock (1982) but differ from Cochrane (1991) and others in the investment-based asset pricing literature, with the critical implication that investment returns are distinct from stock returns. We express the degree of decreasing returns to scale as $s = (1 - \alpha - \beta) / \beta > 0$ so that higher s represents stronger decreasing returns to scale and higher profitability.

We next specify the equations of motion for the state variables. Capital evolves according to the standard linear specification but with the refinement that depreciation depends in part on usage as is emphasized by McGrattan and Schmitz (1999):

$$K_{t+1} = (1 - \delta) K_t - \gamma U_t + I_t \tag{3}$$

Capital increases with existing capital and investment, and decreases in the intensity of its current utilization. The rate of deprecation becomes equal to $\delta + \gamma u_t$. We interpret investment broadly to include changes in working capital so that, under clean surplus accounting, capital becomes conceptually equal to total assets and the book value of the firm.

The exogenous productivity indicator follows a linear Markov process:

$$\theta_{t+1} = (1-\rho)\overline{\theta} + \rho\theta_t + \sigma\varepsilon_{t+1} + \eta_{t+1}, \tag{4}$$

Where η_t is a firm-specific i.i.d. random variable with arbitrary distribution that has mean zero and variance σ_η^2, and ε_t is an aggregate i.i.d. variable, ε_t, with an arbitrary distribution that is standardized to have zero mean and unit variance, and is independent of η_t. The autoregressive formulation for productivity is inherited by the process for profitability (although inversely) and captures two features of the data: persistence of profitability and mean reversion of profitability at the firm level (Fama and French, 2000 and 2006).

The aggregate shock ε_t is the only systematic risk (although we could with minor complications model a vector of such systematic productivity shocks as in Brock, 1982) and we specify the stochastic discount factor exogenously as

$$m_t = \frac{1-h\varepsilon_t}{1+r}. \tag{5}$$

It follows that $1/(E_t m_{t+1}) = 1+r$ so that *r* represents a constant risk free rate; *h* is the constant risk premium of the systematic productivity risk. The stochastic discount factor parameters *h* and *r* , together with the price of investment goods *q*, are the only aggregate parameters in the model. All other parameters may differ across firms. The exogenous stochastic discount factor is in the tradition of Berk, Green, and Naik (1999) and allows us to focus on differences in factor risk sensitivities of individual firms as determinants of returns, while taking the aggregate values for the risk free rate and the risk premium as given.

Optimal investment and utilization

Maximization of the value of the firm in equation (1), subject to equations (2), (3), and (4) with respect to investment and capacity utilization, yields the first-order conditions for the investment choice (barring time subscript *t*, all subscripts indicate partial derivatives):

$$q = E_t[m_{t+1} V_K(\theta_{t+1}, K_{t+1})] \ , \tag{6}$$

and for the capacity utilization choice:

$$\alpha \theta_t^{1-\alpha} U_t^{\alpha-1} K_t^{\beta} = \gamma E_t[m_{t+1} V_K(\theta_{t+1}, K_{t+1})] \ . \tag{7}$$

The first-order conditions together immediately yield a solution for optimal capital utilization:

$$U_t^* = (\alpha / q\gamma)^{\frac{1}{1-\alpha}} \theta_t \, K_t^{\frac{\beta}{1-\alpha}} \ . \tag{8}$$

The optimal capital stock is subsequently found in Appendix A as

$$K_{t+1}^* = [A(z + \rho\theta_t)]^{\frac{1-\alpha}{1-\alpha-\beta}}, \quad \text{with } A \equiv \beta(\alpha / q\gamma)^{\frac{\alpha}{1-\alpha}} / q(r+\delta) \, , \; z \equiv (1-\rho)\bar{\theta} - h\sigma \, . \tag{9}$$

Optimal investment I_t^* may be inferred directly from equations (3), (8) and (9).

3. Implications

The model solutions allow us to relate stock returns to investment returns, profitability measures, and value measures, providing several new testable implications in the process.

Investment returns and stock returns

In equation (6), $q = E_t[m_{t+1}V_K(\theta_{t+1}, K_{t+1})]$, which implies that the investment return $r_{t+1}^I \equiv [V_K(\theta_{t+1}, K_{t+1}) - q]/q$ can be viewed as a regular asset return because $E_t[m_{t+1}(1+r_{t+1}^I)] = 1$. The excess investment return is derived straightforwardly in Appendix A:

$$r_{t+1}^I - r = \left(\frac{\sigma(h + \varepsilon_{t+1}) + \eta_{t+1}}{z + \rho\,\theta_t} \right)(r + \delta). \tag{10}$$

The expected excess investment return equals $E_t r_{t+1}^I - r = (r + \delta)\,\sigma\, h/(z + \rho\,\theta_t)$.

In the constant returns to scale (CRTS) framework of Cochrane (1991, 1996) the marginal investment return equals the average investment return which in turn equals the stock return: $r_{t+1}^I = r_{t+1}^S$. But in our decreasing returns (DRTS) model the two are not identical and a comparison is instructive. Compare $1 + r_{t+1}^I \equiv V_K(\theta_{t+1}, K_{t+1})/q$ and $1 + r_{t+1}^S \equiv V(\theta_{t+1}, K_{t+1})/P_t$. Under CRTS (with or without adjustment cost) it is necessarily true that both $V_K(\theta_{t+1}, K_{t+1}) = V(\theta_{t+1}, K_{t+1})/K_{t+1}$ and $P_t = q\,K_{t+1}$ where, in the case of adjustment costs, q represents the full price of a capital good – the cost of purchasing *and* installing the capital good. It follows then that $r_{t+1}^I = r_{t+1}^S$.

Under DRTS there are two sources of difference because (a) average returns to capital and marginal returns to capital differ, $V(\theta_{t+1}, K_{t+1})/qK_{t+1} \neq V_K(\theta_{t+1}, K_{t+1})/q$, and because (b) book-to-market values are not one: $b_t = q\,K_{t+1}/P_t \neq 1$ implying $V(\theta_{t+1}, K_{t+1})/qK_{t+1} \neq V(\theta_{t+1}, K_{t+1})/P_t$. As shown in Appendix B and as also consistent with Abel and Eberly (2011) in a related framework (but focusing on investment rather than asset prices): b_t in this model is always lower than one,

$b_t = qK_{t+1}/P_t < 1$, because the firm has a strictly positive intangible asset value (in spite of not facing adjustment costs).[10] Thus, variations in the scale of the firm and in the book-to-market value of the firm cause stock returns to deviate from investment returns. These differences are intriguing because they correspond to the well-documented size and value effects, respectively.

Appendix B derives an expression for stock returns in relation to investment returns:

$$r_{t+1}^S = \pi_{t+1} b_t + g_{t+1}(1-b_t), \qquad \pi_t \equiv r_t^I + s(r_t^I + \delta). \tag{11}$$

The book-to-market ratio $b_t = b(\theta_t) = q K_{t+1}/P$ represents a predetermined weight $0 < b_t < 1$, and $g_{t+1} = g(\theta_{t+1}, \theta_t)$ is the rate of increase in the firm's intangible asset value. We obtain the *average* investment return as $\pi_t = r_t^I + s(r_t^I + \delta)$ which equals the *marginal* return on investment r_t^I (stated in equation 10) plus a markup that results from decreasing returns to scale. Abel and Eberly (2011, equation 3) show that, in a formally identical model, the markup can also be interpreted as the profit arising from market power. The markup here is the product of the degree of decreasing returns, $s = (1-\alpha-\beta)/\beta$, and the appropriate user cost of investment, which equals the investment return (the risk free rate plus a compensation for investment risk), plus the depreciation rate, $r_t^I + \delta$. Essentially stock returns are a weighted average of the return on tangible assets (the average investment return) and the return on intangible assets (the rate of increase in the value of growth options) with the weights equal to b_t and $1-b_t$. Note that both

[10] The intangible asset value is the expected present value of future streams of residual income. The residual income is the abnormal profit, the net income after adjusting for the opportunity cost of capital, and here arises exclusively from the profit markup caused by decreasing returns to scale.

the mean value and the risk of the average investment return increase directly in the degree of decreasing returns to scale, *s*.

The intuition for why unlevered stock returns deviate from investment returns is that decreasing returns imply that the (marginal) investment return affecting real decisions is below the average return paid out to stockholders; i.e., average investment returns are larger than marginal investment returns. Additionally, even the average investment return is only the return from tangible assets going to stockholders and should be weighted by the tangible part of total equity value. Another part of the asset's market value affecting stockholder returns derives from profitability prospects. The change in the value of these "growth options" provides a second component of the stock return, weighted by the share of intangible assets in total equity value.

In our model, profit margins and investment returns are high when investment exposes the firm to high systematic risk. High profit margins thus proxy for high σ (see equation 10), signifying high levels of systematic risk and high (productivity) betas.[11]

Profitability and stock returns

The average investment return can be interpreted as a profitability measure. Rearranging the definition in equation (11), $\pi_t + \delta = (1+s)(r_t^I + \delta)$ represents a gross return which is shown in Appendix B to equal the gross profit of the firm as a fraction of the initial book value,

[11] Hou, Xue, and Zhang (2012) argue that an investment-based model with an investment factor and a profitability factor in addition to the traditional market and size factor can explain a large variety of financial market anomalies. Their motivation for separate investment and profitability factors is based on a framework in which investment returns and stock returns are equal but they break up the investment return into parts depending on the return on equity and the investment-to-capital ratio. They treat these components as separate systematic risk factors rather than indicators of risk sensitivities.

$\pi_t + \delta = (Y_t - \gamma U_t) / qK_t$, which equals operating income minus maintenance costs divided by the book value of assets. It is similar in spirit to Novy-Marx's measure of gross profitability, although our theoretical model is not detailed enough to distinguish this measure from other profitability measures such as the return on assets.[12] Thus,

PROPOSITION 1. Given decreasing returns to scale technology, expected stock returns increase in expected gross profitability: $dE_t(r_{t+1}^S) / dE_t(\pi_{t+1}) = b_t > 0$.

This follows directly from equation (11). Akin to the approach in Berk, Green, and Naik (1999), higher profitability means that the firm is more sensitive to the risk of current productivity shocks and therefore has higher expected return. For a given productivity level, the firm has chosen riskier investment projects (higher σ) which imply higher profitability, from equation (10), as well as higher expected return, from equation (11).

Novy-Marx (2013) finds that the gross profitability of firms – current revenue minus the cost directly attributable to current revenue generation – provides another dimension of value and has significant forecast power for returns that is separate from the traditional book-to-market effect. Empirically he finds in double-sorting US firms from 1963-2010 that the monthly returns between high and low profitability quintiles is 0.68% per month, averaged over all book-to-value

[12] The model, however, is detailed enough to eliminate cash flow measures (such as Free Cash Flow) as a proxy for profitability in this context because the investment expenditures that must be subtracted to calculate cash flows are not subtracted here in deriving the average investment returns.

quintiles; and the monthly return between high and low book-to-market quintiles is 0.54%, averaged over all profitability quintiles.

The effect of profitability on stock returns may also be related to the effect of operating income on stock returns that Li, Livdan, and Zhang (2009) find numerically in their model and confirm empirically. They employ the Brock model but add convex investment adjustment costs. For given positive investment, they find that higher operating income relative to assets has a *negative* impact on stock returns. This result appears to conflict with the empirical Novy-Marx (2013) result and with our theoretical result, both implying a *positive* impact of operating income on stock returns. The likely reason is that Li et al. (2009) consider only the interaction between operating income and investment, and not operating income in isolation.

The modification from marginal investment returns to average investment returns in linking to stock returns is analogous to the impact of operating leverage emphasized by Carlson, Fisher, and Giammarino (2004) and Novy-Marx (2011), but here represents a profit markup derived from the extent of the decreasing returns *s* measured by $\frac{1-\alpha-\beta}{\beta}$, and has diametrically opposed empirical implications. Novy-Marx (2013, p.16) points out that in existing models (Carlson et al., 2004, Zhang, 2005, and Novy-Marx, 2011) operating leverage and risk, and hence expected returns, are increasing in fixed costs. Therefore, since higher fixed costs lower profits, expected returns are *negatively* linked with profitability, implying that profitable firms should underperform unprofitable firms in the stock market. In our model, however, the "operating" leverage arises directly from the inherent profit markup and is linked *positively* to profitability and stock returns (though negatively to the productivity level).

Kogan and Papanikolaou (2013) also generate the observed positive correlation between profitability and expected stock returns that we find in our model. The positive correlation arises because firms that are currently more profitable have less of their value linked to future investment and they are therefore less susceptible to investment-specific productivity shocks. In turn, investment-specific productivity shocks are found to mitigate market risk so that highly profitable firms are riskier. This intuition relies on highly profitable firms typically being value firms and appears to be inconsistent with the negative correlation between profitability and book-to-market ratios identified by Fama and French (1995).

Model predictions relating to the value effect

Separately, b_t, the book-to-market ratio also affects the firm's expected stock return. The effect is positive and magnifies the profitability effect if the average investment return $r_t^I + s(r_t^I + \delta)$ exceeds the rate of increase in intangible assets g_{t+1}. This is highly likely since the average return on tangible assets is generally strongly positive while the *rate of increase* in intangible assets must be zero in the unconditional average because the productivity shocks are stationary, and, in fact, should be negative after risk correction as we argue next.

The risk-adjusted stock price must follow a martingale process as is implied by $1 = E_t[m_{t+1}(1 + r_{t+1}^S)]$. Remarkably, while the stock return in equation (11) is a convex combination of the average investment return and the appreciation rate of intangible assets, it is *not* true that the average investment return and the intangible asset appreciation rate follow martingale processes. Because $E_t[m_{t+1}(1 + r_{t+1}^I)] = 1$ it follows from $\pi_{t+1} = r_{t+1}^I + s(r_{t+1}^I + \delta)$ that

$E_t[m_{t+1}(1+\pi_{t+1})]>1$ for $s>0$. In mathematical terms, the average investment value follows a strict *sub*martingale process. Accordingly, $E_t[m_{t+1}(1+g_{t+1})]<1$, so that risk-adjusted intangible assets follow a strict *super*martingale process (see Appendix B). The reason the value of intangible assets (adjusted for risk and time value) is expected to decrease over time is that here the intangible asset consists of the present value of future profit markup which produces profits in the next period that are counted as part of the average investment payoff, not the intangible asset payoff.[13]

The practical implication is that, in typical cases, value effects must be positive: in equation (11) higher b_t implies that stock return is higher by an extent related to the positive difference between the returns on a submartingale and a supermartingale (which is positive in the time series average). The value effect therefore arises because value stocks have more weight on tangible returns which normally are larger than the growth rate of the intangible component. Our model accordingly provides a direct explanation for the Novy-Marx results: the comprehensive value returns stem from firm-level preferences for high-profit-margin production projects with accompanying high exposure to systematic shocks, and the effect is magnified in "value" firms that also have more tangible assets relative to intangibles assets.

Another implication of our theory, a further refinement of the value effect not tested by Novy-Marx (2013), is that the standard book-to-market premium should be the *opposite* (i.e.,

[13] The component of intangible assets that enhances the average investment return can alternatively be interpreted as the tangible return on the fixed factor (location, brand name, disembodied know how, plant specific human resources or management skills, etc.) responsible for decreasing returns.

negative) for the (presumably small) segment of firms that has rates of increase in intangible assets expected to exceed the return on tangible assets (see Appendix B). For these firms an increase in the book-to-market ratio, raising the weight on the tangible asset return, *lowers* the overall stock return, causing an inverse value premium. Of course these firms would necessarily have relatively low exposure to productivity risk in their tangible assets (assets in place) compared to their intangible assets (present value of future residual income). In summary,

> **PROPOSITION 2.** Book-to-market ratios affect expected stock returns (given decreasing returns and for given profitability): $dE_t(r^S_{t+1})/db_t = E_t(\pi_{t+1} - g_{t+1})$. The effect is (a) *positive* unconditionally: $E(\pi_{t+1} - g_{t+1}) = E(\pi_{t+1}) > 0$, and (b) *negative* only for particular firms with $E_t(g_{t+1}) > E_t(\pi_{t+1})$, for which the increase in intangible asset values is expected to exceed the return on tangible assets.

The result follows from equation (11) and because θ_t and, so intangible value $G(\theta_t)$, is stationary, causing $E(g_{t+1})$, the unconditional growth rate of $G(\theta_t)$, to be zero (see Appendix B).

A higher book-to-market ratio implies a higher expected return because, with more tangible assets, a current productivity shock has a larger impact on market value. The reason is that tangible assets benefit directly from the shock, whereas intangible assets capitalize the future impact on profit which diminishes due to the mean reversion of θ_t assumed in equation (4). In particular cases, higher book-to-market values *lower* expected excess returns. Namely, for the subset of firms that have expected rates of increase in intangible assets higher than their expected average investment returns, an increase in b_t implies less risk and lower expected stock returns.

Our economic argument for why value firms have higher average returns is different from that in the existing literature. Zhang (2005) argues that value firms are riskier because they are stuck with high (convex) adjustment costs when marginal utility is high. Cooper (2006) assuming non-convex adjustment costs argues that value firms are riskier because they can expand costlessly and benefit more strongly from positive shocks when their production capacity is high. Both arguments hinge on adjustment costs and the conditional variation of risk premia, which we avoid. The explanation of Kogan and Papanikolaou (2013) avoids both adjustment costs and conditional variation of risk premia and holds that growth firms are more susceptible to investment-specific productivity shocks which have negative risk premia (under plausible assumptions). These explanations are not mutually exclusive and, in principle, each could contribute to explaining the value premium.

Novy-Marx (2013) finds that the traditional value effect is not merely separate from the profitability effect, but is in fact enhanced when he controls for profitability. Kogan and Papanikolaou (2013) also confirm this observation which their model can match quantitatively even though book-to-market ratios and profitability rates are *positively* correlated in their model. Our model generates the same result stemming from the fact that book-to-market ratios and profitability rates are *negatively* correlated in our model as is consistent with Fama and French (1995). The negative correlation arises from a higher productivity level implying both a lower profitability rate (more capital lowers the average return on capital) and a higher book-to-market ratio (current productivity boosts raise tangible asset values more than intangible asset values due to mean reversion). The negative correlation between book-to-market ratios and profitability rates means that a high profit rate, for instance in part due to high σ and in part due to low θ_t, is associated with a lower book-to-market ratio which partly or fully offsets the effect of the profit rate on stock returns. Sorting by book-to-market ratio in addition to profitability, avoids the cases in which profitability is high for reasons having relatively small impact on expected returns (low θ_t for instance), implying a larger profitability premium when portfolios are double sorted.

Productivity and stock returns

Higher current productivity θ_t at a particular firm forecasts *lower* expected stock returns $E_t(r_{t+1}^s)$ for a given book-to-market ratio. This follows from equation (11) since both tangible and intangible asset returns are expected to drop when the productivity level rises. Regarding the tangible asset return, $dE_t(\pi_{t+1})/d\theta_t < 0$ as follows because $\pi_{t+1} + \delta = (1+s)(r_{t+1}^I + \delta)$ and $E_t r_{t+1}^I - r = (r+\delta)\sigma h/(z+\rho\theta_t)$. The expected investment return is lower because the marginal value of capital is lower at the higher capital level chosen in response to a higher productivity level. Furthermore, $dE_t(g_{t+1})/d\theta_t < 0$ resulting from the mean reverting process for θ_t.

The current productivity level θ_t is *positively* related to the proportional level of investment $i_t = I_t / K_t$: from equations (A3) and (9), the new capital stock is directly related to $E_t(m_{t+1}\theta_{t+1})$ and thus depends positively on current productivity as well. It is also *positively* related to the utilization rate $u_t = U_t / K_t$: from equation (8) u_t is proportional to θ_t. Both investment and utilization provide distinct information about productivity which is important because productivity itself cannot be observed directly and in practice is typically measured as the Solow residual.[14] By employing investment and utilization we bypass using the Solow residual. Utilization helps pin down the current state of productivity, and investment helps pin down the level of productivity expected in future periods, both of which help to predict next period's productivity level.

Equations (8) and (9) together with the capital accumulation equation (3) to determine investment relate both $i_t = I_t / K_t$ and $u_t = U_t / K_t$ to the two state variables θ_t and K_t. By the implicit function theorem we can solve for $\theta_t = \theta(i_t, u_t)$ and $K_t = K(i_t, u_t)$. Thus, we may replace productivity θ_t by two instruments u_t and i_t that jointly perfectly describe it. Furthermore, we know that, conditionally on b_t, $dE_t(r^s_{t+1}) / d\theta_t < 0$. Thus,

> **PROPOSITION 3.** The level of productivity negatively affects expected stock returns conditional on the book-to-market ratio: $dE_t(r^s_{t+1} \mid b_t) / d\theta_t < 0$ (given decreasing returns). Without loss of information, θ_t may be replaced by $\theta_t = \theta(i_t, u_t)$ so that (a) $dE_t(r^s_{t+1} \mid b_t, u_t) / di_t < 0$, and (b) $dE_t(r^s_{t+1} \mid b_t, i_t) / du_t < 0$.

The cost of capital

The single systematic factor in the model implies theoretically that any conditional one-factor model, such as a conditional version of the CAPM, must apply equally well as our

[14] Given our broader interpretation of productivity shocks and the complications of its measurement in the presence of changes in utilization, the Solow residual is even less useful. Standard measurement of the Solow residual considers the quantity of capital and not its utilization. If utilization increases, production increases but the cost measurement does not, leaving a spuriously higher Solow residual.

production-based model (using an array of productivity shocks as in Brock, 1982, would of course avoid this issue). However, for empirical purposes we would have no guidance as to the nature of time variation in the market beta. Empirically, the customary approach would be to estimate beta with a moving 60-month window to apply the CAPM. At the end of the empirical section we compare our model's ability to forecast the cost of capital with asset pricing models such as the CAPM implemented in traditional fashion.

Explicit solutions for firm-level expected stock returns over time

An explicit solution for the value function and expected returns requires specialization of the model to a linear-quadratic case, which we achieve by selecting a particular value for one of the production function parameters: the exponent on utilization in the production function must be related to the exponent on capital as follows

$$\beta = (1-\alpha)/2 \quad , \tag{12}$$

and by assuming normal distributions for ε_t and η_t. The method of undetermined coefficients in Appendix C then provides an explicit solution for the stock price of the firm and its expected excess return as:

$$P(\theta_t) = B[\rho^2\,\theta_t^2 + c_1\,\theta_t + c_0 + (z+\rho\theta_t)^2(1+r-\rho^2)/(r+\delta)]\,. \tag{13}$$

$$E_t r_{t+1}^S - r = h\sigma\ \left(\frac{2(1+r)(z+\rho\theta_t) + c_1 + 2\rho^2\,h\sigma}{\rho^2\,\theta_t^2 + c_1\,\theta_t + c_0 + (z+\rho\theta_t)^2(1+r-\rho^2)/(r+\delta)}\right), \tag{14}$$

with:

$$c_1 = \frac{2\rho\,z\,(1+r)}{1+r-\rho}, \quad c_0 = \frac{z^2(1+r+\rho)(1+r)}{r\,(1+r-\rho)} + \rho^2[(1-h^2)\,\sigma^2 + \sigma_\eta^2], \ \ B = \frac{\beta^2(\alpha/q\gamma)^{\alpha/\beta}}{q(r+\delta)(1+r-\rho^2)}\,.$$

Interpretation and discussion

For further intuition about the closed-form expression in equation (14), we consider a few simple cases. As many of the comparative statics results are ambiguous (by nature in a reasonably rich model) specific empirical implications are obtained in the next section for standard parameter values.

Some of the comparative statics results are clear cut. Note first that the constant *B* does not show up in the expected return expression as it multiplies both the price and the expected net payoff. As a result, the production parameters, α, γ do not affect the excess returns: $d(E_t r_{t+1}^S - r)/d\alpha = 0$ and $d(E_t r_{t+1}^S - r)/d\gamma = 0$. While these parameters do not affect the riskiness of the operations, they affect profitability and thus are important for valuation, affecting the stock price proportionately through *B*, but they affect the net payoff similarly so that the effect on expected return vanishes.

The directional effect of depreciation is clear as well: $d(E_t r_{t+1}^S - r)/d\delta > 0$. An increased depreciation rate raises the user cost of capital, here $r + \delta$, thus lowering the optimal capital stock, future profitability, and the price per share of the firm. The sensitivity to the factor risk increases as a result of the diminishing returns to investment: at a decreased capital stock, the marginal value of capital is larger so that given productivity shocks have a larger impact.

Higher variance of idiosyncratic productivity shocks σ_η^2 raises c_0 and therefore increases the stock price and decreases expected returns. This is consistent with the empirical results of Ang, Hodrick, Xing, and Zhang (2006) which pose the puzzle that firms with higher idiosyncratic risk have lower average returns. In our model higher idiosyncratic variability enhances the option value arising from a firm's flexibility to ramp production up or down with changes in productivity: a positive shock is amplified by adding capital, and a negative shock is mitigated by shedding capital. As evident from (A13) and (A14) and the definition of c_0 in Appendix C, higher idiosyncratic risk raises stock prices for given systematic operational risk. Firms with higher idiosyncratic risk have lower average stock returns because the higher prices for the given systematic risk imply less systematic operational risk per dollar invested.

For other parameters, the comparative statics are generally ambiguous. Typically, h (the risk premium for the aggregate productivity shock) and σ (the sensitivity of firm productivity to the aggregate productivity shock) increase the expected excess return. In addition, h usually raises the firm's beta (risk sensitivity). The reason is that an increase in h raises the cost of capital which reduces the optimal capital stock, raises marginal productivity, and thus the sensitivity to productivity shocks. An increase in the persistence of the shock, ρ, typically has a positive effect on the expected excess return because it raises the strength of the firm's reaction to initial shocks (raising beta). Increases in both the long-run productivity level $\bar{\theta}$ and the current productivity level θ_t raise the optimal capital stock, and therefore lower the marginal productivity of capital. The latter reduces the marginal impact of productivity shocks and, hence, risk sensitivity and expected stock returns.

Numerical solution for standard parameter values

We present some simple numerical results to obtain an idea of the quantitative importance of particular responses, and generate comparative statics results for the empirically relevant parameter space. We set h to 0.32. Since the Sharpe ratio is the volatility of the stochastic discount factor divided by the expected value of the stochastic discount factor, from equation (5) for the stochastic discount factor, h essentially defines the maximum Sharpe ratio of an asset in this economy. The Sharpe ratio of the market return in our sample is 0.32. We set the risk-free rate to 2.04% and the relative price of investment q equal to one.

As an imperfect proxy for the persistence of exogenous profitability factors, we set the persistence of the level of productivity ρ to 0.89, the median of the AR1 coefficients of total factor productivity of all industries in our sample. It is less persistent than the number reported in King and Rebelo (1999), which is for aggregate productivity. The standard deviation of the productivity shock is set to 0.37 and is similar to that used in Pastor and Veronesi (2003) and Zhang (2005). Pastor and Veronesi (2003) show that the average volatility of firm-level profitability has risen from 10% per year in the early 1960s to about 45% in the late 1990s. Zhang (2005) sets the standard deviation of his firm-level productivity to 10% a month which translates to 35% per year. Therefore, 37% (0.37) seems reasonable given the range estimated in this literature. We set the deprecation rate δ to 8% a year, as in King and Rebelo (1999), and γ to 4% a year, as in McGrattan and Schmitz (1999), to reflect the fact that expenses related to utilization are about half of physical capital investment (based on the sample of Canadian firms examined by McGrattan and Schmitz).

We are left with two free parameters, α and $\bar{\theta}$ (not β since it is tied to α), to match the utilization-capital ratio (EK), the investment-capital ratio (IK), and the excess returns (R_s^e) in the economy. To this end, we choose them to be 0.13 and 1.5, respectively. We also set θ_t to its long run average of 1.5 and this exercise shows (see Table 1) that the implied utilization-capital ratio is 81.6%, close to that reported in Cooper, Gerald and Wu (2005), and the investment-to-capital ratio is 11.3%, indicating a 1% average monthly depreciation combining normal depreciation and utilization-related depreciation, and a 6.1% annual equity premium which are close to the averages in our sample. The average investment return is 9.7%.[15] In Figure 1, we show how *u, i,* profits, and excess returns vary when θ_t deviates from $\bar{\theta}$. We keep other parameters at their original values and we vary θ_t between 0.5 and 2.5. We confirm that, when θ_t rises, both *u* and *i* rise, and excess stock returns and profitability fall.

4. **The Data**

Test data are based on the COMPUSTAT annual file and the Manufacturing Industry Database jointly provided by the National Bureau of Economic Research and the Center of Economic Studies (NBER-CES).[16] The model's investment-to-capital ratio *i* (IK) is calculated using firm-level COMPUSTAT data and is defined as the change in property, plant and equipment plus the change in inventory normalized by lagged total assets. The capacity utilization rate in the model *u* (EK) is calculated using industry-level NBER-CES data and is defined as real spending on electricity (nominal spending deflated by the price index for

[15] The gross average investment return is therefore 16.7%. This is less than half of the gross profit margin of the median firm, which is equal to 35.7% in Panel A of Table 2. In this dimension the average investment return thus is not a good proxy for the gross profit margin, and is a bit closer to the return on assets (which is 4.9% for the median firm in our sample, so 12.9% on a gross basis).

[16] http://www.nber.org/nberces/nbprod96.htm.

electricity) divided by the real capital stock. Our industry-level data provide annual industry-level historical figures for 459 industries on the stock of physical capital, spending on electricity, their price indexes, and total factor productivity for the years from 1958 thru 2009. We merge the NBER-CES data with the COMPUSTAT data by SIC code and assume that firms within an industry have the same utilization rate. Note that real electricity use is, in principle, a very good proxy for the intensity with which a firm's resources are used. Whereas construction of standard capacity utilization data requires arbitrary choices of what is labeled "full" capacity, electricity usage provides a continuous measure combining the time period during which, and the intensity with which, the firm's total production capacity is utilized. [17]

Monthly firm-level cum-dividend returns are taken from the Center for Research on Stock Prices (CRSP), and the three-month T-bill rate is subtracted to calculate excess returns. To obtain portfolio-level characteristics, we first calculate annual firm-level characteristics and then take the means of the characteristics of all stocks that belong to each portfolio as the portfolio-level characteristic. We consider various characteristics studied in Fama and French (2008): size (price per share times shares outstanding), the book-to-market ratio (the book value divided by the market value), the gross profit margin (the gross profit scaled by total assets), and momentum (the cumulative excess return over the past 12 months). All firm-level accounting data are obtained from COMPUSTAT. Excess market returns, SMB, HML, and the risk-free rate are

[17] Earlier literature, such as Burnside, Eichenbaum and Rebelo (1995, 1996) also employs electricity usage as a proxy for capital utilization and finds that the resulting productivity shock differs substantially from the typical Solow residual-based productivity shock.

taken from Kenneth French's website.[18] Our sample starts at 1963 and ends at 2009 (limited by the availability of the NBER-CES data).

Table 2 provides descriptive statistics of key variables. We first calculate the means of these variables for each firm and then report their cross-sectional summary statistics. The median IK ratio across all firms is 7.31%, with 80% of the firms in the range from -0.22% to 20.25%, and the median EK ratio across all firms is 2.78%, with 80% of the firms between 1.18% and 6.8%. After fitting an autoregressive model of order one to each industry's IK, EK, BM, and GP at the cross-section, we find that median AR-1 coefficients are 0.92, 0.74, 0.95, and 0.95, respectively, suggesting that the levels of investment, utilization, book-to-market, and profitability are quite persistent. Therefore, factor sensitivities derived from these firm characteristics are time-varying but likely to be reasonably stable. For the 558 months of our sample period, the average values of the Market excess return, SMB, HML, and Risk free rate are, respectively, 4.2%, 2.5%, 4.1%, and 4.5%.

5. Empirical Results

We address in turn the following sets of model implications: (1) the impact on excess stock returns of firm-level production flow decisions, (2) the predictability of stock returns from firm-level stocks and flows, (3) the performance of the production-based model in comparison to traditional asset pricing models.

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[18] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/.

Investment and capacity utilization decisions effect on stock returns

Table 3 provides an initial look, employing one-way sorting, at the hypotheses that the flows of capital investment and capital services both have a negative impact on required returns. At June of each year t, we allocate all firms to five portfolios using year t-1 IK or EK quintile values (with firm-level data for IK and industry-level data for EK). Portfolio L includes firms with IK or EK values below the 20 percentile cutoff, and portfolio H includes industries with IK or EK values above the 80 percentile cutoff values. Monthly portfolio excess returns from July of year t to June of year t+1 are computed as the equal-weighted averages for the excess returns of all firms in the portfolio. For each portfolio we report the equal-weighted excess return and characteristics including market capitalization, book-to-market ratio, gross profitability margin, investment-to-capital ratio, electricity-to-capital ratio, and cumulative excess return in the past 12 months.

Panel A presents the results for the five portfolios sorted by IK and EK. Portfolio L, with the lowest 20% IK ratios, has monthly average return of 1.52%, Portfolio H (the highest 20% of IK ratios) has average return of 0.95%. The return spread, L-H, is significantly positive as predicted at 0.58% per month. When adjusting for risk using the Fama-French three-factor model (1996), the risk-adjusted return is a bit lower at 0.48% but still significant. The Gibbons, Ross and Shanken (1989) joint test of the five risk-adjusted excess returns reveals that these are jointly significant as is consistent with Xing (2008) and Hou, Chen and Zhang (2012). Panel D in Table 2 shows that the correlations of monthly returns of the low minus high IK portfolio with the market excess return, size factor and value factor are -0.18, 0.05 and 0.32 respectively. Panel B in Table 3 presents characteristics of each of the five IK portfolios and the difference of characteristics across low IK and high IK portfolios. We find that firms with larger IK ratios tend to be growth firms and have performed relatively poorly in the past 12 months. These findings are in line with those in Hou, Chen and Zhang (2012) in suggesting that an investment-based asset pricing model is consistent with various financial market anomalies.

The results of sorting by EK are as follows. Here Portfolio L (lowest 20% EK ratios) has an average monthly return of 1.37%, and Portfolio H (the highest 20% EK ratios) has average return of 1.13%. The return spread, L-H, is positive as expected at 0.23% but not significant. The risk-adjusted return is slightly higher and significant at 0.29% per month, and the GRS test rejects the hypothesis of zero joint risk-adjusted excess returns. Correlations between the return difference of the low EK portfolio and high EK portfolio and the market excess return, the size factor, and the value factor are 0.28, 0.47, and -0.46 respectively (Table 2, Panel D). As does the high IK portfolio, the high EK portfolio tends to include firms that have performed relatively poorly in the past 12 months. High EK portfolio further are significantly less profitable and have larger book-to-market ratios than low EK portfolios.

Table 4 presents the results of five-by-five double sorting of the firms into 25 portfolios, so that we can control for the impact of a second selection criterion. In Panel A, in June of each year t, we sequentially form five IK and then five EK portfolios using year t-1 information. We calculate portfolio excess return as the equal-weighted average of excess returns of all firms in the portfolio. For each level of EK, the return difference between low-IK and high-IK portfolios is positive, at 0.60%, 0.71%, 0.69%, 0.52%, and 0.34%, confirming the importance of IK for returns in the predicted direction. For each level of IK the return difference between high-EK and low-EK portfolios is also positive as predicted but smaller, at 0.48%, 0.07%, 0.13%, 0.21%, and 0.21%. The smaller excess returns and lower level of significance relative to IK may be linked to the fact that firm-level EK values are instrumented by their industry values (one of 434). The corresponding risk-adjusted excess returns are also positive for all low-EK minus high-EK groups, and all low-IK minus high-IK groups. The GRS statistic is 6.04 with p-value of 0.0000, which indicates that the risk-adjusted excess returns jointly deviate from zero. Panel B displays the results for the reverse sequential sort, sorting first by EK and then by IK. These results are similar to those in Panel A.

Predicting stock returns from production decisions and value indicators

Table 5 presents Fama and MacBeth (1973) regression results of using year t-1 EK, IK, and other firm-characteristic variables to predict monthly industry-level excess returns starting from July of year t to June of year t+1. The results are consistent with our earlier sorting results. In Panel A, EK has a negative coefficient of -0.014 but is insignificant, IK has a significantly negative coefficient of -0.012. When book-to-market (BM) is added in the regression, the coefficient on IK is similar but the EK coefficient now is -0.024 and is marginally significant. The coefficient on book-to-market is 0.0034 and is significant at the 1% level. We further control for size, and stock price momentum in the past 12 months, and find that momentum remains a robust indicator of future excess returns, but that the explanatory power of EK, IK, and BM remains intact, when these variables are included.[19]

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[19] We also include a financial leverage variable as suggested by Liu, Whited, and Zhang (2009). However, this variable is insignificant in our sample and has no notable impact on the results so we omit it here.

Panel B presents Fama and MacBeth (1973) results using the same variables, but now to predict profitability (measured by Gross Profit Margin, GP). As expected, EK negatively and significantly predicts future profitability. On the other hand, IK has a positive (and marginally significant) impact which is counter to our predictions. However, when we add BM in the regression, and also when we further add size and momentum, both EK and IK have significantly negative coefficients as expected.

While the value effect is confirmed strongly in this context as predicted, our model also suggests specific firm characteristics for which we expect the effect to be reversed. Table 6 presents the extreme portfolios from a four-way sorting designed to examine the book-to-market effect for firms with returns on assets predicted to be below the appreciation rate on intangible assets. This is uncommon, because of the submartingale property of risk-adjusted tangible assets and the supermartingale property of risk-adjusted intangible assets, so we choose firms with the highest EK and IK ratios as this predicts the *lowest return on tangible assets* (average investment return); and firms with the *highest growth of research and development expenses* per unit of capital (RDG) as a predictor of a high appreciation rate of intangible assets. While usage of R&D as a sorting variable eliminates a large fraction of the data (only 20% of COMPUSTAT firm-year observations have R&D measures), in this instance we attempt to identify the specific and presumably small subset of firms anticipated to have change in intangible assets larger than the tangible return and it seems essential to search for them within the set of firms with high R&D: the high RDG firms are expected to have larger intangible returns while their tangible returns measured as gross profits are not affected (which, as Novy-Marx, 2013, stresses, presents an advantage of sorting by gross profits). To have a reasonable number of firms in each cell (portfolio) we start the sample in 1981 which implies an average of around 150 firm years in each cell.

In Panel A we first sort firms by RDG – the growth of each firm's R&D expenses, normalized by lagged total assets to reflect the overall importance of R&D for this firm. We put the 30% firms with lowest RDG in portfolio L and the 30% firms with highest RDG in portfolio H. The second sorting criterion addresses the investment returns, and we again put the firms with 30% highest IK and EK in portfolios H and those with the 30% lowest IK and EK in portfolios L. The prediction is that the returns of higher RDG and IK/EK firms exhibit a smaller value effect, and that the value effect is actually reversed for the highest RDG and IK/EK firms. Panel A shows that, indeed, the value effect (return difference between highest 30%, H, and lowest 30%, L, book-to-market ratio firms) reverses for firms, with the above 70-th percentile (marked by H) in RDG, IK, and EK: portfolios 15 and 16. The effect is small, a little below one percent annually, and not significant. However, the value effect has the standard positive sign in all other cases, for which at least one of the sorting variables is below the 30-th percentile (marked by L), and is, generally, the larger the more of the sorting variables are in bottom 30% , L, portfolios.

Performance of traditional and production-based approaches

Table 7 provides a forecast experiment in which the impact of EK, IK, and BM is allowed to be time-varying. We predict excess returns based on the parameters of cross-sectional regressions of firm-level excess returns on the forecast variables (EK and IK, with or without BM). At June of year t, we form five portfolios from predicted excess returns, which are calculated using information variables from December of year t-1 and average coefficients across previous periods. We consider two sets of average coefficients: those that use data of the previous 10 years, and those that use data up to date (Rolling, Expanding). Portfolio H has the highest predicted returns (Pred). For each portfolio, we then track its excess return from July of year t to June of year t+1 and report the average realization (Real). We follow a similar approach for two competing models: the CAPM and the Fama-French three-factor model. Here for the "rolling" case we estimate betas using five years of data (the standard 60 monthly data points) and for the "expanding" case we use all previous data points to estimate betas.

The results indicate that each of the models generates a reasonable spread between Portfolio H (20% firms with the highest predicted returns) and Portfolio L (20% firms with the lowest predicted returns), ranging from 0.58% per month (IK and EK), 0.64% (CAPM), 0.80% (Fama-French three-factors), to 0.95% (IK, EK, and BM). However, the prediction errors differ dramatically between the models. The mean squared errors (MSE) computed from the differences between predicted and realized returns for each of the five portfolios are far lower for both the IK and EK, and the IK, EK, and BM models compared to the CAPM and Fama-French model by at least a factor three. When we standardize the prediction errors by the total variation in predicted returns, the difference is even more pronounced. We also present t-statistics for the differences between the realized and predicted returns. The discrepancy between predicted and realized difference for Portfolio H versus Portfolio L is statistically significant for the CAPM and Fama-French models but not for our models. In fact, the CAPM and the Fama-French models perform worse than the average random draw as returns from buying portfolio H and selling portfolio L are negative! Table 8 shows that these results are quite consistent over the decades.

We thus provide strong empirical evidence for the simulation-based results of Lin and Zhang (2013) that production-based models outperform traditional models: although the production-based and traditional consumption-based approaches theoretically are two sides of the same coin, the production-based approach seems to work better in predicting a firm's cost of capital.

6. Conclusion

In traditional estimation of required returns, factor sensitivities are obtained from time series of returns and factor realizations. Empirically motivated conditioning approaches aside, the tradition of estimating factor sensitivities from simple time series persists in spite of the theoretical contributions of Cox, Ingersoll, and Ross (1985) and Berk, Green, and Naik (1999) that provide a framework for firm choice of risk sensitivities. Given the prices of risk as determined economy-wide and the market and productivity conditions at the firm level, individual firms choose their production and investment activities to supply risk – firms choose their sensitivities to risk factors. The resulting sensitivities depend on firm-level characteristics implied by the market and productivity constraints faced by the firm, and can be estimated structurally.

The investment-based approach of Cochrane (1991, 1996) provides a specific market and productivity environment for firm choices that has been limited to constant returns to scale technologies. But the limitation is mostly for the sake of tractability and we avoid it here with the purpose of focusing on endogenous fluctuations in profitability. We find that higher investment and production (capacity utilization) choices both are associated with a lower marginal product of capital which decreases the sensitivity of a firm to the risk of productivity shocks. As a result, risk sensitivities and required stock returns decrease as do investment returns and standard profitability measures.

At the same time, book-to-market ratios have a measurable impact on required returns that is separate from profitability. For given expected profitability of book assets (the tangible capital stock) higher book-to-market ratios imply more risk sensitivity: given mean reversion, current shocks to capital productivity have more impact when a larger fraction of shareholder equity is tied up in tangible assets. An exception is for uncommon cases in which expected returns on tangible capital are smaller than expected appreciation rates of intangible assets. In these cases we expect an inverted value effect because higher book-to-market ratios now imply less overall risk as the importance of intangible assets is reduced relative to tangible assets and, quantitatively in these uncommon cases, the effect of lower exposure to the risk of reduction of intangible asset values dominates the effect of higher exposure to the risk of tangible assets.

The theoretical results support the finding by Novy-Marx (2013) of dual dimensions to value – profitability levels and book-to-market levels – both raising required returns. Our view is that higher profitability relates to higher average product of capital making firms more sensitive to current productivity shocks. A higher book-to-market ratio further increases the sensitivity to productivity shocks as this implies less weight on the intangible asset component which has relatively low loadings on the current productivity shocks. Empirically, we confirm that both the level of capital expansion and the level of capital utilization predict lower required returns, and that higher book-to-market value is associated with higher required returns, the traditional value effect. But we also provide an indication that the value effect is inverted in the predicted cases – for firms with low expected profitability and high expected intangible asset appreciation.

Our results hinge on an intangible asset perspective that parts ways with that of the growth options literature (Berk et al., 1999) and the investment-based asset pricing literature (Cochrane, 1996). The view of this literature is that book-to-market ratios deviate from one because the ability of firms to profitably expand their future activities is not incorporated in book values yet is priced in the market. But, in our model, firms can expand to their desired size without friction so intangible asset values are not related to expansion options. They arise as the present value of future residual income stemming from decreasing returns to scale and/or market power (and may also be tied to the earnings power of capitalized previous research and development expenses, although we do not model this aspect). These intangible asset components have in common that they add to profitability, but because of the documented mean reversion of profitability (Fama and French, 2000 and 2006), are less sensitive than tangible assets to current productivity shocks.

Discarding the constant returns to scale formulation in the investment-based framework is vital for generating the positive co-movement between a firm's expected stock returns and profitability in our model. Firms with stronger decreasing returns have higher profit margins resulting from increased leverage of the marginal investment return, but the leverage of the marginal investment return also implies proportionately higher risk, and therefore higher expected stock returns. In contrast, the literature starting with Carlson et al. (2004) relies on operating leverage to generate fluctuations in risk and return. Operating leverage and risk increase with the fixed costs of capital in place, but profitability decreases with this fixed cost, generating a counterfactual negative co-movement between expected return and profitability as stressed by Kogan and Papanikolaou (2013) and Novy-Marx (2013).

We further offer a direct comparison between the performance of the traditional asset pricing approach and the production-based asset pricing approach to predict required returns or costs of capital. Lin and Zhang (2013) provide simulation results supporting the production-based perspective; we provide empirical results in support of this approach. In comparison with the CAPM and the Fama-French three-factor model, with factor sensitivities estimated from time series, we find that our production-based model, with structural estimation of factor sensitivities, performs better in two dimensions: (1) generating more variation in predicted returns across assets, and, especially, (2) predicting realized asset returns.

Production-based asset pricing provides a promising complement to traditional asset pricing. It affords new insights into the supply of risk which may prove to provide better clues about variation in the cost of capital and methods for determining more reliable estimates of this important financial decision gauge. Our theoretical and empirical results suggest that a more detailed view of production decisions is already useful in generating better forecasts of the cost of capital, and also points at additional production-based variables that may provide a direction for further improvements to cost of capital estimation in future production-based asset pricing research.

Appendix

A. The optimal capital stock and investment returns

The solution for optimal investment from equation (6) requires further information about the value function. We obtain a "concentrated" current value function by substituting equations (3) and (2) into the Bellman equation (1) and then using equation (8) to eliminate U_t. Then

$$V(\theta_t, K_t) = (1-\alpha)(\alpha / q\gamma)^{\frac{\alpha}{1-\alpha}} \theta_t K_t^{\frac{\beta}{1-\alpha}} + (1-\delta)qK_t - qK_{t+1}^* + E_t[m_{t+1} V(\theta_{t+1}, K_{t+1}^*)], \qquad \text{(A1)}$$

where K_{t+1}^* is the capital stock implied by the optimal investment policy. The marginal value of capital, $V_K(\theta_{t+1}, K_{t+1})$ may be obtained straightforwardly by updating the concentrated value function by one period and using the envelope theorem:

$$V_K(\theta_{t+1}, K_{t+1}) = \beta(\alpha / q\gamma)^{\frac{\alpha}{1-\alpha}} \theta_{t+1} K_{t+1}^{\frac{\beta}{1-\alpha}-1} + (1-\delta)\, q\,. \qquad \text{(A2)}$$

Thus, $K_{t+1}^{\frac{\beta}{1-\alpha}-1} = [1-(1-\delta)E_t(m_{t+1})]\,q / \beta(\alpha / q\gamma)^{\frac{\alpha}{1-\alpha}} E_t(m_{t+1}\theta_{t+1})$ from equations (6) and (A1). The functional forms in equations (4) and (5) imply straightforwardly that

$$E_t(m_{t+1}\theta_{t+1}) = (z + \rho\theta_t)/(1+r), \quad z \equiv (1-\rho)\bar{\theta} - h\sigma. \qquad \text{(A3)}$$

Equation (9) follows:

$$K_{t+1}^* = [A\,(z + \rho\theta_t)]^{\frac{1-\alpha}{1-\alpha-\beta}}, \quad A \equiv \beta(\alpha / q\gamma)^{\frac{\alpha}{1-\alpha}} / q(r+\delta)\,. \qquad \text{(A4)}$$

From (A2), (A3), and (A4), using the definition $1 + r_{t+1}^I \equiv V_K(\theta_{t+1}, K_{t+1}) / q$ we obtain equation (10):

$$r_{t+1}^I - r = \left(\frac{\sigma(h + \varepsilon_{t+1}) + \eta_{t+1}}{z + \rho\,\theta_t} \right)(r+\delta)\,. \qquad \text{(A5)}$$

B. Components of stock returns

From (A4) it is clear that K_{t+1}^* is a function of θ_t and not K_t. Hence, we may express the disembodied component of equity value, the intangible assets, as:

$$G(\theta_t) = P_t - qK_{t+1}^*, \quad P_t = E_t[m_{t+1} V(\theta_{t+1}, K_{t+1}^*)]\,. \qquad \text{(A6)}$$

We derive explicitly the relation between investment returns and stock returns. From (A1), (A2), and (A6), and using the definition $s = (1-\alpha-\beta)/\beta$:

$$V(\theta_{t+1}, K_{t+1}) = K_{t+1}\left[(1+s)V_K(\theta_{t+1}, K_{t+1}) - s(1-\delta)q\right] + G(\theta_{t+1})\,. \qquad \text{(A7)}$$

To obtain equation (11), the expression for stock returns, divide by the stock price on both sides and then subtract one on both sides (net returns are in lower case: $r_t^X \equiv R_t^X - 1$):

$$r_{t+1}^S = \pi_{t+1} b(\theta_t) + g(\theta_{t+1}, \theta_t)[1 - b(\theta_t)], \quad \pi_t \equiv r_t^I + s(r_t^I + \delta)\,. \qquad \text{(A8)}$$

Here $b(\theta_t) = q\,K_{t+1} / P_t$ is the book-to-market ratio and $g(\theta_{t+1}, \theta_t) = [G(\theta_{t+1}) - G(\theta_t)] / G(\theta_t)$ is the rate of increase in the firm's intangible assets.

We define $\pi_t = r_t^I + s(r_t^I + \delta)$ representing the *average return on investment* which equals the marginal return on investment r_t^I (given in A5) plus a markup due to decreasing returns to scale. Gross average return also equals: $\pi_t + \delta = (1+s)(r_t^I + \delta) = [V_k(\theta_t, K_t)/q] - (1-\delta)$. From (A2) we have $[V_K(\theta_t, K_t)/q] - (1-\delta) = \beta(\alpha/q\gamma)^{\frac{\alpha}{1-\alpha}} \theta_t K_t^{\frac{\beta}{1-\alpha}-1}/q$. Then from $Y_t = \theta_t^{1-\alpha} U_t^{\alpha} K_t^{\beta}$ and equation (8) we obtain $(Y_t - \gamma U_t)/qK_t = (1-\alpha)(\alpha/q\gamma)^{\frac{\alpha}{1-\alpha}} \theta_t K_t^{\frac{\beta}{1-\alpha}-1}/q$. It follows that the gross average return on investment also equals the *gross profit margin*, $\pi_t + \delta = (Y_t - \gamma U_t)/qK_t$.

To prove that the book-to-market ratio is always less than one in our model with decreasing returns to scale, we need to show that $G(\theta_t) = P_t - qK_{t+1}^* > 0$ (which implies $qK_{t+1}^*/P_t < 1$). Multiply (A7) by m_{t+1} and take expectations. This yields from $s = (1-\alpha-\beta)/\beta$ and equation (6) that $E_t[m_{t+1} V(\theta_{t+1}, K_{t+1})] = [1 + s(r+\delta)/(1+r)]qK_{t+1} + E_t[m_{t+1} G(\theta_{t+1})]$. From (A4) and (A6) then

$$G(\theta_t) = \left(\frac{s(r+\delta)}{1+r}\right) q K_{t+1} + E_t[m_{t+1} G(\theta_{t+1})]. \tag{A9}$$

Equation (A9) entails by induction that, for all *t*, $G(\theta_t) > 0$ since $K_{t+1} > 0$ and $s > 0$.

Intangible asset values adjusted for risk and time value follow a strict *supermartingale* process: since $E_t(m_{t+1} G_{t+1}) < G_t$ for $s > 0$ from (A9), we have $E_t[m_{t+1}(1 + g_{t+1})] < 1$. Similarly, tangible asset values adjusted for risk and time value follow a strict *submartingale* process: because investment returns are a martingale $E_t[m_{t+1}(1 + r_{t+1}^I)] = 1$ it follows from $\pi_{t+1} = r_{t+1}^I + s(r_{t+1}^I + \delta)$ that $E_t[m_{t+1}(1 + \pi_{t+1})] > 1$ for $s > 0$.

Since $E_t(m_{t+1} G_{t+1}) < G_t$, the *adjusted* value of intangible assets must decrease over time. However, the expected growth rate of intangible assets, $E_t(g_{t+1}) = [E_t(G_{t+1}) - G_t]/G_t$, may be expected to either be positive or negative depending on whether the interest cost and the systematic risk compensation together exceed or fall short of the "supermartingale deficit", $[s(r+\delta)/(1+r)]qK_{t+1}$. Note, however, that the unconditional average growth rate of intangible assets must be zero due to the stationarity of the productivity shock process: $E(g_{t+1}) = 0$.

From $E_t[m_{t+1}(1 + r_{t+1}^I)] = 1$ it follows that $E_t(r_{t+1}^I) = r + RP_t^I$ (with RP^I the risk premium for the investment return). So $E_t(\pi_{t+1}) - r = RP_t^I + s(r + \delta + RP_t^I) = RP_t^I + C_t^I$, with $C_t^I > 0$. Further, $E_t[m_{t+1}(1 + g(\theta_{t+1}, \theta_t))] < 1$ so that $E_t g(\theta_{t+1}, \theta_t) = r + RP_t^G - C_t^G$, with $C_t^G > 0$ from the strict supermartingale nature of the intangible assets. Hence, the effect on the expected excess stock return $E_t(r_{t+1}^S) - r$ of an increase in the book-to-market ratio b_t, taking expectations in equation (15), equals $E_t[\pi_{t+1} - g(\theta_{t+1}, \theta_t)] = C_t^I + C_t^G + RP_t^I - RP_t^G$ which is typically positive unless the risk premium on intangible assets, RP_t^G, and thus $E_t g(\theta_{t+1}, \theta_t)$, is unusually large.

C. Explicit solutions for firm-level expected stock returns over time

Assume normality and set

$$\beta = (1-\alpha)/2 \quad , \tag{A10}$$

Proceed by employing the method of undetermined coefficients given a quadratic assumption for $G(\theta_t)$ in equation (A9). It is straightforward, but tedious, from equations (A9), (4), and (5) to confirm the quadratic solution for the following specific parameter values:

$$G(\theta_t) = B\,(c_2\theta_t^2 + c_1\theta_t + c_0)\,, \tag{A11}$$

with $c_2 = \rho^2$, $c_1 = \dfrac{2\rho\, z\,(1+r)}{1+r-\rho}$, $c_0 = \dfrac{z^2(1+r+\rho)(1+r)}{r\,(1+r-\rho)} + \rho^2[(1-h^2)\,\sigma^2 + \sigma_\eta^2]$, and

$$B \equiv \beta^2(\alpha/q\gamma)^{\alpha/\beta}/\,q(r+\delta)(1+r-\rho^2)\,.$$

(A1) becomes from equations (A10) and (A11):

$$V(\theta_t, K_t) = (1-\alpha)(\alpha/q\gamma)^{\frac{\alpha}{1-\alpha}}\theta_t\, K_t^{1/2} + (1-\delta)qK_t + c_2\theta_t^2 + c_1\theta_t + c_0\,, \tag{A12}$$

From equations (A4) and (A6) we can also find the stock prices as

$$P(\theta_t) = B\,[c_2\,\theta_t^2 + c_1\,\theta_t + c_0 + (z+\rho\theta_t)^2(1+r-\rho^2)/(r+\delta)]\,. \tag{A13}$$

The expected return is $E_t r_{t+1}^S - r = h\sigma\; E_t[V_\theta(\theta_{t+1}, K_{t+1}^*)]/P_t$: From $1 = E_t[m_{t+1}(1+r_{t+1}^i)]$ and the definition of (conditional) covariance, the expected net stock return of the firm is $E_t r_{t+1}^S = r - Cov_t(m_{t+1}/E_t m_{t+1}, r_{t+1}^S)$. Using the definition of return and the stochastic discount factor specification in equation (5) then $E_t r_{t+1}^S - r = h\; E_t[\varepsilon_{t+1}\; V(\theta_{t+1}, K_{t+1}^*)]/P_t$ .Given the normality of ε_{t+1} , Stein's Lemma implies that $E_t r_{t+1}^S - r = (h\sigma/P_t)\; E_t[V_\theta(\theta_{t+1}, K_{t+1}^*)]$. Straightforward subsequent derivation provides the closed-form solution for the expected excess stock return as

$$E_t r_{t+1}^S - r = h\sigma\; \left(\frac{2(1+r)(z+\rho\theta_t) + c_1 + 2\rho^2 h\sigma}{\rho^2\,\theta_t^2 + c_1\,\theta_t + c_0 + (z+\rho\theta_t)^2(1+r-\rho^2)/(r+\delta)}\right). \tag{A14}$$

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Table 1. Numerical Solution for Typical Parameter Values

We set the physical capital depreciation rate, δ, to 0.08 as in King and Rebelo (1999), γ to 0.04 to account for McGrattan and Schmitz's (1999) finding that maintenance expenses related to utilization are approximately half of that of physical capital investment, the persistence of the productivity, ρ, to 0.89, which is the median of AR-1 coefficients of total factor productivity (using all industries in our sample), the standard deviation of the productivity shock, σ to 0.37, as in Zhang (2005), the risk-free rate, r, to 0.0204, h, to 0.32, which is the Sharpe ratio of the market excess return in our sample. We then set α to 0.131 and $\overline{\theta}$ and θ_t to 1.5 to achieve reasonable estimates for the investment rate (IK), the utilization rate (EK), the average investment return (R_{gp}), and the equity premium (R_s^e).

α	β	δ	γ
0.1310	0.4345	0.0800	0.0400
ρ	$\overline{\theta}$	σ	
0.8900	1.5000	0.3700	
r	b	q	
0.0204	0.3200	1.0000	
u	i	R_s^e	R_{gp}
0.8182	0.1127	0.0610	0.0972

Table 2. Summary Statistics, 1963/07-2009/12

In Panel A, we present the mean, median, 10th percentile and 90th percentile values, and standard deviation (Mean, Median, P10, P90, Std) of the Investment-to-Capital ratio, the Electricity-to-Capital ratio, the Book-to-Market ratio, and the Gross Profit Margin (IK, EK, BM, and GP) across all firms. EK is calculated using the NBER-CES Manufacturing Industry Database obtained from http://www.nber.org/nberces/nbprod96.htm. It is defined as real spending on electricity (spending deflated by the price index for electricity) divided by the real capital stock. IK is the Investment-to-Capital Ratio, which is defined as the sum of changes in gross property, plant and equipment (COMPUSTAT item PPEGT) and change in inventory (INVT) scaled by lagged total assets (AT). GP is gross profit margin and it is the gross profit margin (COMPUSTAT item GP) normalized by total assets. In Panel B we report the AR1 time series correlations across all firms for IK, EK, BM, and GP. Panel C reports means and t-values of time-series of the excess market return, SMB, and HML, as well as two Low minus High portfolios constructed from IK and EK (IK L-H, EK L-H). Panel D reports the correlations of these variables. To construct the Low minus High IK/EK portfolios, we merge industry-level EK to CRSP-COMPUSTAT firms by 4-digit SIC code. At June of each year t, we allocate all firms into five quintiles based on the IK or EK values available at the end of year t-1, and we track monthly excess returns of these firms from July of year t to June of year t+1. Portfolio excess returns are the equal-weighted averages of excess returns of firms in each portfolio. Portfolio 1 (L) includes firms with IK or EK values below the 20th percentile, and Portfolio 5 (H) includes firms with IK or EK values above the 80th percentile, etc. IK L-H or EK L-H is the difference in returns of Portfolio L and Portfolio H. Excess market return, SMB and HML returns are taken from http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/ (Kenneth French's website).

Panel A: Average EK across Firms					
Variable	Mean	Median	P10	P90	Std
IK	0.1012	0.0731	-0.0022	0.2025	0.2647
EK	0.0359	0.0278	0.0118	0.0680	0.0328
BM	0.9727	0.7590	0.2256	1.8982	0.9874
GP	0.3556	0.3571	0.1083	0.6545	0.2901
Panel B: Average AR1 Correlation across Firms					
Variable	Mean	Median	P10	P90	Std
IK	0.9104	0.9186	0.8711	0.9532	0.0584
EK	0.4949	0.7366	-0.3895	0.9737	0.5700
BM	0.9309	0.9455	0.8740	0.9803	0.0655
GP	0.9343	0.9501	0.8740	0.9832	0.0643
Panel C: Factors					
	IK LMH	EK LMH	MKT	SMB	HML
Mean	0.0058	0.0023	0.0042	0.0025	0.0041
t-value	6.5198	1.5954	2.2118	1.8704	3.2873
Panel D: Correlations					
Corr.	IK L-H	EK L-H	MKT	SMB	HML
IK L-H	1.0000	0.0577	-0.1800	0.0543	0.3151
EK L-H		1.0000	0.2801	0.4651	-0.4586
MKT			1.0000	0.3045	-0.3220
SMB				1.0000	-0.2404
HML					1.0000

Table 3. Portfolios Formed on IK or EK, One-dimensional Sorting, 1963/07-2009/12

At June of each year t, we allocate all firms to five quintile portfolios based on cutoff values for the IK or EK variables available at the end of year t-1, and we track monthly excess returns of these firms from July of year t to June of year t+1. Portfolio excess returns are equal-weighted averages of excess returns of firms in each portfolio. Portfolio L includes firms with IK or EK values below the 20th percentile, and Portfolio H includes firms with IK or EK values above the 80th percentile, etc. Industry-level EK values are computed using data from the NBER-CES Manufacturing Industry Database. For each portfolio, in Panel A we report the mean of the portfolio excess return (Ret), and risk-adjusted returns (Alpha) from the Fama-French (1996) three-factor model. In Panel B we report average portfolio characteristics, which include market capitalization, book-to-market ratio, gross profit margin, investment-to-capital ratio, electricity-to-capital ratio, and cumulative excess return in the past 12 months (ME, BM, GP, IK, EK, MOM). The GRS statistic and its p-value in Panel A are the results from a joint test of the significance of risk-adjusted returns of the quintile portfolios following Gibbons, Ross and Shanken (1989).

Panel A: Returns and Alphas							
Variables	Ret.	L	2	3	4	H	L-H
IK	mean	0.0152	0.0138	0.0131	0.0120	0.0095	0.0058
	t-value	5.5856	5.7723	5.7356	5.0267	3.4933	6.5198
	Alpha	0.0063	0.0059	0.0056	0.0047	0.0015	0.0048
	t-value	5.8430	7.6967	7.7920	6.4230	1.7117	5.7085
	GRS	25.0540	p-value	0.0000			
EK	mean	0.0137	0.0137	0.0130	0.0119	0.0113	0.0023
	t-value	4.7346	5.4476	5.3875	4.7032	4.8623	1.5954
	Alpha	0.0062	0.0059	0.0052	0.0035	0.0033	0.0029
	t-value	5.5467	6.0558	6.4862	3.8681	3.8969	2.3554
	GRS	11.6052	p-value	0.0000			
Panel B: Characteristics							
IK	Char.	L	2	3	4	H	IK L-H
	ME	1195.6	2359.5	2474.9	2355.6	1332.0	-136.4
	BM	1.2360	1.0528	0.9444	0.8330	0.7683	0.4677
	GP	0.3648	0.3813	0.4073	0.4269	0.3990	-0.0342
	IK	-0.0781	0.0248	0.0627	0.1098	0.3162	-0.3942
	EK	0.0387	0.0393	0.0417	0.0422	0.0425	-0.0038
	MOM	0.1195	0.0903	0.0836	0.0685	0.0406	0.0790
EK	Char.	L	2	3	4	H	EK L-H
	ME	2170.9	2173.9	1771.4	1434.8	2133.7	37.2
	BM	0.8834	0.8555	0.9420	1.0220	1.1339	-0.2504
	GP	0.4310	0.4178	0.4085	0.4068	0.3167	0.1143
	IK	0.0789	0.0882	0.0859	0.0876	0.0948	-0.0160
	EK	0.0158	0.0236	0.0301	0.0418	0.0933	-0.0776
	MOM	0.0879	0.0913	0.0823	0.0752	0.0658	0.0221

Table 4. Portfolios Formed on IK and EK, Two-dimensional Sorting, 1963/07-2009/12

We sequentially form 25 portfolios based on the IK and EK values. In Panel A, each June we first form five IK portfolios and then divide each IK portfolio into five EK portfolios using all firms. The portfolio excess return is the equal-weighted average of firm excess returns from July of year t to June of year t+1. Portfolio 1 (L) has the lowest 20% IK or EK values and portfolio 5 (H) has the largest IK or EK values. For each portfolio, we record its mean excess returns and risk-adjusted returns (Alpha) using the Fama-French three-factor model (1996). The GRS statistic is a joint test of whether risk-adjusted returns significantly deviate from zero, following Gibbons, Ross and Shanken (1989). Panel B reverses the sorting order, sorting by EK first and IK second.

Panel A: Sequential Sorting on IK and EK													
Ret.	IK-L	IK-2	IK-3	IK-4	IK-H	IK L-H	Alpha	IK-L	IK-2	IK-3	IK-4	IK-H	IK L-H
EK-L	0.0170	0.0136	0.0130	0.0129	0.0110	0.0060		0.0095	0.0057	0.0061	0.0057	0.0038	0.0057
EK-2	0.0166	0.0155	0.0142	0.0124	0.0095	0.0071		0.0072	0.0080	0.0068	0.0055	0.0018	0.0055
EK-3	0.0162	0.0137	0.0140	0.0118	0.0093	0.0069		0.0075	0.0060	0.0064	0.0045	0.0014	0.0061
EK-4	0.0139	0.0132	0.0121	0.0120	0.0087	0.0052		0.0040	0.0052	0.0045	0.0044	0.0001	0.0039
EK-H	0.0123	0.0129	0.0118	0.0108	0.0089	0.0034		0.0035	0.0046	0.0039	0.0033	0.0007	0.0028
EK L-H	0.0048	0.0007	0.0013	0.0021	0.0021	0.0081		0.0061	0.0011	0.0022	0.0024	0.0031	0.0064
t-value													
EK-L	5.2114	4.7955	5.0065	4.4639	3.1930	3.4261		5.3931	4.3512	5.2881	4.4759	2.1959	3.2597
EK-2	5.5367	6.1186	5.9382	4.9293	3.3477	4.2706		4.4631	6.8027	6.2541	4.9775	1.3808	3.3207
EK-3	5.8236	5.4227	5.7862	4.7460	3.3763	4.4120		5.2682	4.7528	5.5624	3.9328	1.1344	3.8632
EK-4	4.7254	5.2433	5.2711	4.8918	2.9869	3.4408		2.9790	4.4504	4.7047	4.1866	0.0865	2.6192
EK-H	4.6568	5.4282	4.9226	4.6347	3.4139	2.3446		2.5788	4.4504	3.5214	3.1528	0.5593	1.9154
EK L-H	2.2586	0.4024	0.8333	1.2200	0.9449	3.7100		3.1334	0.7050	1.4868	1.5348	1.5379	4.3300
GRS								6.0392					
p-value								0.0000					
Panel B: Sequential Sorting on EK and IK													
Ret.	EK-L	EK-2	EK-3	EK-4	EK-H	EK L-H	Alpha	EK-L	EK-2	EK-3	EK-4	EK-H	EK L-H
IK-L	0.0176	0.0170	0.0155	0.0133	0.0133	0.0043		0.0092	0.0082	0.0067	0.0034	0.0044	0.0048
IK-2	0.0138	0.0149	0.0129	0.0131	0.0124	0.0015		0.0064	0.0072	0.0051	0.0049	0.0044	0.0020
IK-3	0.0130	0.0145	0.0140	0.0137	0.0119	0.0011		0.0059	0.0070	0.0065	0.0058	0.0040	0.0019
IK-4	0.0122	0.0125	0.0112	0.0109	0.0102	0.0020		0.0048	0.0057	0.0043	0.0032	0.0030	0.0018
IK-H	0.0108	0.0102	0.0107	0.0090	0.0088	0.0019		0.0036	0.0025	0.0027	0.0005	0.0007	0.0029
IK L-H	0.0068	0.0069	0.0048	0.0043	0.0045	0.0088		0.0056	0.0057	0.0040	0.0030	0.0055	0.0055
t-value													
IK-L	5.3789	5.7978	5.6378	4.5288	5.0258	2.1111		5.3001	4.9562	5.1246	2.4280	3.2680	2.5406
IK-2	4.9127	5.7788	5.2242	5.2735	5.2860	0.8434		4.7406	5.4365	4.7096	4.3267	4.1807	1.2757
IK-3	4.6895	5.9368	5.9034	5.6692	5.0045	0.6193		4.6822	6.0985	5.9767	5.6731	3.5947	1.1755
IK-4	4.1679	5.0193	4.5588	4.4193	4.4336	1.1735		3.8299	4.7407	3.8994	3.0156	2.9269	1.1487
IK-H	3.1553	3.5387	3.8795	3.0794	3.4034	0.8747		2.1528	1.9257	2.1128	0.3512	0.5696	1.4916
IK L-H	3.8189	4.0223	3.2185	2.8809	3.1695	4.1100		3.1631	3.3889	2.6335	2.0147	2.6043	4.2300
GRS								5.3509					
p-value								0.0000					

Table 5. Predicting Future Excess Returns and Gross Profit Margin, 1963/07-2009/12

Panel A reports results from regressing monthly firm-level excess return from July of year t to June of year t+1 on beginning-of-year t characteristics following Fama and MacBeth (1973). We report the average coefficients and Newey-West t-values with four lags to adjust for heteroskedasticity and autocorrelation. Control variables include ME, BM, and MOM. Panel B presents Fama and MacBeth (1973) estimation results from regressing annual next-year gross profit margin on combinations of current IK, EK, BM and MOM. We adjust heteroskedasticity and autocorrelation with two lags. In both regressions, we take natural logs of ME and BM. Three stars indicate significance at the 1% level, two stars indicate significance at the 5% level, and one star indicates significance at the 10% level.

Panel A: Excess Stock Return							
Model		EK	IK	BM	ME	MOM	Adj. R2
1	Coeff.	-0.0137	-0.0116***				0.0040***
	t-value	(-1.0306)	(-7.0769)				(12.6325)
2	Coeff.	-0.0244*	-0.0089***	0.0034***			0.0098***
	t-value	(-1.9137)	(-6.6723)	(5.1628)			(13.5915)
3	Coeff.	-0.0193*	-0.0079***	0.0025***	-0.0008*	0.0044**	0.0363***
	t-value	(-1.8271)	(-6.0139)	(3.8222)	(-1.8585)	(2.2755)	(15.1915)
Panel B: Gross Profit Margin							
Model		EK	IK	BM	ME	MOM	Adj. R2
1	Coeff.	-1.0984***	0.0306*				0.0332***
	t-value	(-13.159)	(1.6790)				(5.1127)
2	Coeff.	-0.9264***	-0.0264**	-0.0735***			0.1158***
	t-value	(-12.401)	(-2.3913)	(-5.6527)			(4.2848)
3	Coeff.	-0.9244***	-0.0242**	-0.0823***	-0.0056	0.0260***	0.1350***
	t-value	(-13.433)	(-2.0785)	(-5.0466)	(-1.5160)	(3.9673)	(4.7942)

Table 6. Reversal of the Book-to-Market Effect, 1981/07-2009/12

We perform a four-dimensional sequential sorting by research and development growth, investment, utilization, and the book-to-market ratio (RDG, IK, EK and BM). RDG is a three-year average of, the change in research and development spending (COMPUSTAT item XRD) normalized by lagged total assets, IK is the investment-to-capital ratio, EK is the electricity-to-capital ratio, and BM is book-to-market ratio. We use only those COMPUSTAT firms whose SIC codes are also available in the NBER-CES Manufacturing Industry Database. We present the extreme portfolios of a four-way sequential sort by these four variables. Portfolio H represents the portfolio of the stocks with the highest 70% RDG, IK, EK or BM firms; Portfolio L represents the portfolio of the stocks with the lowest 30% RDG, IK, EK, or BM firms. The sample starts in 1981 to ensure there are observations in each portfolio. Portfolios are rebalanced at June of each year, we track excess returns from July of year t to June of year t+1, and portfolio returns (Ret) are equal-weighted. We also report mean values of ME, BM, RDG, IK, EK, and the number of firms (N) for each portfolio.

Four-dimensional Sequential Sorting, 1981-2009											
Port.	RDG	IK	EK	BM	Ret	ME	BM	RDG	IK	EK	N
1	L	L	L	L	0.0129	2853.8	0.3374	-0.0193	-0.1418	0.0130	4.0
2	L	L	L	H	0.0193	168.2	1.6597	-0.0096	-0.1132	0.0126	5.0
3	L	L	H	L	0.0023	5154.0	0.3655	-0.0098	-0.1152	0.0496	4.5
4	L	L	H	H	0.0173	838.7	2.0519	-0.0035	-0.1163	0.0519	5.4
5	L	H	L	L	0.0018	1106.1	0.2286	-0.0366	0.2233	0.0136	4.0
6	L	H	L	H	0.0183	265.0	1.5177	-0.0183	0.1486	0.0142	5.0
7	L	H	H	L	0.0063	4641.3	0.3987	-0.0059	0.1617	0.0682	4.5
8	L	H	H	H	0.0086	4259.5	1.5572	-0.0019	0.1319	0.0682	5.5
9	H	L	L	L	0.0084	2839.2	0.2908	0.0548	-0.0225	0.0119	3.6
10	H	L	L	H	0.0133	782.7	1.3165	0.0277	-0.0224	0.0119	4.6
11	H	L	H	L	0.0103	2581.8	0.2493	0.0341	-0.0245	0.0326	5.1
12	H	L	H	H	0.0109	684.8	1.4383	0.0166	-0.0200	0.0359	6.1
13	H	H	L	L	0.0063	5232.6	0.1923	0.1033	0.2717	0.0128	3.8
14	H	H	L	H	0.0165	1866.8	0.9059	0.0221	0.2365	0.0126	4.7
15	H	H	H	L	0.0093	6972.1	0.2090	0.0482	0.2681	0.0363	4.7
16	H	H	H	H	0.0086	1943.5	1.1580	0.0170	0.2593	0.0384	5.6

Table 7. Predicted and Realized Excess Returns, 1973/07-2009/12

At June of year t, we form five portfolios based on predicted excess returns, which are calculated using December of year t-1 EK, IK, and/or BM information and average coefficients from previous periods. We consider two sets of average coefficients that use data of the previous 10 years, or data up to date (Rolling and Expanding, respectively). Portfolio 5 (H) has the highest predicted returns (Pred), and Portfolio 1 (L) has the lowest predicted returns. For each portfolio, we track its excess return from July of year t to June of year t+1 and report the mean and t-value of its equal-weighted average returns (Real). We also report the difference and t-value of predicted return and realized return (Pred-Real, t(Pred-Real)).We consider IK and EK combined, and IK, EK and BM combined. We use the same approach for the CAPM and the Fama-French 3-factor model to construct portfolios based on exposure to market risk, and market risk, size risk, and value risk, respectively, in which we calculate the risk exposures from the previous 5 years monthly data or data up to date. The risk premium is obtained from second pass estimation of average returns on betas. We also report mean squared errors (MSE), which are the mean of the sum of squared deviations of realized returns from predicted returns, and the total sum of squared deviations (TSE), as a ratio of the total sum of squared deviations of predicted returns from their own means (TSEPRED).

	Rolling					Expanding				
Port.	Pred	Real	Real-Pred	t(Real)	t(Real-Pred)	Pred	Real.	Real-Pred	t(Real)	t(Real-Pred)
	Panel A: IK+EK									
L	0.0099	0.0099	0.0000	3.30	0.01	0.0100	0.0096	-0.0004	3.21	-0.13
2	0.0127	0.0125	-0.0002	4.64	-0.07	0.0127	0.0123	-0.0004	4.50	-0.16
3	0.0135	0.0131	-0.0004	4.94	-0.15	0.0134	0.0133	-0.0001	5.07	-0.06
4	0.0141	0.0136	-0.0006	4.95	-0.21	0.0139	0.0137	-0.0002	5.06	-0.08
H	0.0156	0.0143	-0.0014	4.61	-0.43	0.0154	0.0145	-0.0009	4.67	-0.29
L-H	-0.0058	-0.0044	0.0014	-3.67	1.14	-0.0054	-0.0049	0.0005	-4.49	0.47
MSE			0.0015					0.0011		
TSE/TSEPRED			0.1287					0.0796		
	Panel B: IK+EK+BM									
L	0.0078	0.0077	-0.0001	2.63	-0.02	0.0073	0.0073	-0.0001	2.47	-0.02
2	0.0116	0.0119	0.0003	4.29	0.10	0.0111	0.0118	0.0007	4.23	0.23
3	0.0132	0.0133	0.0001	4.88	0.04	0.0128	0.0135	0.0007	4.99	0.27
4	0.0147	0.0141	-0.0006	5.03	-0.21	0.0143	0.0142	-0.0001	5.00	-0.03
H	0.0172	0.0165	-0.0008	5.31	-0.26	0.0170	0.0166	-0.0004	5.46	-0.13
L-H	-0.0095	-0.0088	0.0007	-5.47	0.46	-0.0097	-0.0094	0.0003	-5.82	0.20
MSE			0.0010					0.0011		
TSE/TSEPRED			0.0212					0.0213		
	Panel C: CAPM									
L	0.0101	0.0115	0.0014	3.47	0.42	0.0096	0.0125	0.0029	3.22	0.74
2	0.0123	0.0132	0.0010	4.70	0.34	0.0121	0.0131	0.0010	4.37	0.32
3	0.0132	0.0134	0.0002	5.02	0.06	0.0130	0.0126	-0.0005	4.66	-0.17
4	0.0142	0.0135	-0.0006	5.05	-0.23	0.0138	0.0129	-0.0010	5.42	-0.42
H	0.0165	0.0122	-0.0043	4.04	-1.41	0.0158	0.0128	-0.0031	5.58	-1.33
L-H	-0.0064	-0.0008	0.0057	-0.35	2.58	-0.0063	-0.0003	0.0059	-0.16	2.85
MSE			0.0047					0.0044		
TSE/TSEPRED			0.9607					0.9309		
	Panel D: FF3 Factors									
L	0.0094	0.0129	0.0035	4.11	1.10	0.0085	0.0122	0.0037	3.69	1.12
2	0.0120	0.0132	0.0013	4.92	0.46	0.0114	0.0125	0.0011	4.48	0.39
3	0.0130	0.0126	-0.0004	4.78	-0.15	0.0124	0.0136	0.0012	5.14	0.45
4	0.0142	0.0131	-0.0010	4.90	-0.39	0.0134	0.0133	-0.0001	5.07	-0.03
H	0.0174	0.0120	-0.0054	3.78	-1.71	0.0164	0.0122	-0.0043	4.22	-1.47
L-H	-0.0080	0.0009	0.0089	0.52	5.08	-0.0079	0.0000	0.0080	0.03	5.03
MSE			0.0067					0.0059		
TSE/TSEPRED			1.2818					1.0301		

Table 8. Predicted and Realized Excess Returns, 1973/07-2009/12 Subsamples

At June of year t, we form five portfolios based on predicted excess returns, which are calculated using December of year t-1 EK, IK, and/or BM information and average coefficients from previous periods. We consider two sets of average coefficients that use data of the previous 10 years, or data up to date (Rolling and Expanding, respectively). Portfolio 5 (H) has the highest predicted returns (Pred) and Portfolio 1 (L) has the lowest predicted returns. For each portfolio, we track its excess return from July of year t to June of year t+1 and report the mean and t-value of its equal-weighted realized average returns (Real). We also report the difference and t-value of predicted return and realized return (Pred-Real, t(Pred-Real)).We consider IK and EK combined, and IK, EK and BM combined. We use the same approach for the CAPM and the Fama-French 3-factor model to construct portfolios based on exposure to market risk, and market risk, size risk, and value risk, respectively, in which we calculate the risk exposures from the previous 5 years of monthly data or data up to date. Risk premiums are calculated from second pass estimation of average returns on betas. We report the L minus H returns for predicted excess returns and realized excess returns by decade.

	Rolling					Expanding				
L-H in subperiod	Pred	Real	Real-Pred	t(Real)	t(Real-Pred)	Pred	Real	Real-Pred	t(Real)	t(Real-Pred)
Panel A: IK+EK										
1973-1979	-0.0046	-0.0067	-0.0021	-2.45	-0.77	-0.0045	-0.0083	-0.0038	-2.92	-1.34
1980-1989	-0.0076	-0.0056	0.0020	-3.40	1.23	-0.0066	-0.0069	-0.0003	-4.18	-0.18
1990-1999	-0.0043	-0.0041	0.0002	-2.23	0.13	-0.0051	-0.0061	-0.0010	-3.29	-0.52
2000-2009	-0.0061	-0.0023	0.0038	-0.73	1.21	-0.0049	0.0003	0.0052	0.11	2.12
Panel B: IK+EK+BM										
1973-1979	-0.0091	-0.0147	-0.0057	-2.49	-0.96	-0.0088	-0.0155	-0.0067	-2.63	-1.14
1980-1989	-0.0117	-0.0098	0.0019	-4.09	0.81	-0.0104	-0.0099	0.0005	-4.20	0.20
1990-1999	-0.0078	-0.0062	0.0016	-2.28	0.57	-0.0097	-0.0068	0.0029	-2.52	1.07
2000-2009	-0.0092	-0.0070	0.0022	-2.39	0.76	-0.0096	-0.0081	0.0015	-2.64	0.48
Panel C: CAPM										
1973-1979	-0.0088	0.0040	0.0127	0.64	2.03	-0.0088	0.0040	0.0128	0.61	1.93
1980-1989	-0.0047	-0.0108	-0.0060	-4.05	-2.20	-0.0074	-0.0025	0.0048	-0.89	1.68
1990-1999	-0.0086	-0.0001	0.0085	-0.05	3.37	-0.0066	-0.0002	0.0064	-0.07	2.61
2000-2009	-0.0047	0.0060	0.0107	1.04	1.83	-0.0035	-0.0007	0.0028	-0.13	0.54
Panel D: FF3 Factors										
1973-1979	-0.0095	0.0034	0.0129	0.60	2.25	-0.0094	0.0025	0.0119	0.38	1.81
1980-1989	-0.0059	-0.0024	0.0034	-0.91	1.28	-0.0067	-0.0010	0.0057	-0.45	2.45
1990-1999	-0.0102	0.0024	0.0127	0.89	4.66	-0.0100	-0.0004	0.0096	-0.18	4.07
2000-2009	-0.0071	0.0013	0.0084	0.35	2.25	-0.0063	0.0002	0.0065	0.08	2.31

Figure 1. Utilization, Investment, Profit, and Excess Return as a Function of Productivity

The physical capital depreciation rate, δ, is set to 0.08 as in King and Rebelo (1999). Attrition due to utilization, γ, is set to 0.04 to account for McGrattan and Schmitz's (1999) finding that maintenance expenses related to utilization are approximately half of that of physical capital investment. Persistence of the productivity, ρ, is set to 0.89, which is the median of AR-1 coefficients of total factor productivity using all industries in our sample. The standard deviation of the productivity shock, σ is set to 0.37, as in Zhang (2005). The risk-free rate, r, is set to 0.0204. The Maximum Sharpe ratio, h, is set to 0.32, which is the Sharpe ratio of the market excess return in our sample. The production function parameter, α, is set to 0.131. The long-run average productivity level $\bar{\theta}$, is set to 1.5. We vary the productivity level θ_t between 0.5 and 2.5 and track how the utilized capital-to-capital ratio (u), the investment-to-capital ratio (i), average investment return or gross profitability (R_{gp}), and the excess stock returns (R_s^e) vary.