Investment Irreversibility, Real Activity and Asset Return Dynamics

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Abstract

We conduct an empirical investigation of an emerging strand of models, pioneered by Berk, Green and Naik (1999), relating firms' real investment and asset return dynamics. We introduce a novel theoretically derived economically fundamental variable, namely the rate of capacity utilization, and test its relationships with return volatility, systematic risk and expected returns. Our evidence on the roles of assets in place and growth options in stock return dynamics is broadly consistent with the predictions of the new strand of models. We also propose a novel measure for the degree of investment irreversibility, namely the volatility of the capacity utilization rate.

1 Introduction

In this paper we test the principal predictions stemming from models in a new and growing literature linking firms' real investment behavior and asset return dynamics. This string of recent papers, pioneered by Berk, Green and Naik (1999), includes Gomes, Kogan and Zhang (2003), Kogan (2004), Zhang (2005a and 2005b), Carlson, Fisher and Giammarino (2004, 2005), Cooper (2005), Gourio (2005) and Gala (2005). This literature ties firms' characteristics, such as their book-to-market ratio (hereafter B/M), to their systematic risk within models that derive the asset pricing implications of firms' optimal production and investment decisions. In these models systematic risk is conditional in nature. B/M is correlated with the true, conditional systematic risk of the firm, namely its conditional market beta and its conditional loadings with respect to other risk factors. All these models share some main features and common predictions. For example, a central common feature is the existence of frictions in the capital adjustment technology and in particular a degree of investment irreversibility, giving rise to a role for B/M in conveying information about risk and conditional moments of returns.[1] Thus, while we are testing an extension of Cooper's (2005) model, our results constitute a test of some of the common predictions about the relations among B/M, risk and return dynamics shared by all of the models in this literature.

We extend the model in Cooper (2005) and derive and test empirically its implications in terms of relationships between a variable related to economic fundamentals, namely the rate of capacity utilization (hereafter CAPU), and risk and return. We note several advantages of our approach. First, in our model CAPU conveys exactly the same information as B/M, but while B/M has already been shown to predict average returns both in the cross-section and in the time series, to the best of our knowledge the role of CAPU in asset return dynamics has not yet been explored. Second, unlike the B/M ratio, our variable is directly linked to the production decisions of the firms and is immune to Berk's (1995) critique of using price ratios in predicting returns. Third, while the predictive power of B/M both in the cross-section and in the time-series is consistent with theories based on behavioral biases, CAPU does not depend on the firm's market value and is therefore less likely to reflect stock mispricing. Fourth, CAPU, and potentially other theoretically derived economic variables, can serve in asset pricing tests aiming to resolve the value premium puzzle and possibly other anomalies. Fifth, we introduce a novel measure for the degree of industries'

[1] There is considerable evidence that investment is to a large extent irreversible at the plant and firm level. See, for example, Caballero, Engel and Haltiwanger (1995), Doms and Dunne (1998), and Ramey and Shapiro (2001).

investment irreversibility, namely the volatility of CAPU. The rationale is that in the absence of irreversibility and capital adjustment costs the firm will always fully utilize its capital and will adjust to profitability shocks by investing or disinvesting. Irreversibility and capital adjustment costs give rise to volatility of CAPU. Since a common feature of the recent models linking corporate real investment decisions and asset returns is a degree of investment irreversibility, we use this measure to examine whether the predictions of the models find stronger empirical support within industries whose investment is characterized by a larger degree of irreversibility.[2] This measure of irreversibility is novel and could potentially be used for other applications in economics.[3]

Under investment irreversibility, operating leverage and production expansion options on one hand and growth options on the other hand affect the riskiness and return volatility of the firm in two opposing ways. The intuition is as follows. Consider a firm that has experienced a sequence of positive profitability shocks but has not yet exercised its option to invest. Such a firm has relatively low book-to-market ratio and high CAPU. The firm's growth options, namely its options to invest, move 'in the money': As the firm nears full utilization of its capital stock, the value of its option to expand capacity through investment increases. The increased 'moneyness' of the firm's growth options increases return volatility. Moreover, since the value of the option to invest is positively correlated with productivity shocks, and in particular with aggregate productivity shocks, the firm's stock return becomes more sensitive to aggregate conditions implying that the firm's systematic risk (and therefore expected returns) increase. However, the firm's operating leverage decreases with the shocks, thereby reducing its risk and return volatility. Furthermore, the firm's option to easily expand production without undertaking costly investment moves 'out of the money', reducing return volatility and risk.

Adverse profitability shocks, which lead to higher B/M and lower CAPU, increase the riskiness and return volatility of the firm as they increase its operating leverage and increase the value of its option to easily expand production. This is true particularly when the firm's growth options are 'out of the money', i.e. when CAPU is low and B/M is high.[4] This is reflected in the convexity

[2] Note that adjustment costs of investment lead to a degree of irreversibility: it is costly to disinvest if in the future profitability conditions will improve and the firm will want to increase its stock of capital again.

[3] The only other measure we are aware of is by Caballero, Engel and Haltiwanger (1995), who construct a measure for excess capacity by estimating the elasticity of the demand for capital.

[4] Note that although financial leverage is not modelled in our paper, its effect on risk and return volatility is similar to the effect of operating leverage. That is, in addition to increasing risk and return volatility through increasing operating leverage, adverse profitability shocks have similar impact on risk and volatility of returns through increasing

of the graph depicting the relation between B/M and risk (see Figure 1). For low B/M values the slope of the graph becomes flat, reflecting the opposing impact of the two effects. In fact, under certain parameter values the graph has a U-shape. That is, for sufficiently low (high) values of B/M (CAPU), risk increases as B/M (CAPU) declines (increases). This intuition is also closely related to the model in Carlson, Fisher and Giammarino (2005) who show that upon exercising their growth options firms that conduct SEO become less risky, even if their operating leverage increases. Lyandres, Sun and Zhang (2005) present empirical evidence that lend support for the theoretical predictions of Carlson, Fisher and Giammarino (2005). We appeal to the intuition above in our empirical tests. Specifically, we test whether the relation between CAPU (and B/M) and return dynamics when CAPU is high (and B/M low) is different from that relation for low values of CAPU (and high B/M).

Within the framework of a general equilibrium model, Kogan (2004) shows that the relation between B/M and conditional moments of stock returns is not monotonic. In Kogan's model a small industry is facing irreversible investment and convex adjustment costs of investment. When the irreversibility constraint is particularly severe (and Tobin's q is low), the supply of capital is inelastic. Consequently the price of the industry's installed capital is highly volatile, and both conditional volatility of returns and expected returns are negatively related to Tobin's q (market-to-book). When Tobin's q exceeds one and the rate of investment is bounded because of the adjustment costs, volatility and expected returns become positively related to Tobin's q since the supply of capital is again relatively inelastic. Using industry portfolios Kogan presents empirical evidence in support of his model's predictions regarding return volatility but not expected returns. Our empirical investigation focuses primarily on the relation between CAPU and return dynamics (which we also derive theoretically) whereas Kogan focuses on the relations among M/B, expected returns and return volatility. Hence our tests complement the tests in Kogan (2004). We also examine the relation between CAPU (and B/M) and risk as measured by the loadings of returns with respect to the three factors of Fama and French (1993).

We conduct our empirical analysis using industry portfolios for which the Federal Reserve publishes capacity utilization data.[5] Our use of industry portfolios is driven by data availability

financial leverage. As operating and financial leverage increase, CAPU decreases and B/M increases.

[5]In our model the firm is able to vary its capital utilization rate but not its labor utilization rate. Thus, in the model capital utilization is identical to capacity utilization. The Federal Reserve's data includes data on both capital utilization as well as labor utilization. We use the capacity utilization rate as a proxy for the rate of capital

considerations, as data on capacity utilization is only available at the industry-level. While our model is a firm-level model, its implications pertain to the industry as well. If, for example, the majority of firms in an industry utilize much of their capacity, the industry's CAPU is high. Positive industry-wide shocks will increase firms', as well as the industry's, CAPU. As CAPU and the moneyness of firms' growth options increase, their return volatility increases. That is, the sensitivity of their return to firm-specific shocks,industry shocks and aggregate shocks increases. This implies that the industry portfolio return becomes more volatile as well: industry-wide and aggregate shocks will have a greater impact on the industry's portfolio return. Similarly, the industry portfolio's systematic risk and expected return increase.

Our findings can be summarized as follows. First, we find that CAPU tracks economically and statistically significant variation in expected returns. For the typical industry, an increase in CAPU equal to twice its time-series standard deviation forecasts a 6.8% decrease in expected returns. This finding lends support to the models' predictions. Importantly, CAPU remains statistically and economically significant even after controlling for B/M. This suggests that CAPU predicts returns not solely because it correlates with B/M, which, according to some researchers, predicts returns due to mispricing. Second, consistent with the conjecture that operating leverage and production expansion options on one hand and growth options moneyness on the other hand affect the risk of the firm in opposing ways, and with the intuition in Kogan's (2004) model, we find that the coefficient on CAPU changes signs: for values of CAPU that are below industries' time-series median (implying high B/M in general) we document a strong negative relationship between CAPU and future returns (and a strong positive relation between B/M and future returns). When CAPU is low (and B/M is high), the growth options are 'out of the money' and the dominant effects any increase in CAPU (and decline in B/M) is the reduction in operating leverage and the reduction in the moneyness of the production expansion options. When CAPU is above industries' time-series median (B/M is low) the relation between CAPU (and B/M) and future returns becomes statistically and economically insignificant. This is consistent with the conjecture that when CAPU is high (B/M is low) the effects of the operating leverage and production expansion options on one hand, and the growth options on the other hand, on the riskiness of the firm offset each other.

utilization. If capital adjustment costs are substantially larger than labor adjustment costs then firms tend to respond to shocks by changing the rate of capital utilization and by changing the quantity, not utilization rate, of labor. Thus, variations in the rate of capacity utilizations are mainly due to variations in capital utilization.

Third, consistent with the models' predictions, CAPU is negatively related to return volatility when CAPU is low and positively so when CAPU is high. Fourth, we find some evidence that within industries facing a higher degree of investment irreversibility (as measured by the volatility of CAPU) the relation between CAPU and future returns is more negative, especially when CAPU is below the industry time series median. When CAPU is relatively high, the relation between the degree of irreversibility and future returns ceases to be statistically and economically significant.

The different models exploring the implications of production and real investment for the cross-section and time-series of stock returns provide distinct rationales for a relationship between book-to-market and systematic risk. Berk, Green and Naik (1999) present an irreversible investment model in which new investment opportunities are heterogenous in risk. As firms exploit investment opportunities their systematic risk changes. In their model valuable investment projects are characterized by low systematic risk. This leads to a role for book-to-market because the firm's market value changes as the composition of assets changes. Gomes, Kogan and Zhang (2003) derive a general equilibrium model in a setting that is related to that of Berk, Green and Naik (1999). Zhang (2005a) presents an industry equilibrium model and shows that costly reversibility of investment and counter-cyclical price of risk give rise to a value premium that is counter-cyclical. Carlson, Fisher and Giammarino (2004) and Cooper (2005) stress the role of both investment irreversibility and operating leverage in generating a value premium. Zhang (2005b) shows that under certain conditions stock returns equal investment returns which are directly tied to firm characteristics. Zhang then demonstrates that many asset pricing anomalies can be consistent with the Q-theory of investment. Gourio (2005) presents a putty-clay technology model in which a value premium arises from operating leverage that is related to imperfect capital-labor substitutability. Gala (2005) presents a general equilibrium model with heterogenous firms facing irreversibility and adjustment costs of investment. In Gala's model growth firms provide "consumption insurance" since they are able to mitigate the effects of adverse aggregate productivity shocks through reducing investment. Consumption volatility in his model is countercyclical due to the irreversibility constraints, which magnifies the value premium.

A related strand of literature studies the relation between stock return dynamics and the returns on real investment using production based asset pricing models. For example, Cochrane (1991) examines the relation between aggregate investment returns and the aggregate stock market. Restoy and Rockinger (1994) provide a theoretical derivation of the link between stock return

and investment in a model with adjustment costs. Cochrane (1996) examines the relationship of the cross-section and time series of expected stock returns and aggregate investment returns. Gomes, Yaron and Zhang (2006) use a production based asset pricing model that incorporates costly external finance to investigate whether financial market imperfections are quantitatively important for pricing the cross-section of returns.

Lewellen (1999) documents that B/M is strongly associated with changes in risk, as measured by the Fama and French (1993) three-factor model. Our findings complement Lewellen's findings in the sense that we are using economically fundamental variables related to the production decisions of the firm and find that CAPU is associated with risk in a similar fashion to the relation between B/M and risk.

Our work contributes to the ongoing debate among finance researchers as to whether the book-to-market effect is related to omitted state variables or is driven by mispricing. The models in the literature linking production, real investment and asset returns, tie the book-to-market ratio to the firm's systematic risk. The observed value premium is consistent with the predictions of these models but, as mentioned above, it is also consistent with mispricing. We show that these models find empirical support not only in their predictions regarding the relation between B/M and average stock returns, but also in their other predictions, namely relationships among B/M, CAPU, risk and conditional moments of returns.

In a related paper, Xing and Zhang (2004) evaluate the empirical relevance of the recent theories linking the value premium to economic fundamentals. They study the cyclical behavior of economic fundamentals of value and growth firms and find that the fundamentals of value firms (such as dividend growth and earnings growth) are more adversely affected by negative business cycle shocks than those of growth firms. Our focus is different in that we investigate the relations among CAPU, risk and conditional moments of stock returns, and hence complements the work of Xing and Zhang (2004).

Anderson and Garcia-Feidjoo (2005) use a different approach to investigate the empirical implications of the model in Berk, Green and Naik (1999). Berk, Green and Naik argue that firms that invest are exercising their growth options and therefore their riskiness declines. Consistent with this argument, Anderson and Garcia-Feidjoo find that firms with the highest growth in capital expenditures have lower future returns than the firms with the lowest capital expenditures.

This paper is organized as follows. Section 2 describes the model. Section 3 provides some

comparative statics and simulation results. The data is described in Section 4. Section 5 presents the empirical hypotheses, tests and results. Section 6 concludes. Some technical details are contained in the Appendix.

2 The Model

In this section we present a continuous time model of a firm that is facing irreversible real investment, is incurring fixed and variable production costs, and has the flexibility to vary its capital utilization rate. Our model differs from Cooper (2005) along two important dimensions that facilitate our empirical tests. First, the firm in our model can vary its capital utilization rate. We demonstrate that the rate of capital utilization is directly related to the systematic risk, expected returns and return volatility of the firm. Second, we examine the combined effects of operating leverage and growth options on the firm's risk and conditional moments of returns. We show how the rate of capital utilization can be directly related to operating leverage and growth options. In our model all information regarding firms' conditional moments of returns and risk is summarized in the rate of capital utilization. Furthermore, the rate of capital utilization and the book-to-market ratio reflect the same information.

Labor is costlessly adjustable. As shown in Appendix A, the firm's revenue after labor has been optimized over is

$$f(\eta, K, U) = D\eta (KU)^{\alpha}, \tag{1}$$

where D is a constant, η is the productivity level, K is the capital stock, U is the capital utilization rate and $0 < \alpha < 1$ reflects decreasing returns to scale.[6] Decreasing returns to scale of the revenue function can arise from the scarcity of certain factors of production, for example land, or from imperfect competition.

Note that in the model the firm is able to vary the rate of capital utilization but not the rate of labor utilization. Thus, capacity utilization is identical to capital utilization in our model. In our empirical tests we are using data on capacity utilization as a proxy for capital utilization.

The firm's flow of profits is given by

$$\hat{\Pi}(\eta, K, U) = D\eta (KU)^{\alpha} - mU^{\phi}K - cK, \tag{2}$$

[6] The constant D includes the wage rates and parameters related to the shares of labor and capital in production.

where m is the cost per unit of utilized capital and c is the fixed operating cost per unit of capital. m can be interpreted as maintenance, energy cost or input costs and we assume, as in Abel and Eberly (1998) that $\phi > 1$, or that variable operating costs per unit of capital increase with the utilization rate. The fixed production costs parameter c can be interpreted as reflecting long-term labor contract, contracts with suppliers or necessary maintenance that is unrelated to the rate of capital utilization. Note that the fixed production costs give rise to operating leverage.

The firm sets utilization so as to maximize the instantaneous profits. This implies that the optimal utilization rate is (see Appendix B for details):

$$U^* = \left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}} \eta^{\frac{1}{\phi-\alpha}} K^{\frac{\alpha-1}{\phi-\alpha}}. \tag{3}$$

Appendix B shows that after optimizing over the utilization rate, the profit of the firm is given by

$$\Pi(\theta, K) = B\theta^{1-\gamma}K^{\gamma} - cK, \tag{4}$$

where $B = D^{\frac{\phi}{\phi-\alpha}}\left[\left(\frac{\alpha}{m\phi}\right)^{\frac{\alpha}{\phi-\alpha}} - m\left(\frac{\alpha}{m\phi}\right)^{\frac{\phi}{\phi-\alpha}}\right]$, $\gamma = \frac{\alpha(\phi-1)}{\phi-\alpha}$ and $\theta = \eta^{\frac{1}{1-\alpha}}$.

Investment is irreversible and entails no adjustment costs.[7] The law of motion for capital is

$$dK = -\delta K dt + I, \tag{5}$$

where I is the firm's investment and δ is the capital depreciation rate. The good produced in the economy can be either consumed or used as a capital good. The price of the good is constant and normalized to one. The value of the firm is denoted $J(\theta, K)$. Note that the profit function is linearly homogenous in θ and K. Therefore $J(\theta, K)$ is also linearly homogenous in θ and K. Denote $Z = \frac{K}{\theta}$. Then we can write $J(\theta, K) = \theta V(Z)$.

The productivity level of the firm θ is composed of an aggregate component as well as an idiosyncratic component as follows,

$$\theta = \theta_A \theta_i, \tag{6}$$

where θ_A is aggregate productivity and θ_i is idiosyncratic productivity. Both the aggregate productivity and the idiosyncratic productivity follow geometric Brownian motions as follows:

$$\frac{d\theta_A}{\theta_A} = \mu_A dt + \sigma_A dw_A, \tag{7}$$

[7] Cooper (2005) and Carlson, Giammarino and Fisher (2004) find that adjustment costs play no role in generating a value premium.

and

$$\frac{d\theta_i}{\theta_i} = \sigma_i dw_i, \tag{8}$$

where dw_A and dw_i are increments to independent standard Wiener processes, representing shocks to the aggregate and idiosyncratic productivity levels, respectively. μ_A is the drift of the aggregate productivity process. σ_A and σ_i are the volatilities of the aggregate productivity and idiosyncratic productivity, respectively.

It follows that the firm's productivity is also a geometric Brownian motion

$$\frac{d\theta}{\theta} = \mu_A dt + \sigma dw, \tag{9}$$

where $\sigma = \sqrt{\sigma_A^2 + \sigma_i^2}$ and $dw = \frac{\sigma_A dw_A + \sigma_i dw_i}{\sqrt{\sigma_A^2 + \sigma_i^2}}$.

Applying the solution techniques in Cooper (2005) we obtain the following expression for the function $V(Z)$:

$$V(Z) = V_{AP}(Z) + V_{GO}(Z), \tag{10}$$

where $V_{AP}(Z) = \frac{B}{r+\delta\gamma+\mu(\gamma-1)-\frac{1}{2}\sigma^2\gamma(\gamma-1)} Z^{\gamma} - \frac{m}{r+\delta} Z$ represents the value of the firm's assets in place and $V_{GO} = D_N Z^{\lambda_N}$ is the value of the firm's option to invest (i.e. the value of its growth options). As shown in Cooper (2005), $D_N > 0$ and $\lambda_N < 0$ so that the value of the firm's growth options declines with Z. Intuitively, when $Z = \frac{K}{\theta}$ is high, capital productivity is low and the firm has excess capital capacity, implying that the value of the option to add more capital (invest) is low.

For the empirical investigation to follow it is useful to restate the state variable Z in terms of characteristics of the firm's real activity. We now proceed to express Z in terms of the firm's rate of capital utilization. First note that

$$U^* = \left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}} \eta^{\frac{1}{\phi-\alpha}} K^{\frac{\alpha-1}{\phi-\alpha}} = \left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}} \theta^{\frac{1-\alpha}{\phi-\alpha}} K^{\frac{\alpha-1}{\phi-\alpha}} = \left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}} Z^{\frac{\alpha-1}{\phi-\alpha}}, \tag{11}$$

implying that

$$Z = (U^*)^{\frac{\phi-\alpha}{\alpha-1}} \left[\left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\alpha-\phi}}\right]^{\frac{\phi-\alpha}{\alpha-1}}. \tag{12}$$

Note that Z is inversely related to U^* because $\alpha - 1 < 0$. Thus, when capital is in excess capacity, it is optimal for the firm to reduce its utilization rate.

To understand the links between investment irreversibility, book-to-market, and the firm's risk and returns we need to model the dynamics of the firm's returns and exposure to systematic risk. The firm's conditional expected return per unit of time is

$$\frac{1}{dt}E\left[\frac{dJ}{J}\right] = E\left[\frac{d\theta}{\theta}\right] + E\left[\frac{dV}{V}\right] = \mu + \frac{-\left(\delta+\mu\right)ZV_Z + \frac{1}{2}\sigma^2 V_{ZZ}Z^2}{V}, \tag{13}$$

and the conditional volatility per unit of time is

$$\frac{1}{dt}Std\left[\frac{dJ}{J}\right] = \sigma\left[1 + \frac{\left(V_Z Z\right)^2}{V^2} - \frac{V_Z Z}{V}\right]^{\frac{1}{2}}. \tag{14}$$

Appendix C shows the derivations of equation (14). To derive the dynamics of the firm's exposure to systematic market risk, we need to link the return on the risk factors to the source of systematic risk in our model. Let the return on risk factor s be given by

$$R_s = \mu_s dt + \sigma_s dw_A. \tag{15}$$

The return on factor s is positively correlated with the aggregate shock, and therefore with the economy's discount factor. The firm's loading with respect to risk factor s is then

$$\beta_s = \frac{1}{Var\left(R_s\right)}\sigma_s\left[\sqrt{\sigma_A^2 + \sigma_i^2} - \sigma_A V_Z \frac{Z}{V}\right]. \tag{16}$$

Note that the book-to-market ratio in the model is given by

$$\frac{K}{J} = \frac{K}{\theta V} = \frac{Z}{V}. \tag{17}$$

Thus

$$\beta_s = \frac{1}{Var\left(R_s\right)}\sigma_s\left[\sqrt{\sigma_A^2 + \sigma_i^2} - \sigma_A V_Z \frac{K}{J}\right]. \tag{18}$$

Since the state variable Z characterizing the current value and future profit prospect of the firms can be re-expressed in terms of the capital utilization rate, the firm's expected returns, volatility and systematic risk can also be related to CAPU. The loadings with respect to risk factors can be expressed as a function of the firm's optimal rate of capital utilization:

$$\beta_s = \frac{1}{Var\left(R_s\right)}\sigma_s\left[\sqrt{\sigma_A^2 + \sigma_i^2} - \sigma_A \frac{V_Z}{V}\left(U^*\right)^{\frac{\phi-\alpha}{\alpha-1}}\left[D\left(\frac{\alpha}{m\phi}\right)^{-\frac{1}{\phi-\alpha}}\right]^{\frac{\phi-\alpha}{\alpha-1}}\right]. \tag{19}$$

3 Numerical Examples and Simulations

In this section we present numerical examples of our model that facilitate our empirical tests. As in Cooper (2005) we choose the model parameter values to match empirical findings. Details of the parameter selection are as follows. Real business cycle models usually assign values between 8 percent and 12 percent for the annual depreciation rate (see, Kydland and Prescott, 1982). We choose a depreciation rate of 8 percent per annum. The annual real interest rate in our simulations is 0.80 percent, which is the value reported by Jermann (1998). α, the share of utilized capital in production is 0.90. Note that α is the share of utilized capital divided by one minus the share of labor (see the Appendix). Thus, a value of 0.95 for α is consistent with a share of labor of 0.58 and a share of capital of 0.38, consistent with the estimates for the average shares of capital and labor as reported in Barro and Sala-I-Martin (1995). We select the values of the parameters D, m and ϕ so that the average rate of capital utilization in model simulations is close to that in the data. That rate is 44 percent which is the average of the two different mean capital utilization rates reported by Shapiro (1986) and Orr (1989). The only restriction imposed by the model on the values of these parameters is $\phi > 1$. As empirical estimates on the values of these three parameters are very scarce, once we set the value of one of them, we have two degrees of freedom in determining the other two. We choose $D = 1$, $m = 0.75$ and $\phi = 2$, and conduct extensive robustness checks. We follow Cooper (2005) and select the parameter c, which is reflecting the capital operating costs, to be 0.48. After expermineting with various values for c we find that for lower values of c risk can actually decline with book-to-market for growth stocks. We test this conjecture in our empirical tests and find supporting evidence for it.

Figure 1 depicts the relation between the logarithm of book-to-market and market beta. Consistent with our explanation for the value premium, we find that the relationship is positive. Note that the relation is convex because for low book-to-market ratios the effect of growth options offsets the effect of operating leverage. Figure 2 presents the relation between the optimal rate of capital utilization and the market beta. This relationship is negative. As optimal utilization rate increases, the market beta declines. Note that here too, the relation is convex. Finally, Figure 3 shows that return volatility is also negatively related to the rate of capital utilization. At higher utilization rate, return volatility is lower. Again, the relation is convex.

4 Data Description

We perform our empirical investigation using the industry portfolios available on Kenneth French's website. The dataset covers monthly and annual returns and annual book-to-market for 48 industries constructed from the NASDAQ and NYSE files of the Center for Research in Security Prices (CRSP) at the University of Chicago. The returns and characteristics are available both for equally weighted and value weighted industry portfolios and we use both to conduct our tests. We present results only for equally weighted portfolios. All of our results for value weighted portfolios are very similar. We conduct our analysis using annual returns. Since the model predicts that portfolio expected returns, volatility and risk are time-varying as a function of firms' or industries' characteristics and real activity (book-to-market or the rate of capital utilization), our investigation requires yearly estimates of contemporaneous portfolio betas and volatility. To get the beta estimates, we re-estimate yearly portfolio betas and volatilities using daily returns on the industry portfolios during that year. Both traditional and Scholes-Williams betas are computed.[8] The results are qualitatively the same and we only report results based on Scholes-Williams betas corrected for non-synchronous trading. Volatility estimates are based on daily returns on the industry portfolio returns during that year and the previous year. The industry capacity utilization is from the Federal Reserve Board G17 publication, available on the Board's website. The documentation to the tables on the Board's web site lists the NAICS industry codes composition for all the industries for which capacity utilization data is reported, as well as the correspondence between NAICS and SIC codes. We then manually match the Fed's industry definitions with the SIC industry definitions in the return data. The resulting sample includes 32 Fama-French industries for which capacity utilization and return series are available. The complete sample period is from 1972 to 2002. We then compute the industry capacity utilization sample volatility as a proxy for investment irreversibility.

Table 1 reports time series summary statistics for the monthly returns of the 32 Fama-French industries for which we have matched capacity utilization data. In Panel A of Table 2 we report cross-sectional summary statistics of the industry portfolios' mean capacity utilization, capacity utilization volatility, mean book-to-market and book-to-market volatility. The mean and volatility of capacity utilization and book-to-market ratios are computed using sample mean and sample standard deviation of the respective time series. The correlation between the mean and the volatility of capacity utilization is negative. This implies that the correlation between the mean and volatil-

[8] We thank Ken French for graciously computing and making available industry daily returns.

ity of excess capacity utilization is positive, consistent with the model's prediction that excess capacity utilization and book-to-market ratio convey the same information regarding the conditional moments of returns. Note that the correlation between book-to-market mean and volatility is positive at 0.801. For industries facing largely irreversible investment we expect high average book-to-market ratio because in these industries the book value of assets is fairly constant since no disinvestment is undertaken. Thus at times of low profitability the book-to-market ratio will be high. In contrast industries with reversible investment will disinvest due to adverse profitability shocks, implying that their book-to-market ratio is on average lower. These industries will also exhibit lower volatility of book-to-market since they tend to respond to adverse profitability shocks by reducing their stock of capital, implying that their book value moves together with their market value. In contrast, when investment is irreversible the firm cannot disinvest so the book-to-market ratio is more volatile. The same intuition applies for the relation between the mean and volatility of capacity utilization. Indeed we find a negative correlation of -0.249.

In Panel B of Table 2 we report the correlation between capacity utilization and book-to-market. We expect a priori a negative relationship, which is supported by the pooled correlation coefficient of -0.089, although the correlation is quite weak. The industry by industry correlations between capacity utilization and book-to-market are rather noisy, but overall are consistent with the model's prediction. The average across industries of these correlation is -0.205, which is slightl more negative than the pooled coefficient. There are 7 industries with positive correlations, yet there are 25 industries with negative correlations.

5 Empirical Analysis and Tests

In this section we draw and test empirical hypotheses from the model. The model predicts that CAPU and B/M reflect the same information about the industry's conditional expected returns and conditional volatility of returns. We begin by examining the relations among our economically fundamental variable, namely CAPU, as well as B/M, and expected returns. We then test the relation of each of these variables in isolation with the first and second moment of returns. Subsequently we turn to testing whether CAPU is related to risk as measured by the conditional loadings with respect to the three Fama and French (1993) factors. Finally, we examine whether these relations are stronger within industries characterized by a larger degree of investment irre-

versibility as captured by the unconditional volatility of CAPU. In our regression analysis we are using the pooled sample of industries. In all of the regressions we are using annual data.

The model predicts that when CAPU is high (and B/M low) the relative effect of growth options on return dynamics is stronger than when CAPU is low (and B/M high). In the event of low CAPU, the firm's production expansion options and operating leverage strongly affect return dynamics. This implies that for high values of CAPU (and low B/M ratios), when the growth options are 'in the money', risk, expected returns and return volatility rise with CAPU (and decline with B/M), and vice versa when CAPU is low (and B/M high). To test this prediction, throughout our tests we present results for the full sample of pooled industries as well as results for subsamples of low CAPU (high B/M) and high CAPU (low B/M). We define $CAPU_i(t)$ $(B/M_i(t))$ to be 'low' when it is below industry $i's$ time-series median CAPU (B/M), and 'high' when it is above the time-series median of industry i.

5.1 Predicting returns

We test whether CAPU and B/M are related to expected return and if this relationship depends on whether CAPU and B/M are relatively low or high. We begin by testing the relation between lagged CAPU and lagged B/M and returns using the whole sample. This is aimed at testing the unconditional relations (unconditional in the sense that the relation does not depend whether CAPU (B/M) is high or low). We then split the sample into two subsamples. The first subsample includes observations for which CAPU is below its time series median. The second subsample includes observations for which CAPU is 'high', i.e. higher than its time series median. We examine if the coefficient in the regression of returns on lagged CAPU changes across the two subsamples. The models predict that the relation between CAPU and expected return is more negative when CAPU is below the time series median than when it is above that median. We repeat the process of separating the sample into two subsamples for high and low values of B/M and examine whether the coefficient in the regression of returns on lagged B/M changes across the two subsamples.

We begin with a multivariate regression of industry returns on lagged CAPU and lagged B/M. While the model predicts that CAPU and B/M contain identical information concerning risk and conditional return moments, we note that in our sample CAPU and B/M are only weakly (negatively) correlated. It is useful to examine whether CAPU has explanatory power in the presence of B/M in predictive regressions. Because the B/M effect is consistent not only with the predictions of

the models in the new literature but also with the prediction of models that are based on behavioral biases, such explanatory power of CAPU would provide new evidence in support of the models that we examine.

We run the following regression equation for the pooled sample of industry portfolios

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \gamma_{2i} B/M_i\,(t-1) + \epsilon_i(t) \qquad \forall i. \tag{20}$$

The results are presented in the second column of Panel A of Table 3. The estimated coefficients on both CAPU and B/M conform to the theoretical predictions. The estimate of γ_1 is -0.31 and it is statistically significant with a t-statistic of -2.27 while the estimated value of γ_2 is positive (0.14) and is also statistically significant (t-statistic of 5.53). Thus, the results provide support to the models' predictions and raise the possibility that mispricing is not the only factor (if at all) in driving industry stock return predictability.

5.1.1 The overall sample

Hypothesis 1 below is a central prediction of our model. It tests the model's prediction that CAPU is negatively related to expected returns. Note that in this stage we do not separate the sample to observations with CAPU below and above the median. The models in the literature that we empirically evaluate all predict unconditional positive relation between B/M and expected return (a value premium) which, according to our model, is equivalent to predicting a negative unconditional relation between CAPU and expected returns.

Hypothesis 1: Expected returns are decreasing in CAPU.

We test the following regression equation, allowing for industry fixed effects,

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \epsilon_i(t) \qquad \forall i. \tag{21}$$

Hypothesis 1 implies that $\gamma_1 < 0$.

The third column of Panel A of Table 3 reports the regression results of pooled industry portfolio returns on the previous year's average rate of capacity utilization. Note that, as the model predicts, the lagged value of CAPU is negatively related to returns. We find that CAPU tracks economically and statistically significant variation in expected returns. Consistent with hypothesis 1, the coefficient on lagged CAPU is negative (with value of -0.67 and t-statistic of -3.92). An increase in CAPU equal to twice its time-series standard deviation forecasts a 6.8% decrease in

expected returns for the typical industry portfolio. CAPU explains, however, only a small fraction of portfolio returns, about 1% of total return volatility.

Our model also predicts a positive relation between B/M and expected returns.

Hypothesis 2: Expected returns are increasing with B/M.

The following regression constitutes our test of hypothesis 2. We allow for industry fixed effects

$$R_i(t) = \gamma_{0i} + \gamma_{1i} B/M_i(t-1) + \epsilon_i(t) \qquad \forall i. \tag{22}$$

Hypothesis 2 implies that $\gamma_1 > 0$.

The estimated coefficient of this regression are displayed in the last column of Panel A of Table 3. The results indicate a positive relation between B/M and expected returns. The coefficient on lagged B/M is highly economically and statistically significant with t-statistic of 10.23. An increase in B/M of twice its standard deviation leads to an increase of 15.60% in annual returns. We note that B/M is only slightly better than CAPU in explaining the variation of portfolio returns (B/M explains about 3% of total return volatility) as seen in Table 3. Lewellen (1999) obtains very similar R^2 when regressing industry portfolio returns on lagged book-to-market ratio (see Table 3 in Lewellen).[9]

5.1.2 Subsample of low CAPU (high B/M)

Next we turn to testing the relation between CAPU and expected returns for values of CAPU that are below its industry time series median. Our model predicts a negative relation because in the region in which CAPU is low, growth options are 'out of the money' and the effect of operating leverage and the option to easily expand production dominate the relation between CAPU and risk and expected returns.

Hypothesis 3: For values of CAPU below industry $i's$ time series median, expected returns are decreasing in CAPU.

We test the following regression equation using only observations for which CAPU is below industry $i's$ time series median, allowing for industry fixed effects,

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \epsilon_i(t) \qquad \forall\ CAPU_i\,(t-1) \leq \text{median } CAPU_i. \tag{23}$$

[9] Lewellen (1999) finds R^2 smaller than one percent on average. The somewhat different R^2 that we obtain can be explained by the fact that Lewellen tests the relation between B/M and future returns using monthly frequencies whereas we are using annual frequencies.

Hypothesis 3 implies that $\gamma_1 < 0$.

Note that we have assumed that the slope of the relation between expected returns and CAPU changes at the median value of CAPU. As long as this is a satisfactory assumption, the model predicts that $\gamma_1 < 0$. The results are reported in column 2 ofPanel B of Table 3. The results are very similar to those using the whole sample and are supportive of the theoretical prediction. The coefficient on lagged CAPU is -0.69 and it is statistically significant with a t-statistic of -2.32. This result supports the model's prediction, as well as the prediction of Kogan's (2004) model.

Low values of CAPU correspond to high B/M values. Our model predicts that B/M is positively related to expected returns when B/M is above its time series median. This prediction is shared by Kogan's (2004) model.

Hypothesis 4: For values of B/M above industry i's time series median, expected returns are increasing in B/M.

We test the following regression equation allowing for industry fixed effects,

$$R_i(t) = \gamma_{0i} + \gamma_{1i} B/M_i(t-1) + \epsilon_i(t) \qquad \forall B/M_i\,(t-1) > \text{median } B/M_i. \tag{24}$$

Hypothesis 3 implies that $\gamma_1 > 0$.

Column 4 of Panel B of Table 3 presents the results of this regression. The coefficient on B/M for this subsample (0.38) is somewhat larger than for the overall sample (0.34) and is highly statistically significant with t-statistic of 6.79. The economic effect is large. This result complements the result of testing hypothesis 3 and provides further support to the model's prediction. Kogan's (2004) model prediction is also supported by our results.

5.1.3 Subsample of high CAPU (low B/M)

Next we examine the relation between lagged CAPU and returns for CAPU values that are above the time series median of CAPU and B/M values that are below the time series median of B/M. The model predicts that two factors are affecting systematic risk and expected returns. Recall that irreversibility implies a region of investment inaction. When the firm's profitability is high relative to the size of its stock of capital, it utilizes more of its capital (high CAPU) and its market value is high relative to its stock of capital (low B/M). At such times, the value of the firm's option to invest is higher, and is 'in the money'. Thus, in this region the growth options effect implies a positive relation between CAPU and expected returns and a negative relation between B/M and expected

returns. However, the operating leverage and the option to easily expand production effects imply a negative relation between CAPU and expected returns and a positive relation between B/M and expected returns regardless of the firm's rate of capacity utilization and book-to-market ratio, thereby offsetting the effect of growth options. The net effect remains an empirical question. The only clear prediction of the model is that in this region the relation between CAPU (B/M) and expected returns is less negative (less positive) than in the region in which CAPU (B/M) is low (high). We begin by examining the relation between CAPU and expected returns.

Hypothesis 5: For values of CAPU above industry $i's$ time series median, the relation between CAPU and expected returns is less negative than that relation in the subsample of low CAPU.

We test the following regression equation allowing for industry fixed effects

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \epsilon_i(t) \qquad \forall\ CAPU_i\,(t-1) > \text{median } CAPU_i. \tag{25}$$

The results are presented in the third column of panel B of Table 3. Consistent with the model's predictions the relation between lagged CAPU and returns is much weaker when CAPU is high than when it is low. The coefficient on lagged CAPU is about half its size than in the subsample for low CAPU (-0.36 in the high CAPU sample versus -0.69 in the low CAPU subsample). Furthermore the coefficient is statistically indistinguishable from zero (t-statistic of -0.65).

We repeat the test for B/M.

Hypothesis 6: For values of B/M below industry $i's$ time series median, the relation between B/M and expected returns is less positive than that relation in the subsample of high B/M.

We run the following regression equation allowing for industry fixed effects

$$R_i(t) = \gamma_{0i} + \gamma_{1i} B/M_i(t-1) + \epsilon_i(t) \qquad \forall B/M_i\,(t-1) \leq \text{median } B/M_i. \tag{26}$$

As the results in the last column of panel B indicate, the coefficient on lagged B/M is substantially smaller than for the subsample of high B/M (0.23 in this subsample compared to 0.38 for the high B/M subsample), consistent with the model's prediction. In addition the coefficient ceases to be statistically significant at conventional significance levels, with a t-statistic of 1.56 (compared to a t-statistic of 6.79 for the high B/M subsample).

We conclude that the predictions of the models we evaluate regarding the relations between B/M and CAPU and expected returns are broadly consistent with industry level data.

5.2 Return volatility, CAPU and B/M

Now we turn to testing the relation between CAPU (and B/M) and return volatility. Operating leverage and the production expansion option imply that return volatility decreases with CAPU and increases with B/M. Growth options imply the opposite, namely that volatility of returns is increasing with CAPU since at higher CAPU rates growth options are more 'in the money': as the firm nears full utilization of its capital, the value of its option to expand capacity increases. Similarly growth options imply that return volatility is higher for low B/M values. To test the model's prediction we again separate the sample into two subsamples, according to whether CAPU (B/M) is below (above) or above (below) its time series median. The model predicts that the relation between CAPU and return volatility is more positive in the subsample of high CAPU than in the subsample of low CAPU. Similarly the model predicts that the relation between return volatility and B/M is more positive in the subsample of high B/M than in the subsample of low B/M. We estimate volatility of year t as the volatility of the 24 monthly returns of years t and $t-1$.

We start by examining the relation between CAPU and return volatility in the whole sample. We run the following regression equation with industry fixed effects,

$$Vol_i\,(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t) + \epsilon_i(t) \qquad \forall i. \tag{27}$$

Note that we are using contemporaneous CAPU as an explanatory variable in this regression. The reason is that the model predicts that volatility of returns is related to contemporaneous CAPU. Results are very similar when we use lagged CAPU as the regressor. The second column of Panel A of Table 4 shows that the relation between CAPU and return volatility is statistically and economically insignificant (coefficient of -0.04 with a t-statistic of -1.27).

The third column in Panel A of Table 4 shows the results of the following regression allowing for industry fixed effects,

$$Vol_i\,(t) = \gamma_{0i} + \gamma_{1i} B/M_i(t) + \epsilon_i(t) \qquad \forall i. \tag{28}$$

B/M is strongly negatively related to return volatility (coefficient of -0.04 and t-statistic of -5.44). Results are very similar when we use lagged B/M as the regressor. We note that using a different specification of volatility, Kogan (2004) finds a negative relation between return volatility and lagged B/M in 10 out of 13 industries (in 4 of which the relation is statistically significant). For the other 3 industries that Kogan (2004) examines, the relation is statistically insignificant. Thus, our results are similar to Kogan's.

5.2.1 Subsample of low CAPU (high B/M)

Next we examine the relation between CAPU and return volatility for CAPU values that are below the industry median. The model predicts that in this region the effect of operating leverage and the production expansion option are stronger than the effect of growth options so that the relation between return volatility and CAPU is negative.

Hypothesis 7: For values of CAPU below industry $i's$ time series median, the volatility of returns is decreasing in CAPU.

We run the following regression allowing for industry fixed effects,

$$Vol_i\,(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t) + \epsilon_i(t) \qquad \forall\ CAPU_i\,(t) \leq \text{median } CAPU_i. \tag{29}$$

Hypothesis 7 implies that $\gamma_1 < 0$. Results are presented in Panel B of Table 4. The coefficient on CAPU is larger (in absolute value) for this subsample than for the entire sample (-0.13 in the low CAPU subsample versus -0.04 for the whole sample), but it is slightly less than two standard errors from zero (with t-statistic of -1.90).

Hypothesis 8 is the book-to-market analogue of hypothesis 7.

Hypothesis 8: For values of B/M above industry $i's$ time series median, volatility of returns is increasing in B/M.

We test the following regression equation with industry fixed effects,

$$Vol_i\,(t) = \gamma_{0i} + \gamma_{1i} B/M_i(t) + \epsilon_i(t) \qquad \forall\ B/M_i\,(t) > \text{median } B/M_i. \tag{30}$$

Hypothesis 8 implies that $\gamma_1 > 0$. The results in column 4 of Panel B of Table 4 shows that the coefficient on B/M is positive (0.014) but is substantially less than two standard errors from zero (with t-statistic of 1.39). However, the coefficient is larger than the coefficient for the entire sample and the difference is statistically significant. The 95% confidence interval of the coefficient in the high B/M subsample is [-0.006,0.034], as compared to a coefficient of -0.04 and 95% confidence interval of [-0.05, -0.02].

5.2.2 Subsample of high CAPU (low B/M)

Times when the firm optimally utilizes a large fraction of its capital are times when its option to increase its stock of capital is highly valuable. That is, the moneyness of its growth options is high.

At these times return volatility is increasing with CAPU because higher values of CAPU imply that the firm's growth options moneyness increases. Hypothesis 9 formalizes this argument.

Hypothesis 9: For values of CAPU above industry $i's$ time series median, the coefficient in a regression of volatility of returns on CAPU is larger than the coefficient when using the subsample of low CAPU.

We test the following regression equation allowing for industry fixed effects,

$$Vol_i\,(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t) + \epsilon_i(t) \qquad \forall\ CAPU_i\,(t) > \text{median } CAPU_i. \tag{31}$$

The results are presented in column three of Panel B of Table 4. The estimated coefficient on CAPU is 0.18 (with a t-statistic of 1.76 and a 95% confidence interval of [-0.02, 0.38]) which is larger than the coefficient using the low CAPU subsample (-0.13 and 95% confidence interval of [-0.27, 0.005]).

Next we test whether the model's prediction concerning the relation between return volatility and B/M holds as well. The rationale here is that when the firm's profitability is high, its B/M ratio is low, and its growth options are 'in the money'. At such times positive profitability shocks reduce the firm's B/M ratio and lead to increased moneyness of the growth options, leading to increased return volatility. The operating leverage and production expansion option still affect volatility but in the opposite direction. That is, positive profitability shocks reduce operating leverage and reduce the moneyness of the option to easily expand production and therefore reduce return volatility. The model predicts that the relative effect of growth options is larger in the low B/M subsample than in the high B/M subsample. Hypothesis 10 formalizes this prediction.

Hypothesis 10: For values of B/M below industry $i's$ time series B/M median, the coefficient in a regression of volatility of returns on B/M is smaller than the coefficient when using the subsample of high B/M.

Kogan's (2004) model predicts a negative relation between return volatility and B/M in the low B/M region.

We test the following regression equation allowing for industry fixed effects,

$$Vol_i\,(t) = \gamma_{0i} + \gamma_{1i} B/M_i(t) + \epsilon_i(t) \qquad \forall\ B/M_i\,(t) \leq \text{median } B/M_i. \tag{32}$$

Results are again presented in Panel B of Table 4. Estimated γ_1 is -0.09 and is statistically significant (with t-statistic of -2.72). Thus, the estimated coefficient on B/M using the subsample

of low B/M is indeed smaller than the coefficient on B/M using the high B/M subsample (0.014). The difference between the estimates is statistically significant.

We conclude that our empirical results lend support to the predictions of the models in the new literature regarding the dynamics of return volatility.

5.3 CAPU, B/M and the loadings with respect to the three Fama French (1993) factors

Having shown evidence in support for the model's predictions regarding the relations among CAPU,B/M, expected returns and return volatility, we now turn to testing whether these predictions hold for the relation between systematic risk and firm characteristics as well. Operating leverage and the option to easily expand production without undertaking costly investment entail a negative relation between CAPU and systematic risk and a positive relation between B/M and systematic risk. The effect of growth options implies that systematic risk is increasing with CAPU (and decreasing with B/M). The model predicts that in the subsample of low CAPU (high B/M) the relative effect of operating leverage and the production expansion option are stronger.

We measure systematic risk with the loadings of industry portfolios with respect to the three Fama and French (1993) Factors. We follow Lewellen (1999) and run multifactor regressions that employ the methodology of Shanken (1990). Our conditional regressions allow the factor loadings to vary with CAPU or B/M. We specify a linear relation between the conditioning variables and the loadings with respect to the Fama and French (1993) three factors, allowing for industry fixed effects. When we use CAPU as the conditioning variable, the regression is specificied as follows,

$$\begin{aligned} R_i(t) &= \gamma_{0i} + (\beta_{0i} + \beta_{1i} CAPU_{i,t}) R_{M,t} \\ &\quad + (\delta_{0i} + \delta_{1i} CAPU_{i,t}) SMB_t + (\lambda_{0i} + \lambda_{1i} CAPU_{i,t}) HML_t + u_i(t) \qquad \forall i. \quad (33) \end{aligned}$$

The first 2 columns of Table 5 presents the results of the conditional factor model wher CAPU is used as conditioning variable. As the model predicts, CAPU is negatively related to market beta: the estimated β_1 is negative (-1.42) and statistically significant (with a t-statistic of -2.77). CAPU seems unrelated to time variation in the loadings with respect to SMB and HML.

Next we repeat the conditional three factor regression allowing the loadings with respect to the

three factors to vary with B/M. We run the following regression,

$$\begin{aligned} R_i(t) &= \gamma_{0i} + (\beta_{0i} + \beta_{1i} BM_{i,t}) R_{M,t} \\ &\quad + (\delta_{0i} + \delta_{1i} BM_{i,t}) SMB_t + (\lambda_{0i} + \lambda_{1i} BM_{i,t}) HML_t + u_i(t) \qquad \forall i. \end{aligned} \tag{34}$$

The last two columns of Table 5 presents the results of the estimation of this equation. B/M is positively related to time variation in industry portfolios' loadings with respect to HML (coefficient of 0.26 and t-statistic of 2.11) but appears to be unrelated to time variation in the loadings with respect to the market beta and SMB.

Our results in the multifactor regressions are consistent with our results from the univariate regression of beta on CAPU. We find that an increase in CAPU leads to a decline in the market beta whereas an increase in B/M leads to an increase in risk as captured by the loading with respect to HML.

5.4 Irreversible investment, capacity utilization, book-to-market and expected returns

Empirical proxies for the degree of investment irreversibility are scarce. Caballero, Engel and Haltiwanger (1995) construct a measure for 'capital imbalance' which is aimed at capturing the degree to which the firm's capital stock deviates from its desired level if adjustment costs (and irreversibility) were to be momentarily removed. Caballero, Engel and Haltiwanger's measure involves an estimation of the elasticity of the demand for capital with respect to the cost of capital and is thus subject to measurement errors. Ramey and Shapiro (2001) conduct a case study of the aerospace industry and measure irreversibility by the difference between the purchase price and resale price of capital. In this paper we introduce a novel measure for the degree of investment irreversibility, namely the (time series) volatility of an industry's rate of capacity utilization. The rationale is that firms can respond to profitability shocks by either adjusting their capital stock upward or downward or, if such adjustment is costlier than the benefits involved in the adjustment, by changing the rate of their capital utilization. Thus, high capital adjustment costs and irreversibility lead to high volatility of the rate of capital utilization. We note that our measure for irreversibility is not perfect since capacity utilization volatility can stem from volatile productivity shock process or volatile price in the product and factors of production markets. Thus, even if an industry faces a small degree of investment irreversibility, it might still display highly volatile CAPU if its fundamentals are very

volatile.

We now link the relation between expected returns, CAPU and the degree of investment irreversibility, as measured by the time-series volatility of CAPU. A central assumption of the models in the new literature is that investment is, at least partly, irreversible. Investment irreversibility, entailed for example by a resale price of capital that is lower than the capital's purchase price, gives rise to a region of investment inaction. Within the inaction region the firm's book value of assets is fairly constant but its market value responds to shocks, leading to variation in CAPU and B/M.

Note that the link between the degree of investment irreversibility and the relation between CAPU and asset return dynamics depends on several parameters. For example, the model predicts that in the absence of fixed production costs (that give rise to operating leverage) higher degree of irreversibility leads to a positive relation between CAPU and risk, whereas when fixed production costs are high, this relation turns negative. Other model parameters can also have an effect on this link. The effect of all model parameters on the link between investment irreversibility and asset return dynamics is beyond the scope of this paper and is left for future research.

We conduct our tests as follows. We sort industries by their unconditional CAPU time series volatility. Then we define a dummy variable D_i such that $D_i = 1$ if the volatility of $CAPU_i$ is in the top 20% of all industry volatilities and zero otherwise. We consider industries for which $D_i = 1$ as industries with highly irreversible investment.

We begin with testing how the degree of investment irreversibility affects the relation between CAPU and expected returns.

We test the following regression equation

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \gamma_{2i} * D_i * CAPU_i(t-1) + \epsilon_i(t) \qquad \forall i \qquad (35)$$

The results are reported in column two of Table 6. γ_{2i} is economically and statistically insignificant. As we argue above, this cannot be interpreted as evidence against the predictions of the models since the link between CAPU and expected returns depends on the degree of operating leverage and possibly other parameters.

5.4.1 Subsample of low CAPU

Next we run the same regression equation as in (34) but for values of CAPU that are below the industries' time series median. Here the models have a clearer prediction: when investment is

largely irreversible, for low CAPU values CAPU is more negatively related to expected returns than for high CAPU values. The intuition for this prediction is that since the firm's growth options are 'out of the money' when CAPU is low, a positive profitability shock, that leads to an increase in CAPU, has a smaller effect on the firm's risk than when the firm's growth options are 'in the money'. Hypothesis 11 formalizes this prediction.

Hypothesis 11: For low CAPU values CAPU is more negatively related to expected returns than for high CAPU values. This relation is stronger when the degree of investment irreversibility is higher.

We run the following regression equation,

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \gamma_{2i} * D_i * CAPU_i(t-1) + \epsilon_i(t) \quad \forall\ CAPU_i\,(t) \leq \text{median } CAPU_i. \quad (36)$$

In view of the results for the whole sample, hypothesis 11 implies that γ_2 is negative. Table 6 presents the results. The estimated γ_2 is negative (-0.065) and is statistically significant at the 10% level (t-statistic of -1.81). Thus, we find some support for the models' predictions that the negative relation between CAPU and returns is stronger for industries with a higher degree of irreversibility.

5.4.2 Subsample of high CAPU

Given a large degree of investment irreversibility, high CAPU implies that the firm's growth option's moneyness is higher. This causes an increase in CAPU to raise expected returns. Hypothesis 12 formalizes this prediction.

Hypothesis 12: For high CAPU values, CAPU is more positively related to expected returns than for low CAPU values. This relation is stronger when the degree of investment irreversibility is higher.

We run the following regression,

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \gamma_{2i} D_i CAPU_i(t-1) + \epsilon_i(t) \quad \forall\ CAPU_i\,(t) > \text{median } CAPU_i. \quad (37)$$

Hypothesis 12 implies that γ_2 is positive. The regression results are displayed in column 3 of table 6. The estimated γ_2 is positive (0.04), hence has the 'right' sign, but the t-statistic is low (1.05). However the 95% confidence interval ([-0.033, 0.11]) does not contains the value of the estimate of the same coefficient for the subsample of low CAPU (-0.065). This suggests that the link between CAPU and returns is different not only between high and low capacity utilization states, but also for different degree of irreversibility.

6 Summary and Conclusions

We conduct an empirical investigation of some of the shared predictions of an emerging strand of models, pioneered by Berk, Green and Naik (1999), relating firms' real investment behavior under investment irreversibility and asset return dynamics. We first extend the model of Cooper (2005) to introduce a novel, theoretically motivated, economically fundamental variable, namely the rate of capital utilization, and derive the model's testable implications in terms of relationships between the rate of capital utilization, return volatility, systematic risk and expected returns.

Our evidence using the rate of capacity utilization (CAPU) as a proxy for capital utilization, and using B/M suggests that, consistent with the predictions of our model, CAPU and B/M explain industry portfolios' expected returns, return volatility and time variation of market beta (CAPU) and the loading with respect to HML (B/M). Furthermore, consistent with the predictions of the model, that operating leverage and the option to easily expand production on the one hand and growth options on the other hand affect the riskiness of the firm in two opposing ways, we find that the relation between CAPU and return dynamics when CAPU is relatively low is different from that relation when CAPU is relatively high. Specifically, consistent with the conjecture that when CAPU is high, the firm's growth options' moneyness is high, we find that CAPU is positively related to return volatility for the subsample of observations in which CAPU is higher than its time series median. Consistent with the conjecture that operating leverage and the production expansion option dominate the relation between CAPU and return dynamics for low values of CAPU, we find that CAPU is negatively related to expected returns, return and volatility in the subsample of observations for which CAPU is lower than the time series median.

Our results provide empirical support not only to the predictions of our model, but also to those of the new strand of models relating real investment and asset return dynamics, as these models share many of the same predictions.

Appendix

A. The shares of capital and labor

Consider a firm that uses capital and labor to produce. Let

$$f_0(\nu, K, U, L) = \nu (KU)^{\psi} L^{\lambda} \tag{A1}$$

be the production function where ν is the productivity level, K is the firm's capital, U is the capital utilization rate and L is labor. The operating profits are given by

$$g_0(\nu, K, U, L) = \nu (KU)^{\psi} L^{\lambda} - WL, \tag{A2}$$

where ν is the productivity level, K is the firm's capital, U is the capital utilization rate, L is labor and W is the wage rate. Assuming that labor can be costlessly adjusted, at each point in time the firm will choose the quantity of labor so as to maximize the instantaneous profits. The first order condition with respect to labor implies that

$$L^{1-\lambda} = \frac{\lambda}{W} \nu (KU)^{\psi}. \tag{A3}$$

This implies that the optimal labor is given by

$$L^* = \left(\frac{\lambda}{W}\right)^{\frac{1}{1-\lambda}} \nu^{\frac{1}{1-\lambda}} (KU)^{\frac{\psi}{1-\lambda}}. \tag{A4}$$

Substituting the optimal labor into the production function yields

$$f_1(\nu, K, U) = \left(\frac{\lambda}{W}\right)^{\frac{\lambda}{1-\lambda}} \nu^{\frac{1}{1-\lambda}} (KU)^{\frac{\psi}{1-\lambda}}. \tag{A5}$$

Denote $D = \left(\frac{\lambda}{W}\right)^{\frac{\lambda}{1-\lambda}}$, $\eta = \nu^{\frac{1}{1-\lambda}}$ and $\alpha = \frac{\psi}{1-\lambda}$. Then equation (1) in the text follows, i.e. the production function becomes $f(\eta, K, U) = D\eta (KU)^{\alpha}$. f is the reduced form production function. Note that α is the share of capital divided by one minus the share of labor.

B. The reduced form of the profit function

At each point in time the firm sets the rate of capital utilization to maximize instantaneous profits:

$$\underset{U}{Max} \hat{\Pi}(\eta, K, U) = D\eta (KU)^{\alpha} - mU^{\phi}K - cK. \tag{B1}$$

The first order condition with respect to the optimal utilization rate is

$$\alpha D\eta K^{\alpha} U^{\alpha-1} - \phi m U^{\phi-1} K = 0. \tag{B2}$$

The optimal rate of capital utilization is

$$U^* = \left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}} \eta^{\frac{1}{\phi-\alpha}} K^{\frac{\alpha-1}{\phi-\alpha}}. \tag{B3}$$

Substituting the optimal rate of capital utilization into the profit function yields

$$\begin{aligned}\hat{\Pi}(\eta, K, U) &= D\eta K^{\alpha}\left[\left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}}\eta^{\frac{1}{\phi-\alpha}}K^{\frac{\alpha-1}{\phi-\alpha}}\right]^{\alpha} - mK\left[\left(D\frac{\alpha}{m\phi}\right)^{\frac{1}{\phi-\alpha}}\eta^{\frac{1}{\phi-\alpha}}K^{\frac{\alpha-1}{\phi-\alpha}}\right]^{\phi} \quad \text{(B4)}\\ -cK &= D^{\frac{\phi}{\phi-\alpha}}\left[\left(\frac{\alpha}{m\phi}\right)^{\frac{\alpha}{\phi-\alpha}} - m\left(\frac{\alpha}{m\phi}\right)^{\frac{\phi}{\phi-\alpha}}\right]\eta^{\frac{\phi}{\phi-\alpha}}K^{\frac{\alpha(\phi-1)}{\phi-\alpha}} - cK\end{aligned}$$

We define $\gamma \equiv \frac{\alpha(\phi-1)}{\phi-\alpha}$. Next we define θ such that $\theta^{1-\gamma} \equiv \eta^{\frac{\phi}{\phi-\alpha}}$ which implies $\theta = \eta^{\frac{\phi}{(\phi-\alpha)(1-\gamma)}} = \eta^{\frac{\phi}{(\phi-\alpha)\phi\frac{(\alpha-1)}{(\phi-\alpha)}}} = \eta^{\frac{1}{1-\alpha}}$. Finally, B is defined as $B \equiv D^{\frac{\phi}{\phi-\alpha}}\left[\left(\frac{\alpha}{m\phi}\right)^{\frac{\alpha}{\phi-\alpha}} - m\left(\frac{\alpha}{m\phi}\right)^{\frac{\phi}{\phi-\alpha}}\right]$. This implies that the profit function can be presented as

$$\Pi(\theta, K) = B\theta^{1-\gamma}K^{\gamma} - cK, \quad \text{(B5)}$$

which is equation (4) in the text.

C. Conditional volatility of returns

The variance of the return on the firm per unit of time is given by

$$\frac{1}{dt}Var\left[\frac{dJ}{J}\right] = Var\left[\frac{d(\theta V)}{\theta V}\right] = Var\left[\frac{d\theta}{\theta} + \frac{dV}{V}\right] = Var\left[\frac{d\theta}{\theta}\right] + Var\left[\frac{dV}{V}\right] + 2Cov\left(\frac{d\theta}{\theta}, \frac{dV}{V}\right). \quad \text{(C1)}$$

Note that $\frac{d\theta}{\theta} = \mu dt + \sigma dw \implies \frac{1}{dt}Var\left(\frac{d\theta}{\theta}\right) = \sigma^2$,and $dV = \left[V_Z Z\mu_Z + \frac{1}{2}V_{ZZ}\sigma^2 Z^2\right]dt - V_Z Z\sigma dw \implies \frac{1}{dt}Var\left(\frac{dV}{V}\right) = \frac{1}{V^2}\left(V_Z Z\sigma\right)^2$, and $\frac{1}{dt}Cov\left(\frac{d\theta}{\theta}, \frac{dV}{V}\right) = \frac{1}{dt}\frac{1}{V}Cov\left(\sigma dw, -V_Z Z\sigma dw\right) = -\frac{\sigma^2 V_Z Z}{V}$.

It follows that the variance of the return on the firm per unit of time is given by

$$\frac{1}{dt}Var\left[\frac{dJ}{J}\right] = \sigma^2 + \frac{(V_Z Z\sigma)^2}{V^2} - \frac{\sigma^2 V_Z Z}{V}. \quad \text{(C2)}$$

Note that return volatility is a function of the firm's excess capital capacity, Z. Figure 3 depicts the relation of return volatility to Z.

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Table 1 - Summary statistics of equally weighted industry excess returns.

This table report summary statistics for the monthly returns (in percentage) of the equal-weighted 32 Fama-French industries with available matched industry capacity utilization data. The sample period is from 1972 to 2002.

	Food	*Soda*	*Beer*	*Smoke*	*Toys*	*Books*	*Hshld*	*Clths*	*MedEq*	*Drugs*	*Chems*	*Rubbr*	*Txtls*	*BldMt*	*Steel*	*FabPr*
	A. Excess returns summary statistics															
Mean	0.714	1.064	0.368	1.017	0.523	0.925	0.678	0.403	0.879	1.050	0.743	0.916	0.450	0.770	0.495	0.587
Med.	0.685	1.315	-0.010	0.685	0.545	1.055	0.655	0.195	0.560	0.855	0.735	0.925	0.280	0.660	0.215	0.155
Min.	-26.11	-23.37	-20.03	-23.44	-29.78	-28.54	-29.91	-30.81	-30.52	-33.99	-31.41	-30.44	-32.10	-29.17	-31.89	-27.85
Max.	19.78	32.86	33.21	29.99	36.47	19.96	32.21	34.00	33.84	60.67	20.35	32.51	32.07	38.42	29.83	30.51
StDev.	4.65	5.34	5.28	6.37	7.65	5.70	5.98	6.44	7.26	7.80	5.41	6.73	6.87	6.15	6.46	7.02
Skew.	-0.41	0.12	0.42	0.49	0.41	-0.40	-0.13	0.22	0.06	0.93	-0.57	0.04	0.20	0.25	0.01	0.28
p-val.	0.000	0.299	0.000	0.000	0.000	0.000	0.248	0.048	0.611	0.000	0.000	0.718	0.078	0.028	0.900	0.015
Kurt.	3.47	4.04	4.39	3.28	2.76	2.16	3.55	3.41	2.23	8.32	3.95	2.36	3.20	4.78	2.72	2.41
p-val.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BJ	244.35	314.03	384.44	224.42	159.67	101.23	243.47	227.22	95.05	1402.48	325.46	106.59	199.37	443.99	141.82	117.11
p-val.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Q	26.35	26.90	22.32	8.48	29.14	50.06	45.72	53.13	26.21	21.74	31.36	41.50	53.65	43.91	26.44	38.47
p-val.	0.010	0.008	0.034	0.746	0.004	0.000	0.000	0.000	0.010	0.041	0.002	0.000	0.000	0.000	0.009	0.000
Order	**B. Autocorrelations**															
1	0.185	0.129	0.119	0.060	0.165	0.245	0.225	0.263	0.212	0.186	0.167	0.196	0.271	0.201	0.152	0.136
2	0.005	0.003	-0.048	-0.058	-0.012	-0.014	0.000	0.055	-0.019	-0.010	-0.060	0.028	0.020	-0.013	-0.052	-0.021
3	-0.035	0.006	0.001	0.029	-0.039	-0.041	-0.011	-0.008	-0.033	-0.070	-0.044	-0.009	-0.020	-0.056	-0.053	-0.038
4	-0.031	-0.016	-0.015	0.061	0.002	-0.036	-0.042	-0.015	-0.006	0.035	-0.056	-0.036	-0.050	-0.018	-0.055	-0.097
5	0.028	-0.001	0.003	0.022	-0.001	0.008	-0.032	0.029	-0.022	-0.022	-0.011	-0.029	-0.023	-0.001	-0.021	0.003
6	-0.026	0.010	-0.034	-0.011	-0.047	-0.016	-0.082	-0.015	-0.046	-0.008	-0.060	-0.012	-0.019	-0.026	-0.050	-0.051

	Mach	*ElcEq*	*Autos*	*Aero*	*Ships*	*Gold*	*Mines*	*Coal*	*Oil*	*Util*	*Comps*	*Chips*	*LabEq*	*Paper*	*Boxes*	*Other*
	A. Excess returns summary statistics															
Mean	0.723	0.905	0.629	0.949	0.442	1.008	0.620	0.990	0.800	0.465	0.816	1.093	0.971	0.652	0.818	0.465
Med.	0.860	0.790	0.405	0.605	0.160	0.055	0.435	0.615	0.835	0.415	0.170	0.580	0.595	0.810	0.650	0.360
Min.	-31.93	-30.98	-32.45	-29.53	-43.72	-32.01	-33.66	-28.82	-25.94	-12.66	-33.56	-33.26	-30.79	-26.16	-26.78	-33.22
Max.	23.98	35.75	31.38	36.33	33.43	60.11	36.73	50.27	25.72	22.18	43.96	50.16	34.39	20.09	23.27	26.47
StDev.	6.10	7.95	6.40	7.21	7.33	10.52	7.42	7.89	7.01	3.56	8.95	9.21	7.69	5.30	5.83	7.64
Skew.	-0.31	0.22	-0.14	0.40	-0.12	1.14	0.30	0.74	-0.02	0.33	0.40	0.49	0.22	-0.36	-0.27	0.00
p-val.	0.006	0.054	0.210	0.000	0.298	0.000	0.007	0.000	0.826	0.004	0.000	0.000	0.056	0.001	0.015	0.998
Kurt.	2.49	2.41	3.44	2.96	3.70	4.72	3.22	4.02	1.51	3.33	2.18	2.84	1.63	2.13	2.19	2.28
p-val.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BJ	126.40	114.88	228.24	180.66	264.63	530.13	205.66	353.02	43.62	220.78	103.36	173.43	54.17	96.63	97.66	99.32
p-val.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Q	46.24	29.73	36.23	30.29	28.75	5.93	25.16	8.46	23.89	22.51	29.49	23.44	33.14	28.03	23.89	42.06
p-val.	0.000	0.003	0.000	0.003	0.004	0.920	0.014	0.748	0.021	0.032	0.003	0.024	0.001	0.005	0.021	0.000
Order	**B. Autocorrelations**															
1	0.233	0.205	0.209	0.180	0.123	0.063	0.154	0.080	0.149	0.066	0.181	0.168	0.224	0.164	0.159	0.229
2	-0.021	-0.028	-0.024	0.019	-0.001	-0.012	-0.024	-0.031	0.066	-0.059	-0.010	-0.003	-0.002	-0.042	-0.023	-0.016
3	-0.064	-0.028	-0.018	-0.068	-0.007	-0.044	-0.016	-0.007	0.062	0.037	-0.025	-0.033	-0.018	-0.018	-0.013	-0.035
4	-0.067	-0.043	-0.025	0.010	-0.050	0.057	0.044	-0.006	0.015	0.002	-0.081	-0.034	-0.036	-0.091	-0.101	-0.017
5	-0.057	-0.014	0.003	0.008	-0.041	-0.007	-0.005	0.039	0.053	0.144	-0.047	-0.017	-0.016	0.011	0.006	-0.022
6	-0.047	0.008	0.014	-0.020	-0.072	-0.022	0.033	-0.023	0.026	-0.012	-0.037	0.006	-0.002	-0.016	-0.011	-0.025

Table 2. Cross-sectional summary statistics of industry characteristics.

Panel A reports the cross-sectional summary statistics of industry characteristics for the 32 Fama-French industries for which we have capacity utilization data. Capacity utilization data is from Federal Reserve G17 statistical releases. Book-to-market data is from Ken French's website. Capital utilization (book-to-market) mean and volatility are the time series sample mean and sample standard deviation of the capacity utilization rate (book-to-market) for each of these industries, and their cross-sectional statistics are reported. Capacity utilization is expressed in percentages. Panel B reports correlations between capacity utilization and book-to-market. The sample period is from 1972 to 2002.

Panel A: Cross-sectional summary statistics.(N = 32)

	CAPU Mean	CAPU Vol.	B/M Mean	B/M Vol.
Mean	81.17	5.08	0.627	0.236
Median	81.27	4.58	0.605	0.210
St.Dev	3.78	2.19	0.231	0.086
25^{tile}	78.50	3.96	0.455	0.180
75^{tile}	83.56	6.31	0.752	0.274
Min	73.39	1.71	0.271	0.103
Max	88.47	10.07	1.135	0.465
	$\rho^{CAPU}_{Mean,Vol}: -0.249$		$\rho^{B/M}_{Mean,Vol}: 0.801$	

Panel B: Time series correlation between CAPU and B/M

Pooled: -0.089

Industry by industry

Food	Soda	Beer	Smoke	Toys	Books	Hshld	Clths
0.029	0.030	0.129	-0.223	-0.432	0.015	-0.125	-0.061
MedEq	Drugs	Chems	Rubbr	Txtls	BldMt	Steel	FabPr
-0.408	-0.206	-0.329	-0.486	-0.383	-0.535	-0.308	-0.253
Mach	ElcEq	Autos	Aero	Ships	Gold	Mines	Coal
-0.130	-0.097	-0.472	-0.025	-0.209	0.277	-0.249	-0.436
Oil	Util.	Comps	Chips	LabEq	Paper	Boxes	Other
-0.308	-0.649	-0.187	-0.084	0.351	0.055	-0.396	-0.462

Average across all industries: -0.205

Table 3. Predictability of industry returns

Regressions of annual industry returns on lagged industry capacity utilization and lagged industry book-to-market. $R_i(t)$ is the portfolio's annual return. CAPU is the rate of capacity utilization. B/M is the book-to-market ratio. Industry fixed effects are included in the regressions. The industry portfolio returns and book-to-market ratios are from Kenneth French's web site. Panel A reports results for the full sample. Panel B reports results for sub-samples with CAPU and book-to-market ratios above/below their industry time-series medians. CAPU data is taken from Federal Reserve G17 statistical releases and expressed in percentages. The sample period is from 1972 to 2002. All standaed errors are robust and reported in parentheses. *, ** indicates statistical significance at the 5%, 10% level, respectively.

Panel A: full sample				
constant	0.312*	0.692*	-0.064*	
	(0.113)	(0.138)	(0.022)	
lagged CAPU	-0.307*	-0.666*		
	(0.135)	(0.170)		
lagged B/M	0.138*		0.339*	
	(0.025)		(0.033)	
adjusted R^2	0.038	0.009	0.034	
F-test (p-val)	0.000	0.000	0.000	
Panel B: sample with CAPU/BM above/below median				
	high CAPU	low CAPU	high B/M	low B/M
constant	0.420	0.715*	-0.092*	-0.019
	(0.460)	(0.229)	(0.046)	(0.064)
lagged CAPU	-0.355	-0.685*		
	(0.543)	(0.295)		
lagged B/M			0.377*	0.227
			(0.056)	(0.145)
adjusted R^2	0.000	0.006	0.012	0.001
F-test (p-val)	0.513	0.021	0.000	0.119

Table 4. Regressions of industry return volatility

Regressions of annual industry return volatility on industry capacity utilization and industry book-to-market. We estimate volatility as the sample standard deviation of the trailing 24 monthly returns. CAPU is the rate of capacity utilization. B/M is the book-to-market ratio. Industry fixed effects are included in the regressions. The industry portfolio returns and book-to-market ratios are from Kenneth French's web site. Panel A reports results for the full sample. Panel B reports results for sub-samples with CAPU and book-to-market ratios above/below their industry time-series medians. CAPU data is taken from Federal Reserve G17 statistical releases and expressed in percentages. The sample period is from 1972 to 2002. All standaed errors are robust and reported in parentheses. *, ** indicates statistical significance at the 5%, 10% level, respectively.

Panel A: full sample				
constant	0.197*	0.186*		
	(0.028)	(0.005)		
CAPU	-0.044			
	(0.035)			
B/M		-0.039*		
		(0.007)		
adjusted R^2	0.000	0.022		
F-test (p-val)	0.205	0.000		
Panel B: sample with CAPU/BM above/below median				
	high CAPU	low CAPU	high B/M	low B/M
constant	0.007	0.265*	0.138*	0.215*
	(0.087)	(0.054)	(0.008)	(0.015)
CAPU	0.180**	-0.132**		
	(0.102)	(0.069)		
B/M			0.014	-0.091*
			(0.010)	(0.033)
adjusted R^2	0.012	0.003	0.003	0.015
F-test (p-val)	0.079	0.058	0.166	0.007

Table 5: Pooled Lewellen-type regressions of annual industry returns

Pooled Lewellen type regressions of annual industry returns on the three Fama French (1993) factors (the market index, SMB and HML), and interaction terms between the Fama French Factors with CAPU, as well as with lagged book-to-market (B/M).

$$R_i(t) = \gamma_{0i} + (\beta_{0i} + \beta_{1i} CAPU_{i,t}) R_{M,t} + (\delta_{0i} + \delta_{1i} CAPU_{i,t}) SMB_t + (\lambda_{0i} + \lambda_{1i} CAPU_{i,t}) HML_t + u_i(t)$$

$$R_i(t) = \gamma_{0i} + (\beta_{0i} + \beta_{1i} BM_{i,t}) R_{M,t} + (\delta_{0i} + \delta_{1i} BM_{i,t}) SMB_t + (\lambda_{0i} + \lambda_{1i} BM_{i,t}) HML_t + u_i(t)$$

CAPU is the rate of capacity utilization. B/M is the book-to-market ratio. Industry fixed effects are included in the regressions. The industry portfolio returns and book-to-market ratios are from Kenneth French's web site. CAPU data is taken from Federal Reserve G17 statistical releases and expressed in percentages. The sample period is from 1972 to 2002. All standaed errors are robust and reported in parentheses. *, ** indicates statistical significance at the 5%, 10% level, respectively.

	estimate	std. error	estimate	std. error
constant	0.072*	(0.007)	0.074*	(0.007)
market	1.906*	(0.414)	0.687*	(0.073)
SMB	1.685*	(0.640)	0.957*	(0.099)
HML	0.741	(0.557)	0.007	(0.084)
CAPU X market	-1.418*	(0.511)		
CAPU X SMB	-0.980	(0.776)		
CAPU X HML	-0.741	(0.687)		
B/M X market			0.132	(0.102)
B/M X SMB			-0.124	(0.146)
B/M X HML			0.260*	(0.123)
adjusted R^2	0.512		0.507	
F-test(p-val)	0.000		0.000	

Table 6: Regressions of annual industry returns with irreversibility dummy variable

Regression of annual industry returns on the lagged CAPU and the interaction between CAPU and an irreversibility dummy variable.

$$R_i(t) = \gamma_{0i} + \gamma_{1i} CAPU_i(t-1) + \gamma_{2i} D_i \times CAPU_i(t-1) + \epsilon_i(t) \qquad \forall i$$

CAPU is the rate of capacity utilization. The dummy variable D_i equals one if the volatility of $CAPU_i$ is in the top quintile of all industry volatilities and zero otherwise. Industry fixed effects are included in the regressions. The industry portfolio returns and book-to-market ratios are from Kenneth French's web site. CAPU data is taken from Federal Reserve G17 statistical releases and expressed in percentages. The sample period is from 1972 to 2002. All standaed errors are robust and reported in parentheses. *, ** indicates statistical significance at the 5%, 10% level, respectively.

	full sample	high CAPU	low CAPU
constant	0.474*	0.064	0.496*
	(0.111)	(0.253)	(0.153)
lagged CAPU	-0.398*	0.057	-0.388*
	(0.136)	(0.300)	(0.195)
Dummy X lagged CAPU	0.001	0.038	-0.065**
	(0.040)	(0.037)	(0.036)
adjusted R^2	0.007	0.001	0.013
F-test(p-val)	0.014	0.063	0.057

Figure 1: A numerical example of the relationship between the firm's market beta and the logarithm of its book-to-market ratio.

The functional form of the relationship between the firm's market beta and the logarithm of its book-to-market ratio is given in equation (18) in the text. The parameter values of this numerical example are selected to match key empirical findings and are discussed in detail in the text.

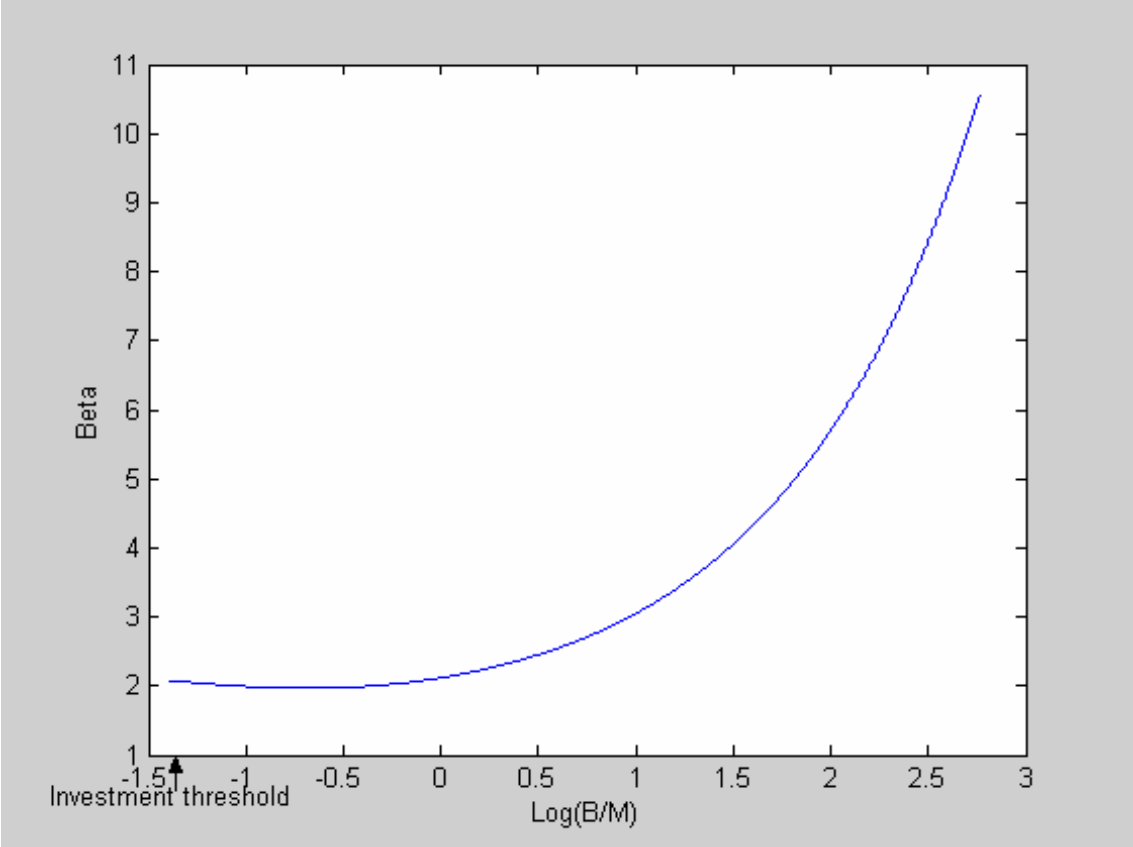

Figure 2: A numerical example of the relationship between the firm's market beta and the rate of capital utilization.

The functional form of the relationship between the firm's market beta and its rate of capital utilization is given in equation (19) in the text. The parameter values of this numerical example are selected to match key empirical findings and are discussed in detail in the text.

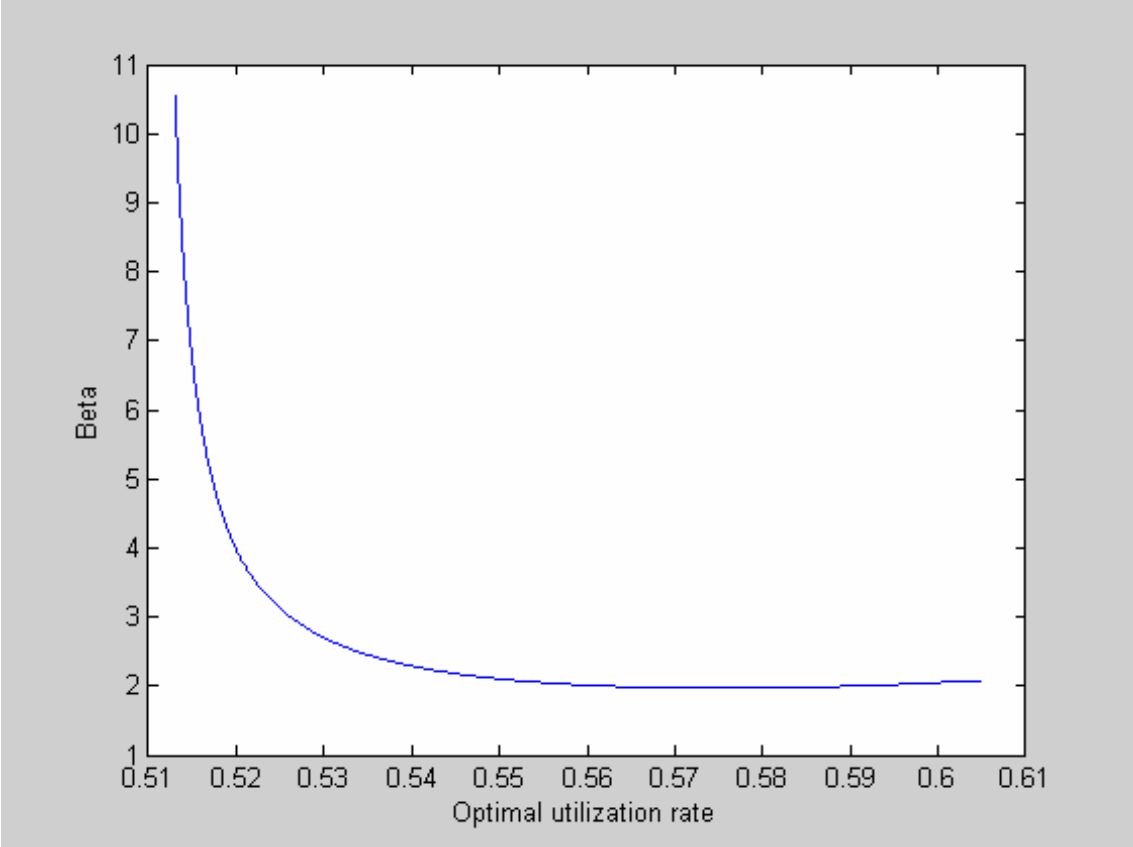

Figure 3: A numerical example of the relationship between the firm's return volatility and its rate of capital utilization.

The functional form of the relationship between the firm's return volatility and its rate of capital utilization is given in equation (14) in the text. The parameter values for this example are selected to match key empirical findings and are discussed in detail in the text.