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Article (Accepted version) (Refereed)

Original citation:
Aretz, Kevin and Pope, Peter F. (2018) *Real options models of the firm, capacity overhang, and the cross-section of stock returns.* Journal of Finance. ISSN 0022-1082

DOI: 10.1111/jofi.12617

Forthcoming in The Journal of Finance

Real Options Models of the Firm, Capacity Overhang, and the Cross-Section of Stock Returns

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ABSTRACT

We use a stochastic frontier model to obtain a stock-level estimate of the difference between a firm's installed production capacity and its optimal capacity. We show that this "capacity overhang" estimate relates significantly negatively to the cross-section of stock returns, even when controlling for popular pricing factors. The negative relation persists among small and large stocks, stocks with more or less reversible investments, and in good and bad economic states. Capacity overhang helps explain momentum and profitability anomalies, but not value and investment anomalies. Our evidence supports real options models of the firm featuring valuable divestment options.

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Garcia-Feijóo, Massimo Guidolin, Dirk Hackbarth, Andrew Karolyi, Holger Kraft, Peter Nyberg, Gil Sadka, Mark Shackleton, Mathijs Van Dijk, Michela Verado, Rafal Wojakowski, Ania Zalewska, and seminar participants at the University of Bath, University of Bristol, University of Cambridge, University of Dauphine (Paris), University of Exeter, University of Lille, Lisbon School of Economics and Management, London School of Economics, Luxembourg School of Finance, University of Surrey, University of Trier, the 2012 INQUIRE Autumn Seminar in London, the 2013 London Quant Group Seminar in Oxford, the 2014 Arne Ryde Workshop in Financial Economics in Lund, the 2014 Old Mutual Global Investors Quant Conference in Oxford, the 2015 Real Options Conference in Athens, and the 2015 Deutsche Bank Annual Global Quantitative Strategy Conference in New York for insightful comments. We thank Kenneth French, Jens Hilscher, and Lu Zhang for providing their data. Neither Kevin Aretz nor Peter Pope have anything to disclose.

Recent studies use real options theory to establish links between a firm's capacity related decisions, systematic risk, and characteristics. Considering a firm owning both installed production capacity and costly to reverse growth options, a common thread in these studies is that the firm's expected return depends on the difference between its installed capacity and the level of capacity that maximizes firm value net of capacity installation costs ("capacity overhang").[1,2] Despite that, the studies disagree about the exact nature of the expected return-capacity overhang relation. For example, assuming highly irreversible, but cheap to exercise growth options, Carlson, Fisher, and Giammarino (2004), Zhang (2005), and Cooper (2006) predict a mostly positive relation, potentially explaining value and investment anomalies in stock returns. Assuming more reversible growth options, Sagi and Seasholes (2007), Guthrie (2011), and Hackbarth and Johnson (2015) predict a negative relation, potentially explaining momentum and profitability anomalies. Combining low investment reversibility with expensive to exercise growth options, Hackbarth and Johnson (2015) show that the relation can also be U-shaped, potentially explaining both groups of anomalies referred to above.[3]

[1]Assuming the cost of a capacity unit does not depend on installed capacity, we can intuitively think of the capacity level that maximizes net firm value ("optimal capacity") as the initial capacity chosen by a start-up firm with the same values for the state variable and the model parameters. Firms sometimes build up capacity in excess of that level because capacity installation costs exceed the resale value of capacity, creating a wedge between the state variable value at which the firm invests and the value at which it divests.

[2]We think it important to highlight that capacity overhang is a related, but not identical concept to "excess capacity," usually defined as the proportion of a firm's installed capacity used in production. We focus on capacity overhang first because capacity overhang is a more fundamental concept than excess capacity (i.e., capacity overhang determines excess capacity, but not necessarily vice versa) and second because our stochastic frontier model approach allows us to estimate capacity overhang, but not excess capacity.

[3]Value anomalies describe the tendency of value stocks to have higher returns than growth stocks. Investment anomalies describe the tendency of non-investing (or divesting) stocks to have higher returns than investing stocks. Momentum anomalies describe the tendency of high intermediate-term past return stocks (winners) to have higher returns than low intermediate-term past return stocks (losers). Profitability anomalies describe the tendency of profitable stocks to have higher returns than unprofitable stocks.

Given the strong theoretical foundations underlying the expected return-capacity overhang relation, there is surprisingly little empirical research into the shape of the relation or its implications for stock anomalies. The lack of empirical research probably reflects the difficulty of estimating stock-level capacity overhang. In our paper, we make an effort to close that gap in the literature. We use a stochastic frontier model to estimate stock-level capacity overhang. Using the model's estimates, we run portfolio sorts and Fama-Macbeth (FM; 1973) regressions to study the shape of the stock return-capacity overhang relation. We also run horse races between the capacity overhang estimate and value, momentum, investment, and profitability variables, allowing us to study whether capacity overhang helps explain the anomalies.

We start with a theoretical analysis of a version of Pindyck's (1988) real options model of the firm allowing for costly investment reversibility. Doing so, we show that a standard demand based real options model is able to reproduce the different expected return-capacity overhang relations established in earlier work. More crucially, we also deduce lessons for our empirical estimation of capacity overhang from the model. The model considers a firm that sells output at a price driven by stochastic demand. The firm maximizes value by taking costless production (i.e., capacity utilization) decisions and capacity adjustment (i.e., investment and divestment) decisions under fixed capacity purchase and sale prices. In the absence of capacity adjustment options, the model produces a positive expected return-capacity overhang relation. This occurs because a firm with sufficiently high capacity overhang produces below full capacity. Thus, such a firm is able to increase (decrease) its capacity utilization rate as the output price increases (decreases), rendering its profits more sensitive to changes in the output price.

Endowing the firm with capacity adjustment options changes the expected return-capacity overhang relation. Growth options enable an optimal capacity firm to invest and further increase profits as the output price rises, increasing the firm's expected return. Divestment options enable a high capacity overhang firm to divest and mitigate falling profits as the output price drops, lowering the firm's expected return. Thus, introducing growth options, the expected return-capacity overhang relation can become U-shaped. Introducing both growth options and divestment options, the relation can become negative.

In our empirical work, we advocate a novel approach to estimating stock-level capacity overhang using a stochastic frontier model. The stochastic frontier model decomposes installed production capacity into an optimal capacity term and a capacity overhang term, identifying the terms using different determinants and appropriate distributional assumptions. The most important distributional assumption is that capacity overhang cannot be negative. In our main specification, we use a firm's property, plant, and equipment plus its intangible assets to proxy for installed production capacity. Informed by the real options model, we specify optimal capacity as a function of sales, operating and non-operating costs, volatility, systematic risk, and the risk-free rate of return. We include industry fixed effects to capture unobservable optimal capacity determinants (e.g., investment costs). Also informed by the real options model, we model capacity overhang as a function of variables reflecting past decreases in a firm's demand. We estimate the model recursively, ensuring that the capacity overhang estimate could have been computed in real-time. Validation tests suggest that the capacity overhang estimate captures time-series and cross-sectional variations in stock-level investment behavior and industry-level capacity utilization rates obtained from surveys.

We next form value-weighted portfolios sorted on estimated capacity overhang to study the stock return-capacity overhang relation. Mean excess returns decline almost monotonically over the portfolios, with a spread across the extreme portfolios of –12.5% per annum (t-statistic: –4.20). Adjusting for risk using the CAPM, Hou, Xue, and Zhang's (2015) q-theory model, or the Fama-French (2015) five-factor model, the spread return attracts a negative and strongly significant loading on the profitability factors in the q-theory and five-factor models, helping toward explaining the mean spread return. In contrast, the spread return loads positively, although less significantly on all other factors in the models. In total, the alphas of the spread portfolio thus do not differ much from its mean excess return. In the same vein, FM regressions of single-stock returns on the capacity overhang estimate and the joint set of firm characteristics underlying the CAPM, the q-theory model, and the five-factor model also produce significant negative capacity overhang premia, with t-statistics consistently below minus three.

We run several robustness tests. We first repeat the portfolio sorts by market size subsamples to alleviate concerns that our results are driven by micro stocks. We also repeat the portfolio sorts by investment reversibility subsamples, testing the real options model prediction that lower investment reversibility produces a less negative or U-shaped expected return-capacity overhang relation. We finally examine the capacity overhang portfolios separately in good and bad economic states, testing the hypothesis that, if the expected return-capacity overhang relation were U-shaped, the positive part of the relation would more likely crystalize in bad states with high capacity overhang. The robustness tests corroborate the evidence from our main tests that the stock return-capacity overhang relation is negative.

Our pricing results are most consistent with real options models in which the firm owns valuable divestment options, causing the expected return to decline with capacity overhang. Prior theoretical work highlights that such models have the potential to explain momentum and profitability anomalies. This happens since past returns and profitability are likely negatively related to capacity overhang, suggesting that profitable winner stocks have lower capacity overhang and thus higher returns than unprofitable loser stocks, as is the case. Conversely, such models do not have the potential to explain value and investment anomalies. This happens since value variables (investment rates) are likely positively (negatively) related to capacity overhang, suggesting that investing growth stocks have lower capacity overhang and thus higher returns than non-investing (or divesting) value stocks, as is not the case.

We next offer formal tests of the ability of capacity overhang to explain stock anomalies. We run horse races between estimated capacity overhang and each of 20 well known value, momentum, investment, and profitability anomaly variables from prior studies. The horse races confirm that capacity overhang helps explain momentum and profitability anomalies, but not value and investment anomalies. Controlling for capacity overhang reduces Jegadeesh and Titman's (1993) six and eleven-month past return (momentum) premia by 30-40%, with it, however, only rendering the six-month premium insignificant. That capacity overhang does not completely eliminate momentum anomalies is consistent with Asness, Moskowitz, and Pedersen's (2013) observation that real options models cannot be the entire explanation for such anomalies. Crucially, however, our results suggest that real options models significantly contribute to that explanation. Controlling for capacity overhang also greatly reduces profitability premia, with it, for example, eliminating Novy-Marx' (2013) and Fama and French's (2015) gross and total profitability premia, respectively, but not Hou, Xue, and Zhang's (2015) return-on-equity (ROE) premium. Conversely, controlling for capacity overhang has only marginal effects on, for example, Fama and French's (1992) book-to-market premium or Titman, Wei, and Xie's (2004) and Cooper, Gulen, and Schill's (2008) investment premia, while it reinforces DeBondt and Thaler's (1985) long-term reversal premia.

A possible caveat of our empirical analysis is that capacity adjustment costs excluded from our theoretical work, such as convex or fixed adjustment costs, may diminish the suitability of stochastic frontier models to estimate capacity overhang. In the presence of fixed adjustment costs, firms invest only when the investment induced increase in firm value net of linear costs covers the fixed costs. In this case, two firms with the same values for the optimal capacity determinants and values for the capacity overhang determinants signalling little or no capacity overhang can have a (slightly) different installed capacity. Since the stochastic frontier model is unable to explain that difference using either set of determinants, the difference ends up in the optimal capacity residual, rendering our capacity overhang estimate less accurate, but not invalidating it. In the presence of convex adjustment costs, a firm's adjustments toward optimal capacity depend on the entire history of the firm's state variable values. While it would be challenging to model that dependence, Cooper and Haltiwanger (2006) and Bloom (2009) find that convex adjustment costs are negligible relative to linear, fixed, and investment irreversibility induced adjustment costs. Thus, convex adjustment costs are unlikely to greatly distort the ability of stochastic frontier models to estimate capacity overhang.

Our work contributes to the real options asset pricing literature, as pioneered by the theoretical work of Berk, Green, and Naik (1999) and Gomes, Kogan, and Zhang (2003). Cooper, Wu, and Gerard (2005) use capacity utilization rates obtained from surveys to proxy for industry-level capacity overhang, reporting that capacity overhang positively prices the cross-section of industry returns. Cooper and Priestley (2009) use de-trended industrial production to proxy for capacity overhang, reporting that capacity overhang positively predicts the time-series of market returns. In contrast, our stock-level tests suggest a negative expected return-capacity overhang relation. Garcia-Feijóo and Jorgensen (2010) and Novy-Marx (2011) use operating leverage to proxy for capacity overhang, reporting that capacity overhang positively prices the cross-section of stock returns. In contrast, our more direct capacity overhang proxy suggests a negative relation. Hackbarth and Johnson (2015) use a calibration exercise of a real options model to study the expected return-capacity overhang relation. They also find a negative relation. Our work complements theirs by using more standard asset pricing tests facilitated by our new capacity overhang proxy. Using our proxy, we are able to incorporate cross-sectional variations in firm parameters (e.g., in demand volatility) into our empirical analysis.

Our work is also relevant for studies testing real options model predictions for the effect of investment on stock returns. Anderson and Garcia-Feijóo (2006) show that growth stocks invest more than value stocks, supporting Berk, Green, and Naik's (1999) prediction that the optimal exercise of low-risk growth options decreases both expected return and the book-to-market ratio. Anderson and Garcia-Feijóo (2006) and Xing (2008) report that investment variables are negatively priced in stock returns and help to explain the value anomaly. Lyandres, Sun, and Zhang (2008) show that controlling for investment behavior explains a large fraction of initial-(IPO) and secondary-public offering (SEO) underpricing, consistent with Carlson, Fisher, and Giammarino's (2006) real options model predictions. Cooper and Priestley (2011) show that the negative pricing of the investment variables is linked to systematic risks. Interestingly, our capacity overhang estimate has a close to zero correlation with the above investment variables.

We also make a theoretical contribution to the real options asset pricing literature. Prior theoretical work often claims that fixed production costs underlying operating leverage are necessary to generate a positive expected return-capacity overhang relation. We show that allowing firms to adjust capacity utilization can act as a substitute for fixed production costs in creating a positive relation. Notwithstanding, similar mechanisms complement the operating leverage effects in Carlson, Fisher, and Giammarino's (2004) and Cooper, Wu, and Gerard's (2005) models, although the mechanisms are not explicitly discussed by these authors.

Finally, we are also first in using stochastic frontier models in asset pricing research. Such models are slowly becoming more popular in finance. Hunt-McCool and Warren (1993), Hunt-McCool, Koh, and Francis (1996), and Habib and Ljungqvist (2005) use stochastic frontier models to estimate earnings efficiency, IPO underpricing, and the agency cost of equity.

I. Theoretical Analysis

In this section, we investigate the expected return-capacity overhang relation in an extension of Pindyck's (1988) demand based real options model of the firm allowing for costly investment reversibility. We show that the model is able to predict a positive, negative, or U-shaped relation despite it not including fixed production costs. We also deduce insights for our empirical estimation of capacity overhang from the model.

A. Model Setup

Consider a monopolistic all-equity firm with an infinite horizon. The firm continuously takes production decisions and capacity adjustment decisions to maximize value. At each time $t \in [0, +\infty)$, the firm uses installed capacity to produce and instantaneously sell some quantity of output. The firm's installed production capacity, $\bar{K} \in \{0, +\infty\}$, is the firm's number of production units at time t, with each unit able to produce one output unit per time unit. Accordingly, the firm's output quantity per time unit at time t is $Q \in \{0, \bar{K}\}$.

Output is sold at a price P driven by the downward sloping demand curve $P = \theta - \gamma Q$, where θ is stochastic demand, and γ is the (constant) elasticity of demand. In the main analysis, stochastic demand obeys Geometric Brownian motion (GBM):

$$d\theta = \alpha\theta dt + \sigma\theta dW, \tag{1}$$

where α and $\sigma > 0$ are constants and W is a Brownian motion. The output cost function per time unit is exponentially increasing and given by $C(Q) = c_1 Q + \frac{1}{2} c_2 Q^2$, where $c_1 \geq 0$ and $c_2 \geq 0$ are constants. The firm's time t profit per time unit, $\pi(\theta, Q)$, is then:

$$\pi(\theta, Q) = PQ - c_1 Q - \frac{1}{2} c_2 Q^2 = \theta Q - \gamma Q^2 - c_1 Q - \frac{1}{2} c_2 Q^2. \tag{2}$$

Since adjusting output quantity is costless, the firm maximizes profits and the value of the installed capacity by setting output quantity to $\min\left(\frac{\theta - c_1}{2\gamma + c_2}, \bar{K}\right)$ at each time t.

In addition to adjusting its output quantity, the firm is also able to adjust its installed production capacity at each time t. Denote by $k > 0$ the investment cost of installing one unit of capacity, and by $d \geq 0$ the divestment proceeds realized by selling one unit of capacity, with $k - d \geq 0$. There is no adjustment time, and capacity can be installed and sold without restriction. To maximize value, the firm invests when the value of new capacity exceeds the sum of the investment cost and the value of the option to install that capacity later. Similarly, the firm divests when the value of installed capacity is less than the sum of the divestment proceeds and the value of the option acquired to repurchase that capacity later.

We define the optimal capacity level, K^*, as the value of capacity that maximizes the total value of installed capacity plus growth options minus the total installation cost ($k\bar{K}$). Capacity overhang is the difference between installed capacity, $\bar{K}$, and optimal capacity, K^*. Since we abstract from fixed investment costs and time-to-build, if the firm's installed capacity is below optimal capacity, the firm instantaneously raises its installed capacity to optimal capacity. Thus, capacity overhang is truncated from below at zero. Conversely, since costly investment reversibility implies investment costs exceed divestment proceeds ($k > d$), the firm only divests capacity overhang in excess of some positive threshold value driven by demand and model parameters, most importantly the divestment proceeds d. Crucially, since the threshold value increases to infinity as demand increases to infinity, capacity overhang is not truncated from above. Fixing installed capacity, capacity overhang increases as demand decreases. Fixing demand, capacity overhang increases as installed capacity increases.

Pindyck (1988) suggests to interpret the described firm as a portfolio of incremental options to produce and to grow. Each incremental option to produce consists of an American call option yielding a payoff of $\max(\theta-(2\gamma+c_2)K-c_1, 0)$ per time unit at time t and a perpetual American put option allowing the firm to divest the option to produce at a unit price of d. Upon divestment, the incremental option to produce turns into the corresponding incremental option to grow. Each incremental option to grow is a perpetual American call option allowing the firm to purchase the corresponding option to produce at a unit price of k. Upon exercise, the incremental option to grow turns into the corresponding incremental option to produce. Denoting the value of the option to produce indexed by θ and K as $\Delta V(\theta, K)$ and the value of the option to grow indexed by θ and K as $\Delta F(\theta, K)$, we can write firm value, W, as:

$$W = \int_0^{\bar{K}} \Delta V(\theta, K) dK + \int_{\bar{K}}^{\infty} \Delta F(\theta, K) dK. \tag{3}$$

Consistent with interpreting the firm as a portfolio of real options, the firm's expected excess return, $E[r_A] - r$, can be written as the expected excess return of the portfolio of real options owned by the firm. Exploiting the fact that an option's expected excess return is equal to the product of the option's elasticity and the expected excess return of the underlying asset (see Cox and Rubinstein (1985, p.186)), Equation (4) links the firm's expected excess return to the elasticities of the real options owned by the firm:

$$E[r_A] - r = \left(\int_0^{\bar{K}} \frac{\Delta V(\theta, K)}{W} \Omega_{V(\theta,K)} dK + \int_{\bar{K}}^{\infty} \frac{\Delta F(\theta, K)}{W} \Omega_{F(\theta,K)} dK \right) (\mu - r), \qquad (4)$$

where $E[r_A]$ is the expected firm return, μ the expected return of a demand mimicking portfolio, r the risk-free rate of return, $\Omega_{V(\theta,K)}$ the elasticity of the option to produce, and $\Omega_{F(\theta,K)}$ the elasticity of the option to grow. An option's elasticity is defined as the partial derivative of the option's value with respect to demand times the ratio of demand to option value.

Our model is similar to most real options asset pricing models cited in the introduction in allowing for linear investment costs and costly investment reversibility. However, similar to only Carlson, Fisher, and Giammarino (2004) and Cooper, Wu, and Gerard (2005), the model also allows for variable production costs and capacity utilization choice. Similar to only Sagi and Seasholes (2007) and Aguerrevere (2009), it allows for mean reversion in demand and Cournot competition among identical firms in an Online Appendix. Unlike most other models, our model does not feature fixed production costs. While it would be easy to include such costs, we avoid doing so to emphasize that the expected return-capacity overhang relation generated by our model is not driven by operating leverage caused by fixed production costs. Finally, our model ignores both convex and fixed (or quasi-fixed) capacity adjustment costs. The theoretical work of Carlson, Fisher, and Giammarino (2004), Cooper (2006), and Hackbarth and Johnson (2015) suggests that the inclusion of fixed adjustment costs does not produce asset pricing conclusions greatly different from those produced by our model. The empirical work of Cooper and Haltiwanger (2006) and Bloom (2009) shows that convex adjustment costs are negligible in the presence of linear, fixed, and investment irreversibility induced adjustment costs.

B. *Model Solution*

Appendix A shows that the value of the production option indexed by θ and K is:

$$\Delta V(\theta, K) = \begin{cases} \Delta F(\theta, K) + d; & \theta \leq \theta' \\ b_1\theta^{\beta_1} + b_3\theta^{\beta_2}; & \theta' \leq \theta \leq (2\gamma + c_2)K + c_1 \\ b_2\theta^{\beta_2} + \theta/\delta - [(2\gamma + c_2)K + c_1]/r; & \theta \geq (2\gamma + c_2)K + c_1, \end{cases} \tag{5}$$

where β_1, β_2, b_1, b_2, b_3, and θ' are constants defined in the Appendix, and $\delta \equiv \mu - \alpha$. The component solutions can be interpreted as follows. If demand is below θ', the firm sells the option to produce, realizing divestment proceeds d and acquiring an option to repurchase the option to produce at a later date. If demand lies between θ' and $(2\gamma + c_2)K + c_1$, the firm retains the option to produce, but does not use it; its value thus derives from the options to use the option to produce if demand rises ($b_1\theta^{\beta_1}$) and to sell it if demand drops ($b_3\theta^{\beta_2}$). If demand is above $(2\gamma + c_2)K + c_1$, the firm uses the option to produce; its value thus derives from the option to stop using the option to produce if demand drops ($b_2\theta^{\beta_2}$) and the cash flows arising from perpetually using the option to produce ($\theta/\delta - [(2\gamma + c_2)K + c_1]/r$).

The Appendix also shows that the value of the growth option indexed by θ and K is:

$$\Delta F(\theta, K) = \begin{cases} a\theta^{\beta_1}; & \theta \leq \theta^* \\ \Delta V(\theta, K) - k; & \theta \geq \theta^*, \end{cases} \tag{6}$$

where a and θ^* are constants defined in the Appendix. The component solutions can be interpreted as follows. If demand is below θ^*, the firm waits to exercise the growth option. The option's value thus derives from the possibility of a later exercise ($a\theta^{\beta_1}$). If demand is above θ^*, the firm exercises the growth option; the option's value is thus equal to the value of the corresponding option to produce minus the investment cost k.

The model solutions imply that the elasticity of a "used" option to produce (satisfying

$K \leq (\theta - c_1)/(2\gamma + c_2)$) is $(b_2\beta_2\theta^{\beta_2} + \theta/\delta)/\Delta V(\theta, K)$, while the elasticity of an "idle" option to produce (satisfying $K \geq (\theta - c_1)/(2\gamma + c_2)$) is $(b_1\beta_1\theta^{\beta_1} + b_3\beta_2\theta^{\beta_2})/\Delta V(\theta, K)$. In contrast, the elasticity of a growth option is always β_1. Assuming that divestment proceeds d are zero and investments are completely irreversible, the elasticities of idle options to produce and of growth options become equal to β_1, while the elasticities of used options to produce lie below β_1 (see Appendix A and Lemma 2 in Appendix B). Thus, in contrast to most other real options asset pricing models studied in the literature, allowing for capacity utilization choice enables our model to generate options to produce that are as risky as growth options.[4]

Appendix A also shows that the optimal exercise level θ^* satisfies the equation:

$$b_2\left(\frac{\beta_1 - \beta_2}{\beta_1}\right)(\theta^*)^{\beta_2} + \left(\frac{\beta_1 - 1}{\beta_1}\right)\frac{\theta^*}{\delta} - \frac{(2\gamma + c_2)K + c_1}{r} - k \;=\; 0, \qquad (7)$$

which also defines the optimal installed capacity level K^* for each demand level θ. A numerical analysis of Equation (7) reveals intuitive results: optimal capacity K^* increases with demand (θ) and the divestment proceeds (d); it decreases with explicit and implicit production costs (c_1, c_2, and γ), demand volatility (σ), systematic risk (μ), and the capacity installation cost (k); and it has an ambiguous relation with the risk-free rate of return (r).

C. Model Conclusions

C.1. Irreversible Investments

Assuming zero divestment proceeds, investments are completely irreversible and the model collapses to Pindyck's (1988) model. In this case, Proposition 1 summarizes a firm's expected return-capacity overhang relation conditional on capacity utilization:

[4]Sagi and Seasholes (2007) and Kogan and Papanikolaou (2013, 2014) show that alternative ways to generate production options that are as risky or even riskier than growth options is to assign a finite maturity date to the growth options or to allow for stochastic variations in investment costs, respectively.

PROPOSITION 1: *Assuming zero divestment proceeds ($d = 0$), consider a firm optimally using its entire installed capacity to produce output (i.e., a firm operating at a 100% capacity utilization rate and satisfying $\bar{K} \leq (\theta - c_1)/(2\gamma + c_2)$). The effect of an installed capacity ($\bar{K}$) induced increase in capacity overhang on the firm's expected excess return, $E[r_A] - r$, is given by:*

$$\begin{aligned}\frac{\partial E[r_A] - r}{\partial \bar{K}} &= \Bigg(\frac{\Delta V(\theta, \bar{K})}{W}\left(\frac{b_2 \beta_2 \theta^{\beta_2} + \theta/\delta}{\Delta V(\theta, \bar{K})} - (E[r_A] - r)\right) \\ &- \frac{\Delta F(\theta, \bar{K})}{W}\left(\beta_1 - (E[r_A] - r)\right)\Bigg)(\mu - r). \qquad (8)\end{aligned}$$

The partial derivative in Equation (8) can be positive, zero, or negative.

Now consider a firm that uses less than its entire installed capacity to produce output (i.e., a firm operating at a capacity utilization rate below 100% and satisfying $\bar{K} > (\theta - c_1)/(2\gamma + c_2)$). The effect of an installed capacity ($\bar{K}$) induced increase in capacity overhang on the firm's expected excess return, $E[r_A] - r$, is given by:

$$\frac{\partial E[r_A] - r}{\partial \bar{K}} = \left(\left(\frac{\Delta V(\theta, \bar{K})}{W} - \frac{\Delta F(\theta, \bar{K})}{W}\right)\left(\beta_1 - (E[r_A] - r)\right)\right)(\mu - r). \qquad (9)$$

The partial derivative in Equation (9) is strictly positive.

Proof: See Appendix B.

Figure 1 illustrates Proposition 1, plotting the expected excess return, $E[r_A] - r$, against demand, θ, and installed capacity, $\bar{K}$. Given demand, optimal capacity, K^*, is given by the lowest available value on the installed capacity axis; see the left end point of the highlighted U-curve in the surface. When installed capacity is at or close to optimal capacity ($\bar{K} \approx K^*$ in the figure), the firm can be interpreted as a portfolio of low-risk *used* production options and high-risk growth options, leading the expected return to be at an intermediate level given by the left-end point of the U-curve. Holding demand constant and increasing installed capacity to a slightly higher level ($\bar{K} > K^*$), the value of the growth options declines and the firm's real

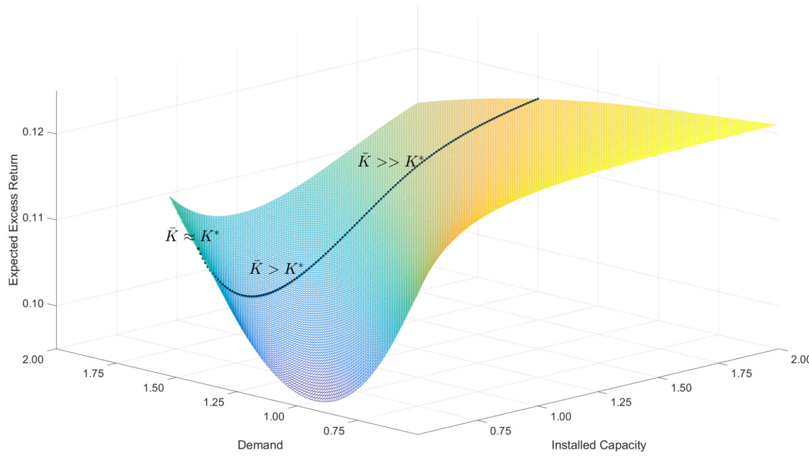

Figure 1: Expected Return-Capacity Overhang Relation Under No Reversibility The figure plots a firm's expected excess return, $E[r_A] - r$, against demand, θ, and installed capacity, $\bar{K}$. Keeping the value of demand fixed, optimal capacity, K^*, is given by the lowest available value on the installed capacity axis. The demand drift rate (α) and volatility (σ) are 0.05 and 0.10, respectively. The demand elasticity (γ) is 0.50. The cost parameters (c_1 and c_2) are zero. The purchase price of capital (k) is ten; the resale price (d) is zero. The expected return of the demand mimicking portfolio (μ) is 0.10. The risk-free rate (r) is 0.04.

options portfolio is re-balanced toward low-risk *used* options to produce. Thus, the expected return declines. However, increasing installed capacity further ($\bar{K} >> K^*$), the firm starts to reduce capacity utilization below 100%. As this happens, the firm's real options portfolio is re-balanced toward high-risk *idle* production options and away from low-risk *used* production options, increasing the expected return. Thus, in accordance with Proposition 1, Figure 1 shows that the effect of an increase in capacity overhang on the expected return depends crucially on the level of capacity overhang. When capacity overhang is low or intermediate (i.e., when Equation (8) holds), the marginal effect of an increase in capacity overhang on the expected return is ambiguous. However, when capacity overhang is high (i.e., when Equation (9) holds), the marginal effect on the expected return is unambiguously positive.[5]

[5]We could alternatively fix installed capacity and let demand decrease from the optimal threshold θ^* to zero. Since $\theta - \theta^*$ contains the same information about capacity overhang as $\bar{K} - K^*$, doing so would also yield the conclusion that a decline in demand causing an increase in capacity overhang decreases the expected return when demand is still close to θ^*, but increases the expected return when demand is further away.

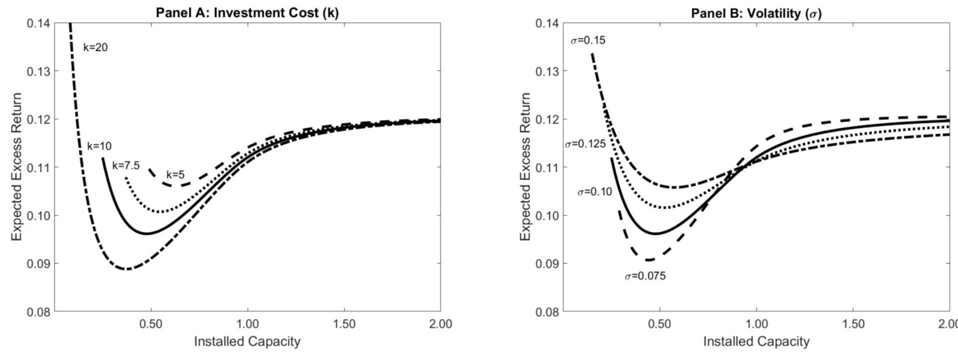

Figure 2: Comparative Statics for the Expected Return-Capacity Overhang Relation Under No Reversibility The figure plots a firm's expected excess return, $E[r_A] - r$, against installed capacity, $\bar{K}$, varying the unit purchase price of capital (k) from five to 20 (Panel A) and demand volatility (σ) from 0.075 to 0.15 (Panel B). Optimal installed capacity, K^*, is the value of installed capacity associated with the left-end point of each curve. Demand (θ) is one. The base-case parameter values are as in Figure 1.

The results in Proposition 1 are relevant for the literature in two ways. First, prior studies suggest that operating leverage resulting from fixed production costs is necessary to produce a positive expected return-capacity overhang relation. Our model features no fixed production costs and thus produces no operating leverage. Despite that, the proposition reveals that the model can produce a positive expected return-capacity overhang relation. This happens because the model treats a firm's installed capacity as a portfolio of *options* to produce, with the risk of these options decreasing with demand, but increasing with option leverage.[6]

The results in Proposition 1 are also relevant for the ability of real options models to explain stock anomalies. Carlson, Fisher, and Giammarino (2004), Zhang (2005), and Cooper (2006) show that real options models similar to the model in this section can produce a (mostly)

[6]The result that capacity utilization choice can substitute for fixed production costs in producing a positive expected return-capacity overhang relation is not special to our demand function. As the proof of Proposition 1 shows, the result holds as long as (i) the marginal option to produce is worth more than the marginal option to grow; and (ii) the marginal option to produce is as risky (or riskier) as the marginal option to grow. Standard arbitrage arguments imply that condition (i) always holds; see the proof of Lemma 1 in the Appendix. Condition (ii) holds as long as both the value of an idle option to produce and the value of an option to grow are given by $b\theta^{\beta_1}$, with b some constant. For example, it is easy to show that condition (ii) holds under the multiplicative (isoelastic) demand function $P = \theta Q^{-1/\gamma}$.

positive expected return-capacity overhang relation. Since in these models capacity overhang is positively related to value variables (e.g., the book-to-market ratio), but negatively to investment rates, such models have the potential to explain value and investment anomalies. However, similar to Hackbarth and Johnson (2015), our analysis suggests that the expected return-capacity overhang relation is only (mostly) positive if the effect of growth options on the expected return is sufficiently small at low to intermediate capacity overhang levels. One way to ensure that is to choose model parameters reducing the values or elasticities of growth options. To see this, Figure 2 plots the expected return against installed capacity, varying either investment costs (k) or demand volatility (σ). The figure shows that lowering investment costs (reducing the elasticities of growth options) or demand volatility (reducing both their elasticites and values) renders the relation between expected return and installed capacity — and thus capacity overhang — closer to being monotonically positive. It is in this spirit that Zhang (2005, p.68) concludes that investing must be "relatively easy" for models with no or highly costly investment reversibility to explain value and investment anomalies.

C.2. Costly Investment Reversibility

Section I.C.1 shows that our model produces a mostly positive or U-shaped expected return-capacity overhang relation when investments are completely irreversible. We now show that when investments are reversible the model can also produce a negative relation. To this end, Figure 3 plots the expected return against demand and installed capacity, using the same parameter values as Figure 1 except that we now allow capacity to be sold at a divestment price of five (i.e., $d = 5$). Holding demand constant, the figure suggests that, in this case, the expected return mostly declines with installed capacity. For example, considering the line highlighted in the surface, the expected return monotonically declines from 10.3% to 8.7%. The reason is that allowing for costly investment reversibility is equivalent to endowing a firm with options to sell installed capacity. Since the values of these options decline with demand, the

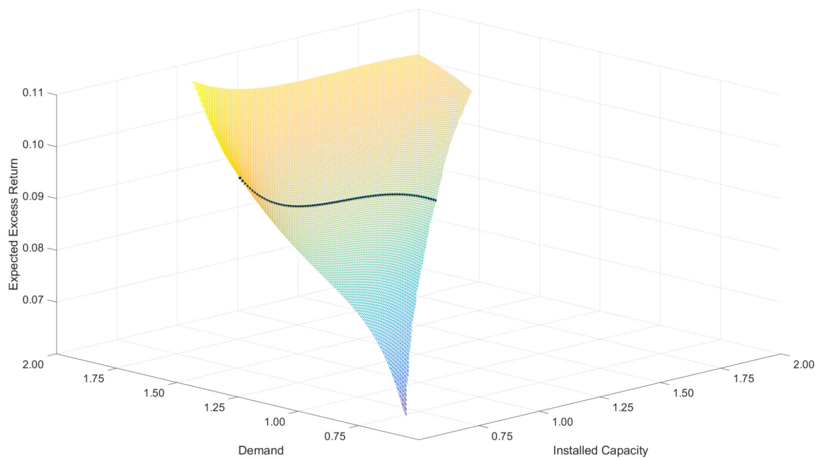

Figure 3: Expected Return-Capacity Overhang Relation Under Costly Reversibility The figure plots a firm's expected excess return, $E[r_A] - r$, against demand, θ, and installed capacity, $\bar{K}$. Keeping the value of demand fixed, optimal capacity, K^*, is given by the lowest available value on the installed capacity axis, while the optimal divestment capacity value is given by the highest available value. The resale price of capital (d) is five. Other parameter values are the same as those in Figure 1.

options have a negative elasticity. The negative elasticity lowers the expected return, especially when divestment options are most valuable: at high capacity overhang levels.

Our results in this section align with those in Sagi and Seasholes (2007), Guthrie (2011), and Hackbarth and Johnson (2015), who study models similar to ours. Since real options models predict capacity overhang to be negatively related to past returns and profitability, real options models with reversible investments could explain momentum and profitability anomalies.

C.3. Other Extensions

In our Online Appendix, we examine two extensions of the real options model studied in this part of the paper. In line with Aguerrevere (2009), we first study the implications of allowing for Cournot competition among identical firms, finding that such competition does not affect the shape of the expected return-capacity overhang relation. Second, in line with Sagi and Seasholes (2007), we study the implications of using a mean-reverting square root process to model demand, finding that more mean reversion turns the expected return-capacity overhang relation closer to being monotonically positive. This happens because mean reversion lowers the value of capacity adjustment options. More details are in the Online Appendix.

II. Empirical Analysis

In this section, we empirically examine the shape of the expected return-capacity overhang relation and its implications for stock anomalies. To this end, we first describe how we use a stochastic frontier model to estimate stock-level capacity overhang. We next use capacity overhang estimates obtained from that model in portfolio sorts and Fama-MacBeth (FM; 1973) regressions to identify the shape of the expected return-capacity overhang relation, expecting a positive or U-shaped relation when investments are costly to reverse and a negative relation when investments are cheap to reverse. We finally use the capacity overhang estimates in horse races with value, momentum, investment, and profitability anomaly variables, studying whether real options models help explain the stock pricing ability of the anomaly variables.

An alternative approach to investigate whether real options models help explain stock anomalies would be to calibrate the models to data (see Carlson, Fisher, and Giammarino (2004), Cooper (2006), and Hackbarth and Johnson (2015)). While calibration exercises are informative, they have two drawbacks. First, while it is hard to justify any a priori choice of values for the nonintuitive and unobservable capacity adjustment prices k and d in a calibration exercise, it is the values of the capacity adjustment prices that largely determine the shape of the expected return-capacity overhang relation. Estimating k and d by calibrating the real options model to stock data does not completely solve that problem since the estimated values will likely simply reflect the dominant anomalies in the data. A second drawback is that calibration exercises assume firms are homogeneous in model parameters, as, for example, in demand volatility. As a result, we believe that our more standard asset pricing tests are able to provide complementary evidence to calibration exercises.

A. *Measuring Capacity Overhang*

A.1. *The Stochastic Frontier Model*

We first review our stochastic frontier model approach to estimating stock-level capacity overhang.[7] Stochastic frontier models are suitable to estimate stock-level capacity overhang since the real options model in Section I suggests that capacity overhang is truncated from below at zero. To see how stochastic frontier models work, decompose firm i's installed capacity at time t, $\bar{K}_{i,t}$, into optimal capacity, $K^*_{i,t}$, and a capacity overhang term $\xi_{i,t}$:

$$\bar{K}_{i,t} = K^*_{i,t}\xi_{i,t}, \tag{10}$$

where $\xi_{i,t} \in [1, +\infty)$. Taking the natural log of both sides, we obtain:

$$\ln(\bar{K}_{i,t}) = \ln(K^*_{i,t}) + \ln(\xi_{i,t}) = \ln(K^*_{i,t}) + u_{i,t}, \tag{11}$$

where $u_{i,t} \equiv \ln(\xi_{i,t}) \geq 0$. We next assume that the natural log of optimal capacity, $\ln(K^*_{i,t})$, is a linear function of optimal capacity determinants, possibly including fixed effects (see Greene (2005)), and a normally distributed white-noise error term $v_{i,t}$. We can then write:

$$\ln(\bar{K}_{i,t}) = \alpha_k + \boldsymbol{\beta}'\mathbf{X}_{i,t} + v_{i,t} + u_{i,t} = \alpha_k + \boldsymbol{\beta}'\mathbf{X}_{i,t} + \epsilon_{i,t}, \tag{12}$$

where $\mathbf{X}_{i,t}$ is a vector of optimal capacity determinants, α_k are fixed effects, $\boldsymbol{\beta}$ is a vector of parameters, $v_{i,t} \sim N(0, \sigma_v^2)$, with σ_v^2 being a parameter, and $\epsilon_{i,t} \equiv v_{i,t} + u_{i,t}$ is the combined error term. The model is completed by assuming a distribution for the log capacity overhang term $u_{i,t}$, with prior studies offering a menu of choices. We choose the normal distribution truncated from below at zero since it is the only distribution allowing us to model the conditional mean of the

[7]Stochastic frontier models were independently developed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Brook (1977). An excellent textbook treatment is Kumbhakar and Lovell (2000).

$u_{i,t}$ term as a function of determinants, imposing further discipline. Thus, $u_{i,t} \sim N^{+}(\boldsymbol{\gamma}'\boldsymbol{Z}_{i,t}, \sigma_u^2)$, where $\boldsymbol{Z}_{i,t}$ is a vector of capacity overhang determinants, $\boldsymbol{\gamma}$ is a vector of parameters, and σ_u^2 is a parameter. Crucially, since $\mathbf{X}_{i,t}$ and $\boldsymbol{Z}_{i,t}$ contribute differently to an observation's likelihood, it is important to distinguish between the variables contained in $\mathbf{X}_{i,t}$ and in $\boldsymbol{Z}_{i,t}$.

We use maximum likelihood techniques to recursively estimate the stochastic frontier model on monthly data. The first recursive window is July 1963 to December 1971. We expand the recursive windows on an annual basis, ending each in December, so that, for example, the second window ends in December 1972. The final window ends in December 2013.

While we are ultimately interested in the log capacity overhang term $u_{i,t}$, the estimation output only provides us with an estimate of the combined error term $\epsilon_{i,t}$, but not $u_{i,t}$. Following other studies in the stochastic frontier literature, we thus calculate the conditional expectation of the $u_{i,t}$ term. To do so, define $\mu_{i,t}^* = \frac{\epsilon_{i,t}\sigma_u^2 + \boldsymbol{\gamma}'\boldsymbol{Z}_{i,t}\sigma_v^2}{\sigma_u^2+\sigma_v^2}$ and $\sigma_{i,t}^* = \sigma_u\sigma_v/\sqrt{\sigma_u^2+\sigma_v^2}$. We then calculate the conditional expectation of the log capacity overhang term, $\hat{u}_{i,t}$, using:

$$\hat{u}_{i,t} = E[u_{i,t}|\epsilon_{i,t}, \boldsymbol{Z}_{i,t}] = \mu_{i,t}^* + \sigma_{i,t}^* \left(\frac{n(-\mu_{i,t}^*/\sigma_{i,t}^*)}{N(\mu_{i,t}^*/\sigma_{i,t}^*)} \right), \tag{13}$$

where $n(.)$ and $N(.)$ are the standard normal-density and -cumulative density, respectively. In calculating $\hat{u}_{i,t}$, we always combine $\mathbf{X}_{i,t}$ and $\boldsymbol{Z}_{i,t}$ with model parameters estimated using the recursive estimation window ending in December of the prior calendar year, ensuring that $\hat{u}_{i,t}$ could have been calculated by real-time investors in month t.

A.2. Model Variables and Data

We next describe the variables used in the stochastic frontier model, with more details in Table AI in the Appendix. In our main specification, we use the sum of a firm's gross property, plant, and equipment (PP&E) and intangible assets to measure installed capacity. We include intangible assets because in the real options model the firm produces *and sells* output, and many intangibles facilitate the selling process.[8] However, for consistency with prior studies, in two alternative specifications we use gross PP&E on its own and total assets to measure installed capacity. Total assets is likely to be a noisy proxy for installed capacity because it includes financial assets not used in the production and selling process. We nevertheless use total assets, first for falsification purposes and second because it is often used in investment based asset pricing studies (e.g., Cooper, Gulen, and Schill (2008)).

We choose the optimal capacity determinants in $\boldsymbol{X}_{i,t}$ based on Equation (7), the implicit function identifying a firm's optimal capacity in the real options model. The equation suggests that optimal capacity depends on demand, the elasticity of demand, production costs, the capacity purchase and resale prices, systematic risk, demand volatility, and the risk-free rate of return. We include the natural logs of sales, costs of goods sold (COGS), and selling, general, and administrative costs (SG&A) to capture demand and production cost effects; the conditional market beta estimate proposed by Lewellen and Nagel (2006) to proxy for systematic risk; historical stock volatility calculated from daily data over the prior twelve months to proxy for demand volatility; and the three-month T-Bill rate to proxy for the risk-free rate of return. We capture unobservable variables such as the elasticity of demand and the capacity adjustment prices using industry fixed effects. We calculate the industry fixed effects based on Campbell's (1996) twelve-industry classification scheme.

We choose the capacity overhang determinants in $\boldsymbol{Z}_{i,t}$ based on the real options model's implication that a firm with positive capacity overhang must have enjoyed a higher demand for its output at some point in the past than now. To capture the effects of falling demand, we include the recent decline in sales, defined as the percentage decline in sales over the prior twelve months, and the more distant decline in sales, defined as the percentage decline in

[8] Examples include customer related intangibles, such as customer lists, order backlogs, and customer relations; contract related intangibles, such as franchises, licensing agreements, service contracts, and use rights; and technology related intangibles, such as patents, software, and trade secrets.

the twelve-month lagged maximum of a firm's sales over its entire history to twelve-month lagged sales. We set negative declines to zero. We separately study recent and more distant sales declines to see how persistent the effects of sales declines are. We also include a dummy variable indicating if a firm realized a loss over the prior twelve months. We do so since optimal capacity firms are always profitable in real options models.[9] We note that the asymmetries in the capacity overhang determinants give us identification different from other studies.[10]

Market data are from CRSP, while accounting data are from COMPUSTAT. Since capacity overhang is unlikely to have a long lasting effect on stock returns,[11] we require a timely estimate of capacity overhang. To this end, we use quarterly data to calculate the accounting variables used in our estimations, relying on annual data only when quarterly data are unavailable. In line with Campbell, Hilscher, and Szilagyi (2008), we assume that quarterly accounting data are reported with a two-month lag, while annual accounting data are reported with a three-month

[9] In a robustness test, we also include interactions between each capacity overhang determinant and the investment reversibility proxy introduced below, allowing the effects of the capacity overhang determinants to vary with investment reversibility costs. Since these interactions are, however, never important, we do not use them in the models estimated in the paper. The insignificance of the interactions is consistent with our later empirical finding that the effect of investment reversibility does not vary strongly across stocks.

[10] The evidence in Bloom (2009) supports the asymmetries in the capacity overhang determinants. In particular, Bloom (2009) notes that "[profitable] firms are located near their hiring and investment thresholds, above which they hire/invest and below which they have a zone of inaction[, so that] small positive shocks generate a hiring and investment response while small negative shocks generate no response" (p.625).

[11] When investments are reversible, neither the high expected returns of low capacity overhang stocks nor the low expected returns of high capacity overhang stocks are persistent. Consider a low capacity overhang firm. Upon goods news, this firm invests, converting high-risk growth options into low-risk production options; upon bad news, the firm's options portfolio re-balances toward lower-risk production options. Thus, any news lowers this firm's expected return. Consider a high capacity overhang firm. Upon good news, the firm's options portfolio re-balances toward higher-risk production options; upon bad news, the firm divests, converting low-risk production options into high-risk growth options. Thus, any news raises this firm's expected return.

lag.[12] To ensure numbers calculated from annual and quarterly data are comparable and not affected by seasonal variations, flow variables calculated from quarterly data are four-quarter trailing sums. Since the vast majority of firms start reporting quarterly data only from 1972, the use of annual accounting data allows us to obtain a first set of recursively estimated stochastic frontier model parameters in December 1971. For the same reason, the capacity overhang estimate used in our asset pricing tests starting in January 1972 typically relies on annual accounting data only through the stochastic frontier model parameter estimates, but not the model's variables. We study common stocks traded on the NYSE, Amex, or NASDAQ, excluding financial stocks (SIC Code: 6000-6999) and utilities (4900-4949). All variables except for the stock return are winsorized at the first and 99th percentiles, calculated each month; level variables are deflated using the Producer Price Index (PPI).

A.3. Model Estimates

We next discuss the estimation results from the stochastic frontier model. While we use a recursively fitted capacity overhang estimate in our asset pricing tests, Table I shows the results obtained over the full sample period. Columns (1)–(2) use PP&E plus intangibles to measure installed capacity; columns (3)–(4) use PP&E; and columns (5)–(6) use total assets. In each case, we estimate one model specification using all optimal capacity determinants and one using all optimal capacity determinants except stock volatility. We drop stock volatility from some model specifications since Ang et al. (2006, 2009) show that stock volatility negatively prices stocks, raising concern that it could drive the stock return-capacity overhang relation found in our empirical work. The plain numbers in Panels A, B, and C are the coefficient estimates of the optimal capacity determinants, the coefficient estimates of the capacity overhang determinants,

[12]Lagging the quarterly and annual accounting data by one or two more months does not change any of our empirical conclusions.

and the σ_v and σ_u estimates, respectively. T-statistics are in square parentheses.

<u>TABLE I ABOUT HERE</u>

Panel A suggests that sales is the most important determinant of optimal capacity, with its coefficient being positive and highly significant in all columns. COGS and SG&A costs also have significant positive coefficients, although coefficient magnitudes are in general lower than for sales. The more positive effect of sales is unsurprising since sales reflect the price at which output is sold (P) and output volume (Q), with both variables expected to be positively related to optimal capacity. In contrast, the cost variables reflect average unit costs (determined by c_1 and c_2) and output volume (Q), with average unit costs expected to be negatively, but output volume expected to be positively related to optimal capacity. In accordance with real options theory, stock volatility is significantly negatively related to optimal capacity. While the market beta and the risk-free rate of return also produce statistically significant coefficients in all model specifications, their effects on optimal capacity are economically negligible.

Panel B shows that the capacity overhang determinants also produce significant coefficients with the anticipated signs in the vast majority of cases. For example, with the exception of the sales decline over the more distant past in columns (3)–(4), sales declines over both the recent past and the more distant past increase capacity overhang. Crucially, however, recent sales declines have a much stronger effect than more distant sales declines, suggesting that firms divest capacity overhang over time and that investments are not completely irreversible. Finally, the loss dummy variable also loads positively and significantly on capacity overhang.

Panel C shows that the volatility of the log capacity overhang term $u_{i,t}$ is about twice the volatility of the optimal capacity error $v_{i,t}$. This is noteworthy because, if the volatility of $v_{i,t}$ strongly dominated the volatility of $u_{i,t}$, the stochastic frontier model estimates would converge to their OLS counterparts in the asymptotic limit (see Kumbhakar and Lovell (2000)). In this

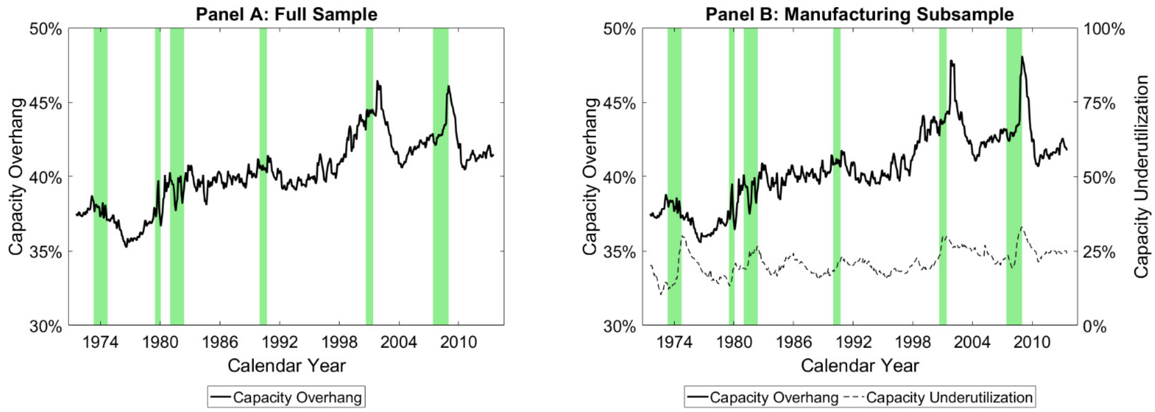

Figure 4: Mean Capacity Overhang-to-Installed Capacity Ratio Over Sample Period The figure plots the mean of the capacity overhang-to-installed capacity ratio, calculated as $1 - 1/\exp(\hat{u}_{i,t})$, over the 1972 to 2013 sample period. Panel A calculates the mean over the whole sample. Panel B calculates the mean over only those stocks operating in industries for which we can also calculate and plot a survey based estimate of mean capacity underutilization. The green bars identify NBER-defined recession periods.

case, we would no longer need to distinguish between the variables in $\boldsymbol{X}_{i,t}$ and $\boldsymbol{Z}_{i,t}$.

Figure 4 plots the mean capacity overhang-to-installed capacity ratio, $(\bar{K}_{i,t} - K^*_{i,t})/\bar{K}_{i,t} = 1 - 1/\exp(\hat{u}_{i,t})$, over our sample period, using the capacity overhang estimate based on the sum of PP&E and intangibles and including stock volatility. Panel A plots the mean over the full sample of stocks. Panel B plots the mean over only those stocks in industries for which we also have a Bureau of Economic Analysis (BEA) survey estimate of capacity utilization, allowing us to add mean industry-level capacity "underutilization" (i.e., one minus capacity utilization) to the panel. The green bars identify NBER-defined recession periods. The figure indicates that the mean capacity overhang-to-installed capacity ratio lies between 35% and 49%. In line with intuition, the mean ratio rises sharply in recessions. Confirming Cooper, Wu, and Gerard's (2005) idea that capacity underutilization proxies for capacity overhang, mean capacity overhang shares a correlation of about 0.60 with mean capacity underutilization.

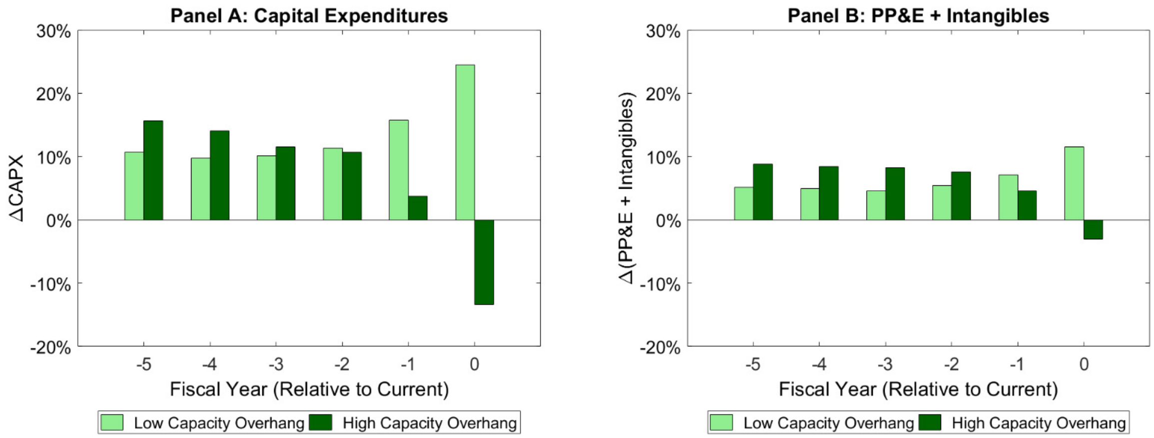

Figure 5: Investment Behavior of High and Low Capacity Overhang Stocks The figure plots the annual growth in CAPX (Panel A) and PP&E plus intangibles (Panel B) of high and low capacity overhang stocks over the prior six fiscal years. We define high (low) capacity overhang stocks as stocks with a capacity overhang value above the ninth decile (below the first decile) at the end of December of year 0.

A.4. Capacity Overhang Validation Tests

We use two tests to validate the capacity overhang estimate based on the sum of PP&E and intangibles and including stock volatility. We first compare the past investment behavior of high and low capacity overhang stocks, expecting high (low) capacity overhang stocks to have decreased (increased) their investments over the recent past. Figure 5 plots the mean annual growth rates in capital expenditures (CAPX; Panel A) and capacity (PP&E plus intangibles; Panel B) for the two groups of stocks over the prior six years. High (low) capacity overhang stocks are top (bottom) capacity overhang decile stocks at the end of December of year t. The growth rate in year $t-j$ is the net percentage change from the fiscal year ending in year $t-j-1$ to the fiscal year ending in year $t-j$, where $j \in \{0,1,2,3,4,5\}$. More details about the variables are in Table AI in the Appendix. We calculate means separately by year t, lag j, and capacity overhang decile 1 or 10 and then average over the sample years.

Figure 5 reveals that, while high capacity overhang stocks have significantly reduced their investment rates over the recent past, low capacity overhang stocks have significantly raised theirs, especially over the two most recent years. For example, Panel A shows that the CAPX growth of high capacity overhang stocks has decreased by an average of close to 30 percentage points from year $t-5$ to year t, while the CAPX growth of low capacity overhang stocks has increased by an average of about 14 points. Interestingly, the high capacity overhang stocks have a higher average CAPX and capital growth than the low capacity overhang stocks in year $t-5$, suggesting they are similar to Chan and Chen's (1991) "fallen angels." Also interestingly, the high capacity overhang stocks have a negative average capacity growth in year t, again suggesting that investment decisions cannot be completely irreversible.

In our second validation test, we investigate the ability of estimated capacity overhang to explain cross-sectional variations in industry-level capacity underutilization obtained from BEA survey data, as also used in Figure 4. At the end of each month in our sample period, we calculate the value-weighted average of the capacity overhang estimate for each of the 22 industries surveyed by the BEA. We sort the 22 industries into twelve portfolios according to the contemporaneous industry-level capacity overhang estimate, with portfolios 1 and 12 each containing one industry and the other portfolios two industries. Portfolio 1 contains the lowest capacity overhang industry, while portfolio 12 contains the highest. Figure 6 suggests that mean capacity underutilization increases almost monotonically over the portfolios. While portfolio 1 has a mean underutilization of about 17%, portfolio 12 has a mean underutilization of about 24%. The difference is a highly significant 7% (t-statistic: 5.24).

B. The Pricing of Capacity Overhang

B.1. Univariate Capacity Overhang Portfolios

We first use univariate portfolio sorts to study the pricing of capacity overhang. At the end of each month $t-1$ in our sample period, we sort stocks into portfolios according to the 5th, 10th, 20th, 40th, 60th, 80th, 90th, and 95th percentiles of recursively estimated capacity overhang (see Equation (13)). Similar to Campbell, Hilscher, and Szilagyi (2008), our portfolio sorts pay greater attention to the tails of the capacity overhang distribution to produce a more

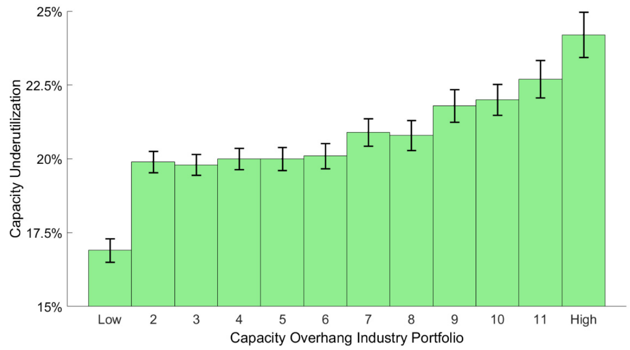

Figure 6: Capacity Utilization of Capacity Overhang-Sorted Industry Portfolios The figure plots the average capacity underutilization (one minus capacity utilization) of capacity overhang-sorted industry portfolios, where the average is calculated as the time-series average of the cross-sectional average taken over all industries in a portfolio. The black lines are the 95% confidence intervals. The industry-level capacity overhang estimate is the value-weighted average of the single-stock estimate over all stocks in an industry in a month. Industries are sorted into portfolios according to the contemporaneous industry-level capacity overhang estimate, with portfolios 1 and 12 each containing one industry and all others two.

even increase in capacity overhang over the portfolios. The first portfolio ("00–05") contains stocks with low capacity overhang values, while the last portfolio ("95–100") contains stocks with high values. Unless otherwise stated, in all portfolio sorts we use the capacity overhang estimate derived from the sum of PP&E and intangibles and including stock volatility; we calculate portfolio breakpoints exclusively from NYSE stocks; and we value-weight portfolios and hold them over month t. We finally construct a capacity overhang spread portfolio long on the highest and short on the lowest capacity overhang portfolio ("LS9505").

We adjust for risk by regressing a portfolio's "excess return" (i.e., the portfolio's return minus the risk-free rate of return) on the benchmark factors of the CAPM, the Hou, Xue, and Zhang (2015) q-theory model, or the Fama and French (2015) five-factor model and reporting the intercept ("alpha").[13] We use the Gibbons, Ross, and Shanken (GRS; 1989) F-test to

[13]The CAPM's only benchmark factor is the excess market return. Both the q-theory and five-factor models add the returns of spread portfolios on size (small-minus-large), investment (conservative-minus-aggressive), and profitability (profitable-minus-unprofitable). The five-factor model also adds the return on a book-to-market spread portfolio (high-minus-low book-to-market). See Fama and French (2015) and Hou, Xue, and Zhang (2015) for details. We thank Kenneth French and Lu Zhang for providing their benchmark factor data.

determine whether the models correctly price the portfolios. Unless otherwise stated, our asset pricing tests are run over monthly data from January 1972 to December 2013. Stock data are from CRSP. More details about our asset pricing variables are in Table AI in the Appendix.

Table II shows the mean excess returns and alphas (both annualized and in percent) and selected characteristics of the capacity overhang portfolios. The characteristics are the average number of stocks, the average capacity overhang-to-installed capacity ratio, and the average log market size, where the last two averages are time-series averages of the cross-sectional averages taken over the stocks in a portfolio. We show the t-statistics of the mean excess return and alphas of the spread portfolio, calculated using Newey and West's (1987) formula with a lag length of twelve, in square parentheses. The table shows that mean excess returns decline almost monotonically over the capacity overhang portfolios, from 10.0% for the lowest capacity overhang portfolio to –2.5% for the highest portfolio. The spread is a highly significant –12.5% (t-statistic: –4.20). Interestingly, about two-thirds of the spread come from the highest capacity overhang portfolio. The portfolios are well diversified, with even the extreme portfolios containing more than 200 stocks on average. Owing to our choice of portfolio breakpoints, average capacity overhang rises close to evenly over the portfolios. Finally, both high and low capacity overhang stocks are relatively small stocks.

Table II About Here

The alphas of the spread portfolio in Table II suggest that the CAPM, the q-theory model, and the five-factor model cannot explain the mean spread return over the capacity overhang portfolios. While the spread portfolio alphas of the CAPM and the five-factor model are even more negative and significant than the corresponding mean excess return, the alpha of the q-theory model is about 25% less negative, but still highly significant (t-statistic: –4.13). To better understand the alphas, Figure 7 shows the betas of the capacity overhang portfolios

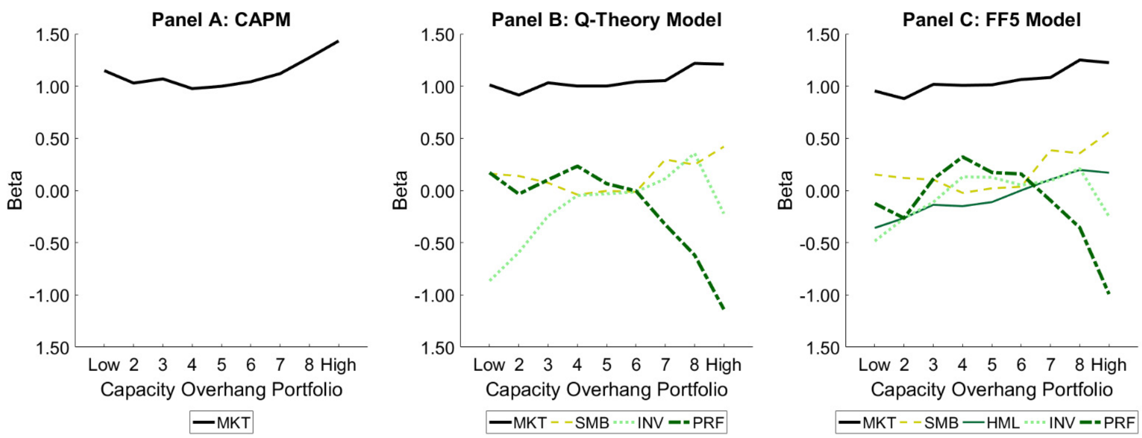

Figure 7: Betas of the Capacity Overhang Portfolios The figure plots the CAPM (Panel A), q-theory model (Panel B), and five-factor model (Panel C) beta exposures of the capacity overhang portfolios. "MKT" is the market beta, "SMB" the small-minus-big size beta, "HML" the high-minus-low book-to-market ratio beta, "INV" the low-minus-high investment beta, and "PRF" the profitable-minus-unprofitable beta.

on the benchmark factors of the three models. Panel A suggests that the CAPM market beta increases over the capacity overhang portfolios, rendering the model unable to explain why high capacity overhang stocks underperform low capacity overhang stocks. Conversely, Panels B and C suggest that the profitability betas of the q-theory model and the five-factor model fall sharply over the capacity overhang portfolios, from 0.15 to –1.12 for the q-theory model and from –0.12 to –0.97 for the five-factor model. While the spreads in the profitability betas help the two models explain the mean spread portfolio return (with the q-theory model's profitability factor explaining a greater fraction of the mean spread portfolio return mostly because its premium is about twice the premium of the five-factor model's profitability factor), the spreads in the betas of the models' other benchmark factors all work against explaining the mean spread portfolio return. Most strikingly, the beta of the q-theory model's investment factor increases over the capacity overhang portfolios, from –0.89 to –0.23.

Accordingly, the GRS tests in Table II suggest that the CAPM, the q-theory model, and the five-factor model all misprice the capacity overhang portfolios. While the CAPM (q-theory model) struggles to price high (low) capacity overhang stocks, the five-factor model struggles to price both high and low capacity overhang stocks. Adjusting for the benchmark factors of the q-theory or five-factor model, mean excess returns decline more evenly over the portfolios, with a significant fraction of the spread now coming from low capacity overhang stocks.

B.2. Double-Sorted Capacity Overhang and Market Size Portfolios

To address Fama and French's (2008) concern that many asset pricing results are driven by microcap stocks, we next study portfolios independently double-sorted on capacity overhang and market size. At the end of each month $t-1$ in our sample period, we first sort stocks into three portfolios according to the first decile and the first quartile of market size. We label the stocks in the first, middle, and last portfolio micro stocks, small stocks, and large stocks, respectively. We independently sort stocks into portfolios according to the 5th, 10th, 20th, 40th, 60th, 80th, 90th, and 95th percentiles of the capacity overhang estimate in month $t-1$. The intersection of the market size and capacity overhang breakpoints produces 27 double-sorted portfolios. Within each market size portfolio, we finally construct a spread portfolio long on the highest capacity overhang portfolio and short on the lowest ("LS9505").

Table III shows the same statistics as Table II, this time, however, separately for micro stocks (Panel A), small stocks (Panel B), and large stocks (Panel C). The table shows that each market size portfolio accounts for an average of about one-third of the cross-section. The average market size of micro stocks is, however, only about \$24 million, relative to about \$163 million for small stocks and about \$3.7 trillion for large stocks. More importantly, the table shows that both mean excess returns and alphas decline over the capacity overhang portfolios within each market size portfolio. Although the spreads over the portfolios are, in general, more negative and more significant within the micro-stock and small-stock portfolios, even large stocks produce negative and significant spreads, with, for example, the mean spread portfolio return being –11.8% per annum for those stocks (t-statistic: –3.68). While we can thus confirm Fama and French's (2008) conjecture that asset pricing results are often weaker among larger stocks, the evidence in this subsection demonstrates that the pricing of the capacity overhang estimate does not exclusively come from micro or small stocks.

<u>Table III About Here</u>

B.3. Double-Sorted Capacity Overhang and Reversibility Portfolios

We next study portfolios independently double-sorted on capacity overhang and an investment reversibility proxy. We do so to test the real options model prediction that costlier to reverse investments increase expected returns, especially for high capacity overhang stocks, perhaps generating a U-shaped stock return-capacity overhang relation among stocks with costlier to reverse investments (see Section I.C.1). To proxy for investment reversibility, we rely on Cooper, Wu, and Gerard's (2005) insight that higher investment reversibility implies that a firm starts to divest at a lower capacity overhang level, reducing the maximum capacity overhang level the firm can build up. Similar to these authors, we thus calculate the inverse of the time-series volatility of industry capacity overhang, where industry capacity overhang is the median of the capacity overhang estimate for each two-digit SIC industry and volatility is calculated using the full sample period. We next assign the resulting estimates to all firms operating in each industry. A higher proxy value indicates that a firm operates in an industry with less extreme capacity overhang values, suggesting higher investment reversibility.[14]

Table IV shows the average numbers of stocks and annualized five-factor model alphas of

[14]While Cooper, Wu, and Gerard (2005) actually use the time-series volatility of industry-level capacity utilization rates from BEA surveys, the intuition behind their proxy and ours is identical. An advantage of using our proxy is that it can be calculated for firms operating in industries not included in the BEA surveys, making up about half of our sample. Notwithstanding, using Cooper, Wu, and Gerard's (2005) proxy in our tests produces similar albeit slightly noisier results relative to those in our paper. Using Schlingemann, Stulz, and Walking's (2002), Silbilkov's (2009), and Ortiz-Molina and Phillips' (2014) investment reversibility proxy based on the activity in an industry's real assets market or Kim and Kung's (2016) proxy based on how widely an industry's real assets are used in other industries also produces similar results.

the double-sorted portfolios.[15] We form the double-sorted portfolios in the table in exactly the same way as those in Table III except that we use the median to sort stocks into investment reversibility portfolios. We do so because the investment reversibility proxy takes on only a limited number of values, implying that portfolios would often be ill diversified using a larger set of breakpoints. Supporting real options model predictions, the table suggests that higher investment reversibility decreases the five-factor model alpha, especially for high capacity overhang stocks. To see this, note that the alpha of the lowest capacity overhang portfolio does not significantly vary across the high and low investment reversibility portfolios. In contrast, the alpha of the highest capacity overhang portfolio is 8.4% per annum lower in the high than in the low investment reversibility portfolio (t-statistic: –2.64). An implication is that the decline in the alpha over the capacity overhang portfolios is 10.9% per annum lower in the high than in the low investment reversibility portfolio (t-statistic: –2.19). Notwithstanding this observation, the decline in alpha is close to monotonic and significant in *both* the high and low investment reversibility portfolio, suggesting that not even low investment reversibility stocks produce a U-shaped stock return-capacity overhang relation.

Table IV About Here

B.4. Portfolio Timing

We next study the stock return-capacity overhang relation in different economic states, arguing that, if the true relation were U-shaped, the upward sloping part of the relation would more likely crystalize in bad states with a higher aggregate capacity overhang (see Figure 4). To do so, Table V repeats the univariate portfolio sorts in Table II, this time, however, separately reporting five-factor model alphas in good and bad economic states. We use GDP growth over

[15]Mean excess returns, CAPM alphas, and q-theory alphas produce similar results both in the tests in this section and also in the portfolio timing tests reported in Section II.B.4.

the prior four quarters, industrial production growth over the prior twelve months, and the market return over months $t-36$ to $t-1$ to identify the state, using macroeconomic data from two months after their official release date. We assume to be in a good (bad) state if the state proxy is above (below) its full-sample median. We obtain the macroeconomic data from the Federal Reserve Bank of St. Louis Economic Database.

TABLE V ABOUT HERE

Table V suggests that the spread in the five-factor model alpha over the capacity overhang portfolios is more negative in good than in bad states. For example, the table shows that the spread is –18.5% per annum in high industrial production growth states and –11.2% per annum in low industrial production growth states. Nevertheless, the spread is consistently negative in good and bad states. Thus, in line with prior results, our evidence again suggests that the stock return-capacity overhang relation is negative, and not U-shaped.

B.5. Fama-MacBeth Regressions

We finally run FM regressions of single-stock returns over month t on the month $t-1$ values of each of the capacity overhang estimates derived from the stochastic frontier models in Table I and controls. The capacity overhang estimates in columns (1)–(2) of Table VI rely on PP&E plus intangibles as installed capacity proxy, those in columns (3)–(4) on PP&E, and those in columns (5)–(6) on total assets. The capacity overhang estimates in columns (1), (3), and (5) include stock volatility as optimal capacity determinant; those in the other columns do not. To alleviate outlier effects resulting from the capacity overhang estimates being right skewed, we take the natural log of the estimates. As controls, we use the market beta, market size, the book-to-market ratio, profitability, the return-on-equity (ROE), and asset growth. See Tables AI and AII in the Appendix for more details about the variables. To alleviate microstructure biases, the regressions exclude a stock from the start of July of year t to the end of June of year $t+1$ if the stock's price is below \$1 at the end of June of year t.

<u>TABLE VI ABOUT HERE</u>

Table VI suggests that all stochastic frontier model capacity overhang estimates are significantly priced in FM regressions. Columns (1)–(4) show that the estimates based on PP&E plus intangibles or on PP&E on its own have premia of about –60 basis points per month, with highly significant t-statistics around minus five. Conversely, Columns (5)–(6) show that the estimates based on total assets have premia of about –20 basis point, with t-statistics of "only" about minus three. The less significant pricing of the total assets based estimates is consistent with the idea that total assets is a less powerful proxy for installed capacity since it includes financial assets. The table also suggests that including stock volatility among the optimal capacity determinants does not greatly influence the pricing of capacity overhang. The pricing of the controls aligns with the empirical evidence in other studies.

C. Capacity Overhang and Stock Anomalies

C.1. Choosing Value, Momentum, Investment, and Profitability Variables

Our evidence in Section II.B suggests that capacity overhang is negatively related to stock returns, supporting real options models of the firm able to explain momentum and profitability anomalies, but not those able to explain value and investment anomalies. To directly test the ability of real options models to explain stock anomalies, we next select anomaly variables whose ability to price stocks could potentially be explained by real options models. Table AII in the Appendix shows that the 20 selected variables include: (i) momentum variables (e.g., the past six- and eleven-month returns; see Panel A); (ii) profitability variables (e.g., sales growth, operating profitability, total profitability, the ROE, and the failure probability; see

Panel B);[16] (iii) value variables (e.g., the book-to-market ratio and two long-term past returns; see Panel C); and (iv) investment variables (e.g., total accruals, operating accruals, abnormal investment, PP&E growth, and asset growth; see Panel D). We also include asset turnover, defined as the ratio of sales to total assets, since it could be interpreted as a less sophisticated proxy for capacity overhang. We calculate the anomaly variables in exact accordance with the established asset pricing literature, detailing our procedures in Table AII.

To test whether capacity overhang helps to explain the pricing of an anomaly variable, we run FM regressions of single-stock returns over month t on a capacity overhang estimate, the anomaly variable, and controls in month $t-1$, both separately and jointly using the capacity overhang estimate and the anomaly variable. In our main tests, we use the capacity overhang estimate derived from using PP&E plus intangibles as the installed capacity proxy and including stock volatility among the optimal capacity determinants. We use the other capacity overhang estimates in tests reported in the Online Appendix. Since the studies identifying the 20 selected anomalies typically control for the market beta, market size, and the book-to-market ratio, we use the same controls in our tests. See Table AI and AII in the Appendix for more details about the controls. We only include an observation in the FM regressions related to an anomaly variable if the capacity overhang estimate, the anomaly variable, and the controls are all non-missing. We exclude a stock's data from start of July of year t to end of June of year $t+1$ if the stock's price at the end of June of year t is below \$1.

C.2. Momentum and Profitability Anomalies

We first study the ability of capacity overhang to explain momentum and profitability anomalies. Table VII shows the results of FM regressions on the capacity overhang estimate

[16] All FM regressions involving the failure probability are run over the sample period from 1981 to 2013. The reason is that the recursively estimated coefficients of Campbell, Hilscher, and Szilagyi's (2008) logit failure model are only available from January 1981. We thank Jens Hilscher for providing the coefficients.

(Panel A), on each of the momentum and profitability anomaly variables (Panel B), and on the capacity overhang estimate and the anomaly variable (Panel C). While we do not report estimates, all FM regressions include a constant and the controls. Panel D shows the percentage change in the absolute premium of the anomaly variable (capacity overhang estimate) obtained from adding the capacity overhang estimate (anomaly variable) to the FM regression excluding it. The panel also shows the average cross-sectional correlation between the capacity overhang estimate and each of the anomaly variables.

Table VII About Here

Table VII suggests that capacity overhang helps explain momentum and profitability anomalies. Panel A shows that the capacity overhang estimate is always significantly priced in models only also including the controls, with premia and t-statistics consistent with those in Table VI. Conversely, Panel B shows that Jegadeesh and Titman's (1993) six- and eleven-month past (momentum) returns are also significantly priced in models only also including the controls, with premia of about 60 basis points per month (t-statistics: 2.41 and 3.17, respectively). Including capacity overhang alongside either past return and the controls, the past return premia shrink by about 30-40%, rendering the six-month premium insignificant and the eleven-month premium significant at a lower significance level (t-statistic: 2.21; see Panel C). In contrast, the capacity overhang premium hardly changes. That the eleven-month past return retains some significance in our tests supports Asness, Moskowitz, and Pedersen's (2013) claim that real options models cannot fully explain momentum anomalies, based on their finding that such anomalies exist in asset classes in which real options are not important. Crucially, however, while real options models may not fully explain momentum anomalies, our evidence in this section suggests that they significantly contribute to explaining such anomalies.[17]

[17] Johnson (2002) and Liu and Zhang (2014) show that other neoclassical investment models also help explain momentum anomalies in stock returns.

Turning to the profitability anomalies, Panel B shows that Lakonishok, Shleifer, and Vishny's (1994) sales growth, Haugen and Baker's (1996) asset turnover, and Campbell, Hilscher, and Szilagyi's (2008) failure probability are not significantly priced in models only also including the controls. The insignificant asset turnover premium is surprising since the variable shares a correlation of –0.47 with the capacity overhang estimate (see Panel D), consistent with asset turnover being a crude proxy for capacity overhang. Conversely, the profitability variables of Lev and Nissim (2004), Soliman (2008), Novy-Marx (2013), Fama and French (2015), and Hou, Xue, and Zhang (2015) are significantly positively priced in models only also including the controls, with t-statistics above 2.28. Including capacity overhang alongside each anomaly variable and the controls eliminates the premia of all profitability variables except the ROE, without significantly changing the capacity overhang premium (see Panel C). The inability of capacity overhang to affect the ROE premium is surprising since the correlation between the capacity overhang estimate and the ROE is –0.36, similar to the capacity overhang estimate's correlations with the other profitability variables. Interestingly, controlling for capacity overhang renders the asset turnover premium significantly negative, while it renders the failure probability premium significantly positive.

The Online Appendix shows that the capacity overhang estimate based on PP&E performs almost as well in explaining momentum and profitability anomalies as the estimate based on PP&E plus intangibles. In contrast, the capacity overhang estimate based on total assets performs markedly worse. The Online Appendix further shows that the inclusion of stock volatility among the optimal capacity determinants hardly matters for the ability of the capacity overhang estimate to explain momentum and profitability anomalies.

C.3. Value and Investment Anomalies

We next investigate the ability of capacity overhang to explain value and investment anomalies. Table VIII shows the results from FM regressions analogous to those in Section II.C.2

except that we replace the momentum and profitability variables with value and investment variables. The table (which is identical in design to Table VII) suggests that capacity overhang does not help explain value and investment anomalies. Panel A shows that the capacity overhang estimate is always significantly negatively priced in models only also including the controls. Conversely, Panel B suggests that, of the value anomalies, Fama and French's (1992) book-to-market ratio is significantly positively priced in models only also including the controls (t-statistic: 4.20), while DeBondt and Thaler's (1985) long-term past returns are not significantly priced. Of the investment anomalies, both the accruals variables and the investment variables are significantly negatively priced, with t-statistics between –2.47 and –3.36 for the accruals variables and between –3.81 and –5.89 for the investment variables.

TABLE VIII ABOUT HERE

Including capacity overhang alongside each anomaly variable and the controls does not greatly influence the pricing of the book-to-market ratio and the investment variables (see Panel C), consistent with the correlations between the capacity overhang estimate and these anomaly variables being close to zero (see Panel D). Including capacity overhang alongside the long-term past returns and the accruals variables renders the long-term past return premia significantly negative (with t-statistics of –3.11 for the two-year return and –1.97 for the five-year return) and raises the significance of the accruals premia (see Panel C).

The Online Appendix shows that capacity overhang estimates based on other installed capacity proxies and either including or excluding stock volatility perform no better in explaining value and investment anomalies than the estimate used in the paper.

C.4. Return on Equity

Given the ability of capacity overhang to explain the pricing of other profitability variables in Section II.C.2, we find it surprising that it cannot explain the pricing of Hou, Xue, and Zhang's (2015) ROE. Novy-Marx (2016) offers a possible explanation for this finding, arguing that the former ROE variable is not a profitability proxy, but instead an "earnings surprise proxy-in-disguise." To test this claim, Table IX shows the results from FM regressions of single-stock returns over month t on the month $t-1$ values of the ROE, the capacity overhang estimate, and Novy-Marx' (2016) two earnings surprise variables: the earnings announcement return and standardized unexpected earnings. See Table AII in the Appendix for the definitions of the earnings surprise variables. As before, we only include an observation in the FM regressions if the ROE, the capacity overhang estimate, and the two earnings surprise variables are all non-missing. We also again exclude a stock's data from start of July of year t to end of June of year $t+1$ if the stock's price at the end of June of year t is below \$1.

Table IX About Here

Table IX supports Novy-Marx' (2016) claim. While the ROE premium is a significant 61 basis points per month in the model excluding either earnings surprise variable (t-statistic: 2.88; see column (1)), it is virtually zero in the model including both the earnings announcement return and the standardized earnings surprise (see column (2)). In contrast, the earnings surprise variables reduce the capacity overhang premium by only about 40%, without eliminating its significance (see columns (3)–(4)). Jointly including capacity overhang, the ROE, and the earnings variables in the model in column (5), the capacity overhang premium remains significantly negative (t-statistic: –2.64), while the ROE premium is insignificant (t-statistic: –0.08). Thus, while the pricing ability of the ROE comes almost entirely from earnings surprises, capacity overhang contains important incremental pricing information.

III. Conclusion

Prior theoretical studies suggest that real options models of the firm are able to produce a variety of expected firm return-capacity overhang relations, with different relations offering the prospect of explaining different stock anomalies. Despite strong theoretical foundations, there is, however, little empirical research into the expected return-capacity overhang relation and its implications for stock anomalies. We try to close that gap in the literature. We use a stochastic frontier model to derive a stock-level estimate of capacity overhang. Using capacity overhang estimates derived from that model in portfolio sorts and FM regressions, we study the pricing of capacity overhang and its ability to explain stock anomalies. Our empirical work suggests that capacity overhang is significantly and close to monotonically negatively related to the cross-section of stock returns, in line with real options models in which the firm owns important divestment options. The negative relation persists among small and large stocks, firms with more or less reversible investments, and in good and bad economic states. Our empirical work further suggests that capacity overhang helps explain momentum and profitability anomalies in stock returns, but not value and investment anomalies.

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Appendix:

A. Model Solution

The value of the production option indexed by θ and K, $\Delta V(\theta, K)$, must satisfy the following ordinary differential equation (see, e.g., Dixit and Pindyck (1994)):

$$\frac{1}{2}\sigma^2\theta^2\frac{\partial^2\Delta V(\theta,K)}{\partial\theta^2} + (r-\delta)\theta\frac{\partial\Delta V(\theta,K)}{\partial\theta} - r\Delta V(\theta,K) + C(\theta,K) = 0, \tag{A1}$$

where $C(\theta, K)$ is the profit produced by that production option.

Let θ' denote the demand level at or below which the firm decides to sell off the production option. When demand is above this level, but below the level at which the firm switches on the production option (i.e., $\theta' \leq \theta \leq (2\gamma + c_2)K + c_1$), the unit profit of the option is zero (i.e., $C(\theta, K) = 0$). In this case, the value of the production option is of the form:

$$\Delta V(\theta, K) = b_1\theta^{\beta_1} + b_3\theta^{\beta_2}, \tag{A2}$$

where:

$$\beta_1 = -\frac{(r-\delta-\sigma^2/2)}{\sigma^2} + \frac{1}{\sigma^2}\left[(r-\delta-\sigma^2/2)^2 + 2r\sigma^2\right]^{(1/2)} > 1, \tag{A3}$$

$$\beta_2 = -\frac{(r-\delta-\sigma^2/2)}{\sigma^2} - \frac{1}{\sigma^2}\left[(r-\delta-\sigma^2/2)^2 + 2r\sigma^2\right]^{(1/2)} < 0, \tag{A4}$$

and b_1 and b_3 are free parameters. When $\theta \geq (2\gamma+c_2)K+c_1$, the firm switches on the production option, and the unit profit of the production option is $C(\theta, K) = \theta - (2\gamma + c_2)K - c_1$. In this case, the value of the production option is of the form:

$$\Delta V(\theta, K) = b_2\theta^{\beta_2} + \frac{\theta}{\delta} - \frac{(2\gamma + c_2)K + c_1}{r}, \tag{A5}$$

where b_2 is a free parameter, and we use the boundary condition $\lim_{\theta \to +\infty} \Delta V(\theta, K) = (\theta/\delta) - ((2\gamma + c_2)K + c_1)/r$ to rule out the independent solution involving β_1.

We determine the values of b_1, b_2, b_3 and θ' using the following value-matching and smooth-pasting conditions at the optimal capacity switch-on demand threshold, $\theta^P \equiv (2\gamma + c_2)K + c_1$, and the optimal capacity divestment demand threshold, θ':

$$
\begin{aligned}
b_1(\theta^P)^{\beta_1} + b_3(\theta^P)^{\beta_2} &= b_2(\theta^P)^{\beta_2} + \frac{(\theta^P)}{\delta} - \frac{(2\gamma + c_2)K + c_1}{r}, && \text{(A6)} \\
b_1\beta_1(\theta^P)^{\beta_1 - 1} + b_3\beta_2(\theta^P)^{\beta_2 - 1} &= b_2\beta_2(\theta^P)^{\beta_2 - 1} + \frac{1}{\delta}, && \text{(A7)} \\
b_1(\theta')^{\beta_1} + b_3(\theta')^{\beta_2} &= \Delta F(\theta', K) + d, && \text{(A8)} \\
b_1\beta_1(\theta')^{\beta_1 - 1} + b_3\beta_2(\theta')^{\beta_2 - 1} &= \frac{\partial \Delta F(\theta', K)}{\partial \theta'}, && \text{(A9)}
\end{aligned}
$$

where $\Delta F(\theta', K)$ is the value of the growth option indexed by θ and K at the optimal divestment demand threshold θ'. Using Equations (A6) and (A7), we find that:

$$
\begin{aligned}
b_1 &= \frac{r - \beta_2(r - \delta)}{r\delta(\beta_1 - \beta_2)}[(2\gamma + c_2)K + c_1]^{1 - \beta_1} > 0, && \text{(A10)} \\
b_2 - b_3 &= \frac{r - \beta_1(r - \delta)}{r\delta(\beta_1 - \beta_2)}[(2\gamma + c_2)K + c_1]^{1 - \beta_2} > 0. && \text{(A11)}
\end{aligned}
$$

The value of the growth option indexed by θ and K, $\Delta F(\theta, K)$, must satisfy:

$$
\frac{1}{2}\sigma^2\theta^2 \frac{\partial^2 \Delta F(\theta, K)}{\partial \theta^2} + (r - \delta)\theta \frac{\partial \Delta F(\theta, K)}{\partial \theta} - r\Delta F(\theta, K) = 0, \tag{A12}
$$

which implies that the value of that growth option is of the form:

$$
\Delta F(\theta, K) = a\theta^{\beta_1}, \tag{A13}
$$

where a is a free parameter, and we use the boundary condition $\lim_{\theta \to 0} \Delta F(\theta, K) = 0$ to rule out the independent solution involving β_2. We use the following value-matching and smooth-pasting conditions at the demand level at which the growth option is optimally exercised and converted, θ^*, to determine the values of both a and θ^*:

$$b_2(\theta^*)^{\beta_2} + \frac{\theta^*}{\delta} - \frac{(2\gamma + c_2)K + c_1}{r} - k = a(\theta^*)^{\beta_1}, \tag{A14}$$

$$b_2\beta_2(\theta^*)^{\beta_2 - 1} + \frac{1}{\delta} = a\beta_1(\theta^*)^{\beta_1 - 1}. \tag{A15}$$

Conditional on θ^*, we can solve Equation (A15) for a:

$$a = b_2\frac{\beta_2}{\beta_1}(\theta^*)^{\beta_2 - \beta_1} + \frac{(\theta^*)^{1-\beta_1}}{\beta_1\delta}. \tag{A16}$$

To complete the solution, we need to solve the following system of three equations in the three unknown parameters b_2, θ', and θ^*:

$$b_1(\theta')^{\beta_1} + (b_2 - b_d)(\theta')^{\beta_2} = a(\theta')^{\beta_1} + d, \tag{A17}$$

$$b_1\beta_1(\theta')^{\beta_1 - 1} + (b_2 - b_d)\beta_2(\theta')^{\beta_2 - 1} = a\beta_1(\theta')^{\beta_1 - 1}, \tag{A18}$$

$$b_2(\theta^*)^{\beta_2} + \frac{\theta^*}{\delta} - \frac{(2\gamma + c_2)K + c_1}{r} - k = a(\theta^*)^{\beta_1}, \tag{A19}$$

where the first two equations follow from Equations (A8) and (A9), respectively, with $b_d \equiv b_2 - b_3$ given in (A11), and the last equation is Equation (A14). Conditional on the value of a given in Equation (A16), we can solve Equations (A17) and (A18) for θ' and b_2:

$$\theta' = \left(\frac{\beta_2 d}{(a - b_1)(\beta_1 - \beta_2)}\right)^{\frac{1}{\beta_1}}, \tag{A20}$$

$$b_2 = (a - b_1)\left(\frac{\beta_2 d}{(a - b_1)(\beta_1 - \beta_2)}\right)^{1 - \frac{\beta_2}{\beta_1}} + d\left(\frac{\beta_2 d}{(a - b_1)(\beta_1 - \beta_2)}\right)^{-\frac{\beta_2}{\beta_1}} + b_d. \tag{A21}$$

Substituting the solutions for a and b_2 into Equation (A19), we numerically solve the resulting implicit function of the optimal investment demand threshold for θ^*.

B. Proof of Proposition 1

When capacity cannot be sold at a positive price ($d = 0$), it follows from Equations (A20) and (A21) that b_3 and θ' are zero and that the model collapses to Pindyck's (1988) model. We first derive two lemmas that are helpful in proving Proposition 1:

LEMMA 1: *The strict ordering of functions $\Delta V(\theta, K)$ and $\Delta F(\theta, K)$, given by:*

$$\Delta V(\theta, K) > \Delta F(\theta, K), \tag{A22}$$

holds over the entire domain of θ and K.

Proof of Lemma 1: Lemma 1 follows from the result that a call option must be worth less than its underlying asset. Assume the opposite, that is, that $\Delta V(\theta, K) \leq \Delta F(\theta, K)$. In this case, an arbitrageur could purchase the underlying asset and short-sell the option, realizing an immediate cash flow of $\Delta F(\theta, K) - \Delta V(\theta, K) \geq 0$. When the option is exercised, the arbitrageur transfers the underlying asset, receiving a cash flow of k in return. Thus, the arbitrageur earns a zero or positive cash flow today, an operating profit equal to $\max(\theta - (2\gamma + c_2) - c_1, 0)$ per time unit at each time t until exercise, and a positive cash flow upon exercise. Ruling out arbitrage opportunities, it must be the case that $\Delta V(\theta, K) > \Delta F(\theta, K)$.

LEMMA 2: *The elasticity of an idle production option or an unexercised growth option, β_1, is greater or equal to the elasticity of a used production option, $(b_2\beta_2\theta^{\beta_2} + \theta/\delta)/\Delta V(\theta, K)$.*

Proof of Lemma 2: The lemma claims that:

$$\beta_1 \geq \frac{b_2\beta_2\theta^{\beta_2} + \theta/\delta}{b_2\theta^{\beta_2} + \theta/\delta - [(2\gamma + c_2)K + c_1]/r} \tag{A23}$$

over the interval $\theta \in \{(2\gamma + c_2)K + c_1, \infty\}$. To see that this inequality holds, multiply by

$\Delta V(\theta, K) = b_2\theta^{\beta_2} + \theta/\delta - [(2\gamma + c_2)K + c_1]/r > 0$ and rearrange:

$$(\beta_1 - \beta_2)b_2\theta^{\beta_2} + (\beta_1 - 1)\theta/\delta - \beta_1[(2\gamma + c_2)K + c_1]/r) \geq 0. \tag{A24}$$

Substituting the solution of b_2 from Appendix A into the inequality, we obtain:

$$\frac{r - \beta_1(r-\delta)}{r\delta}[(2\gamma + c_2)K + c_1]^{1-\beta_2}\theta^{\beta_2} + (\beta_1 - 1)\theta/\delta - \beta_1[(2\gamma + c_2)K + c_1]/r) \geq 0. \tag{A25}$$

Multiplying by $r > 0$ and $[(2\gamma + c_2)K + c_1]^{(\beta_2 - 1)}\theta^{(-\beta_2)} > 0$ and rearranging, we obtain:

$$\frac{r - \beta_1(r-\delta)}{\delta} + \frac{r(\beta_1 - 1)}{\delta}\left(\frac{\theta}{(2\gamma + c_2)K + c_1}\right)^{(1-\beta_2)} - \beta_1\left(\frac{\theta}{(2\gamma + c_2)K + c_1}\right)^{(-\beta_2)} \geq 0. \tag{A26}$$

Inequality (A26) holds if its left-hand side (i) is zero at $\theta = \theta^P \equiv (2\gamma + c_2)K + c_1$ and (ii) increases with θ for θ above θ^P. To see that condition (i) holds, plug the definition of θ^P into the left-hand side, noting that $\beta_1 = \frac{r-\beta_1(r-\delta)}{\delta} + \frac{r(\beta_1-1)}{\delta}$. To see that condition (ii) holds, note that the partial derivative of the left-hand side with respect to θ is:

$$\frac{r(1-\beta_2)(\beta_1 - 1)}{\delta[(2\gamma + c_2)K + c_1]}\left(\frac{\theta}{(2\gamma + c_2)K + c_1}\right)^{-\beta_2} + \frac{\beta_1\beta_2}{(2\gamma + c_2)K + c_1}\left(\frac{\theta}{(2\gamma + c_2)K + c_1}\right)^{-\beta_2 - 1}. \tag{A27}$$

This expression is positive if and only if:

$$\frac{r(1-\beta_2)(\beta_1 - 1)}{\delta} + \beta_1\beta_2\left(\frac{\theta}{(2\gamma + c_2)K + c_1}\right)^{-1} > 0, \tag{A28}$$

where $\frac{r(1-\beta_2)(\beta_1-1)}{\delta} > 0$ and $\beta_1\beta_2\left(\frac{\theta}{(2\gamma+c_2)K+c_1}\right)^{-1} < 0$ (as $\beta_2 < 0$). Evaluating the partial derivative at $\theta = \theta^P$, we obtain: $\frac{r}{\delta}(\beta_1 + \beta_2 - \beta_1\beta_2 - 1) + \beta_1\beta_2$. Using the definitions of β_1 and β_2 in Appendix A, we find that $\beta_1 + \beta_2 = -\frac{2(r-\delta-\sigma^2/2)}{\sigma^2}$ and $\beta_1\beta_2 = -\frac{2r}{\sigma^2}$. Substituting back into the partial derivative, we find: $\frac{r}{\delta}\left(-\frac{2(r-\delta-\sigma^2/2)}{\sigma^2} + \frac{2r}{\sigma^2} - 1\right) - \frac{2r}{\sigma^2} = 0$, implying that the partial derivative is zero if $\theta = \theta^P$. Raising θ above θ^P, only the negative summand in Inequality (A28) changes, from $\beta_1\beta_2$ to $\beta_1\beta_2((2\gamma + c_2)K + c_1)/\theta$. When $\theta > \theta^P$, $((2\gamma + c_2)K + c_1)/\theta < 1$, decreasing the magnitude of the negative summand on the left-hand side of Inequality (A28) and ensuring that the inequality is fulfilled when demand θ exceeds the level θ^P.

Proof of Proposition 1: The expected excess return of a firm satisfying $K^* < \bar{K} \leq (\theta - c_1)/(2\gamma + c_2)$ is given by:

$$E[r_A] - r = \frac{1}{W}\left(\beta_2\theta^{\beta_2}\int_0^{\bar{K}} b_2(v)dv + \theta/\delta\int_0^{\bar{K}} dv + \beta_1\int_{\bar{K}}^{\infty} \Delta F(\theta, v)dv\right), \tag{A29}$$

where, without loss of generality, we have set $(\mu - r)$ equal to unity.

The partial derivative of the expected excess return with respect to capacity, $\bar{K}$, is:

$$\begin{aligned}\frac{\partial E[r_A] - r}{\partial \bar{K}} &= \frac{1}{W^2}\Bigg[(\beta_2\theta^{\beta_2}b_2(\bar{K}) + \theta/\delta - \beta_1\Delta F(\theta, \bar{K})) \cdot W - (\Delta V(\theta, \bar{K}) - \Delta F(\theta, \bar{K})) \\ &\times \left(\beta_2\theta^{\beta_2}\int_0^{\bar{K}} b_2(v)dv + \theta/\delta\int_0^{\bar{K}} dv + \beta_1\int_{\bar{K}}^{\infty} \Delta F(\theta, v)dv\right)\Bigg],\end{aligned} \tag{A30}$$

or, alternatively:

$$\frac{\Delta V(\theta, \bar{K})}{W}\left(\frac{b_2(\bar{K})\beta_2\theta^{\beta_2} + \theta/\delta}{\Delta V(\theta, \bar{K})} - (E[r_A] - r)\right) - \frac{\Delta F(\theta, \bar{K})}{W}\left(\beta_1 - (E[r_A] - r)\right). \tag{A31}$$

Lemma 2 suggests that $\beta_1 - (E[r_A] - r) > 0$. As a result, a sufficient condition for the partial derivative to be negative is $\frac{b_2(\bar{K})\beta_2\theta^{\beta_2} + \theta/\delta}{\Delta V(\theta, \bar{K})} \leq E[r_A] - r$. Since we can interpret $\frac{b_2(\bar{K})\beta_2\theta^{\beta_2} + \theta/\delta}{\Delta V(\theta, \bar{K})}$ as the elasticity of the marginal production option and $E[r_A] - r$ as the (scaled) value-weighted average of the elasticities of the firm's options, the expected firm return decreases with capacity overhang if the marginal production option's risk is below the risk of the firm.

The expected excess return of a firm satisfying $\bar{K} \geq (\theta - c_1)/(2\gamma + c_2)$ is given by:

$$E[r_A]-r = \frac{1}{W}\left(\int_0^{\frac{\theta-c_1}{2\gamma+c_2}} (b_2(v)\beta_2\theta^{\beta_2} + \theta/\delta)dv + \beta_1 \int_{\frac{\theta-c_1}{2\gamma+c_2}}^{\bar{K}} \Delta V(\theta,v)dv + \beta_1 \int_{\bar{K}}^{\infty} \Delta F(\theta,v)dv\right). \tag{A32}$$

The partial derivative of the expected excess return with respect to capacity, $\bar{K}$, is:

$$\begin{aligned}\frac{\partial E[r_A]-r}{\partial \bar{K}} &= \frac{1}{W^2}\Bigg[\beta_1(\Delta V(\theta,\bar{K}) - \Delta F(\theta,\bar{K})) \cdot W - (\Delta V(\theta,\bar{K}) - \Delta F(\theta,\bar{K})) \\ &\times \left(\int_0^{\frac{\theta-c_1}{2\gamma+c_2}} (b_2(v)\beta_2\theta^{\beta_2} + \theta/\delta)dv + \beta_1 \int_{\frac{\theta-c_1}{2\gamma+c_2}}^{\bar{K}} \Delta V(\theta,v)dv \right. \\ &+ \left. \beta_1 \int_{\bar{K}}^{\infty} \Delta F(\theta,v)dv\right)\Bigg],\end{aligned} \tag{A33}$$

or, alternatively:

$$\frac{\partial E[r_A]-r}{\partial \bar{K}} = \left(\frac{\Delta V(\theta,\bar{K})}{W} - \frac{\Delta F(\theta,\bar{K})}{W}\right)\Big(\beta_1 - (E[r_A]-r)\Big). \tag{A34}$$

Lemma 1 suggests that $(\Delta V(\theta,\bar{K}) - \Delta F(\theta,\bar{K})) > 0$. Equation (4) shows that $E[r_A] - r$ is the scaled value-weighted average of the elasticities of the production and growth options owned by the firm. Lemma 2 suggests that β_1 is the maximum possible elasticity, implying $(\beta_1 - (E[r_A] - r)) > 0$. Thus, the partial derivative is unambiguously positive.

Table AI: Analysis Variables

The table defines all variables used in our tests except the anomaly variables. In our asset pricing tests, we use *CapacityOverhang*, *GDPGrowth*, *IndProductionGrowth*, and *PastMarketReturn* values from the end of month $t-1$ to condition single-stock returns over month t; *MarketBeta* and *MarketSize* values from June of year t to condition monthly single-stock returns over the period from July of year t to June of year $t+1$; and time-invariant *InvReversibility* values to condition single-stock returns over month t. We show the mnemonics assigned to the input variables by the data providers (CRSP and COMPUSTAT) in parentheses.

Variable Name	Variable Definition
Panel A: Capacity Overhang Variables	
CapacityOverhang	Log of the spread between a stock's installed production capacity and its optimal production capacity, recursively estimated using a stochastic frontier model with industry fixed effects.
InstalledCapacity	(i) Log of the sum of gross property, plant, and equipment (ppegt or ppegtq) and intangible assets (intan or intanq). (ii) Log of gross property, plant, and equipment (ppegt or ppegtq). (iii) Log of total assets (at or atq).
Sales	Log of sales over the prior four fiscal quarters (sale or saleq).
COGS	Log of COGS over the prior four fiscal quarters (cogs or cogsq).
SG&A	Log of SG&A costs over the prior four quarters (xsga or xsgaq).
StockVolatility	Log of volatility of daily returns (ret) over the prior twelve months.
MarketBeta	Sum of slope coefficients from a stock-level regression of excess stock return (ret) on current, one-day lagged, and sum of two-, three-, and four-day lagged excess market returns, where the regression is run using daily data over the prior twelve months (see Lewellen and Nagel (2006) for more details about the methodology).
RiskfreeRate	Three-month Treasury Bill rate (see Kenneth French's website).
RecentSalesDecline	Percentage decrease in sales (sale or saleq) over the most recent four fiscal quarters; the variable is set to zero if the decrease is negative.
DistantSalesDecline	Percentage decrease in sales (sale or saleq) from a stock's maximum sales calculated twelve months ago to sales twelves months ago; the variable is set to zero if the decrease is negative.
LossDummy	Dummy set equal to one if a firm ran a loss (negative ni or niq) over the prior four fiscal quarters; otherwise, the variable is set to zero.

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Table AI: Analysis Variables (cont.)

Variable Name	Variable Definition
Panel B: Investment Reversibility Variables	
InvReversibility	The inverse of the time-series volatility of the cross-sectional median of *CapacityOverhang* per two-digit SIC code industry assigned to all stocks in an industry, where volatility is taken over the full sample period and the variable is only calculated for industries consistently featuring ten or more stocks (see Cooper, Wu, and Gerard (2005)).
Panel C: State Variables	
GDPGrowth	Percent change in GDP over the prior four quarters.
IndProductionGrowth	Percent change in industrial production over the prior twelve months.
PastMarketReturn	Cumulative market return over the prior 36 months.
Panel D: Other Variables	
$\Delta CAPX$	Net percent change in capital expenditures (capx) from the fiscal year ending in calendar year $t-2$ to that ending in year $t-1$.
Δ*(PP&E+Intangibles)*	Net percent change in PP&E (ppegt) + intangibles (intan) from the fiscal year ending in calendar year $t-2$ to that ending in year $t-1$.
CapacityUtilization	Industry capacity utilization rates obtained from BEA surveys.
MarketSize	Log of the product of the stock price (abs(prc)) times common shares outstanding (shrout).
Panel E: Campbell (1996) Industry Definitions	
Petroleum	SIC Codes: 13, 29.
Consumer durables	SIC Codes: 25, 30, 36-37, 50, 55, 57.
Basic goods	SIC Codes: 10, 12, 14, 24, 26, 28, 33.
Food/tobacco	SIC Codes: 1, 20, 21, 54.
Construction	SIC Codes: 15-17, 32, 52.
Capital goods	SIC Codes: 34-35, 38.
Transport	SIC Codes: 40-42, 44, 45, 47.
Textiles/trade	SIC Codes: 22-23, 31, 51, 53, 56, 59.
Services	SIC Codes: 72-73, 75, 80, 82, 89.
Leisure	SIC Codes: 27, 58, 70, 78-79.

Table AII: Anomaly Variables
The table defines the anomaly variables used in our tests. In our asset pricing tests, we update the variables indexed by an "M" on a monthly basis and use their values to condition single-stock returns over month $t+1$. We update the variables indexed by an "A" on an annual basis and use their values to condition (monthly) single-stock returns over the period from July of year t to June of year $t+1$. We set the variables indexed by an "MR" to the values from their most recent earnings announcement date (COMPUSTAT item: rdq) and use these to condition single-stock returns over month $t+1$. We show the mnemonics assigned to the input variables by the data providers (CRSP and COMPUSTAT) in parentheses.

Variable Name	Variable Definition
Panel A: Momentum Variables	
SixMonthMom (M)	Log of the compounded stock return (ret) over the period from month $t-6$ to month $t-1$ (see Jegadeesh and Titman (1993)).
ElevenMonthMom (M)	Log of the compounded stock return (ret) over the period from month $t-11$ to month $t-1$ (see Jegadeesh and Titman (1993)).
Panel B: Profitability Variables	
SalesGrowth (A)	Weighted average of the sales (sale) growth decile to which a stock belonged over the previous five years, where sales growth is calculated from the fiscal year end in calendar year $t-j-1$ to that in calendar year $t-j$ and the average is calculated as: $\sum_{j=1}^{5} \frac{6-j}{150} \times$ Sale Growth Decile($t-j$) (see Lakonishok, Shleifer, and Vishny (1994)).
AssetTurnover (A)	Log of the ratio of sales (sale) to total assets (at), where the variables are from the fiscal year end in calendar year $t-1$ (see Haugen and Baker (1996)).
ProfitMargin (A)	Ratio of operating income after depreciation (oiadp) to sales (sale), where the variables are from the fiscal year end in calendar year $t-1$ (see Soliman (2008)).
OperatingProfit (A)	Ratio of gross profits (sale minus cogs) to total assets (at), where the variables are from the fiscal year end in calendar year $t-1$ (see Novy-Marx (2013)).
Profit (A)	Ratio of sales (sale) net of costs of goods sold (cogs), selling, general, and administrative expenses (xsge), and interest expenses (xint) to the book value of equity, where the book value of equity is total assets (at) minus total liabilities (lt) plus deferred taxes (txditc, zero if missing) minus preferred stock (pstkl, pstkrv, prfstck, or zero, in that order of availability) and the variables are from the fiscal year end in calendar year $t-1$ (see Fama and French (2015)).

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Table AII: Anomaly Variables (cont.)

Variable Name	Variable Definition
ReturnOnEquity (MR)	The ratio of quarterly income before extraordinary items (ibq) to the quarterly book value of equity, where the book value of equity is shareholders' equity (seqq, ceqq+pstkq, or atq–ltq, in that order of availability) plus deferred taxes and investment tax credits (txditcq, zero if missing) minus the book value of preferred stock (pstkrq, zero if missing). Quarterly income is from the latest earnings announcement date (rdq), while all other variables are from the one before. The variable is set to missing if the earnings announcement date is more than six months after the earnings date (see Hou, Xue, and Zhang (2015)).
TaxableIncome (A)	The ratio of pre-tax (pi) to net income (ni), where the variables are from the fiscal year end in year $t-1$ (see Lev and Nissim (2004)).
FailureProb (MR)	The probability of a stock failing (i.e., filing for bankruptcy, defaulting, or being delisted for performance reasons) over the coming twelve months, calculated from a logit model estimated using only data available until month t and using market and accounting variables, such as, for example, net income, total liabilities, and stock volatility, as failure predictors (see Campbell, Hilscher, and Szilagyi (2008)).
Panel C: Value Variables	
BookToMarket (A)	Log of the ratio of the book value of equity to the market value of equity (abs(prc) $\times$ shrout), where the book value of equity is equal to total assets (at) minus total liabilities (lt) plus deferred taxes (txditc, zero if missing) minus preferred stock (pstkl, pstkrv, prfstck, or zero, in that order of availability) and the variables are from the fiscal year end in calendar year $t-1$ (see Fama and French (1992)).
PastRet(-12,-35) (M)	Log of the compounded stock return (ret) over the period from month $t-35$ to month $t-12$ (see DeBondt and Thaler (1985) and Fama and French (1996)).
PastRet(-1,-59) (M)	Log of the compounded stock return (ret) over the period from month $t-59$ to month $t-1$ (see DeBondt and Thaler (1985) and Fama and French (1996)).

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Table AII: Anomaly Variables (cont.)

Variable Name	Variable Definition
Panel D: Investment Variables	
OperatingAccruals (A)	*Pre-1998:* Change in current assets (atc) net of cash (che) minus the change in current liabilities (lct) net of debt included in current liabilities (dlc, zero if missing) and of income taxes payable (txp, zero if missing) minus depreciation & amortization (dp, zero if missing), where the changes are calculated from the fiscal year end in calendar year $t-2$ to the fiscal year end in calendar year $t-1$; *post-1998:* net income (ni) minus net cash flow from operations (oancf). The pre- and post-1998 variables are scaled by total assets from the fiscal year end in calendar year $t-2$ (see Sloan (1996), Hribar and Collins (2002), and Hou, Xue, and Zhang (2015)).
TotalAccruals (A)	*Pre-1998:* Change in net non-cash working capital plus the change in net non-current operating assets plus the change in net financial assets, where net non-cash working capital is current assets (atc) net of cash and short-term investments (che) minus current liabilities (lct) net of debt in current liabilities (dlc, zero if missing); net non-current operating assets is total assets (at) net of current assets (atc) and of investment and advances (ivoa, zero if missing) minus total liabilities (lt) net of current liabilities (ltc) and of long-term debt (ltcc, zero if missing); and net financial assets is the sum of short-term investments (ivst, zero if missing) and long-term investments (ivoa, zero if missing) minus the sum of long-term debt (dltt, zero if missing), debt in current liabilities (dlc, zero if missing) and preferred stock (pstk, zero if missing), where the changes are calculated from the fiscal year end in calendar year $t-2$ to the fiscal year end in calendar year $t-1$; *post-1998:* net income (ni) minus sum of total operating, investing, and financing cash flows (oancf, invcf, and fincf) plus sales of stock (sstk, zero if missing) minus stock repurchases and dividends (prstkc and dv, zero if missing). The pre- and post-1998 variables are scaled by total assets from the fiscal year end in calendar year $t-2$ (see Richardson et al. (2005) and Hou, Xue, and Zhang (2015)).
PercentAccruals (A)	Operating accruals (as defined above) scaled by the absolute value of net income (ni) from the fiscal year ending in calendar year $t-1$, and not total assets (at) from the fiscal year end in calendar year $t-2$ (see Hafzalla, Lundholm, and Van Winkle (2011)).
AbnInvestment (A)	Log of the ratio of capital expenditures (capx) to sales (sale) from the fiscal year ending in calendar year $t-1$ minus the log of the average of that ratio taken over the prior three fiscal year ends (see Titman, Wei, and Xie (2004)).

(continued on next page)

Table AII: Anomaly Variables (cont.)

Variable Name	Variable Definition
InvestmentGrowth (A)	Log of the gross percent change in capital expenditures (capx) from the fiscal year end in calendar year $t-2$ to the fiscal year end in year $t-1$ (see Xing (2008)).
PP&EChange (A)	The ratio of the sum of the change in gross property, plant, and equipment (ppegt) and the change in inventories (invt) to total assets (at), where the changes are calculated from the fiscal year end in calendar year $t-2$ to the fiscal year end in calendar year $t-1$ and total assets is taken from the fiscal year end in calendar year $t-2$ (see Lyandres, Sun, and Zhang (2008)).
AssetGrowth (A)	Log of the gross percent change in total assets (at) from the fiscal year end in calendar year $t-2$ to the fiscal year end in year $t-1$ (see Cooper, Gulen, and Schill (2008)).
Panel E: Earnings Surprise Variables	
EarningsAnnouncementReturn (MR)	The sum of a stock's return (ret) net of the market return from two days prior to the most recent earnings announcement date (rdq) to one day after. The variable is set to missing if the announcement date is more than six months after the earnings date (see Chan, Jegadeesh, and Lakonishok (1996)).
StandardizedUnexpectedEarnings (MR)	The change in quarterly earnings per share (epspxq) from four quarters ago to the value announced at the most recent earnings announcement date (rdq) scaled by the standard deviation of this change over the prior eight quarters. The variable is set to missing if the earnings announcement date is more than six months after the earnings date or if the standard deviation is calculated from fewer than six observations (see Foster, Olsen, and Shevlin (1984)).

Table I: Stochastic Frontier Model Estimates

The table gives the results from estimating the stochastic frontier model in Equation (12) over the full sample period. We proxy for productive capacity using gross property, plant, and equipment (PP&E) plus intangibles in columns (1) and (2), PP&E in columns (3) and (4), and total assets in columns (5) and (6). The optimal capacity determinants (in $\boldsymbol{X}_{i,t}$) consistently include *Sales*, *COGS*, *SG&A*, *MarketBeta*, and *RiskfreeRate*; *StockVolatility* is only included in a subset of the models. The capacity overhang determinants (in $\boldsymbol{Z}_{i,t}$) include *RecentSalesDecline*, *DistantSalesDecline*, and *LossDummy*. Each model also contains Campbell (1996) industry fixed effects. All level variables are deflated to constant U.S. dollar using the Purchaser Price Index (PPI). See Table AI for details about the variables. Panels A and B give the estimates of the optimal capacity and capacity overhang determinant parameters, while Panel C gives the residual volatilities of optimal capacity and capacity overhang. T-statistics are shown in square parentheses. The table also provides the number of observations and the log-likelihood.

	Productive Capacity Proxy					
	PP&E + Intangibles		PP&E		Total Assets	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Optimal Capacity Determinants						
Sales	0.72	0.74	0.63	0.65	0.79	0.81
	[401.8]	[411.5]	[367.3]	[375.8]	[621.0]	[633.1]
COGS	0.23	0.23	0.30	0.31	0.09	0.09
	[142.0]	[144.5]	[194.5]	[198.2]	[77.9]	[77.4]
SG&A	0.02	0.02	0.01	0.01	0.01	0.01
	[50.2]	[48.3]	[19.7]	[18.0]	[15.1]	[11.9]
StockVolatility	-0.22		-0.23		-0.18	
	[-129.0]		[-143.2]		[-186.9]	
MarketBeta	0.06	0.04	0.07	0.05	0.08	0.06
	[53.5]	[32.3]	[67.0]	[44.0]	[134.5]	[103.0]
RiskfreeRate	-0.53	-0.46	0.09	0.16	-0.47	-0.41
	[-152.3]	[-134.1]	[27.4]	[48.5]	[-231.3]	[-199.3]
Panel B: Capacity Overhang Determinants						
RecentSalesDecline	0.72	0.72	0.63	0.64	1.29	1.30
	[85.1]	[83.4]	[73.2]	[70.9]	[215.3]	[212.4]
DistantSalesDecline	0.09	0.13	-0.14	-0.11	0.38	0.42
	[12.7]	[17.3]	[-17.2]	[-13.5]	[77.6]	[83.2]
LossDummy	0.56	0.46	0.44	0.31	0.49	0.41
	[152.2]	[120.7]	[115.2]	[77.9]	[194.8]	[157.6]

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Table I: Stochastic Frontier Model Estimates (cont.)

	Productive Capacity Proxy					
	PP&E + Intangibles		PP&E		Total Assets	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Residual Volatilities						
OptimalCapacity (σ_v^2)	0.58	0.58	0.53	0.51	0.84	0.85
	[168.8]	[159.1]	[129.4]	[112.8]	[886.3]	[882.9]
CapacityOverhang (σ_u^2)	0.97	0.97	1.00	1.01	0.37	0.38
	[940.8]	[935.9]	[964.1]	[949.6]	[625.5]	[634.0]
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations (in 1,000s)	1,550	1,550	1,718	1,718	1,719	1,719
Log Likelihood (in 1,000s)	-2,262	-2,271	-2,532	-2,543	-1,696	-1,714

Table II: Portfolios Sorted by Capacity Overhang
The table gives the mean excess returns and alphas of portfolios univariately sorted on *CapacityOverhang*. We calculate *CapacityOverhang* using gross property, plant, and equipment plus intangibles as the productive capacity proxy and including *StockVolatility* among the optimal capacity determinants. More details about *CapacityOverhang* are in Table AI. At the end of each month $t-1$, we sort all stocks into portfolios, using the fifth, tenth, 20th, 40th, 60th, 80th, 90th, and 95th percentile of the *Capacity Overhang* distribution of NYSE stocks in that month as breakpoints. We value-weight the portfolios and hold them over month t. We form a spread portfolio long the highest and short the lowest portfolio ("LS95-05"). The table shows the mean number of stocks, the mean *CapacityOverhang* value, and the mean log market size per portfolio. It also shows the mean excess return and the CAPM, q-theory model, and five-factor (FF5) model alphas, all annualized and in percent. The t-statistics for the mean excess return and alphas of the spread portfolio, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. The table also shows the F-statistic from the Gibbons, Ross, and Shanken (GRS; 1989) test of the joint significance of the factor model alphas, with the associated p-value shown in parentheses.

Portfolio	Mean Stock Number	Capacity Overhang	Log Market Size	Mean Excess Return	CAPM Alpha	Q Alpha	FF5 Alpha
00-05	242	0.21	11.09	9.99	2.74	6.46	7.82
05-10	178	0.25	11.43	7.70	1.20	4.80	5.14
10-20	290	0.27	11.66	7.63	0.88	1.45	1.69
20-40	463	0.30	11.92	7.56	1.39	0.06	0.28
40-60	422	0.33	12.04	6.41	0.11	−0.16	−0.67
60-80	453	0.37	11.79	6.84	0.26	0.41	−0.75
80-90	313	0.43	11.01	6.25	−0.82	0.12	−2.25
90-95	181	0.50	10.71	6.12	−1.91	−0.19	−3.41
95-100	275	0.61	10.31	−2.47	−11.52	−2.76	−8.06
LS95-05				−12.46	−14.26	−9.23	−15.87
t-statistic				[−4.20]	[−5.11]	[−4.13]	[−6.58]
GRS					3.48	2.50	4.53
p-value					(0.00)	(0.01)	(0.00)

Table III: Portfolios Sorted by Capacity Overhang and Market Size

The table gives the mean excess returns and alphas of portfolios independently bivariately sorted on *CapacityOverhang* and *MarketSize*. We calculate *CapacityOverhang* using gross property, plant, and equipment plus intangibles as the productive capacity proxy and including *StockVolatility* among the optimal capacity determinants. More details about the variables are in Table AI. At the end of each month $t-1$, we sort stocks into capacity overhang portfolios, using the fifth, tenth, 20th, 40th, 60th, 80th, 90th, and 95th percentile of the *CapacityOverhang* distribution of NYSE stocks in that month as breakpoints. We independently sort stocks into size portfolios, using the fifth and the 25th percentile of the *MarketSize* distribution of NYSE stocks in that month as breakpoints. We label the stocks in the three portfolios micro-stocks (Panel A), small stocks (Panel B), and large stocks (Panel C), respectively. The intersection of the two sets of portfolios yields 27 bivariately sorted portfolios. We value-weight the portfolios and hold them over month t. Within each size portfolio, we form a spread portfolio long the highest and short the lowest capacity overhang portfolio ("LS95-05"). The table shows the mean number of stocks, the mean *CapacityOverhang* value, and the mean log market size per portfolio. It also shows the mean excess return and the CAPM, q-theory model, and five-factor (FF5) model alphas, all annualized and in percent. The t-statistics for the mean returns and alphas of the spread portfolios, calculated using Newey and West's (1987) formula with a lag length of twelve months, are shown in square parentheses.

Portfolio	Mean Stock Number	Capacity Overhang	Log Market Size	Mean Excess Return	CAPM Alpha	Q Alpha	FF5 Alpha
Panel A: Micro Stocks (Average Number: 1,032; Average Size: $24 million)							
00-05	103	0.20	9.46	16.55	9.60	9.84	7.34
05-10	63	0.25	9.57	16.02	9.24	9.50	7.24
10-20	88	0.27	9.57	16.11	9.87	8.54	6.34
20-40	123	0.30	9.56	13.16	6.37	6.81	3.81
40-60	114	0.33	9.53	12.80	5.74	7.61	4.00
60-80	144	0.37	9.46	10.90	3.61	6.22	1.85
80-90	143	0.43	9.34	6.82	−0.85	5.53	0.51
90-95	93	0.50	9.29	2.45	−5.65	1.13	−5.85
95-100	161	0.62	9.20	−1.26	−9.66	−1.36	−8.36
LS95-05				−17.81	−19.26	−11.20	−15.69
t-statistic				[−5.35]	[−6.05]	[−3.59]	[−4.94]

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Table III: Portfolios Sorted by Capacity Overhang and Market Size (cont.)

Portfolio	Mean Stock Number	Capacity Overhang	Log Market Size	Mean Excess Return	CAPM Alpha	Q Alpha	FF5 Alpha
Panel B: Small Stocks (Average Number: 928; Average Size: $163 million)							
00-05	88	0.21	11.44	12.08	3.87	2.60	1.63
05-10	66	0.25	11.47	10.67	2.95	1.20	0.21
10-20	107	0.27	11.49	12.68	4.91	2.45	1.65
20-40	159	0.30	11.50	11.46	3.99	1.68	0.50
40-60	131	0.33	11.49	11.21	3.31	2.29	0.85
60-80	139	0.37	11.47	9.45	1.47	1.57	−0.69
80-90	98	0.43	11.42	8.78	0.36	3.58	0.10
90-95	57	0.50	11.40	2.65	−6.34	−2.62	−6.17
95-100	82	0.61	11.35	−4.28	−13.72	−6.31	−11.07
LS95-05				−16.36	−17.59	−8.92	−12.70
t-statistic				[−5.25]	[−5.63]	[−4.08]	[−6.22]
Panel C: Large Stocks (Average Number: 857; Average Size: $3.7 trillion)							
00-05	50	0.21	13.65	10.05	2.80	6.95	8.45
05-10	49	0.25	13.74	7.63	1.20	5.06	5.43
10-20	95	0.27	13.69	7.30	0.61	1.39	1.64
20-40	181	0.30	13.86	7.48	1.36	0.13	0.35
40-60	177	0.33	14.03	6.31	0.04	−0.20	−0.69
60-80	170	0.37	14.00	6.70	0.16	0.37	−0.76
80-90	72	0.43	13.66	5.99	−0.98	−0.19	−2.42
90-95	31	0.50	13.57	7.44	−0.49	1.06	−2.08
95-100	32	0.59	13.35	−1.71	−10.80	−1.47	−6.88
LS95-05				−11.75	−13.60	−8.43	−15.32
t-statistic				[−3.68]	[−4.46]	[−3.28]	[−5.35]

Table IV: Portfolios Sorted by Capacity Overhang and Investment Reversibility The table gives the five-factor (FF5) model alphas of portfolios independently bivariately sorted on *CapacityOverhang* and *InvReversibility*. We calculate *CapacityOverhang* using gross property, plant, and equipment plus intangibles as the productive capacity proxy and including *StockVolatility* among the optimal capacity determinants. More details about the variables are in Table AI. At the end of each month $t-1$, we sort stocks into capacity overhang portfolios, using the fifth, tenth, 20th, 40th, 60th, 80th, 90th, and 95th percentile of the *CapacityOverhang* distribution of NYSE stocks in that month as breakpoints. We independently sort stocks into investment reversibility portfolios, using the median of the *InvReversibility* distribution of NYSE stocks in that month as breakpoints. We label the stocks in the first (low value) portfolio low reversibility stocks and those in the second (high value) portfolio high reversibility stocks. The intersection of the two sets of portfolios yields 18 bivariately sorted portfolios. We value-weight the portfolios and hold them over month t. Within each reversibility (capacity overhang) portfolio, we form a spread portfolio long the highest and short the lowest capacity overhang (reversibility) portfolio ("LS95-05" and "High–Low," respectively)). The table shows the mean numbers of stocks and the five-factor (FF5) model alphas, all annualized and in percent. The t-statistics for the alphas of the spread portfolios, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses.

	Investment Reversibility					
	High		Low		High–Low	
Portfolio	Number Stocks	FF5 Alpha	Number Stocks	FF5 Alpha	FF5 Alpha	t-statistic
00-05	123	8.95	106	6.50	2.45	[0.57]
05-10	78	1.85	77	5.23	−3.38	[−0.98]
10-20	134	0.19	121	3.77	−3.58	[−1.69]
20-40	197	−0.57	207	1.34	−1.90	[−1.13]
40-60	150	−1.29	220	0.03	−1.33	[−0.70]
60-80	146	−5.19	252	0.49	−5.68	[−2.88]
80-90	107	−6.50	176	−1.18	−5.32	[−2.89]
90-95	58	−7.53	105	−2.24	−5.29	[−1.73]
95-100	63	−13.35	189	−4.92	−8.42	[−2.64]
LS95-05		−22.30		−11.43	−10.87	
t-statistic		[−6.09]		[−3.11]	[−2.19]	

Table V: Portfolios Sorted by Capacity Overhang, By Economic State
The table gives the five-factor (FF5) model alphas of portfolios univariately sorted on *CapacityOverhang* separately for good and bad economic states. We calculate *CapacityOverhang* using gross property, plant, and equipment plus intangibles as the productive capacity proxy and including *StockVolatility* among the optimal capacity determinants. More details about *CapacityOverhang* are in Table AI. At the end of each month $t-1$, we sort all stocks into portfolios, using the fifth, tenth, 20th, 40th, 60th, 80th, 90th, and 95th percentile of the *CapacityOverhang* distribution of NYSE stocks in that month as breakpoints. We value-weight the portfolios and hold them over month t. We form a spread portfolio long the highest and short the lowest portfolio ("LS95-05"). The table shows the mean number of stocks and the FF5 model alpha, annualized and in percent, per porfolio. We calculate the FF5 model alphas separately by whether or not one of three state variables is above its full-sample median. The state variables are industrial production growth over the prior twelve months (*IndProdGrowth*), GDP growth over the prior four quarters (*GDPGrowth*), and the market return over the prior 36 months (*PastMarketReturn*). More details about the state variables are in Table AI. The t-statistics for the FF5 model alphas of the spread portfolio, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses.

	Mean	FF5 Model Alpha					
	Number	Ind. Prod. Growth		GDP Growth		Past Mkt. Return	
Portfolio	Stocks	High	Low	High	Low	High	Low
00-05	242	8.96	5.24	8.03	7.00	6.98	7.26
05-10	178	6.84	2.97	8.53	2.03	5.46	3.80
10-20	290	2.04	1.24	0.70	2.29	1.65	2.30
20-40	463	−0.29	0.98	0.56	−0.05	0.17	0.30
40-60	422	−1.49	0.27	−0.54	−1.07	−0.16	−1.00
60-80	453	−2.11	1.13	−2.56	0.49	−0.83	−0.04
80-90	313	−3.63	−0.47	−3.29	−1.53	−4.28	0.56
90-95	181	−6.39	−0.05	−5.47	−0.85	−3.65	−1.56
95-100	275	−9.56	−5.99	−14.31	−2.64	−8.91	−5.99
LS95-05		−18.52	−11.23	−22.34	−9.63	−15.88	−13.25
t-statistic		[−5.52]	[−2.74]	[−6.03]	[−2.54]	[−4.13]	[−3.62]

Table VI: Fama-MacBeth Regressions on Capacity Overhang

The table gives the results of Fama-MacBeth (1973) regressions of single-stock returns over month t on *CapacityOverhang* and control variables calculated using data until the end of month $t-1$. The capacity overhang estimate uses gross property, plant, and equipment (PP&E) plus intangibles (columns (1) and (2)), PP&E (columns (3) and (4)), or total assets (columns (5) and (6)) as the productive capacity proxy. Also, the estimate includes (columns (1), (3), and (5)) or excludes (columns (2), (4), and (6)) *StockVolatility* among the optimal capacity determinants. More details about *CapacityOverhang* and the control variables are provided in Tables AI and AII. Risk premium estimates are per month and in percent; associated t-statistics, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. We exclude a stock from the July of year t to June of year $t+1$ sample period if the stock has a price below $1 at the start of that period.

	Productive Capacity Proxy					
	PP&E + Intangibles		PP&E		Total Assets	
	Incl. Vol.	Excl. Vol.	Incl. Vol.	Excl. Vol.	Incl. Vol.	Excl. Vol.
	(1)	(2)	(3)	(4)	(5)	(6)
CapacityOverhang	−0.62	−0.58	−0.58	−0.58	−0.22	−0.22
	[−5.40]	[−5.15]	[−4.48]	[−4.41]	[−3.08]	[−3.17]
MarketBeta	0.02	0.02	0.02	0.02	0.02	0.01
	[0.31]	[0.32]	[0.32]	[0.30]	[0.23]	[0.22]
MarketSize	−0.09	−0.09	−0.09	−0.09	−0.07	−0.07
	[−2.07]	[−2.13]	[−2.12]	[−2.06]	[−1.57]	[−1.58]
BookToMarket	0.34	0.34	0.33	0.33	0.33	0.33
	[4.24]	[4.24]	[4.12]	[4.14]	[4.07]	[4.07]
Profit	0.04	0.04	0.06	0.07	0.02	0.02
	[0.27]	[0.30]	[0.44]	[0.53]	[0.11]	[0.15]
ReturnOnEquity	1.05	1.05	1.07	1.09	1.27	1.28
	[4.54]	[4.54]	[4.65]	[4.73]	[5.06]	[5.06]
AssetGrowth	−0.93	−0.93	−0.93	−0.93	−0.90	−0.90
	[−6.57]	[−6.61]	[−6.57]	[−6.61]	[−6.07]	[−6.10]
Constant	1.88	1.91	1.89	1.87	2.07	2.07
	[2.78]	[2.86]	[2.75]	[2.72]	[3.00]	[3.05]

Table VII: Fama-MacBeth Regressions on Capacity Overhang, Momentum, and Profitability

The table gives the results of Fama-MacBeth (1973) regressions of single-stock returns over month t on *CapacityOverhang*, momentum and profitability anomaly variables, and control variables calculated using data until the end of month $t-1$. Panel A uses *CapacityOverhang* plus the controls as exogenous variables; Panel B uses each anomaly variable plus the controls; and Panel C uses each anomaly variable, *CapacityOverhang*, and the controls. The capacity overhang estimate is calculated using gross property, plant, and equipment plus intangibles as the productive capacity proxy and includes *StockVolatility* among the optimal capacity determinants. The control variables are *MarketBeta*, *MarketSize*, and *BookToMarket*. The models also always include a constant. More details about the variables are in Tables AI and AII. The regressions in each column consider only observations for which all explanatory variables used in the column are available. Risk premium estimates are per month and in percent; associated t-statistics, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. To be concise, the estimates and t-statistics of the constant and the control variables are not reported. Panel D shows the percentage change in the absolute anomaly (capacity overhang) premium after controlling for *CapacityOverhang* (*AnomalyVariable*) under ΔAnomaly (ΔCO) Pricing. The panel also shows the average cross-sectional correlation between the anomaly variable and the capacity overhang estimate. We exclude a stock from the July of year t to June of year $t+1$ sample period if the stock has a price below \$1 at the start of that period.

	Anomaly Variable									
	Six Month Mom.	Eleven Month Mom.	Sales Growth	Asset Turn-over	Profit Margin	Operat-ing Profit	Profit	Return on Equity	Taxable Income	Failure Prob
Panel A: Pricing Factors = Capacity Overhang and Controls										
CapacityOverhang	−0.86	−0.86	−0.83	−0.86	−0.87	−0.87	−0.87	−0.88	−0.86	−1.01
	[−5.36]	[−5.33]	[−4.94]	[−5.28]	[−5.37]	[−5.38]	[−5.38]	[−5.40]	[−5.96]	[−5.49]
Panel B: Pricing Factors = Anomaly Variable and Controls										
AnomalyVariable	0.57	0.66	−0.09	0.01	0.91	0.65	0.41	1.31	0.10	0.09
	[2.41]	[3.17]	[−0.44]	[0.08]	[2.28]	[3.19]	[2.47]	[5.16]	[2.32]	[1.29]

(*continued on next page*)

Table VII: Fama-MacBeth Regressions on Capacity Overhang, Momentum, and Profitability (cont.)

	Anomaly Variable									
	Six Month Mom.	Eleven Month Mom.	Sales Growth	Asset Turn-over	Profit Margin	Operat-ing Profit	Profit	Return on Equity	Taxable Income	Failure Prob
Panel C: Pricing Factors = Anomaly Variable, Capacity Overhang, and Controls										
AnomalyVariable	0.34	0.46	−0.29	−0.24	0.36	0.26	0.14	1.04	0.06	0.20
	[1.49]	[2.21]	[−1.40]	[−2.47]	[0.91]	[1.50]	[1.03]	[4.51]	[1.39]	[3.04]
CapacityOverhang	−0.88	−0.83	−0.85	−1.09	−0.88	−0.79	−0.83	−0.62	−0.85	−1.26
	[−6.04]	[−5.90]	[−5.17]	[−6.46]	[−6.13]	[−5.29]	[−5.90]	[−4.78]	[−5.94]	[−7.53]
Panel D: Model Diagnostics										
ΔAnomaly Pricing	−0.40	−0.31	2.11	−34.22	−0.60	−0.60	−0.65	−0.21	−0.43	1.26
ΔCO Pricing	0.02	−0.03	0.03	0.27	0.01	−0.09	−0.04	−0.29	−0.01	0.25
Correlation	−0.18	−0.24	−0.14	−0.47	−0.32	−0.35	−0.30	−0.36	−0.07	0.31
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table VIII: Fama-MacBeth Regressions on Capacity Overhang, Value, and Investment Variables

The table gives the results of Fama-MacBeth (1973) regressions of single-stock returns over month t on *CapacityOverhang*, value and investment anomaly variables, and control variables calculated using data until the end of month $t-1$. Panel A uses *CapacityOverhang* plus the controls as exogenous variables; Panel B uses each anomaly variable plus the controls; and Panel C uses each anomaly variable, *CapacityOverhang*, and the controls. The capacity overhang estimate is calculated using gross property, plant, and equipment plus intangibles as the productive capacity proxy and includes *StockVolatility* among the optimal capacity determinants. The control variables are *MarketBeta*, *MarketSize*, and *BookToMarket*. The models also always include a constant. More details about the variables are in Tables AI and AII. The regressions in each column consider only observations for which all explanatory variables used in the column are available. Risk premium estimates are per month and in percent; associated t-statistics, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. To be concise, the estimates and t-statistics of the constant and the control variables are not reported. Panel D shows the percentage change in the absolute anomaly (capacity overhang) premium after controlling for *CapacityOverhang* (*AnomalyVariable*) under ΔAnomaly (ΔCO) Pricing. The panel also shows the average cross-sectional correlation between the anomaly variable and the capacity overhang estimate. We exclude a stock from the July of year t to June of year $t+1$ sample period if the stock has a price below \$1 at the start of that period.

	Anomaly Variable									
	Book to Market	Past Return (-12,-35)	Past Return (-1,-59)	Operat-ting Accruals	Total Accruals	Percent Accruals	Abn. Invest-ment	Invest-ment Growth	PP&E Change	Asset Growth
Panel A: Regressions on Capacity Overhang and Controls										
CapacityOverhang	−0.87	−0.82	−0.84	−0.86	−0.86	−0.86	−0.87	−0.88	−0.85	−0.85
	[−5.38]	[−4.95]	[−4.95]	[−5.32]	[−5.32]	[−5.34]	[−5.38]	[−5.39]	[−5.27]	[−5.29]
Panel B: Regressions on Anomaly Variable and Controls										
AnomalyVariable	0.38	−0.25	−0.06	−1.15	−0.70	−0.05	−0.12	−0.16	−1.02	−0.84
	[4.20]	[−1.86]	[−0.52]	[−3.05]	[−2.47]	[−3.36]	[−3.81]	[−4.50]	[−5.41]	[−5.89]

(continued on next page)

Table VIII: Fama-MacBeth Regressions on Capacity Overhang, Value, and Investment Variables (cont.)

	Anomaly Variable									
	Book to Market	Past Return (-12,-35)	Past Return (-1,-59)	Operat-ting Accruals	Total Accruals	Percent Accruals	Abn. Invest-ment	Invest-ment Growth	PP&E Change	Asset Growth
Panel C: Regressions on Anomaly Variable, Capacity Overhang, and Controls										
AnomalyVariable	0.39	−0.38	−0.20	−1.75	−0.99	−0.07	−0.13	−0.17	−0.95	−0.89
	[4.37]	[−3.11]	[−1.97]	[−5.31]	[−4.01]	[−4.92]	[−4.29]	[−4.97]	[−5.19]	[−6.51]
CapacityOverhang	−0.87	−0.94	−1.00	−0.93	−0.90	−0.91	−0.87	−0.88	−0.83	−0.87
	[−5.38]	[−6.55]	[−6.89]	[−6.01]	[−5.75]	[−5.63]	[−5.40]	[−5.51]	[−5.14]	[−5.58]
Panel D: Model Diagnostics										
ΔAnomaly Pricing	0.03	0.52	2.63	0.52	0.41	0.45	0.07	0.04	−0.07	0.06
ΔCO Pricing	0.00	0.15	0.18	0.08	0.04	0.05	0.00	0.01	−0.03	0.02
Correlation	0.10	−0.24	−0.33	−0.17	−0.14	−0.12	−0.03	−0.03	0.02	−0.06
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table IX: Fama-MacBeth Regressions on Capacity Overhang and ROE
The table gives the results of Fama-MacBeth (1973) regressions of single-stock returns over month t on *ReturnOnEquity*, *CapacityOverhang*, and earnings surprise variables calculated using data until the end of month $t-1$. The capacity overhang estimate is calculated using gross property, plant, and equipment plus intangibles as the productive capacity proxy and includes *StockVolatility* among the optimal capacity determinants. The earnings surprise variables are *EarningsAnnouncementReturn* and *StandardizedUnexpectedEarnings*. More details about the variables are provided in Tables AI and AII. The table only considers observations for which all explanatory variables are available. Risk premium estimates are per month and in percent; associated t-statistics, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. We exclude a stock from the July of year t to June of year $t+1$ sample period if the stock has a price below $1 at the start of that period.

	Regression Model				
	(1)	(2)	(3)	(4)	(5)
ReturnOnEquity	0.61	0.00			−0.02
	[2.88]	[0.00]			[−0.08]
CapacityOverhang			−0.68	−0.41	−0.38
			[−3.76]	[−2.36]	[−2.64]
EarningsAnnouncementReturn		4.98		4.89	4.87
		[14.39]		[14.36]	[13.99]
StandardizedUnexpectedEarnings		0.27		0.24	0.24
		[9.61]		[8.08]	[8.75]
Constant	1.28	1.28	0.81	1.04	1.08
	[4.49]	[4.47]	[2.18]	[2.78]	[3.02]

Forthcoming in The Journal of Finance

Internet Appendix: Real Options Models of the Firm, Capacity Overhang, and the Cross-Section of Stock Returns

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ABSTRACT

In this Internet Appendix, we offer supplementary results for our paper "Real Options Models of the Firm, Capacity Overhang, and the Cross-Section of Stock Returns." In the first part, we examine extensions of the real options model of the firm analyzed in our paper. In the second part, we study whether capacity overhang is able to explain the stock pricing of 20 well known value, momentum, investment, and profitability anomaly variables using alternative capacity overhang estimates.

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In this Internet Appendix, we offer supplementary results for our paper "Real Options Models of the Firm, Capacity Overhang, and the Cross-Section of Stock Returns." Section IA.I studies the expected return-capacity overhang relation in extensions of the real options model of the firm analyzed in Section I of our paper. The first extension shows that Cournot competition among identical firms does not affect the shape of the relation. In contrast, the second extension shows that more mean reversion in demand renders the expected return-capacity overhang relation more positive. Section IA.II repeats the horse races between capacity overhang and the 20 value, momentum, investment, and profitability variables studied in Section II.C of the paper, using capacity overhang estimates based on alternative proxies for installed production capacity and including or excluding stock volatility as optimal capacity determinant. Using the alternative capacity overhang estimates, we find that the results from the new horse races align with those in the paper unless we use total assets as installed capacity proxy.

IA.I. Theoretical Extensions

In this section, we examine the expected return-capacity overhang relation in extensions of the real options model of the firm studied in Section I of the paper. Section IA.I.A studies a model with Cournot competition among identical firms. Section IA.I.B studies a model in which demand follows a mean-reverting process. In each case, we only change those assumptions of the real options model studied in our paper that we explicitly refer to below.

IA.A. Cournot Competition Among Identical Firms

In our first extension, we follow Aguerrevere (2009) and study the implications of Cournot competition among identical firms. Assume that there are n identical firms producing and instantaneously selling homogenous output. The price of the output, P, is given by the following downward sloping demand curve:

$$P = \theta - \bar{\gamma} \sum_{i=1}^{n} Q_i, \tag{IA1}$$

where θ is demand, $\bar{\gamma}$ is the elasticity of demand, and Q_i is the amount of output produced by firm i. Denote total (aggregate) output by $Q = \sum_{i=1}^{n} Q_i = nQ_i$. Also, denote the installed capacity of firm i by $\bar{K}_i$ and total (aggregate) installed capacity by $\bar{K} = \sum_{i=1}^{n} \bar{K}_i = n\bar{K}_i$, where the last equality in each set of equalities follows from the n firms being identical.

The profit of firm i's marginal production option indexed by θ and K is the maximum of the partial derivative of profit with respect to the option's K parameter and zero. The partial derivative of profit with respect to the K parameter, $\frac{\partial \pi_i}{\partial K_i}$, is:

$$\begin{aligned} \frac{\partial \pi_i}{\partial K_i} &= \frac{\partial}{\partial K_i} \left(PK_i - c_1 K_i - (1/2) c_2 K_i^2 \right) \\ &= \frac{\partial}{\partial K_i} \left(\left(\theta - \bar{\gamma} \sum_{j=1}^{n} K_j \right) K_i - c_1 K_i - (1/2) c_2 K_i^2 \right), \end{aligned} \tag{IA2}$$

where $K_i = K_j$ since, if firm i decides to use the first K_i units of installed production capacity, the remaining firms will optimally do the same. Thus:

$$\frac{\partial \pi_i}{\partial K_i} = \theta - \bar{\gamma} \sum_{j=1}^{n} K_j - \bar{\gamma} K_i - c_1 - c_2 K_i = \theta - \bar{\gamma}(n+1) K_i - c_1 - c_2 K_i. \tag{IA3}$$

The last equality in Equation (IA3) shows that more competition (i.e., a higher n) increases implicit production costs by raising $\bar{\gamma}(n+1)K_i$. More interestingly, setting $\gamma = \bar{\gamma}(n+1)$, the main model studied in Section I in the paper captures Cournot competition effects among identical firms, without, however, invalidating the conclusions we derive in Section I.C. In particular, Proposition 1 continues to suggest that, even under Cournot competition among identical firms, the expected return-capacity overhang relation is positive or negative at low to moderate capacity overhang levels, but positive at high capacity overhang levels.

IA.B. Mean Reversion in Demand

IA.B.1. Overview

In our second extension, we follow Sagi and Seasholes (2007) and investigate the implications of mean reversion in demand. To do so, we model the stochastic evolution of demand using a mean reverting square root process instead of Geometric Brownian motion:

$$d\theta = \eta(\bar{\theta} - \theta)dt + \sigma\sqrt{\theta}dW, \tag{IA4}$$

where η, the speed of mean reversion, and $\bar{\theta}$, the level to which demand trends, are new free parameters, and dW is the increment of a Brownian motion. We assume $\eta > 0$.

IA.B.2. Model Solution

Under the new process, Dixit and Pindyck (1994) show that the value of the production option indexed by θ and K, $\Delta V^{MR}(\theta, K)$, must satisfy the ordinary differential equation:

$$\frac{1}{2}\sigma^2\theta\frac{\partial^2\Delta V^{MR}(\theta,K)}{\partial\theta^2} - \left(\mu - \frac{\eta(\bar{\theta}-\theta)}{\theta} - r\right)\theta\frac{\partial\Delta V^{MR}(\theta,K)}{\partial\theta} - r\Delta V^{MR}(\theta,K) + C(\theta,K) = 0, \tag{IA5}$$

where $\left(\mu - \frac{\eta(\bar{\theta}-\theta)}{\theta}\right)$ is the "expected-return shortfall," defined by $\mu - (1/dt)E(d\theta)/\theta$, and $C(\theta, K)$ is the profit produced by the production option indexed by θ and K.

The homogenous part of ordinary differential equation (IA5) can be written as:

$$\theta\frac{\partial^2\Delta V^{MR}(\theta,K)}{\partial\theta^2} - \left(-\frac{2\eta\bar{\theta}}{\sigma^2} - \frac{-2(\mu-r+\eta)}{\sigma^2}\theta\right)\frac{\partial\Delta V^{MR}(\theta,K)}{\partial\theta} - \frac{2r}{\sigma^2}\Delta V^{MR}(\theta,K) = 0. \tag{IA6}$$

Let $\Delta V^{MR}(\theta, K) = g(x, K)$, where $x = \frac{2(\mu-r+\eta)\theta}{\sigma^2}$. Then $\frac{\partial\Delta V^{MR}(\theta,K)}{\partial\theta} = \frac{2(\mu-r+\eta)}{\sigma^2}\frac{\partial g(x,K)}{\partial x}$ and

$\frac{\partial^2 \Delta V^{MR}(\theta,K)}{\partial \theta^2} = \left(\frac{2(\mu-r+\eta)}{\sigma^2}\right)^2 \frac{\partial^2 g(x,K)}{\partial x^2}$. Substituting into Equation (IA6), we obtain:

$$\frac{2(\mu-r+\eta)}{\sigma^2} x \frac{\partial^2 g(x,K)}{\partial x^2} + \left(\frac{2\eta\bar{\theta}}{\sigma^2} - x\right) \frac{2(\mu-r+\eta)}{\sigma^2} \frac{\partial g(x,K)}{\partial x} - \frac{2r}{\sigma^2} g(x,K) = 0, \qquad \text{(IA7)}$$

which is equivalent to:

$$x \frac{\partial^2 g(x,K)}{\partial x^2} + \left(\frac{2\eta\bar{\theta}}{\sigma^2} - x\right) \frac{\partial g(x,K)}{\partial x} - \frac{r}{\mu-r+\eta} g(x,K) = 0, \qquad \text{(IA8)}$$

and also to:

$$x \frac{\partial^2 g(x,K)}{\partial x^2} + (b-x) \frac{\partial g(x,K)}{\partial x} - a g(x,K) = 0, \qquad \text{(IA9)}$$

where $a = \frac{r}{\mu-r+\eta}$ and $b = \frac{2\eta\bar{\theta}}{\sigma^2}$. The last equation is known as Kummer's Equation.

The two solutions to Kummer's Equation are:

$$M(x;a,b) = 1 + \frac{a}{b}x + \frac{a(a+1)}{b(b+1)}\frac{x^2}{2!} + \frac{a(a+1)(a+2)}{b(b+1)(b+2)}\frac{x^3}{3!} + \ldots, \qquad \text{(IA10)}$$

the confluent hypergeometric function, and:

$$U(x;a,b) = \frac{\Gamma(1-b)}{\Gamma(a-b+1)} M(x;a,b) + \frac{\Gamma(b-1)}{\Gamma(a)} x^{1-b} M(x;a-b+1,2-b), \qquad \text{(IA11)}$$

the Tricomi confluent hypergeometric function. They are independent because $a > 0$.

If $\theta \leq (2\gamma + c_2)K + c_1$, the firm does not use the production option, implying that $C(\theta,K) = 0$. In this case, the value of the production option is of the form:

$$\begin{aligned} \Delta V^{MR}(\theta,K) &= b_1^r M\left(\frac{2(\mu-r+\eta)\theta}{\sigma^2}; \frac{r}{\mu-r+\eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right) \\ &\quad + b_3^r U\left(\frac{2(\mu-r+\eta)\theta}{\sigma^2}; \frac{r}{\mu-r+\eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right), \end{aligned} \qquad \text{(IA12)}$$

where b_1^r and b_3^r are parameters. Since $\frac{\partial M(x;a,b)}{\partial x} = \frac{a}{b} M(x;a+1,b+1) > 0$ and $\frac{\partial U(x;a,b)}{\partial x} =$

$(-a)U(x; a+1, b+1) < 0$, b_1^r captures the value of the option to start producing, while b_3^r captures the value of the option to sell off the production option.

If $\theta \geq (2\gamma + c_2)K + c_1$, the firm uses the production option, implying $C(\theta, K) = \theta - (2\gamma + c_2)K - c_1$. In this case, the value of the production option is of the form:

$$\Delta V^{MR}(\theta, K) = b_2^r U\left(\frac{2(\mu - r + \eta)\theta}{\sigma^2}; \frac{r}{\mu - r + \eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right) + \text{particular solution}, \quad \text{(IA13)}$$

where b_2^r is a parameter capturing the value of the option to shut down production. In Equation (IA13), we rely on the fact that the value of the shutting down option decreases as demand increases to rule out the independent solution increasing with θ.

Economic intuition suggests that a particular solution to ordinary differential equation (IA5) is of the form:

$$\Delta V^{MR}(\theta, K) = k + m\theta, \quad \text{(IA14)}$$

where k and m are free parameters. Thus, $\frac{\partial \Delta V^{MR}(\theta, K)}{\partial \theta} = m$ and $\frac{\partial^2 \Delta V^{MR}(\theta, K)}{\partial \theta^2} = 0$. Plugging these terms into Equation (IA5), we obtain $m = \frac{1}{\mu + \eta}$ and $k = \frac{\eta\bar{\theta}}{r(\mu + \eta)} - \frac{(2\gamma + c_2)K - c_1}{r}$.

Thus, the value of the used production option, $\Delta V^{MR}(\theta, K)$, is:

$$\begin{aligned} \Delta V^{MR}(\theta, K) &= b_2^r U\left(\frac{2(\mu - r + \eta)\theta}{\sigma^2}; \frac{r}{\mu - r + \eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right) \\ &\quad + \frac{\theta}{\mu + \eta} + \frac{\eta\bar{\theta}}{r(\mu + \eta)} - \frac{(2\gamma + c_2)K - c_1}{r}. \end{aligned} \quad \text{(IA15)}$$

We use the following value-matching and smooth-pasting conditions at the optimal production switch-on demand level $\theta^P \equiv (2\gamma + c_2)K + c_1$ and at the optimal divestment demand level $\theta^{r\prime}$ to find the values of b_1^r, b_2^r, b_3^r, and $\theta^{r\prime}$:

$$\begin{aligned} & b_1^r M\left(\frac{2(\mu-r+\eta)\theta^P}{\sigma^2};\frac{r}{\mu-r+\eta},\frac{2\eta\bar{\theta}}{\sigma^2}\right) \\ = & (b_2^r-b_3^r)U\left(\frac{2(\mu-r+\eta)\theta^P}{\sigma^2};\frac{r}{\mu-r+\eta},\frac{2\eta\bar{\theta}}{\sigma^2}\right)+\frac{\theta^P}{\mu+\eta}+\frac{\eta\bar{\theta}}{r(\mu+\eta)}-\frac{\theta^P}{r}, \end{aligned} \quad \text{(IA16)}$$

$$\begin{aligned} & \frac{b_1^r r}{\eta\bar{\theta}}M\left(\frac{2(\mu-r+\eta)\theta^P}{\sigma^2};\frac{\mu+\eta}{\mu-r+\eta},\frac{2\eta\bar{\theta}+\sigma^2}{\sigma^2}\right) \\ = & -\frac{2(b_2^r-b_3^r)r}{\sigma^2}U\left(\frac{2(\mu-r+\eta)\theta^P}{\sigma^2};\frac{\mu+\eta}{\mu-r+\eta},\frac{2\eta\bar{\theta}+\sigma^2}{\sigma^2}\right)+\frac{2(\mu-r+\eta)}{(\mu+\eta)\sigma^2}, \end{aligned} \quad \text{(IA17)}$$

$$\begin{aligned} & b_1^r M\left(\frac{2(\mu-r+\eta)\theta^{r\prime}}{\sigma^2};\frac{r}{\mu-r+\eta},\frac{2\eta\bar{\theta}}{\sigma^2}\right) \\ + & b_3^r U\left(\frac{2(\mu-r+\eta)\theta^{r\prime}}{\sigma^2};\frac{r}{\mu-r+\eta},\frac{2\eta\bar{\theta}}{\sigma^2}\right)=\Delta F^{MR}(\theta^{r\prime},K)+d, \end{aligned} \quad \text{(IA18)}$$

$$\begin{aligned} & \frac{r\sigma^2 b_1^r}{2\eta\bar{\theta}(\mu-r+\eta)}M\left(\frac{2(\mu-r+\eta)\theta^{r\prime}}{\sigma^2};\frac{\mu+\eta}{\mu-r+\eta},\frac{2\eta\bar{\theta}+\sigma^2}{\sigma^2}\right) \\ - & \frac{r b_3^r}{(\mu-r+\eta)}U\left(\frac{2(\mu-r+\eta)\theta^{r\prime}}{\sigma^2};\frac{\mu+\eta}{\mu-r+\eta},\frac{2\eta\bar{\theta}+\sigma^2}{\sigma^2}\right)=\frac{\partial\Delta F^{MR}(\theta^{r\prime},K)}{\partial\theta}, \end{aligned} \quad \text{(IA19)}$$

where $\Delta F^{MR}(\theta, K)$ is the value of the growth option indexed by θ and K. Equation (IA16) ensures that, at the optimal production switch-on point θ^P, the value of the "idle" production option equals the value of the "used" production option. Equation (IA17) ensures that, at the same point, the value of the idle production option smooth-pastes into the value of the used production option. Equation (IA18) ensures that, at the optimal divestment point $\theta^{r\prime}$, the value of the idle production option equals the value of the corresponding growth option plus the selling price d. Equation (IA19) ensures that, at the same point, the value of the idle production option smooth-pastes into the value of the growth option.

Define the following functions of q:

$$M(q) \equiv M\left(\frac{2(\mu - r + \eta)q}{\sigma^2}; \frac{r}{\mu - r + \eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right), \tag{IA20}$$

$$M'(q) \equiv M\left(\frac{2(\mu - r + \eta)q}{\sigma^2}; \frac{\mu + \eta}{\mu - r + \eta}, \frac{2\eta\bar{\theta} + \sigma^2}{\sigma^2}\right), \tag{IA21}$$

$$U(q) \equiv U\left(\frac{2(\mu - r + \eta)q}{\sigma^2}; \frac{r}{\mu - r + \eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right), \tag{IA22}$$

$$U'(q) \equiv U\left(\frac{2(\mu - r + \eta)q}{\sigma^2}; \frac{\mu + \eta}{\mu - r + \eta}, \frac{2\eta\bar{\theta} + \sigma^2}{\sigma^2}\right), \tag{IA23}$$

$$R(q) \equiv \frac{q}{\mu + \eta} + \frac{\eta\bar{\theta}}{r(\mu + \eta)} - \frac{(2\gamma + c_2)K - c_1}{r}, \tag{IA24}$$

and the term:

$$R' \equiv \frac{2(\mu - r + \eta)}{(\mu + \eta)\sigma^2}. \tag{IA25}$$

Equations (IA16) and (IA17) then imply that:

$$b_1^r = \frac{\eta\bar{\theta}(U(\theta^P)R' + 2rU'(\theta^P)R(\theta^P)/\sigma^2)}{r(U(\theta^P)M'(\theta^P) + 2\eta\bar{\theta}M(\theta^P)U'(\theta^P)/\sigma^2)}, \tag{IA26}$$

$$b_2^r - b_3^r = \frac{\eta\bar{\theta}M(\theta^P)R' - rM'(\theta^P)R(\theta^P)}{r(U(\theta^P)M'(\theta^P) + 2\eta\bar{\theta}M(\theta^P)U'(\theta^P)/\sigma^2)}. \tag{IA27}$$

The value of the growth option indexed by θ and K, $\Delta F^{MR}(\theta, K)$, must satisfy:

$$\frac{1}{2}\sigma^2\theta\frac{\partial^2\Delta F^{MR}(\theta, K)}{\partial\theta^2} - \left(\mu - \frac{\eta(\bar{\theta} - \theta)}{\theta} - r\right)\theta\frac{\partial\Delta F^{MR}(\theta, K)}{\partial\theta} - r\Delta F^{MR}(\theta, K) = 0. \tag{IA28}$$

Thus, the solution is of the form:

$$\Delta F^{MR}(\theta, K) = a_1^r M\left(\frac{2(\mu - r + \eta)\theta}{\sigma^2}; \frac{r}{\mu - r + \eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right), \tag{IA29}$$

where a_1^r is a parameter, and we use the fact that the value of the growth option increases with increases in demand to rule out the independent solution negatively related to demand.

We use the following value-matching and smooth-pasting conditions at the demand level at which the growth option is optimally exercised, θ^{r*}, to find the values of a_1^r and θ^{r*}:

$$\begin{aligned} & a_1^r M\left(\frac{2(\mu-r+\eta)\theta^{r*}}{\sigma^2}; \frac{r}{\mu-r+\eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right) \\ = \; & b_2^r U\left(\frac{2(\mu-r+\eta)\theta^{r*}}{\sigma^2}; \frac{r}{\mu-r+\eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right) \\ + \; & \frac{\theta^{r*}}{\mu+\eta} + \frac{\eta\bar{\theta}}{r(\mu+\eta)} - \frac{(2\gamma+c_2)K-c_1}{r} - k, \end{aligned} \tag{IA30}$$

$$\begin{aligned} & \frac{ra_1^r}{\eta\bar{\theta}} M\left(\frac{2(\mu-r+\eta)\theta^{r*}}{\sigma^2}; \frac{\mu+\eta}{\mu-r+\eta}, \frac{2\eta\bar{\theta}+\sigma^2}{\sigma^2}\right) \\ = \; & -\frac{2b_2^r r}{\sigma^2} U\left(\frac{2(\mu-r+\eta)\theta^{r*}}{\sigma^2}; \frac{\mu+\eta}{\mu-r+\eta}, \frac{2\eta\bar{\theta}+\sigma^2}{\sigma^2}\right) + \frac{2(\mu-r+\eta)}{(\mu+\eta)\sigma^2}. \end{aligned} \tag{IA31}$$

Using our definitions for $M(q)$, $M'(q)$, $U(q)$, $U'(q)$, $R(q)$, and R', Equation (IA31) suggests that the value of a_1^r conditional on the value of θ^{r*} is given by:

$$a_1^r = \frac{b_2^r U(\theta^{r*}) + R(\theta^{r*}) - k}{M(\theta^{r*})}. \tag{IA32}$$

To complete the solution, we need to solve the following system of three equations in the three unknowns b_2^r, θ^{r*}, and $\theta^{r\prime}$:

$$\begin{aligned} & (a_1^r - b_1^r) M\left(\frac{2(\mu-r+\eta)\theta^{r\prime}}{\sigma^2}; \frac{r}{\mu-r+\eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right) + d \\ = \; & (b_2^r - b_d) U\left(\frac{2(\mu-r+\eta)\theta^{r\prime}}{\sigma^2}; \frac{r}{\mu-r+\eta}, \frac{2\eta\bar{\theta}}{\sigma^2}\right), \end{aligned} \tag{IA33}$$

$$\begin{aligned} & \frac{(a_1^r - b_1^r)\sigma^2}{2\eta\bar{\theta}} M\left(\frac{2(\mu - r + \eta)\theta^{r\prime}}{\sigma^2}; \frac{\mu + \eta}{\mu - r + \eta}, \frac{2\eta\bar{\theta} + \sigma^2}{\sigma^2}\right) \\ = \quad & -(b_2^r - b_d) U\left(\frac{2(\mu - r + \eta)\theta^{r\prime}}{\sigma^2}; \frac{\mu + \eta}{\mu - r + \eta}, \frac{2\eta\bar{\theta} + \sigma^2}{\sigma^2}\right), \end{aligned} \tag{IA34}$$

$$\begin{aligned} & \frac{r a_1^r}{\eta\bar{\theta}} M\left(\frac{2(\mu - r + \eta)\theta^{r*}}{\sigma^2}; \frac{\mu + \eta}{\mu - r + \eta}, \frac{2\eta\bar{\theta} + \sigma^2}{\sigma^2}\right) \\ = \quad & -\frac{2 b_2^r r}{\sigma^2} U\left(\frac{2(\mu - r + \eta)\theta^{r*}}{\sigma^2}; \frac{\mu + \eta}{\mu - r + \eta}, \frac{2\eta\bar{\theta} + \sigma^2}{\sigma^2}\right) + \frac{2(\mu - r + \eta)}{(\mu + \eta)\sigma^2}. \end{aligned} \tag{IA35}$$

where $b_d \equiv b_2^r - b_3^r$ defined in Equation (IA27). Equations (IA33) and (IA34) follow from Equations (IA18) and (IA19), respectively. Equation (IA35) is Equation (IA31). Conditional on the value of $\theta^{r\prime}$, Equation (IA33) suggests that the value of b_2^r is given by:

$$b_2^r = \frac{(a_1^r - b_1^r) M\left(\theta^{r\prime}\right) + d}{U\left(\theta^{r\prime}\right)} + b_d. \tag{IA36}$$

Plugging the solutions for a_1^r, b_1^r, b_2^r, and b_3^r given in Equations (IA32), (IA26), (IA36), and (IA27), respectively, into Equations (IA34) and (IA35), we obtain an implicit system of equations defining θ^{r*} and $\theta^{r\prime}$. We numerically solve this system for θ^{r*} and $\theta^{r\prime}$.

IA.B.3. Model Conclusions

We next numerically evaluate the expected return-capacity overhang relation under a mean reverting square root process. We first derive option elasticities from the option values derived in Section IA.I.B.2 and then calculate the expected excess return using Equation (4) in the paper. Figure IA1 plots the expected excess return, $E[r_A] - r$, against installed capacity, $\bar{K}$, assuming a demand θ equal to 0.50 (Panel A), 1.00 (Panel B), and 1.50 (Panel C) and varying the mean reversion parameter η from 0.025 to 0.10. The long-run average demand level, $\bar{\theta}$, is 1.00, and investments are completely irreversible ($d = 0$).

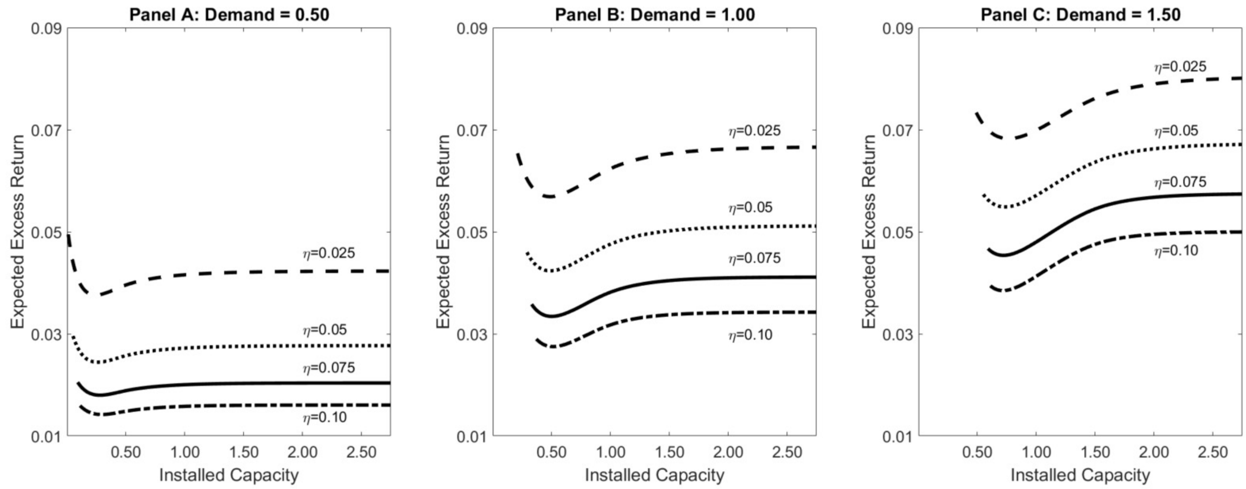

Figure IA1: Comparative Statics for the Expected Return-Capacity Overhang Relation Under Mean Reversion in Demand and No Investment Reversibility The figure plots the expected excess return, $E[r_A] - r$, against installed capacity, $\bar{K}$, at a demand level, θ, of 0.50 (Panel A), 1.00 (Panel B), and 1.50 (Panel C), varying the mean reversion parameter η from 0.025 to 0.10. The demand volatility (σ) and elasticity (γ) are 0.30 and 0.50, respectively. The level to which demand trends, $\bar{\theta}$, is 1.00. The cost parameters (c_1 and c_2) are zero. The unit capacity installation cost (k) is 5; the unit capacity selling price (d) is zero. The expected return of the demand mimicking portfolio (μ) is 0.10. The risk-free rate (r) is 0.04.

Figure IA1 yields two conclusions. First, the expected return increases with the difference between current demand and the long-run average of demand ($\theta - \bar{\theta}$). This happens because, when demand is below its long-run average (as in Panel A), option values are less sensitive to declines in demand — especially when the speed of mean reversion (η) is high — since such declines are likely to revert in the future. Thus, the options have low elasticities at low demand levels, yielding a low expected return. In contrast, when demand is above its long-run average (as in Panel C), option values are less sensitive to increases in demand. Thus, the options have high elasticities at high demand levels, yielding a high expected return. Second, a higher speed of mean reversion (η) renders the expected return-capacity overhang relation more positive at all demand levels. This happens because a higher speed of mean reversion has a more negative effect on the values and elasticities of the growth options than on the values and elasticities of the production options. Intuitively, the ability to expand production capacity becomes less important if increases in demand are only temporary and revert in the future.

While not shown in the figure, mean reversion also decreases the importance of divestment options. Intuitively, the ability to divest production capacity becomes less important if decreases in demand are temporary and revert in the future. Thus, mean reversion renders the expected return-capacity overhang relation more positive even in real options models of the firm allowing for costly investment reversibility ($d > 0$).

IA.II. Additional Horse Races

In this section, we repeat the horse races between capacity overhang and the 20 value, momentum, investment, and profitability variables conducted in Section II.C of the paper, using alternative capacity overhang estimates. Table IA.I repeats the FM regressions of single-stock returns on momentum and profitability variables; Table IA.II repeats those on value and investment variables. The stochastic frontier model estimate in Panel A of each table uses gross property, plant, and equipment (PP&E) plus intangibles as the installed capacity proxy; the estimates in Panels B and C use PP&E on its own; and the estimates in Panels D and E use total assets. The estimates in Panels B and D include stock volatility among the optimal capacity determinants, whereas the estimates in Panels A, C, and E do not.

The first row in each panel shows the capacity overhang premium derived from a model only including the capacity overhang estimate and the controls. The second row shows the anomaly variable premium derived from a model including only the anomaly variable and the controls. The last two rows show the anomaly variable and capacity overhang premia derived from a model including both the anomaly variable and the capacity overhang estimate and the controls. The table also shows the decrease in the absolute anomaly variable (capacity overhang) premium from including the capacity overhang estimate (anomaly variable) in the model. See Tables AI and AII in the Appendix for more details about the anomaly variables, the capacity overhang estimate, and the controls. We only include an observation in the FM regressions related to an anomaly variable if the capacity overhang estimate, the anomaly variable, and the controls are all non-missing. We exclude a stock's data from start of July of year t to end of June of year $t+1$ if the stock's price at the end of June of year t is below \$1.

Table IA.I shows that the capacity overhang estimate based on PP&E on its own is almost as efficient as the estimate based on PP&E plus intangibles in driving out momentum and profitability anomalies. In contrast, the total assets based estimate is markedly less efficient. For example, the latter estimate is unable to drive out the significance of either the six-month or the twelve-month past return premium. The lower ability of the total assets based estimate to explain the anomalies supports our notion that total assets is a noisy proxy for installed capacity because it includes financial assets. Interestingly, while Table I in the paper suggests stock volatility to be an important determinant of optimal capacity, the exclusion of stock volatility from the stochastic frontier model does not greatly affect the ability of the capacity overhang estimate to drive out the momentum and profitability anomalies in Table IA.I.

TABLE IA.I ABOUT HERE

Similar to the results in the paper, Table IA.II suggests that our capacity overhang estimate is unable to drive out the value and investment anomalies, independent of which variable we use to proxy for installed production capacity or whether or not we include stock volatility among the optimal capacity determinants.

TABLE IA.II ABOUT HERE

IA.III. Conclusion

In this Internet Appendix, we examine the expected return-capacity overhang relation in extensions of the real options model of the firm analyzed in the paper. In the extensions, we allow for Cournot competition among identical firms and mean reversion in demand. While Cornout competition among identical firms does not change the shape of the expected return-capacity overhang relation, mean reversion renders the relation more positive since it decreases the importance of capacity adjustment (investment or divestment) options. We also repeat the horse races between capacity overhang and the value, momentum, investment, and profitability anomaly variables, using alternative capacity overhang estimates. We show that capacity overhang estimates based on PP&E have about the same ability to drive out momentum and profitability variables as those based on PP&E plus intangibles. In contrast, capacity overhang estimates based on total assets have a markedly lower ability, consistent with total assets being a noisy proxy for installed capacity. Whether or not we include stock volatility among the optimal capacity determinants does not greatly affect the ability of the capacity overhang estimate to drive out anomalies. As in the paper, neither capacity overhang estimate is able to drive out the stock pricing ability of the value and investment variables.

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Sagi, Jacob S., and Mark S. Seasholes, 2007, Firm-specific attributes and the cross-section of momentum, *Journal of Financial Economics* 84, 389-434.

Table IA.I: Regressions on Capacity Overhang and Momentum and Profitability Anomaly Variables

The table shows the results of Fama-MacBeth (1973) regressions of stock returns over month t on subsets of *CapacityOverhang*, a momentum or profitability anomaly variable, and controls calculated using data until the end of month $t-1$. Using only observations for which the capacity overhang estimate, the anomaly variable, and the controls can be calculated, the estimate in the first line of each panel is obtained from a regression on the capacity overhang estimate plus the controls, the estimate in the second line from a regression on the anomaly variable plus the controls, and the estimates in the last two lines from a regression on the anomaly variable, the capacity overhang estimate, and the controls. The capacity overhang estimate is calculated using either gross property, plant, and equipment (PP&E) plus intangibles (Panel A), PP&E (Panels B and C), or total assets (Panels D and E). It either includes (Panels B and D) or excludes stock volatility (Panels A, C, and E) among the optimal capacity determinants. More details about the variables is in Tables AI and AII in the paper. Monthly risk premium estimates are in bold and in percent; associated t-statistics, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. The table also shows the percent change in the absolute anomaly (capacity overhang) premium after controlling for the capacity overhang estimate (the anomaly variable) under ΔAnomaly Variable Pricing (ΔCapacity Overhang Pricing). The sample excludes a stock from the July of year t to June of year $t+1$ period if the stock has a price below $1 at the end of June of year t.

	Anomaly Variable									
	Six Month Momentum	Eleven Month Momentum	Sales Growth	Asset Turnover	Profit Margin	Operat-ing Prof-itability	Prof-itability	Return on Equity	Taxable Income	Failure Prob
Panel A: PP&E + Intangibles, Excluding Stock Volatility										
Capacity Overhang	-0.805	-0.802	-0.761	-0.800	-0.812	-0.809	-0.809	-0.825	-0.802	-0.940
	[-5.10]	[-5.07]	[-4.65]	[-5.01]	[-5.11]	[-5.11]	[-5.11]	[-5.14]	[-5.66]	[-5.25]
Anomaly Variable	0.565	0.656	-0.093	0.007	0.911	0.646	0.411	5.243	0.099	0.086
	[2.41]	[3.17]	[-0.44]	[0.07]	[2.28]	[3.19]	[2.47]	[5.16]	[2.33]	[1.29]
Capacity Overhang | Anomaly Variable	-0.814	-0.776	-0.786	-1.062	-0.825	-0.752	-0.778	-0.579	-0.794	-1.147
	[-5.62]	[-5.50]	[-4.92]	[-6.31]	[-5.82]	[-5.21]	[-5.61]	[-4.51]	[-5.65]	[-6.83]
Anomaly Variable | Capacity Overhang	0.350	0.464	-0.313	-0.238	0.371	0.265	0.155	4.203	0.058	0.187
	[1.52]	[2.26]	[-1.55]	[-2.39]	[0.92]	[1.53]	[1.10]	[4.51]	[1.41]	[2.91]
ΔAnomaly Variable	-38.1%	-29.2%	237.0%	-3549.5%	-59.3%	-59.0%	-62.4%	-19.8%	-42.0%	118.4%
ΔCapacity Overhang	1.0%	-3.3%	3.2%	32.7%	1.6%	-7.1%	-3.8%	-29.9%	-1.1%	22.1%
Panel B: PP&E, Including Stock Volatility										
Capacity Overhang	-0.819	-0.815	-0.787	-0.817	-0.823	-0.820	-0.820	-0.842	-0.776	-0.949
	[-4.65]	[-4.61]	[-4.34]	[-4.60]	[-4.65]	[-4.65]	[-4.65]	[-4.70]	[-4.92]	[-4.59]
Anomaly Variable	0.576	0.658	-0.034	0.001	0.869	0.628	0.381	5.323	0.089	0.087
	[2.45]	[3.21]	[-0.17]	[0.01]	[2.17]	[3.19]	[2.37]	[5.14]	[2.13]	[1.31]
Capacity Overhang | Anomaly Variable	-0.843	-0.799	-0.806	-1.013	-0.818	-0.731	-0.784	-0.568	-0.769	-1.186
	[-5.26]	[-5.31]	[-4.52]	[-5.98]	[-5.22]	[-4.44]	[-5.06]	[-3.86]	[-4.93]	[-6.24]
Anomaly Variable | Capacity Overhang	0.370	0.473	-0.187	-0.213	0.374	0.302	0.154	4.382	0.044	0.180
	[1.61]	[2.33]	[-0.96]	[-2.30]	[0.94]	[1.81]	[1.15]	[4.68]	[1.14]	[2.85]
ΔAnomaly Variable	-35.7%	-28.1%	451.2%	-17644.4%	-57.0%	-52.0%	-59.7%	-17.7%	-49.9%	107.6%
ΔCapacity Overhang	2.9%	-1.8%	2.4%	24.0%	-0.7%	-10.9%	-4.4%	-32.5%	-0.9%	25.0%

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Table IA.I: Regressions on Capacity Overhang and Momentum and Profitability Anomaly Variables (cont.)

	Anomaly Variable									
	Six Month Momentum	Eleven Month Momentum	Sales Growth	Asset Turnover	Profit Margin	Operating Profitability	Profitability	Return on Equity	Taxable Income	Failure Prob
Panel C: PP&E, Excluding Stock Volatility										
Capacity Overhang	-0.836	-0.831	-0.824	-0.835	-0.841	-0.838	-0.838	-0.860	-0.784	-0.972
	[-4.76]	[-4.71]	[-4.56]	[-4.70]	[-4.75]	[-4.76]	[-4.76]	[-4.77]	[-4.91]	[-4.80]
Anomaly Variable	0.574	0.656	-0.034	0.001	0.869	0.627	0.381	5.324	0.089	0.086
	[2.44]	[3.20]	[-0.17]	[0.01]	[2.17]	[3.19]	[2.37]	[5.14]	[2.13]	[1.31]
Capacity Overhang | Anomaly Variable	-0.853	-0.812	-0.842	-1.020	-0.821	-0.753	-0.792	-0.571	-0.776	-1.185
	[-5.29]	[-5.36]	[-4.75]	[-5.97]	[-5.16]	[-4.76]	[-5.04]	[-3.86]	[-4.92]	[-6.32]
Anomaly Variable | Capacity Overhang	0.395	0.493	-0.209	-0.201	0.416	0.320	0.180	4.487	0.046	0.163
	[1.71]	[2.42]	[-1.07]	[-2.17]	[1.05]	[1.91]	[1.33]	[4.77]	[1.17]	[2.54]
ΔAnomaly Variable	-31.2%	-24.9%	520.3%	-15245.5%	-52.1%	-48.9%	-52.8%	-15.7%	-47.9%	88.9%
ΔCapacity Overhang	2.0%	-2.4%	2.1%	22.2%	-2.3%	-10.1%	-5.5%	-33.6%	-1.0%	22.0%
Panel D: Total Assets, Including Stock Volatility										
Capacity Overhang	-0.389	-0.388	-0.386	-0.386	-0.389	-0.387	-0.387	-0.382	-0.385	-0.482
	[-4.07]	[-4.06]	[-4.00]	[-4.02]	[-4.06]	[-4.05]	[-4.05]	[-3.95]	[-4.69]	[-4.34]
Anomaly Variable	0.578	0.659	-0.032	0.002	0.871	0.628	0.382	5.317	0.089	0.086
	[2.45]	[3.21]	[-0.16]	[0.02]	[2.18]	[3.19]	[2.38]	[5.14]	[2.14]	[1.30]
Capacity Overhang | Anomaly Variable	-0.379	-0.357	-0.396	-0.871	-0.404	-0.317	-0.346	-0.246	-0.378	-0.510
	[-4.11]	[-3.97]	[-4.08]	[-8.29]	[-5.62]	[-3.77]	[-4.55]	[-2.84]	[-4.71]	[-4.71]
Anomaly Variable | Capacity Overhang	0.476	0.577	-0.175	-0.467	0.586	0.257	0.206	5.061	0.052	0.115
	[2.03]	[2.83]	[-0.84]	[-3.96]	[1.43]	[1.53]	[1.51]	[4.94]	[1.38]	[1.78]
ΔAnomaly Variable	-17.6%	-12.4%	440.1%	-31134.1%	-32.8%	-59.0%	-46.1%	-4.8%	-41.3%	34.1%
ΔCapacity Overhang	-2.5%	-8.0%	2.6%	125.6%	3.7%	-17.9%	-10.6%	-35.7%	-1.9%	6.0%
Panel E: Total Assets, Excluding Stock Volatility										
Capacity Overhang	-0.384	-0.383	-0.389	-0.382	-0.384	-0.382	-0.382	-0.376	-0.375	-0.483
	[-4.29]	[-4.28]	[-4.30]	[-4.23]	[-4.28]	[-4.27]	[-4.27]	[-4.16]	[-4.85]	[-4.77]
Anomaly Variable	0.575	0.657	-0.032	0.002	0.871	0.627	0.382	5.318	0.089	0.086
	[2.45]	[3.21]	[-0.16]	[0.02]	[2.18]	[3.18]	[2.38]	[5.14]	[2.14]	[1.30]
Capacity Overhang | Anomaly Variable	-0.366	-0.346	-0.400	-0.876	-0.398	-0.308	-0.338	-0.241	-0.368	-0.498
	[-4.22]	[-4.08]	[-4.41]	[-9.52]	[-6.01]	[-4.19]	[-4.77]	[-2.95]	[-4.89]	[-5.00]
Anomaly Variable | Capacity Overhang	0.486	0.585	-0.177	-0.467	0.590	0.273	0.218	5.101	0.055	0.108
	[2.07]	[2.87]	[-0.85]	[-3.94]	[1.44]	[1.63]	[1.56]	[4.93]	[1.44]	[1.66]
ΔAnomaly Variable	-15.4%	-11.0%	447.6%	-28771.0%	-32.2%	-56.5%	-42.9%	-4.1%	-38.7%	25.9%
ΔCapacity Overhang	-4.7%	-9.8%	2.9%	129.6%	3.7%	-19.2%	-11.4%	-36.0%	-2.0%	3.1%

Table IA.II: Regressions on Capacity Overhang and Value and Investment Anomaly Variables

The table shows the results of Fama-MacBeth (1973) regressions of stock returns over month t on subsets of *CapacityOverhang*, a value or investment anomaly variable, and controls calculated using data until the end of month $t-1$. Using only observations for which the capacity overhang estimate, the anomaly variable, and the controls can be calculated, the estimate in the first line of each panel is obtained from a regression on the capacity overhang estimate plus the controls, the estimate in the second line from a regression on the anomaly variable plus the controls, and the estimates in the last two lines from a regression on the anomaly variable, the capacity overhang estimate, and the controls. The capacity overhang estimate is calculated using either gross property, plant, and equipment (PP&E) plus intangibles (Panel A), PP&E (Panels B and C), or total assets (Panels D and E). It either includes (Panels B and D) or excludes stock volatility (Panels A, C, and E) among the optimal capacity determinants. More details about the variables is in Tables AI and AII in the paper. Monthly risk premium estimates are in bold and in percent; associated t-statistics, calculated using Newey and West's (1987) formula with a lag length of twelve months, are in square parentheses. The table also shows the percent change in the absolute anomaly (capacity overhang) premium after controlling for the capacity overhang estimate (the anomaly variable) under ΔAnomaly Variable Pricing (ΔCapacity Overhang Pricing). The sample excludes a stock from the July of year t to June of year $t+1$ period if the stock has a price below $1 at the end of June of year t.

	Anomaly Variable									
	Book to Market	Lt. Past Return (-12,-35)	Lt. Past Return (-1,-59)	Operat-ting Accruals	Total Accruals	Per-centage Accruals	Abnormal Invest-ment	Invest-ment Growth	Change in PP&E	Asset Growth
Panel A: PP&E + Intangibles, Excluding Stock Volatility										
Capacity Overhang	-0.809	-0.764	-0.782	-0.802	-0.801	-0.804	-0.818	-0.819	-0.795	-0.797
	[-5.11]	[-4.73]	[-4.70]	[-5.05]	[-5.04]	[-5.07]	[-5.17]	[-5.13]	[-5.01]	[-5.01]
Anomaly Variable	0.376	-0.249	-0.055	-1.148	-0.702	-0.045	-0.122	-0.162	-1.023	-0.842
	[4.20]	[-1.86]	[-0.52]	[-3.05]	[-2.46]	[-3.36]	[-3.81]	[-4.50]	[-5.41]	[-5.89]
Capacity Overhang | Anomaly Variable	-0.809	-0.876	-0.924	-0.872	-0.838	-0.848	-0.818	-0.826	-0.772	-0.814
	[-5.11]	[-6.19]	[-6.45]	[-5.76]	[-5.47]	[-5.36]	[-5.19]	[-5.24]	[-4.90]	[-5.33]
Anomaly Variable | Capacity Overhang	0.388	-0.372	-0.190	-1.706	-0.992	-0.064	-0.130	-0.169	-0.968	-0.894
	[4.37]	[-3.03]	[-1.88]	[-5.15]	[-3.98]	[-4.88]	[-4.22]	[-5.01]	[-5.26]	[-6.54]
ΔAnomaly Variable	3.3%	49.4%	246.9%	48.6%	41.4%	42.4%	6.6%	4.5%	-5.3%	6.3%
ΔCapacity Overhang	0.0%	14.6%	18.1%	8.8%	4.7%	5.5%	0.0%	0.9%	-2.9%	2.2%
Panel B: PP&E, Including Stock Volatility										
Capacity Overhang	-0.820	-0.772	-0.800	-0.821	-0.820	-0.822	-0.780	-0.836	-0.809	-0.812
	[-4.65]	[-4.27]	[-4.35]	[-4.63]	[-4.63]	[-4.63]	[-4.37]	[-4.69]	[-4.57]	[-4.59]
Anomaly Variable	0.383	-0.260	-0.061	-1.118	-0.771	-0.043	-0.110	-0.163	-1.087	-0.882
	[4.33]	[-1.96]	[-0.57]	[-3.01]	[-2.69]	[-3.38]	[-3.45]	[-4.51]	[-5.73]	[-6.12]
Capacity Overhang | Anomaly Variable	-0.820	-0.888	-0.938	-0.893	-0.853	-0.873	-0.779	-0.843	-0.762	-0.833
	[-4.65]	[-5.68]	[-6.05]	[-5.23]	[-4.98]	[-4.89]	[-4.36]	[-4.79]	[-4.27]	[-4.90]
Anomaly Variable | Capacity Overhang	0.385	-0.367	-0.179	-1.667	-1.004	-0.063	-0.114	-0.165	-0.958	-0.920
	[4.45]	[-3.06]	[-1.79]	[-5.13]	[-3.95]	[-5.05]	[-3.68]	[-4.79]	[-5.09]	[-6.70]
ΔAnomaly Variable	0.6%	41.4%	194.0%	49.2%	30.1%	48.5%	3.7%	1.2%	-11.8%	4.4%
ΔCapacity Overhang	0.0%	15.0%	17.2%	8.8%	4.0%	6.3%	-0.2%	0.9%	-5.9%	2.5%

(continued on next page)

Table IA.II: Regressions on Capacity Overhang and Value and Investment Anomaly Variables (cont.)

	Anomaly Variable									
	Book to Market	Lt. Past Return (-12,-35)	Lt. Past Return (-1,-59)	Operat-ting Accruals	Total Accruals	Per-centage Accruals	Abnormal Invest-ment	Invest-ment Growth	Change in PP&E	Asset Growth
Panel C: PP&E, Excluding Stock Volatility										
Capacity Overhang	-0.838	-0.785	-0.836	-0.843	-0.842	-0.843	-0.797	-0.858	-0.830	-0.832
	[-4.76]	[-4.33]	[-4.62]	[-4.76]	[-4.76]	[-4.76]	[-4.48]	[-4.82]	[-4.69]	[-4.71]
Anomaly Variable	0.383	-0.260	-0.061	-1.113	-0.769	-0.043	-0.110	-0.163	-1.086	-0.879
	[4.33]	[-1.95]	[-0.57]	[-3.00]	[-2.68]	[-3.38]	[-3.45]	[-4.49]	[-5.72]	[-6.09]
Capacity Overhang | Anomaly Variable	-0.838	-0.888	-0.959	-0.910	-0.875	-0.897	-0.795	-0.866	-0.785	-0.854
	[-4.76]	[-5.51]	[-6.16]	[-5.31]	[-5.09]	[-5.05]	[-4.48]	[-4.92]	[-4.47]	[-5.04]
Anomaly Variable | Capacity Overhang	0.390	-0.354	-0.164	-1.620	-0.979	-0.062	-0.111	-0.165	-0.959	-0.918
	[4.54]	[-2.92]	[-1.62]	[-4.93]	[-3.82]	[-5.11]	[-3.58]	[-4.75]	[-5.15]	[-6.68]
ΔAnomaly Variable	1.8%	36.5%	170.3%	45.5%	27.4%	46.6%	0.8%	1.3%	-11.7%	4.5%
ΔCapacity Overhang	0.0%	13.1%	14.7%	7.9%	3.9%	6.3%	-0.3%	0.9%	-5.4%	2.7%
Panel D: Total Assets, Including Stock Volatility										
Capacity Overhang	-0.387	-0.366	-0.401	-0.389	-0.388	-0.389	-0.400	-0.401	-0.381	-0.383
	[-4.05]	[-3.61]	[-3.96]	[-4.02]	[-4.01]	[-4.02]	[-4.12]	[-4.14]	[-3.93]	[-4.00]
Anomaly Variable	0.383	-0.259	-0.060	-1.125	-0.775	-0.043	-0.110	-0.164	-1.087	-0.884
	[4.33]	[-1.95]	[-0.57]	[-3.03]	[-2.70]	[-3.40]	[-3.44]	[-4.52]	[-5.73]	[-6.13]
Capacity Overhang | Anomaly Variable	-0.387	-0.419	-0.444	-0.398	-0.395	-0.397	-0.399	-0.401	-0.365	-0.361
	[-4.05]	[-4.92]	[-4.72]	[-4.27]	[-4.21]	[-4.15]	[-4.14]	[-4.20]	[-3.77]	[-3.86]
Anomaly Variable | Capacity Overhang	0.382	-0.318	-0.126	-1.286	-0.809	-0.047	-0.117	-0.160	-1.057	-0.826
	[4.34]	[-2.57]	[-1.20]	[-3.75]	[-2.99]	[-3.85]	[-3.89]	[-4.65]	[-5.69]	[-5.73]
ΔAnomaly Variable	-0.2%	22.5%	108.8%	14.4%	4.4%	9.7%	6.7%	-2.0%	-2.8%	-6.6%
ΔCapacity Overhang	0.0%	14.4%	10.9%	2.5%	1.8%	2.1%	-0.2%	0.0%	-4.3%	-5.8%
Panel E: Total Assets, Excluding Stock Volatility										
Capacity Overhang	-0.382	-0.365	-0.402	-0.384	-0.383	-0.384	-0.399	-0.398	-0.377	-0.379
	[-4.27]	[-3.80]	[-4.21]	[-4.23]	[-4.22]	[-4.23]	[-4.42]	[-4.38]	[-4.13]	[-4.22]
Anomaly Variable	0.381	-0.259	-0.060	-1.121	-0.772	-0.043	-0.110	-0.163	-1.086	-0.881
	[4.32]	[-1.95]	[-0.57]	[-3.02]	[-2.69]	[-3.40]	[-3.44]	[-4.50]	[-5.72]	[-6.11]
Capacity Overhang | Anomaly Variable	-0.382	-0.408	-0.430	-0.393	-0.390	-0.392	-0.397	-0.397	-0.362	-0.357
	[-4.27]	[-4.95]	[-4.79]	[-4.50]	[-4.43]	[-4.37]	[-4.43]	[-4.45]	[-3.99]	[-4.09]
Anomaly Variable | Capacity Overhang	0.381	-0.310	-0.117	-1.269	-0.798	-0.046	-0.115	-0.160	-1.060	-0.824
	[4.33]	[-2.48]	[-1.11]	[-3.67]	[-2.92]	[-3.80]	[-3.82]	[-4.61]	[-5.69]	[-5.71]
ΔAnomaly Variable	0.1%	19.9%	94.1%	13.3%	3.5%	8.3%	5.3%	-2.0%	-2.4%	-6.5%
ΔCapacity Overhang	0.0%	11.6%	6.9%	2.3%	1.6%	2.0%	-0.4%	-0.1%	-4.0%	-5.8%