Inflexibility and Stock Returns*

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Abstract

Greater operating flexibility need not reduce expected returns or risk. In a neoclassical model of a firm with costly scale adjustment options, a distinguishing feature of low adjustment costs (i.e., high flexibility) is that risk and expected returns decline with operating leverage, whereas risk and expected returns rise with operating leverage for high inflexibility. Hence inflexibility increases the slope rather than the level of risk premia. Using measures of inflexibility and operating leverage, we provide evidence for cross-firm heterogeneity in real options and support for the model's predicted interaction effect, which is present in returns and risk measures.

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1 Introduction

Do more valuable operating options make stock returns safer and thereby lower expected returns? Intuition suggests that a firm's real flexibility to respond to changes in operating conditions should be a key determinant of the risk its owners bear. Likewise, intuition suggests that risk should increase as a firm's fixed costs rise relative to sales, due to operating leverage. In the context of a neoclassical model of a firm with scale adjustment options and operating costs, neither intuition is strictly correct.

Research on stock returns has focused on models of *ex ante* homogeneous firms that differ only in their history of idiosyncratic shocks. Homogeneity is a restrictive but useful assumption in otherwise complex models, and also enables the isolation of effects that are solely attributable to differences in productivity shocks.[1] To the extent that models of *ex ante* homogeneous firms derive their results from variation in risk that stem from changes in the relative value of firms' operating options, it is natural to study the implications of differences in option values across firms (as well as over time).

While the real options literature has long recognized that variation in option exercise costs can imply important differences in optimal policies (see, e.g., Abel, Dixit, Eberly, and Pindyck (1996) and Abel and Eberly (1996)), the implications of this heterogeneity has received little attention in the asset pricing literature. Moreover, there is empirical research on corporate investment that documents substantial differences across firms in the purchase and resale prices of physical capital.[2] These differences are equivalent to differences in the value of operating options to increase or decrease a firm's scale (i.e., flexibility). This study is among the first to explore the effect of cross-firm differences in real option values for the risk and expected return characteristics of a firm's equity.

[1] It lead to many insights in explaining stock returns (Berk, Green, and Naik (1999), Carlson, Fisher, and Giammarino (2004), Zhang (2005), Cooper (2006), Li, Livdan, and Zhang (2009), Hackbarth and Johnson (2015)).

[2] See, e.g., MacKay (2003), Balasubramanian and Sivadasan (2009), Chirinko and Schaller (2009), or Kim and Kung (2014). In line with the arguments in Dixit and Pindyck (1994) that adverse selection is a likely reason for the partial irreversibility, Li and Whited (2015) show that resale prices are endogenously lower in recessions.

We consider a firm that is composed of assets-in-place, contraction options, and expansion options. The model is both rich enough to encompass *ex ante* heterogeneous firms, and yet simple enough to reveal general patterns of cross-firm variation in the value of these operating options for equity returns. The key state variable is the firm's asset base scaled by its instantaneous operating profit, which increases monotonically with operating leverage. Firms inhabit different ranges of this state variable between their upper and lower scale adjustment boundaries, which are attributable to variation in their adjustment costs. Thus, the model's first implication is that inflexibility can be summarized by the distance of these two operating boundaries (scaled by the volatility of the state variable), because the distance increases with inflexibility.

In the model, assets-in-place increase risk but real options may increase or decrease risk. Exercising the contraction option attenuates firm's exposure to priced risk and exercising the expansion option has the opposite effect: it increases firm's exposure to priced risk.[3] The model's second implication is that, perhaps contrary to intuition, the unconditional relation between flexibility and equity risk premia need not be negative. Lowering some types of adjustment cost can raise expected returns and risk. The finding is not obvious: computing the unconditional effects requires not only solving the firms' problem, but integrating over the (endogenous) distribution of operating states.

The model's third implication is that, while the level of the risk premium is not, in general, increasing in measures of inflexibility, the slope of the risk premium is. That is, the sign of the relationship between operating leverage and expected returns may go either way, depending on the adjustment cost parameters. Again perhaps surprisingly, more flexible firms actually become safer as operating leverage rises. This is because their option to exchange risky assets-in-place for riskless cash becomes increasingly valuable as productivity deteriorates. Thus, flexibility determines the average effect of operating leverage on risk and expected returns. Solving a wide range of model parameter permutations numerically and also estimating return

[3]Operating option values are maximized at their exercise boundaries and hence pre-exercise option values increasingly reflect these risk effects as they move closer to their exercise boundaries.

regressions on simulated data from the calibrated model, we show that the relation between operating leverage and returns is increasingly positive for more inflexible firms.

In interpreting the model, we note that flexibility has many dimensions, such as the ability to alter or transform factor intensity, product mix, pricing strategy, production scale, or technology. Thus, the notion of flexibility extends beyond firm scale or physical capital. One can interpret the firm's production function as dependent on a general factor input which can be viewed as bundle of capital, labor, knowledge, etc. Weber (2014) studies the asset pricing implications of nominal rigidities, which can be interpreted as another aspect of inflexibility.[4] Further, the quasi-fixed costs in the model are not just associated with assets-in-place but may accrue from production inputs acquired under long-term contracts, such as some part of human capital, labor input, raw materials and other supplies, or organization capital.

Turning to the data, these observations suggest that operating flexibility should not be assessed purely with respect to investment activity. Instead, viewing real technologies as industry-specific, we construct an industry-level proxy of inflexibility as the range of an industry's operating costs over sales scaled by the residual standard deviation from a regression of operating costs on sales. Based on the model's first implication, this time-invariant "range measure" of inflexibility captures the inaction region, i.e., typical distance between operating boundaries similarly.[5] Intuitively, flexibility should have more cross- than within-industry variation. Indeed, the range measure shows significant cross-industry variation and we validate it by variables from the industrial organization literature that are related to entry or fixed costs, outsourcing, and productivity dispersion (see Section 3.1). At the firm-level, we assess period-specific operating leverage based on expected quasi-fixed costs over sales, without regard to the source of these costs. To obtain reliable and smooth estimates, we run five-year, rolling-window regressions of quarterly operating costs on their first lag and contemporaneous sales. We then employ two

[4]Other recent contributions to the literature on price or wage rigidities and asset prices are Uhlig (2007), Favilukis and Lin (2015), Li and Palomino (2014), and Gorodnichenko and Weber (2015). Similar to our results, Weber (2014) finds that firms with more infrequent product price adjustment have a higher equity risk premium.

[5]Fischer, Heinkel, and Zechner (1989) use the debt over assets range to measure capital structure adjustments.

alternative measures, i.e., either the intercept plus predicted value or the intercept (both scaled by sales), as firm-level proxies for operating leverage. Intuitively, the intercept may proxy for fixed operating costs, whereas the predicted value may proxy for quasi-fixed operating costs.

With these measures, we test the model's predictions in the data. Consistent with the model, we find a weak unconditional flexibility effect. Portfolios formed on flexibility do not reveal that more flexible firms have unambiguously lower returns. More precisely, the excess return spread between inflexible-industry and flexible-industry portfolios is not always positive and significant. Sorting within industries by operating leverage, however, does reveal the predicted difference in slope between more and less flexible sectors. For example, the monthly excess returns for the high-minus-low operating leverage portfolio in flexible, less flexible, and inflexible industries are 19, 56, and 72 basis points, respectively, with t-statistics of 1.14, 2.44, and 3.28.

In a cross-sectional Fama and MacBeth (1973) return regression framework, these findings are robust to the inclusion of standard controls and to alternative measurement of both the conditioning variables. The interaction effect is about 44 to 95 basis points per month, which is very similar to the test results using the simulated data from the calibrated model. Notably, the interaction effect is consistent with significant cross-firm heterogeneity in the value of operating options. The marginal flexibility effect is small and insignificant, confirming the model's implication of a weak unconditional effect of flexibility.[6]

Finally, we also examine the model's prediction on the second moments of equity returns. That is, systematic and total risk should exhibit the same behavior as expected returns. Indeed, the patterns of portfolio return volatility and average portfolio beta across double sorted portfolios resemble the ones from the return test. Specifically, the sorts reveal that relation

[6]Consistent with our results, Chen, Kacperczyk, and Ortiz-Molina (2011) establish returns are higher for firms in unionized industries (a measure of firms inability to scale down in bad times). Novy-Marx (2011) shows the relation between expected returns and operating leverage is weak and non-monotonic across industries but strong and monotonic within industries, and Bustamante and Donangelo (2014) document operating leverage is higher and is associated with higher returns of firms in more competitive industries. Grullon, Lyandres, and Zhdanov (2012) provide evidence that the positive relation between firm-level stock return and firm-level return volatility is due to the firm's operating options. This study also complements earlier studies by looking at second moments of stock returns.

between portfolio risk measures and operating leverage becomes more positive as inflexibility increases. Moreover, regression results for monthly volatilities or betas on conditioning and control variables provide supportive evidence for the patterns in the portfolio sorts.

To summarize, we demonstrate that differences across firms in scale adjustment flexibility do lead to economically significant differences in the risk and return characteristics of their equity. We document an interaction effect that improves our understanding of the relation between flexibility and returns as well as the operating leverage hypothesis that has served as the foundation for many theoretical models. We conclude that cross-firm variation of real option effects is important for better understanding of expected returns and risk.

The rest of the paper proceeds as follows. Sections 2 develops the model's testable implications. Section 3 describes the data and measures. Sections 4 and 5 present results for first and second moments of equity returns. Section 6 concludes and the model solution is in Appendix A.

2 Model Properties

To study the expected return and risk implications of *ex ante* differences in operating flexibility, we employ the model developed in Hackbarth and Johnson (2015) (hereafter HJ). The model describes the evolution of a firm's optimal investment and disinvestment policy in response to permanent productivity shocks, in a continuous-time, partial-equilibrium economy.[7] HJ derive the firm's risk premium as a closed-form expression of (scaled) productivity. The model solution, however, does not provide an analytical mapping between other firm characteristics and the risk premium. After briefly reviewing the model and describing our interpretation of flexibility, we assess the model's implications for the relation between expected returns or risk and cross-firm variation in operating flexibility.

[7] General equilibrium models of investment-based return effects are, for example, Gomes, Kogan, and Zhang (2003) and Gala (2011). Industry competition is considered, for example, in Aguerrevere (2009) and Novy-Marx (2011).

2.1 Framework

HJ consider a firm with repeated expansion and contraction options that allow it to alter its scale (and operating expenses) in response to productivity shocks, subject to adjustment costs. That work follows the production-based asset pricing literature by viewing the firm's scale as equivalent to its physical capital. The economic logic of the model is not confined to plant and equipment, however. Here we suggest a broader interpretation, and think of the firm's scale as encompassing the composite of productive factors that the firm has in place. Just as accounting rules view long-term leases as capitalized assets, so one could view long-term contracts for other inputs (human capital, labor, raw materials and other supplies, franchise agreements) as being assets-in-place in three senses: (1) they are needed to generate output; (2) their cost contains a fixed component that does not scale with output; and (3) their quantity is costly to adjust. Other assets, such as knowledge, organizational capital, and intellectual property, may similarly share these properties.

With this interpretation in mind, we let A denote the composite scale of the firm, or the total assets-in-place, and write the firm's profit flow per unit time (i.e., net sales minus quasi-fixed operating costs) as:

$$\Pi_t = \theta_t^{1-\gamma} A_t^{\gamma} - m\, A_t, \tag{1}$$

where $\gamma \in (0,1)$ captures returns to scale and $m > 0$ denotes the operating cost per unit of A. Unless adjusted by the firm, A follows $dA/A = -\delta\, dt$, where $\delta \geq 0$ captures the generalized depreciation, or retirement rate of the asset base.

The productivity process θ evolves as a jump-diffusion with drift μ, volatility σ, and obsolescence rate η. The stochastic differential equation is as follows:

$$d\theta/\theta = \mu\, dt + \sigma\, dW^{\theta} - dN, \tag{2}$$

where W is a standard Wiener process and N is a Poisson process whose initial jump terminates the firm's production. We restrict attention to an all equity financed firm. There are no explicit cost of external finance.

The economy is characterized by a stochastic discount factor, Λ, with a fixed drift, r (the riskless interest rate), and fixed volatility, σ_Λ (the maximal Sharpe ratio). That is, Λ obeys the stochastic differential equation:

$$d\Lambda/\Lambda = -r\,dt + \sigma_\Lambda\,dW^\Lambda. \tag{3}$$

The constant coefficients imply that the macroeconomic environment is not a source of variation in the firm's business conditions. The model thus does not capture business cycle effects in the cost of capital. The correlation between dW^Λ and dW^θ, denoted ρ, parameterizes the systematic risk of the firm's earnings stream.[8] We assume $\rho < 0$, i.e., that the risk premium is positive.

The firm's real options to increase or decrease scale in response to shocks to profitability determine its flexibility. Specifically, the value of the real options is dictated by the cost of these adjustments. The model assumes the firm faces both quasi-fixed and variable costs for either upward or downward adjustments. The cash cost to investors of increasing A by ΔA is denoted $P_L\,\Delta A$, and the cash extracted from decreasing A by ΔA is $P_U\,\Delta A$. In addition, the quasi-fixed cost of upward and downward adjustments are written $F_L\,\theta^{1-\gamma}\,A^\gamma$ and $F_U\,\theta^{1-\gamma}\,A^\gamma$, respectively, with $F_L > 0$ and $F_U > 0$. These components are proportional to the firm's net revenue at the time of the adjustment, and can be viewed as capturing the forgone revenue due to diversion of scarce internal resources, such as managerial time. Clearly the firm's real flexibility decreases as F_L and F_U increase.

When thinking of A as physical capital, it is natural to view P_L as the purchase price, e.g., of machinery, with $P_L > 1$ reflecting installation frictions. That is, there is a deadweight loss of $(P_L - 1)\,\Delta A$ of expanding the firm. Likewise P_U may be viewed as the resale price,

[8] It is straightforward to generalize the pricing kernel to incorporate systematic jumps. If these are present and also affect θ, then the firm's risk premium contains an additive constant reflecting the systematic jump risk.

and contraction entails the loss of $(1 - P_U)\ \Delta A$, due to costly disposal. Thus, the firm's real flexibility decreases with the purchase price, P_L, but increases with resale price, P_U. With the broader interpretation of assets-in-place, A, that we have suggested, the frictionless benchmark case may not be $P_L = P_U = 1$, because expanding the scale of labor inputs, for example, might entail no cash outlay by the firm's owners. Still, in this case, the total value of the firm's operating options would decrease with the difference $P_L - P_U$.

Note that the case $P_U = 0$ is similar to scale-irreversiblity in the sense that nothing is recovered upon contractions.[9] Further, $P_U < 0$ is also conceivable due to penalty costs of terminating long-term contracts, clean-up costs, etc.

The firm's objective is to choose a scale policy to maximize its market value of equity. HJ show that the re-scaled productivity variable $Z_t \equiv A_t/\theta_t$ is a sufficient statistic for the firm's problem, and therefore that the optimal policy may be characterized by four scalar constants: upper and lower adjustment boundaries (denoted U and L) for Z, together with optimal contraction and expansion amounts undertaken upon hitting each of these boundaries. That is, if Z hits U at time t, the optimal adjustment is to an interior point $Z = H < U$ which corresponds to a contraction of $\Delta A = (U - H)\theta_t$. And when Z hits L, the optimal adjustment is to $Z = G > L$ which corresponds to an expansion of $\Delta A = (G - L)\theta_t$.[10] Thus the firm's solution is stationary and scale-invariant in the sense that it lives forever on the Z interval $[L, U]$ regardless of the magnitude of A.

Let $J(\theta, A)$ denote the market value of the firm's equity. Given the optimal policy, HJ show that, subject to some regularity conditions, the rescaled value of the firm, $V(Z) = J(\theta, A)/\theta$, is given by

$$V(Z) = B\ Z^{\gamma} - S\ Z + D_N\ Z^{\lambda_N} + D_P\ Z^{\lambda_P}, \tag{4}$$

where B and S are simple functions of the model parameters, and D_N and D_P are two additional

[9] Irreversibility is usually interpreted in the investment literature to imply that the firm's *only* contraction option is to shut down entirely, i.e., $\Delta A = A$, which our model does not impose. See, e.g., Cooper (2006) for details.

[10] Notice that the scaling implies that decreases in Z correspond to good news (high productivity) for the firm.

scalar parameters. Moreover these two constants together with the policy boundaries L, G, H and U are characterized by a six-equation system of algebraic equations that is reproduced in Appendix A. Although not solvable analytically in terms of the firm parameters, solutions are readily obtainable numerically.

For reference, the following table summarizes the key notation.

Notation Index

Quantity:	Symbol:
firm scale	A
returns-to-scale	γ
scale decay	δ
quasi-fixed operating costs	m
productivity	θ
growth rate of θ	μ
volatility of θ	σ
expected lifetime of firm	$1/\eta$
rescaled productivity	$Z = A/\theta$
expansion boundary (rescaled)	L
contraction boundary (rescaled)	U
proportional expansion cost	P_L
proportional contraction cost	P_U
fixed expansion cost	F_L
fixed contraction cost	F_U
instantaneous expected equity return	EER
instantaneous volatility of return	VOL
riskless interest rate	r
pricing kernel volatility	σ_Λ
systematic θ risk	$\rho\,\sigma$

The firm's expected excess return on equity (the risk premium) and the instantaneous volatility of equity returns are then given by

$$EER(Z) = \pi_\theta\,(1 - ZV'/V), \tag{5}$$

and

$$VOL(Z) = \sigma\,(1 - ZV'/V), \tag{6}$$

where $\pi_\theta = \rho\,\sigma\,\sigma_\Lambda$ is the market price of θ risk.

2.2 Hypothesis Development

To explore empirically the effect of flexibility on firm risk and expected return, the first challenge is to measure flexibility. In the context of the model, it is clear that flexibility means the ability to adjust scale with low adjustment costs. Unfortunately, neither adjustment costs nor scale (in the general interpretation we have suggested) are directly observable characteristics of firms. However, from the model's depiction of optimal firm policies, we can plausibly map firm behavior into a proxy that summarizes flexibility.

With no adjustment costs and a given productivity level θ, the firm will always set A to the value $(m/\gamma)^{1/(\gamma-1)}\ \theta$ to maximize the profit function. With adjustment costs, the firm will pursue the discrete adjustment policy described above. Intuitively, as adjustment costs increase, the firm will allow θ to wander farther from this optimal point before incurring the deadweight losses to bring the ratio Z back towards optimality. Thus, inflexibility translates directly into the width of the firm's optimal inaction region. The width of the inaction region will also scale with the potential variability of productivity shocks, which is not directly related to flexibility. An implication of the model, therefore, is that a good summary statistic for scale inflexibility is the distance between the adjustment boundaries, $\log(U/L)$, standardized by the volatility of the productivity process σ. Moreover, the width of that inaction region also describes the observed range of firm profitability, since profitability is a monotonic function of Z. This observation about inaction regions is the basis for the empirical identification strategy described in the next section.

Given an empirical identification strategy for scale flexibility, we can use the model to directly solve for the risk premium function $EER(Z)$, for the return volatility function $VOL(Z)$, as well as for the endogenous stationary distribution of Z for firms of differing degrees of flexibility, in order to determine the cross-sectional asset pricing implications.[11]

The key characteristics of the expected excess return function $EER(Z)$, derived in HJ, follow from the superposition of opposing effects due to (a) assets-in-place; and (b) expansion and contraction options. The risk from assets-in-place monotonically increases with Z due to the increasing degree of operating leverage: as Z rises and profitability falls, quasi-fixed production costs (mA) magnify the exposure of investor profits to fundamental shocks. By contrast, the risk from both real options declines with Z: in response to good news (falling Z), expansion options become closer to exercise and thus increase investor exposure to productivity shocks; whereas bad news (rising Z) brings contraction options closer to exercise, which lowers investor exposure to these shocks and hence to priced risk.

Thus, in comparing firms, the primary comparative static implication of the model concerns the *slope* of the risk premium function, rather than its level. And the primary driver of this slope is the *relative value* of the firm's real options. Here we see the direct connection with flexibility: lower scale adjustment costs imply more valuable real options, and thus a greater contribution to the risk premium function from these options than from assets-in-place. Intuitively it is easier for flexible firms to adjust their scale to respond to profitability shocks. For them, exposure to priced risk does not necessarily increase (and may actually decline) as productivity falls, despite increasing operating leverage. For inflexible firms, exercise of both options occurs only rarely at extreme ranges of productivity. Thus, over most of the range of Z, their risk is determined by assets-in-place implying a positive slope.

In bringing these observations to the data, another identification issue arises from the unobservability of the state variable Z. Since the model only encompasses a single dimension of within-firm variability, essentially all measures of current profitability are monotonic transfor-

[11] The instantaneous volatility of the stock return, $VOL(Z)$, can be expressed as $-EER(Z)/(\rho\,\sigma)$, so it inherits the properties of expected returns discussed in this section.

mations of Z. From the perspective of asset pricing, the salient feature of variation in Z is the changing exposure to fundamental risk incurred due to quasi-fixed operating costs. Our approach will therefore emphasize the ratio of those costs to net sales (which is $m\, Z^{1-\gamma}$) as the primary conditioning variable. We also refer to this measure as QFC or "operating leverage."

Figure 1 illustrates how a firm's scale flexibility affects the relation between risk premia and operating conditions. The left panel shows the effect of changing the liquidation parameter, P_U, on expected excess returns for a particular case (the parameters are given in the figure caption). As the panel illustrates, making the firm's technology more inflexible by lowering the resale price, P_U, has two effects. First, as just emphasized, it raises the *average slope* of the curve: expected excess returns rise steeply with operating leverage (at least over the middle part of the graph) for firms with nearly irreversible assets. Higher P_U values result in the opposite slope. Second, as P_U declines and hence inflexibility increases, the *operating range* on the horizontal axis increases: the firm chooses to increase U, delaying exercise of its contraction option. Thus, as observed above, the inaction region increases with inflexibility.

[Insert Figure 1 Here]

The expected return pattern for low P_U firms is consistent with existing models in the literature based on irreversible investment (see, e.g., Cooper (2006)). Less appreciated, however, is the fact that for firms with even a mild degree of reversibility, the average slope of the risk profile is negative: the firm's equity becomes safer as profits decline and operating leverage increases. For such a firm, the contribution of the contraction option actually overwhelms the effect of operating leverage.[12] Notice also that the effects in the left panel are economically large. Even without invoking extreme ranges of P_U, the effect on the slope and the inaction region may be substantial.

[12] In a simpler model, Guthrie (2011) shows the negative dependence of expected returns on operating leverage for the case of a firm with a one-time abandonment option, but otherwise fixed scale. The intuition in this case is identical to that in HJ. Moreover, the idea is related to the effect in Garlappi, Shu, and Yan (2008) and Garlappi and Yan (2011) where firms approaching bankruptcy experience decreasing risk premia if the absolute priority rule is violated and hence equity holders can extract (less risky) recoveries instead of nothing.

The discussion shows the crucial contribution of P_U in determining the relative contribution of the contraction option to firm risk. Likewise, the key parameter determining the strength of the expansion option is the installation cost parameter, P_L. The right panel in Figure 1 exhibits the effect of varying it. As with the left panel, it is again the case that a less flexible firm (higher P_L) exhibits a steeper (or more positive) average increase in risk premium with operating leverage. Again, too, a less flexible firm inhabits a wider range on the horizontal axis: the firm optimally chooses a lower L.

Comparing the two panels, the variation due to P_L is less dramatic than that due to P_U. This conclusion is broadly true over a large range of parameter values. Also true numerically is that the fixed component of adjustment costs have much less impact on firm risk profiles (and on the width of the inaction region) than the variable components. For reasonable ranges of variation of F_L and F_U, the induced effects on flexibility and risk are second order.

There is another interesting observation from the right panel of Figure 1: the average *level* of the EER curves decreases as P_L increases. Although the variation is not large, in this case, higher inflexibility is not unconditionally associated with higher equity risk. This finding runs somewhat counter to the intuition that firms utilize their real options to buffer investors' exposure to exogenous profitability shocks. Although this *is* true for the contraction options in the left-hand panel (which represent a put on risky firm assets), growth options (a call on further risky assets) raise investor exposure. Thus making those options more valuable via lowering P_L raises the required return on equity, even while conferring increased operating flexibility. Therefore, the model offers no unambiguous prediction as to whether or not there should be an unconditional relation in the data between measures of firm operating flexibility and average stock returns.[13]

While Figure 1 illustrates the main conclusions that we will take to the data, the general cross-sectional implications of the model may be complex because the population of firms

[13]The model could be consistent with either sign of such a relation, depending on whether the cross-firm heterogeneity in P_U is more or less than that of P_L.

contains heterogeneity along numerous dimensions besides scale adjustment costs. Within the context of the model, firms' risk and expected return may also be affected by all the other production parameters. These may also alter both the width of the inaction region (which we will form the basis for our measurement of flexibility) and the distribution of states within that region that firms inhabit. For example, a firm with valuable contraction options (and hence potentially lower risk) may also have parameters (such as high depreciation or growth rates) that push it towards low Z states where its risk is high because of its expansion options. Or a firm with a mostly upward sloping return profile (due to low flexibility) could still spend most of its time in a downward sloping region near one of its adjustment boundaries.

To check the robustness of the relationship that we have inferred, we simulate long time-series for a large number of parameter configurations. Specifically, we assign a high value and a low value to each of nine different parameters in the model and this results in $2^9 = 512$ combinations.[14] Figure 2 shows a scatter plot of the average return *slope* for each firm versus that firm's own adjustment inflexibility, as measured by the scaled operating range $\sigma^{-1}\log(U/L)$. For each firm's history, the slope is determined from the regression of true expected returns (sampled daily) on its operating leverage, measured by quasi-fixed costs over sales. The plot affirms the positive association between inflexibility and the sensitivity of expected returns to operating leverage. Importantly, the positive association holds whether or not one controls for differences in systematic θ risk, as seen by the sets of distinct symbols corresponding to different values of the product $\rho\,\sigma$.

[Insert Figure 2 Here]

Using the same simulations, Figure 3 illustrates our observation that, in general, firm inflexibility may not be a determinant of the unconditional level of expected returns. The plot shows each firm's average risk premium against our inflexibility proxy. Both within and across

[14]The set of parameters is $\{\gamma, \delta, P_L, F_L, P_U, F_U, \mu, \sigma, \rho\}$. The sets of high and low values for those parameters are {0.95, 0.10, 0.05, 0.60, 0.05, 0.04, 0.55, –0.10} and {0.75, 0.00, 1.00, 0.005,0.10,0.005, 0.00, 0.25, –0.90}, respectively.

asset-risk clusters, there is no evidence of a positive association.

[Insert Figure 3 Here]

To gauge the quantitative magnitude of the conditional inflexibility effect, we perform a second simulation that restricts the parameter set more narrowly and realistically, and then run tests that closely parallel our subsequent empirical work. Specifically, we now fix the model parameters to be those estimated by HJ to most closely match an array of operating and financial moments in the population of U.S. listed firms. We then augment their set of baseline parameter values to include heterogeneity in the resale price parameter P_U, which has the most significant effect on the shape of the expected return profile.[15]

As a first exercise, we simulate a long sample for this panel and sort firm-months into a two-by-two array of portfolios according to their inflexibility (as proxied by the operating range $\sigma^{-1}\log(U/L)$) and beginning-of-month operating leverage. Annualized portfolio returns for the simulation are presented in Table 1. Panels A and B report the raw returns and the true expected excess returns, respectively. As is shown in both panels, the portfolio returns largely increase with operating leverage for the most inflexible firms, while the portfolio returns decrease with operating leverage for the most flexible firms. These findings are consistent with the hypothesis that scale flexibility is a primary determinant of the sensitivity of stock returns to operating leverage.

[Insert Table 1 Here]

The model's implication is also confirmed by the simulation of cross-sectional regressions of monthly excess stock returns on observable firm characteristics. QFC is the beginning-of-month ratio of quasi-fixed costs to sales, and *Range* is the standardized range of operating costs for each firm. These variables are expressed in percentile rank in each cross-section. The

[15] The exercise uses the values $P_U = [0.01, 0.07, 0.13, 0.19, 0.25]$ with equal weight to each. Results incorporating two-dimensional heterogeneity with simultaneous variation in P_U and P_L are similar.

interaction variable is the product of the ranked variables. Table 2 shows the average regression results for 200 simulated panels of 2000 firms across 50 years.

[Insert Table 2 Here]

Columns (1) to (4) Table 2 show the regression coefficients for four different specifications. As seen in columns (3) and (4), the coefficients on the interaction term are positive and statistically significant. Moreover, the magnitude is non-trivial economically, as a coefficient of 0.0054 corresponds to 54 basis points of monthly excess return. Since the interaction variable is a product of percentile ranks, the predicted spread between the expected return of the highest and lowest firm ranked by operating leverage is 54 basis points more positive for the least flexible firms than it is for the most flexible firms.

In this panel, there is no unconditional effect of quasi-fixed operating costs (from Column (1)). While there is a marginally positive unconditional effect of inflexibility on expected returns (from Column (2)), this effect is relatively small and loses significance when interacting the two variables. Finally, Column (4) shows that including a standard market risk measure (beta) does not affect the statistical significance of the interaction coefficient.[16] Estimated betas are imperfect measures of true systematic risk because firms' exposure of risk is rapidly changing. For example, Figure 1 reveals that the within-firm risk premium (and hence true beta) can easily vary by a factor of two as a result of productivity shocks. Thus, five-year rolling window beta estimates are noisier proxies for within firm systematic risk than quasi-fixed costs to sales (QFC), which are measured at a monthly frequency in the simulations. Moreover, to the extent that there is cross-firm variation in systematic risk, the inflexibility measure ($Range$) can capture that. As a consequence, adding beta estimates to the return regressions in Table 2 can not capture all variation in the model-simulated data.

To summarize, building on the results of HJ, this section has shown economically how and

[16] Beta is the market-model regression coefficient computed in rolling 60-month lagged windows and the market return is the equal-weighted average of all the firm returns.

why different degrees of scale flexibility affect firms' risk/reward properties. The general lesson is that operating options contribute a downward-sloping component to expected return (and risk) plotted against operating leverage, while assets-in-place contribute an upward-sloping one. Lower adjustment costs (i.e., higher flexibility) increase the influence of the former. Using numerical simulations, we have shown that this relationship persists in the presence of other forms of firm heterogeneity, as well as when using inaction or operating ranges to proxy for unobservable adjustment costs. Finally, simulated panels using calibrated parameters imply that the predicted effect should be detectable statistically and may be economically large.

3 Data and Measures

To test the model's implications in the data, we must differentiate firms according to their scale flexibility. We conjecture that an important determinant of a firm's ability to adjust its scale relates to industry-wide features of physical and technological capital. Economic intuition suggests that industries differ as to what production inputs (e.g., labor input, raw materials, organizational capital) are acquired under long-term contracts, and as to how easily productive capital can be transformed. Hence, we regard adjustment costs as a "fact of life" for firms within an industry and propose time-invariant measures of inflexibility at the industry level. Within an industry, we can then assess each firm's operating leverage based on its expected, period-specific, quasi-fixed production costs. Thus, we attempt to measure time-varying quasi-fixed costs at the firm level. In this section, we build the measures of industry-level inflexibility and firm-level quasi-fixed costs, which we will then use in the tests of the next section.

3.1 Inflexibility Measure

The measure of inflexibility, $INFLEX$, is constructed as the standardized industry range, which the previous section revealed as a sufficient statistic for adjustment costs.[17] We compute

[17] Fischer, Heinkel, and Zechner (1989) employ financial leverage ranges to measure a firm's inaction region.

industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets (i.e., the industry's aggregate value of COMPUSTAT's ATQ). The standardized industry range equals the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant.[18]

[Insert Table 3 Here]

Table 3 lists industries with the lowest and highest value of the inflexibility measure. As Table 3 shows, $INFLEX$ ranges from 6.40 to 19.51. Thus, there is heterogeneity across industries, as also reflected by the standard deviation of about 2.54 relative to a mean $INFLEX$ value of 10.60. While not all the rankings produced by this procedure have obvious causes with respect to industry features, the least flexible firms do include capital-intensive manufacturing businesses.

To gauge the validity of the inflexibility measure, we then examine the relation between $INFLEX$ and a list of variables that should be related to industry inflexibility, based on economic intuition, industrial organization theory, etc. Table 4 reports the regression coefficients of the inflexibility measure on those variables.[19] First, $Asset/Sales$ is defined as the ratio of total assets to sales. $Emp/Sales$ is the ratio of the number of employees to the value of sales. We interpret these two variables as proxies for outsourcing. That is, industries with more outsourced operations tend to be more flexible and hence have lower values of $Assets/Sales$ and $Emp/Sales$. Thus, we should observe a positive correlation between the inflexibility measure and these two proxies for outsourcing. Indeed, Table 4 reveals that both $Assets/Sales$ and

[18] Following the standard practice in the empirical asset pricing literature, we exclude banks (FF=44), insurance companies (FF=45), trading firms (FF=47), and utilities (FF=31).

[19] We also compute the correlation coefficients between $INFLEX$ and this list of six variables and find statistically more significant results. However, we believe that regression coefficients with industry-clustered standard errors are more convincing here. So we choose to report the regression coefficients instead of correlations. The results for correlations are available upon request.

$Emp/Sales$ are reliably positively related to $INFLEX$.

[Insert Table 4 Here]

Second, we examine two total factor productivity (TFP) dispersion measures. TFP_1 is the interquartile range of the Solow residual (i.e., the difference between the 75th and 25th percentiles of the distribution). TFP_2 is the variance of the Solow residual. We follow Basu and Kimball (1997) and Balasubramanian and Sivadasan (2009) to estimate the Solow residual of firm i in year t, TFP_{it}:

$$TFP_{it} \;=\; y_{it} - \alpha_m\, m_{it} - \alpha_k\, k_{it} - \alpha_l\, l_{it}, \tag{7}$$

where y is the log of sales, m is costs of goods sold, k is plant, property, and equipment, and l is the number of employees. According to standard models of industry equilibrium, such as Hopenhayn (1992) and Melitz (2003), productivity dispersion increases with sunk entry costs, which should increase industry inflexibility. Thus, we should observe a positive, significant relation when regressing the industry inflexibility measure on productivity dispersion measures. Table 4 shows that this is indeed the case.

Third, we consider an $Inflexible\ Employment$ index in the spirit of Syverson (2004), which we compute as the ratio of the cost for nonproduction workers to the cost of all employees.[20] As nonproduction workers are generally regarded as skilled workers and production workers as unskilled or semi-skilled workers, we assume that it is easier and less costly for firms to hire or fire production workers compared with nonproduction workers. As such, we anticipate a positive relation between the $Inflexible\ Employment$ index and the inflexibility measure.

Fourth, we consider $Advertising\ Intensity$, which is defined as the total advertising expenditure in an industry divided by the total revenue (see, e.g., Balasubramanian and Sivadasan

[20] The cost for nonproduction workers and the cost for all employees are from the U.S. Census Bureau's economic census data from 1987 to 1992. Variables in that database include "payment for production workers" and "payment for all employees".

(2009)). Since *Advertising Intensity* is positively related to barriers to entry and entry cost, according to industry equilibrium models, high entry costs will reduce the cutoff productivity, indicating an increase in productivity dispersion, which is positively related to industry inflexibility. Therefore, we should expect a positive relation between advertising intensity and inflexibility. As Table 4 shows, the sign of the regression coefficients are consistent with the above predictions, and all these coefficients are statistically significant.

Finally, we examine Balasubramanian and Sivadasan's (2009) index of capital resalability (i.e., the share of used capital investment in total capital investment at the four-digit SIC aggregate level). These authors propose this index as a valid measure of physical capital resalability, and this index should therefore be negatively related to the range measure of inflexibility. Moreover, we consider Kim and Kung's (2014) asset redeployability measure, which is constructed as the weighted average of 180 asset category's redeployability score (i.e., the ratio of the number of industries that use a given asset to the number of total industries in the BEA table, 123) for each of the 123 BEA industries. Intuitively, industries with higher asset redeployability should be more flexible; therefore, we predict a negative relation between redeployability and operating inflexibility. Table 4 confirms these predictions. Overall, the table validates our inflexibility measure using variables from the industrial organization literature that are informative about entry or fixed costs and productivity dispersion.

In our robustness checks, we also construct an alternative inflexibility measure as the standardized mean firm range of operating costs (i.e., the sum of COMPUSTAT's costs of good sold, COGSQ, and, if available, selling, general, and administrative expenses, XSGAQ) over sales (i.e., SALEQ). More specifically, for each firm in an industry, the historical range of operating costs over sales is divided by the residual standard deviation from a regression of operating costs over sales on four of its own lags and a constant. The mean firm range corresponds to the mean value of these ranges across all firms in each of the 48 Fama and French (1997) industries. Anticipating, this alternative measure delivers qualitatively and quantitatively similar results.

3.2 Quasi-Fixed Cost Measure

We also need to measure the firm-specific state variable, Z, which represents the firm's bundle of assets-in-place, A, scaled by the firm's productivity shock, θ. As discussed in Section 2, this variable is inherently unobservable. However, the ratio of quasi-fixed production costs, mA, to net sales, $\theta^{1-\gamma}A^{\gamma}$ is $mZ^{1-\gamma}$, which increases monotonically with Z, can be plausibly measured.

To identify componenets of operating costs and to limit noisiness of observations, we employ a standard rolling-window regression methodology (instead of, e.g., annual or quarterly ratios) to construct empirical counterparts of the ratio of quasi-fixed costs over sales. We denote the resulting proxies of Z by QFC. Using quarterly COMPUSTAT data for the period 1980-2013, we obtain annual, firm-level estimates of QFC by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales, which yields reliable and smooth estimates. The baseline measure of QFC in the year following the 5-year estimation period equals the sum of the regression intercept and predicted operating costs, scaled by sales. This baseline measure is useful, because, intuitively, the intercept proxies for fixed operating costs, and the predicted value proxies for quasi-fixed operating costs.[21]

In a number of robustness tests, we analyze the importance of the two components of QFC (i.e., the regression intercept and the predicted operating costs) by using only the regression intercept scaled by sales as a measure of quasi-fixed costs. Alternatively, we reduce the noisiness of QFC estimates by increasing the minimum number of observations from 10 to 15 for every 5-year window, which inevitably relies on a potentially biased and smaller sample.

[21] See, e.g., Fama and MacBeth (1973) for an early example of 5-year rolling window (beta) regression estimates. To limit the impact of outliers on the regression results, we require that quarterly growth rates in assets, costs, or sales lie inside the [–75%; +75%] interval and that the rolling-window regressions are based on at least 10 observations. We obtain qualitatively similar results when we require the quarterly growth rates in assets, costs, or sales lie inside the [–65%; +65%] interval or the [–85%; +85%] interval.

4 Empirical Results

4.1 Portfolio Sorts

Using these measures of inflexibility and quasi-fixed costs, we now test the model's implication that the sensitivity of returns to operating leverage depends on scale adjustment frictions. Our hypothesis is that the strength of the relation between quasi-fixed costs over sales and expected stock returns increases with inflexibility, that is, when inflexibility is higher, expected stock returns increase more with QFC.

To gauge the economic magnitude of the hypothesized effect, we study the portfolios formed based upon sorts on the two variables. Specifically, for each month, we assign stocks into quintile portfolios based on the measure of industry inflexibility. We then intersect these quintiles with a second sort of firms into quintiles according to their estimated quasi-fixed costs over sales. After assignment to portfolios, stocks are held for one month. Table 5 reports the summary statistics for the 25 sorted portfolios. Specifically, we report six different portfolio characteristics: the inflexibility measure, quasi-fixed costs over sales, return on assets, capital expenditure, market value of debt, and market equity.

Panels A and B of Table 5 show the sorting variables $INFLEX$ and QFC, respectively. Next, Panel C contains return on assets, which becomes much worse as quasi-fixed costs increase. This finding makes intuitive sense, as quasi-fixed costs are inversely related to profitability. Panel D shows a lower level of average capital expenditure for firms in inflexible industries, which is in line with the primary prediction of models of irreversible investment under uncertainty (see, e.g., Abel, Dixit, Eberly, and Pindyck (1996) and Abel and Eberly (1996)). Market leverage in Panel E shows a similar pattern as capital expenditure in Panel D. The table suggests that firms in inflexible industries are associated with lower debt levels than firms in flexible industries, perhaps because financial and real flexibility are substitutes. That is, negative productivity shocks could lead inflexible firms to financial distress or even bankruptcy if such firms have not retained high financial flexibility (by taking on less debt). Lastly, market equity in Panel F exhibits a strong pattern: market equity decreases as quasi-fixed costs increase, irrespective of the industry's inflexibility level.[22]

[Insert Table 5 Here]

We calculate the monthly portfolio return as the equal-weighted average of the returns of all the stocks in a portfolio. Table 6 presents the average monthly portfolio excess returns from 1980 to 2013. Panels A and B show the portfolio excess returns with the baseline measure of QFC and the alternative measure of QFC, respectively.

[Insert Table 6 Here]

The results in Table 6 reveal a significant interaction effect between inflexibility and quasi-fixed costs. Specifically, the excess return spread between the lowest and highest quasi-fixed costs quintile is almost monotonically increasing from the most flexible industry to the least flexible industry. In Panel A, the return spread is about 19 basis points per month and insignificant (t–statistic = 1.14) for the most flexible industry, it increases to 56 basis points (t–statistic = 2.44) per month for the medium flexible industry, and in the least flexible industry, it is about 72 basis points per month with a significance at the 1% level (t–statistic = 3.28). This finding is consistent with the hypothesis that if inflexibility is high (low), then the expected stock returns increase (decrease or flat) with operating leverage.

The results in Panel B is supportive. It remains the case that the return spread between the highest and lowest quasi-fixed costs quintile is almost monotonically increasing from the most flexible industry quintile to the least flexible industry quintile. Specifically, the return spreads in the two most flexible industry quintiles are 26 basis points per month and statistically insignificant or marginally significant (t–statistic = 1.63 or 1.75), whereas in the two least flexible

[22] To limit the impact from small stocks, we exclude penny stocks (stock price less than \$1) from the test sample.

industry quintileis, the return spreads are around 40 basis points with significance at the 5% level (t–statistic = 2.28 or 2.34).

4.2 Return Regressions

To control for other return determinants, we follow the cross-sectional return literature by testing the hypothesis using Fama and MacBeth (1973) return regressions. In this context, the hypothesis suggests that the slope coefficient of an interaction term between inflexibility and quasi-fixed costs over sales should be positive and significant. We carry out the tests using the intersection of the monthly stock returns from CRSP and quarterly COMPUSTAT accounting data for every month from January 1980 to December 2013. The results are presented in Table 7.[23]

[Insert Table 7 Here]

In specifications (5) to (8), we include standard control variables, namely, reversal ($R01$), momentum ($R12$), book-to-market ratio (BM), market leverage (ML), and size (SZ).[24] All variables are transformed into percentile ranks to diminish the possible influence of outliers. With this specification, the coefficient on the interaction term, $INTER$, is positive and statistically significant. For example, for specification (5) with the baseline definition of QFC, the coefficient on the interaction term is 0.0084 with a t-statistic of 3.24. Note that the magnitude of the coefficient is economically large, as a coefficient of 0.0084 corresponds to 84 basis points of monthly excess returns. Since the interaction term is the product of percentile ranks that range from 0 to 1, a coefficient of 0.0084 means that the return spread between the lowest and highest QFC firms is 84 basis points higher for the most inflexible firms than it is for the most flexible firms.

[23]Using clustered standard errors and Newey-West standard errors to account for heteroskedasticity and autocorrelation provide similar t-statistics for the regression coefficients.

[24]The variable $R01$ is the stock return over the previous month; $R12$ is the stock return over the 11 months preceding the previous month; BM denotes the log of the ratio of the book value of equity to the market value of equity; ML is the log of the market leverage ratio defined as the book value of long-term debt divided by the sum of the market value of equity and the book value of long-term debt; and SZ is the log of the market value of equity.

Moreover, in comparing specification (1) with specification (5), we observe that the coefficient estimates on BM are undiminished by the presence of our variables. Neither the unconditional inflexibility effect nor the conditional (interaction) effect with quasi-fixed costs over sales significantly lowers the explanatory power of the book-to-market ratio, suggesting that the value effect is more likely driven by cross-firm differences in risk (i.e. $\rho\,\sigma$ in the model) than by within-firm variation caused by quasi-fixed costs.

Specifications (6)-(8) report results for alternative measures of quasi-fixed costs over sales. Specification (6) uses the intercept of the rolling window regression of operating costs on sales as QFC. Specification (7) uses the intercept plus the predicted costs from the rolling window estimation divided by sales as QFC, and the minimum number of observations increase from 10 to 15. Specification (8) uses the intercept from the rolling window estimation divided by sales as QFC, and the minimum number of observations increases from 10 to 15 as well. Notably, all coefficient estimates for the interaction term are reliably positive and statistically significant at the 10% level at least.

Taken together, the empirical findings in this section strongly support the hypothesis that scale adjustment inflexibility and operating leverage have a positive interaction effect on stock returns. For flexible firms, their contraction option becomes more valuable as their operating leverage rises, lowering their exposure to fundamental (priced) risk and reducing expected stock returns, whereas inflexible firms with fewer (or more costly) contraction options can not reduce scale easily when operating leverage rises. Thus, firms with higher operating leverage are riskier when they also exist in inflexible industries.

5 Further Evidence

Recall that, according to the model, the instantaneous volatility of the stock return, $VOL(Z)$, can be expressed as $-EER(Z)/(\rho\,\sigma)$. If we assume $\rho < 0$, then equity return volatility should follow the same pattern of expected returns. In the preceding section, we tested the model's predictions about the real option effect on equity returns. Now, we provide further evidence by examining the real option effect on the second moments of expected returns.

Specifically, we double sort firms into 25 portfolios based on the value of the inflexibility measure and quasi-fixed costs over sales and then compute the return volatility for each portfolio. We construct portfolio return volatility in two ways. First, we compute portfolio return volatility as the standard deviation of the time series of monthly portfolio returns. Second, we calculate the volatility of each stock in the portfolio and use the average value of those volatilities as the portfolio return volatility. The results are presented in Table 8.

[Insert Table 8 Here]

Panels A and B show the portfolio return volatility for two measures of quasi-fixed costs over sales, respectively. As Panel A shows, the return volatility pattern across portfolios closely resembles the return pattern in Table 5. More precisely, the portfolio return volatility increases monotonically as quasi-fixed costs over sales rises. This positive relation becomes more pronounced as an industry becomes more inflexible. As Table 5 shows, the spread in portfolio return volatility is monotonically increasing from $INFLEX$ quintile 1 to quintile 5. This interesting pattern also applies to the F-statistic of the one-tailed F test on the null hypothesis that the portfolio return volatility for QFC quintile 1 is equal to that for QFC quintile 5. Specifically, the annualized high-minus-low portfolio return volatility is 3.55% in flexible industries with a F-statistic of 1.46, this value increases to 7.80% with a F-statistic of 2.03 for less flexible industries, and it further increases to 8.85% with a F-statistic of 2.14 for inflexible industries. The F tests indicate that the alternative hypothesis – that the portfolio return volatility for QFC quintile 1 is less than that for QFC quintile 5 – can not be rejected at the 0.1% significance level. Panel B with the alternative measure of quasi-fixed costs over sales shows similar portfolio return volatility patterns. Specifically, the annualized high-minus-low portfolio return volatility monotonically increases from 1.78% in flexible industries to 5.47% in inflexible industries; meanwhile, the F-statistic for the one-tailed F test rises from 1.21 to 1.58.

Panels C and D report the average stock return volatility of each portfolio for two measures of quasi-fixed costs over sales, respectively. Stock return volatility is constructed as the standard deviation of CRSP daily return over a one year time period.[25] As shown, this alternative test supports the model's prediction on volatility as well.

The results from portfolio sorts are also confirmed by regressions of stock return volatility on the inflexibility measure, quasi-fixed costs over sales, the interaction term, and last month's return volatility. Again, the inflexibility measure, quasi-fixed costs over sales, and the interaction term are transferred into percentile ranks to minimize the potential impact of outliers. Similar to Fama-MacBeth return regressions, we run the volatility regression every month and then report the mean value of the coefficients in Table 9.

[Insert Table 9 Here]

Columns (1) and (2) show the coefficients when the baseline definition of QFC is employed. Columns (3) and (4) report the coefficients when the alternative definition of QFC is used. As shown, the coefficient on the interaction term is always positive and significant at the 1% level; including lagged return volatility in the regression decreases the magnitude of the coefficients, but the pattern is not changed. For example, in column (2), the coefficient on the interaction term is 0.0153 with a t-statistic of 10.96. Moreover, the marginal effect of inflexibility is much smaller than the interaction effect, and this finding is consistent with the Fama-MacBeth return regression results in Table 7 where the unconditional effect of inflexibility on returns is insignificant.

Moreover, the model implies that systematic risk should follow the same pattern of the expected returns. To assess this prediction, we compute the average stock beta for each of the double sorted portfolios. We obtain the stock beta by running a rolling window regression

[25]We also construct stock return volatility using daily return over a month and similar results are obtained.

of monthly stock returns on the value-weighted market return over the previous 36 months. Panels A and B in Table 10 report the average portfolio beta for the baseline and alternative measures of quasi-fixed cost over sales, respectively.

[Insert Table 10 Here]

As expected, the average portfolio beta follows the same pattern as stock returns in Table 6. In other words, a firm's systematic risk as measured by the market beta is increasing as operating leverage and the inflexibility level increases. Moreover, the beta spread across QFC portfolios is almost monotonically increasing as the inflexibility level rises. For example, in Panel B, the beta spreads in flexible, less flexible, and inflexible industries are −0.0108, 0.1134, 0.1852, respectively, with t-statistics of 0.15, 2.09, and 2.95, respectively. Panel A provides supportive evidence as well. The corresponding beta spread in flexible, less flexible, and inflexible industries are 0.1098, 0.2421, 0.2879, respectively, with t-statistics of 2.67, 4.55 and 4.28, respectively. Also, the regression of firm's market beta on the inflexibility measure, quasi-fixed costs over sales, and their interaction term, while controlling for the market beta in the previous year, delivers the same message. As Table 11 indicates, the beta always loads positively and significantly on the interaction term.

[Insert Table 11 Here]

To summarize, the results from portfolio sorts and regressions of stock return volatility and market beta largely support the model's predictions with respect to the second moments of equity returns: return volatility and systematic risk display interaction effects similar to the ones found for stock returns. We therefore conclude that the presence and, in particular, cross-firm variation of real option effects is important for us to gain a better understanding of expected returns and risk.

6 Conclusion

Much insight about the cross-section of stock returns has emerged from viewing firms as being essentially equal *ex ante* but differing in their capital and in their current production opportunities. We augment this class of models by examining the additional cross-sectional implications of heterogeneity in operating flexibility, or adjustment costs. Of course, this is just one dimension along which firms may vary. The literature has, however, shown that flexibility is crucial in determining how operating risks translate into shareholder risks. In particular, the extreme case of irreversible capital, combined with quasi-fixed operating costs, implies strong relationship between productivity shocks and expected returns or risk. While parameter homogeneity isolates effects that are solely attributable to differences in productivity shocks over time, this suggests that heterogeneity in flexibility may entail interesting cross-firm differences in this relationship.

Indeed, in the context of a simple, one-state variable, partial equilibrium model, we show that flexibility affects the relation between operating leverage and expected returns. We interpret firm scale as a bundle of capital, labor, knowledge, etc. and construct a novel flexibility measure. Empirically, we confirm the important role that inflexibility plays in determining the validity of the operating leverage hypothesis. Specifically, we find that the association between operating leverage and stock returns is weak for flexible industries and that this relation becomes much stronger as an industry's inflexibility level rises. Moreover, we find that inflexibility is associated with higher expected returns when operating leverage is high. That is, we document a strong interaction effect between scale inflexibility and operating leverage on stock returns. Finally, we also find consistent evidence for second moments of stock returns, namely beta and return volatility, which lends further support to the relevance of cross-firm variation in flexibility.

Our findings cast doubt on a simple or unconditional effect of flexibility and operating leverage on firms' risk and return profiles. We emphasize that real option values can change rapidly and significantly a firm's exposure to priced risk when operating conditions deteriorate or improve. That is, scale inflexibility not only affects a firm's optimal investment policy in good states, but also alters a firm's disinvestment policy in bad states. As firms make other operating decisions (e.g., debt policies, acquisition activities, hiring and firing of labor, research and development), the range measure that we construct based on the neoclassical model can certainly be applied to study how adjustment flexibility affects also other operating decisions, which would be a fruitful avenue for future research.

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Appendix A. Model Solution

This appendix provides the system of equations that is needed to solve the model described in Section 2. The firm's objective is to increase or decrease its scale, A, to maximize the market value of its equity:

$$J(\theta, A) = \max_{A_u, u \geq t} \mathrm{E}_t \left\{ \int_t^\infty \Pi(\theta_u, A_u)\ \Lambda_u/\Lambda_t\ du \right\}. \tag{A.1}$$

In terms of the rescaled state variable Z and the rescaled value function V, the task is to choose points G, L, U, H on the positive Z axis to maximize V. Absence of arbitrage imposes the two value matching conditions (VMCs):

$$V(G) = V(L) + F_L L^\gamma + P_L (G - L) \tag{A.2}$$

and

$$V(H) = V(U) + F_U U^\gamma + P_U (H - U). \tag{A.3}$$

The first equation requires that the post-investment value of the firm is the pre-investment value plus the funds injected. The second imposes the same for pre- and post- disinvestment (note $H - U < 0$). Given these, functionally differentiating with respect to the barrier positions, yield the smooth-pasting conditions (SPCs) as necessary conditions of optimality. These are:

$$V'(L) = -\gamma\ F_L L^{\gamma-1} + P_L, \tag{A.4}$$

$$V'(G) = P_L, \tag{A.5}$$

$$V'(U) = -\gamma\ F_U U^{\gamma-1} + P_U, \tag{A.6}$$

$$V'(H) = P_U. \tag{A.7}$$

As described in the text, HJ show that, subject to some regularity conditions, the solution function V satisfies an ordinary differential equation, the form of whose solution is given by equation (4). The constants that appear in the equation are:

$$B = \frac{1}{\hat{r} + \gamma\delta + (\gamma - 1)\mu^{RN} - \frac{1}{2}\gamma(\gamma - 1)\sigma^2}, \quad \text{and} \quad S = \frac{\hat{m}}{\hat{r} + \delta},$$

where

$$\lambda_{P,N} = \frac{b \pm \sqrt{b^2 + 2(\hat{r} - \mu^{RN})\sigma^2}}{\sigma^2},$$

$b = \mu^{RN} + \delta + \frac{1}{2}\sigma^2$, $\mu^{RN} = \mu + \rho\,\sigma\,\sigma_\Lambda$, $\hat{m} = m - \eta\, P_U$, and $\hat{r} = r + \eta$.

When (4) is plugged into each of the SPCs and VMCs, the result is a system of six equations in D_N, D_P, G, L, U, and H. The system is linear in the first two, given the last four unknowns. But the nonlinearity in the last four renders numerical solution necessary.

Figure 1

Effect of Resale Price and Purchase Price.

The left panel shows expected excess returns for firms with resale prices of $P_U = 0.01$ (plotted as squares), $P_U = 0.25$ (circles), and $P_U = 0.6$ (triangles) and a purchase price of $P_L = 1.0$. The right panel shows expected excess returns for firms with purchase prices $P_L = 1.0$ (squares), $P_L = 1.5$ (circles), and $P_L = 2.0$ (triangles) and a resale price of $P_U = 0.25$. In both panels, the horizontal axis is the ratio of quasi-fixed cost, mA, to net sales, $\theta^{1-\gamma}A^{\gamma}$, which equals $mZ^{1-\gamma}$. The other firm parameters are $\gamma = 0.85, m = 0.4, \delta = 0.1, F_L = 0.05, F_U = 0.05, \mu = 0.05, \sigma = 0.3$, and $\rho = -0.5$, and the pricing kernel parameters are $r = 0.04$ and $\sigma_\Lambda = 0.50$.

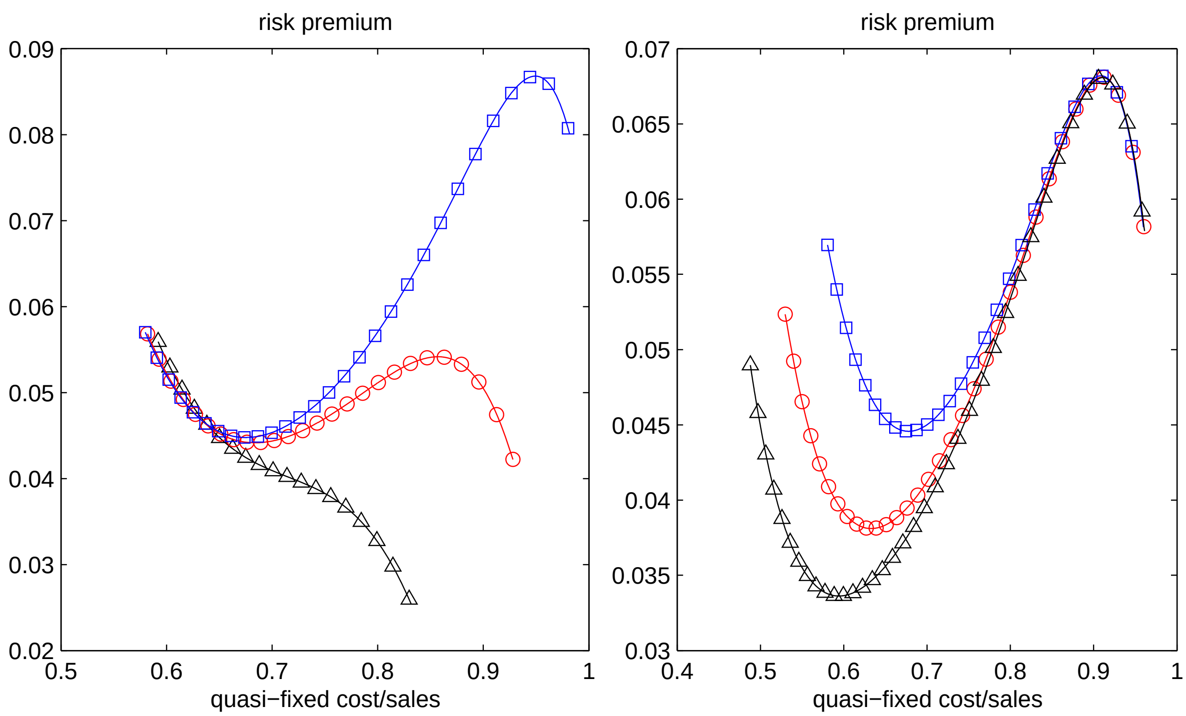

Figure 2

Flexibility and Conditional Returns.

This figure shows a scatter plot of the average slope of the expected return graph for each firm versus that firm's inflexibility, as measured by its scaled operating range, $\sigma^{-1}\log(U/L)$. For each firm's simulated history, the slope is determined from the regression of true expected returns (sample daily) on its operating leverage, measured by quasi-fixed costs over sales. Cases with $\sigma = 0.55$; $\rho = -0.9$ are plotted as triangles. Cases with $\sigma = 0.25$; $\rho = -0.9$ are plotted as circles. Cases with $\sigma = 0.55$; $\rho = -0.1$ are plotted as squares. Cases with $\sigma = 0.25$; $\rho = -0.1$ are plotted as asterisks.

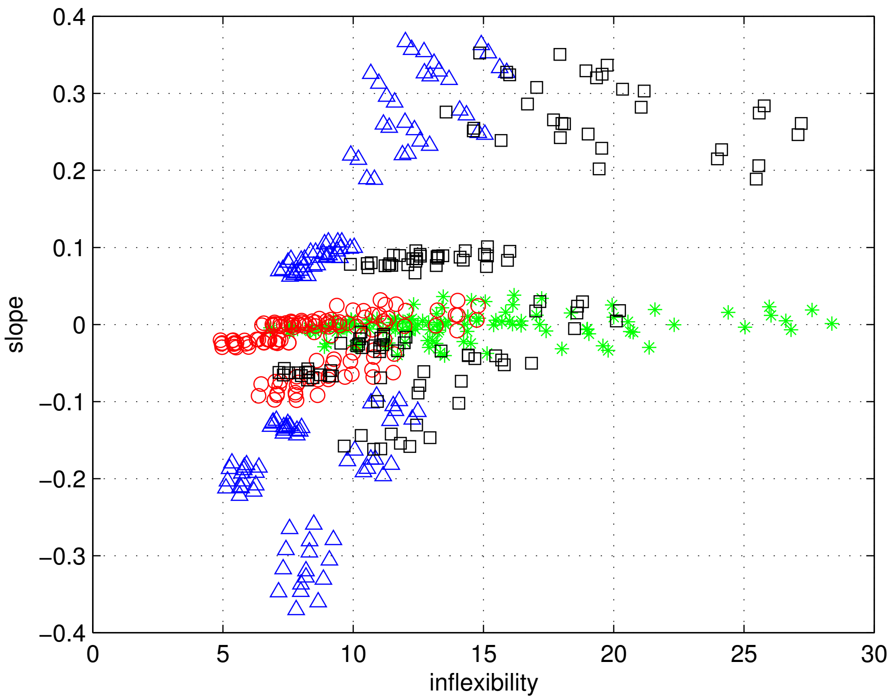

Figure 3

Flexibility and Unconditional Returns.

For each of the 512 models, unconditional expected excess returns are computed by integrating the theoretical risk premium with respect to the distribution of the state variable Z obtained from 1000 year simulations. The average risk premia are plotted against inflexibility, as measured by its scaled operating range $\sigma^{-1}\log(U/L)$. The set of nine different parameters in the model are $\{\gamma, \delta, P_L, F_L, P_U, F_U, \mu, \sigma, \rho\}$. The set of high values and low values for those parameters are {0.95, 0.10, 0.05, 0.60, 0.05, 0.04, 0.55, –0.10} and {0.75, 0.00, 1.00, 0.005,0.10,0.005, 0.00, 0.25, –0.90}, respectively. We assign a high value and a low value to each of the nine different parameters in the model and this results in $2^9 = 512$ combinations of parameters. Cases with $\sigma = 0.55, \rho = -0.9$ are plotted as triangles. Cases with $\sigma = 0.25, \rho = -0.9$ are plotted as circles. Cases with $\sigma = 0.55, \rho = -0.1$ are plotted as squares. Cases with $\sigma = 0.25, \rho = -0.1$ are plotted as asterisks.

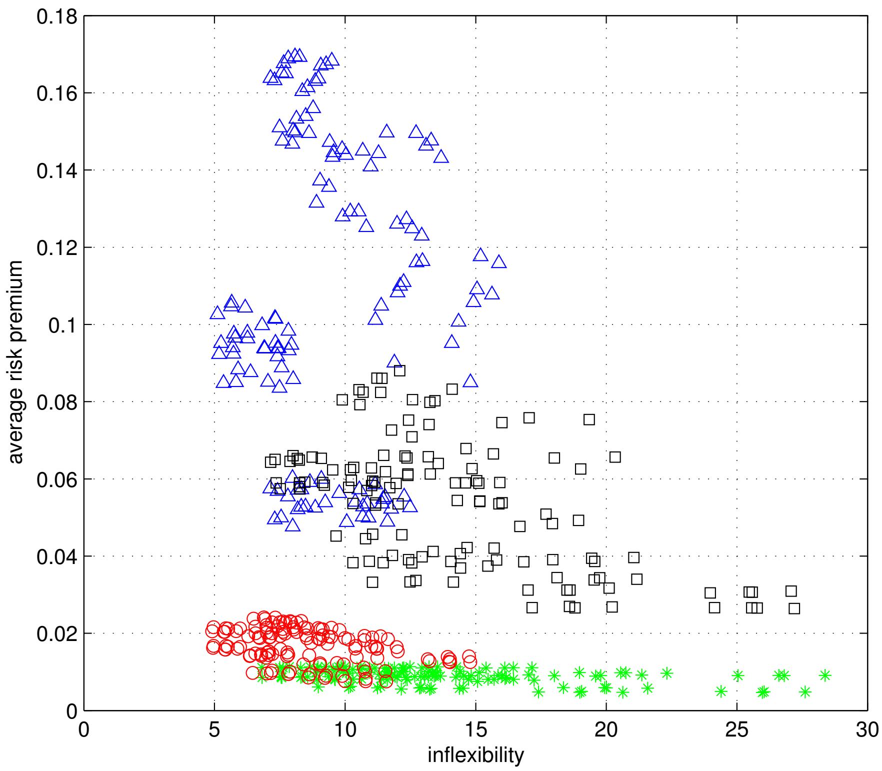

Table 1

Double Sorts on Flexibility and Operating Leverage with Simulated Data.

The table shows the annualized raw returns and true excess expected returns of 25 portfolios formed by sorting on quasi-fixed costs over sales (QFC) and the measure of scale inflexibility (range: $\sigma^{-1}\log(U/L)$) with simulated data. The population consists of firms having the baseline parameter values of HJ with the disposal value of firm assets taking on the values $P_U = [0.01, 0.07, 0.13, 0.19, 0.25]$. Panels A and B show the portfolio raw returns and excess expected returns, respectively. The portfolio returns are reported in %.

Panel A: Simulated raw returns

	QFC(low)	2	3	4	QFC(high)
Range(low)	7.0320	5.9144	5.6839	4.8132	3.9060
2	7.9033	5.9074	5.0394	5.6894	4.8396
3	7.5372	5.9133	5.4802	5.9595	5.8382
4	8.0647	6.0983	5.9917	6.0157	6.7803
Range(high)	7.9383	6.0673	6.0588	6.9215	9.9343

Panel B: True excess expected returns

	QFC(low)	2	3	4	QFC(high)
Range(low)	8.7356	6.6617	5.8044	5.4274	4.6242
2	8.7886	6.7036	5.9511	5.8822	5.3897
3	8.7984	6.7413	6.1010	6.3295	6.3581
4	8.8103	6.7647	6.2304	6.7606	7.1742
Range(high)	8.7922	6.8175	6.3555	7.1742	10.1504

Table 2

Return Regression with Simulated Data.

The table shows the results of Fama and MacBeth (1973) regressions of realized monthly excess stock returns on firm characteristics in 200 simulated panels of 2000 firms for 50 years. The simulation parameters are the same as those used in Table 1. QFC is the beginning-of-month ratio of quasi-fixed costs to sales; range is the standardized range (i.e., the inflexibility measure $\sigma^{-1}\log(U/L)$). These variables are expressed as percentile rank in each cross-section. The interaction variable is the product of the ranks. Beta is the market-model regression coefficient computed in rolling 60-month lagged windows and the market return is the equal-weighted average of all the firm returns. The coefficients and t-statistics in parentheses are the cross-panel means of the Fama-MacBeth estimators. The numbers in brackets are the proportions of panels in which the corresponding t-statistic is less than ± 1.97. The significance levels 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Variable:	(1)	(2)	(3)	(4)
QFC	–0.0013		–0.0055**	–0.0043**
	(0.80)		(2.45)	(2.37)
	[0.68]		[0.34]	[0.38]
Range		0.0018**	–0.0017*	–0.0014*
		(2.32)	(1.93)	(1.72)
		[0.32]	[0.51]	[0.59]
Interaction term			0.0074**	0.0056**
			(2.46)	(2.34)
			[0.31]	[0.36]
Beta				0.0015 **
				(2.03)
				[0.48]

Table 3

Industries with High and Low Inflexibility.

This table reports the seven industries with the largest and smallest values of the inflexibility measure, $INFLEX$. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. The third and fourth columns show, for each industry, the average number of firm observations (Number of obs.) and the average fraction of total market capitalization (% Mkt. Cap.) in each monthly cross-section of our sample period. The sample period ranges from January 1980 through December 2013.

FF CODE	INDUSTRY DESCRIPTION	INFLEXIBILITY	NUMBER OF OBS.	%MKT. CAP.
	Panel A: Seven industries with lowest inflexibility			
6	Toys Recreation	6.40	27.78	0.45
15	Rubber and Plastic Products	7.49	5.37	0.20
40	Transportation	7.53	70.48	4.16
33	Personal Services	7.71	29.72	0.40
48	Other—Almost Nothing	7.91	12.77	0.50
14	Chemicals	8.06	59.86	3.55
2	Food Products	8.14	54.83	2.72
	Panel B: Seven industries with highest inflexibility			
13	Pharmaceutical Products	12.71	87.66	8.69
34	Business Services	13.02	269.06	6.33
37	Measuring and Control Equipment	13.21	63.41	0.93
18	Construction	14.33	38.79	0.44
10	Apparel	14.63	44.85	0.55
35	Computers	15.81	92.68	6.11
12	Medical Equipment	19.51	79.28	2.09

Table 4

Validation Tests.

This table reports the regression coefficient of the inflexibility measure, $INFLEX$, on various kinds of variables. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. *Asset/sales* is the ratio of total asset to sales. *Emp/sales* is the ratio of the number of employees to the value of sales. TFP_1 and TFP_2 are productivity dispersion measures. TFP_1 is the difference between the 75th and 25th percentiles of the distribution of the Solow residual. TFP_2 is the variance of the Solow residual. The Solow residual is estimated following the procedure of Balasubramanian and Sivadasan (2009). *Inflexible Employment* is defined as the ratio of the cost for nonproduction workers to the cost of all employees. *Advertising Intensity* is the total advertising expenditure in an industry divided by the total revenue. *Resal Index* is the capital resalability index defined in Balasubramanian and Sivadasan (2009). *Redeoloyability Index* is the redeployability index defined in Kim and Kung (2014). The sample period ranges from January 1980 to December 2013. t-statistics are reported in parentheses under the estimation coefficient. Standard errors are clustered at the four-digit industry levels. The significance levels 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Outsourcing		Productivity Dispersion		Entry Barriers		Capital Reversibility	
$\frac{Asset}{sales}$	$\frac{Emp}{sales}$	TFP_1	TFP_2	*Inflexible Employment*	*Advertising Intensity*	*Resal Index*	*Redeployability Index*
0.021**	2.55***	3.64***	1.71***	11.18***	965.21***	–11.47**	–15.51***
(2.15)	(3.20)	(4.41)	(3.02)	(5.58)	(3.80)	(2.03)	(5.19)

Table 5

Summary Statistics.

This table reports summary statistics of the 25 portfolios sorted on the inflexibility measure and quasi-fixed costs over sales. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. Panels A, B, C, D, E, and F show the average inflexibility measure, quasi-fixed cost over sales, return on assets, capital expenditure, market leverage, and market equity of the portfolios, respectively. The sample period ranges from January 1980 to December 2013.

	QFC(low)	2	3	4	QFC(high)	QFC(low)	2	3	4	QFC(high)
	Panel A: Inflexibility measure					Panel B: Quasi-fixed costs over sales				
INFLEX(low)	7.808	7.723	7.657	7.640	7.626	0.034	0.095	0.171	0.295	0.641
2	9.045	9.054	9.070	9.057	9.045	0.036	0.096	0.171	0.293	0.702
3	10.468	10.458	10.386	10.214	10.019	0.034	0.096	0.169	0.291	0.744
4	11.988	11.891	11.866	11.897	11.997	0.034	0.096	0.171	0.296	0.746
INFLEX(high)	14.320	14.419	14.399	14.358	14.192	0.035	0.096	0.172	0.301	0.945
	Panel C: Return on assets					Panel D: Capital expenditure				
INFLEX(low)	0.097	0.101	0.093	0.079	0.032	0.073	0.069	0.072	0.081	0.082
2	0.088	0.090	0.082	0.072	-0.001	0.066	0.059	0.058	0.056	0.064
3	0.097	0.107	0.103	0.076	-0.014	0.064	0.066	0.066	0.065	0.062
4	0.087	0.090	0.084	0.060	-0.029	0.074	0.070	0.079	0.084	0.075
INFLEX(high)	0.094	0.098	0.097	0.070	-0.055	0.054	0.050	0.052	0.051	0.049
	Panel E: Market leverage					Panel F: Market equity				
INFLEX(low)	0.276	0.240	0.232	0.242	0.259	2.096	1.716	1.380	1.779	1.231
2	0.295	0.268	0.274	0.259	0.236	4.673	2.039	1.963	1.818	1.318
3	0.250	0.230	0.216	0.196	0.157	3.606	2.985	2.029	1.617	0.740
4	0.245	0.230	0.208	0.204	0.164	4.663	2.424	2.174	1.802	0.767
INFLEX(high)	0.183	0.176	0.138	0.118	0.085	3.871	3.185	2.684	1.579	0.567

Table 6

Portfolio Excess Returns.

The table shows the monthly excess returns of 25 portfolios formed by double sorting on firm-level quasi-fixed costs over sales (QFC) and the measure of scale inflexibility ($INFLEX$). The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. Panel A employs the baseline definition of quasi-fixed costs over sales; Panel B uses an alternative definition of quasi-fixed costs over sales, which is the intercept from a 5-year rolling window regression of operating costs on sales, divided by sales. The sample period ranges from January 1980 to December 2013. The portfolio returns are reported in %. The significance level 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Panel A: Baseline definition of QFC

	QFC(low)	2	3	4	QFC(high)	High-Low	t-stat
INFLEX(low)	1.09	1.07	1.25	1.07	1.29	0.19	(1.14)
2	0.94	0.94	0.98	0.96	1.51	0.57**	(2.70)
3	1.17	1.18	1.22	1.46	1.72	0.56*	(2.44)
4	0.99	1.07	1.18	1.22	1.65	0.66***	(3.10)
INFLEX(high)	1.12	1.04	1.26	1.46	1.84	0.72***	(3.28)

Panel B: Alternative definition of QFC

	QFC(low)	2	3	4	QFC(high)	High-Low	t-stat
INFLEX(low)	1.07	1.02	1.06	1.38	1.34	0.26	(1.63)
2	1.02	0.93	0.93	1.00	1.29	0.26*	(1.75)
3	1.40	1.13	1.17	1.33	1.60	0.20	(1.13)
4	1.15	1.05	1.05	1.24	1.57	0.42**	(2.34)
INFLEX(high)	1.44	1.05	1.18	1.35	1.84	0.40**	(2.28)

Table 7
Fama-Macbeth Return Regressions.
The table shows results from monthly Fama-MacBeth regressions of returns on measures of inflexibility ($INFLEX$), quasi-fixed costs over sales (QFC), and their product ($INTER$), as well as on controls for expected returns. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. The variable $R01$ is the stock return over the previous month; $R12$ is the stock return over the 11 months preceding the previous month; BM denotes the log of the ratio of book value of equity to market value of equity; ML is the log of the market leverage ratio defined as book value of long-term debt divided by the sum of market value of equity and book value of long-term debt; and SZ is the log of the market value of equity. All variables are transformed into percentile rank form. Specification (5) uses baseline definition of QFC; specification (6) uses the alternative definition of QFC; specification (7) uses the baseline definition of QFC from the 5-year rolling window regression with 15 observations for every 5-year window; specification (8) uses the alternative definition of QFC from the 5-year rolling window regression with 15 observations for every 5-year window. R^2 reported is the average value of R^2 from all monthly regressions. The data are monthly observations from January 1980 to December 2013. t-statistics are reported in parentheses under the estimation coefficient. The significance level 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
INFLEX		0.0034*		–0.0017	–0.0011	0.0011	–0.0013	0.0008
		(1.87)		(1.30)	(0.92)	(0.89)	(1.06)	(0.63)
QFC			0.0077***	0.0033**	0.0002	–0.0007	–0.0005	–0.0018
			(3.55)	(2.03)	(0.15)	(0.56)	(0.38)	(1.36)
INTER				0.0079***	0.0084***	0.0044*	0.0095***	0.0058**
				(2.70)	(3.24)	(1.87)	(3.63)	(2.54)
R01	–0.0178***				–0.0181***	–0.0180***	–0.0176***	–0.0176***
	(7.87)				(8.25)	(8.08)	(8.55)	(8.44)
R12	0.0037				0.0038	0.0037	0.0037	0.0036
	(1.32)				(1.43)	(1.36)	(1.43)	(1.35)
BM	0.0097***				0.0108***	0.0105***	0.0096***	0.0092***
	(4.99)				(6.12)	(5.75)	(5.64)	(5.26)
ML	–0.0023*				–0.0008	–0.0014	–0.0001	–0.0007
	(1.72)				(0.67)	(1.14)	(0.09)	(0.56)
SZ	–0.0177***				–0.0160***	–0.0168***	–0.0142***	–0.0151***
	(5.94)				(5.68)	(5.87)	(5.03)	(5.26)
R^2	0.033	0.003	0.004	0.008	0.037	0.036	0.038	0.037

Table 8

Annualized Return Volatility for 25 Double-sorted Portfolios.

This table reports annualized return volatility for each of the 25 double sorted portfolios in Table 5.The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. In Panels A and B, volatility is constructed as the standard deviation of monthly portfolio returns and then the annualized value is reported. In Panels C and D, stock return volatility is constructed as the standard deviation of CRSP daily return data over one year time period, then the average annualized volatility is reported. The sample period ranges from January 1980 to December 2013. The significance level 0.1%, 5%, and 1% are denoted by ***, **, and *, respectively.

Panel A: Baseline definition of QFC: portfolio return volatility

	QFC(low)	2	3	4	QFC(high)	High-Low	F-stat
INFLEX(low)	0.1716	0.1774	0.1739	0.1833	0.2071	0.0355***	(1.46)
2	0.1988	0.2023	0.1982	0.2059	0.2557	0.0568***	(1.65)
3	0.1836	0.1908	0.2001	0.2097	0.2616	0.0780***	(2.03)
4	0.1904	0.1972	0.2033	0.2199	0.2731	0.0827***	(2.06)
INFLEX(high)	0.1913	0.1951	0.2001	0.2210	0.2798	0.0885***	(2.14)

Panel B: Alternative definition of QFC: portfolio return volatility

	QFC(low)	2	3	4	QFC(high)	High-Low	F-stat
INFLEX(low)	0.1791	0.1735	0.1852	0.1780	0.1969	0.0178**	(1.21)
2	0.1977	0.2081	0.2024	0.2044	0.2217	0.0241**	(1.26)
3	0.1926	0.1921	0.1984	0.2028	0.2391	0.0465***	(1.54)
4	0.1968	0.1976	0.2102	0.2130	0.2512	0.0544***	(1.63)
INFLEX(high)	0.2129	0.2017	0.2142	0.2127	0.2676	0.0547***	(1.58)

Panel C: Baseline definition of QFC: average stock return volatility

	QFC(low)	2	3	4	QFC(high)	High-Low	t-stat
INFLEX(low)	0.4384	0.4570	0.4908	0.5118	0.5695	0.1311***	(10.73)
2	0.4211	0.4537	0.4548	0.4734	0.5930	0.1719***	(9.93)
3	0.4636	0.4713	0.5022	0.5649	0.6911	0.2275***	(11.00)
4	0.4725	0.4952	0.5221	0.5870	0.6981	0.2256***	(13.99)
INFLEX(high)	0.5048	0.5031	0.5233	0.5845	0.7178	0.2130***	(12.11)

Panel D: Alternative definition of QFC: average stock return volatility

	QFC(low)	2	3	4	QFC(high)	High-Low	t-stat
INFLEX(low)	0.4766	0.4549	0.4728	0.4956	0.5713	0.0947***	(7.38)
2	0.4454	0.4344	0.4575	0.4664	0.5501	0.1047***	(12.19)
3	0.5207	0.4651	0.4852	0.5287	0.6612	0.1405***	(9.76)
4	0.5133	0.4873	0.5158	0.5545	0.6821	0.1688***	(14.45)
INFLEX(high)	0.5515	0.5112	0.5260	0.5726	0.7201	0.1686***	(11.72)

Table 9

Volatility Regression.

The table shows the results of regressions of stock return volatility on the inflexibility measure, the quasi-fixed cost over sales, their interaction term, and the volatility in the previous month. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. The stock return volatility is constructed as the standard deviation of CRSP daily return data over one month time period. In columns (1) and (2), we use the baseline definition of quasi-fixed cost over sales. In columns (3) and (4), we use the alternative definition of quasi-fixed cost over sales. R^2 reported is the average value of R^2 from all monthly regressions. The sample period ranges from January 1980 to December 2013. t-statistics are reported in parentheses under the estimation coefficient. The significance level 0.1%, 5%, and 1% are denoted by ***, **, and *, respectively.

Variable:	(1)	(2)	(3)	(4)
QFC	0.0407***	0.0177***	0.0224***	0.0100***
	(32.95)	(21.28)	(24.61)	(13.75)
Inflexibility	0.0099***	0.0033***	0.0112***	0.0037***
	(8.83)	(4.28)	(10.79)	(4.87)
Interaction term	0.0348***	0.0153***	0.0404***	0.0175***
	(21.34)	(10.96)	(23.56)	(12.39)
lagged volatility		0.5582***		0.5641***
		(81.79)		(82.47)
R^2	0.048	0.558	0.034	0.344

Table 10

Average Beta for 25 Double-sorted Portfolios.

This table reports average beta for each of the 25 double sorted portfolios in Table 5. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. We regress monthly stock return on the monthly value-weighted market return over the past 36 months. Stock beta is constructed as the regression coefficient on the market return. The sample period ranges from January 1980 to December 2013. The significance level 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Panel A: Baseline definition of QFC

	QFC(low)	2	3	4	QFC(high)	High-Low	t-stat
INFLEX(low)	0.9531	0.9539	0.9784	0.9990	1.0629	0.1098***	(2.67)
2	1.1314	1.1499	1.1027	1.1485	1.2834	0.1520**	(2.20)
3	1.0309	1.0919	1.0885	1.1819	1.2730	0.2421***	(4.55)
4	1.1339	1.1126	1.1687	1.2660	1.4687	0.3348***	(3.67)
INFLEX(high)	1.1420	1.1437	1.1669	1.3012	1.4299	0.2879***	(4.28)

Panel B: Alternative definition of QFC

	QFC(low)	2	3	4	QFC(high)	High-Low	t-stat
INFLEX(low)	0.9790	0.9790	0.9730	0.9807	0.9682	–0.0108	(0.25)
2	1.1706	1.1443	1.1622	1.1136	1.1852	0.0146	(0.26)
3	1.0754	1.1219	1.0945	1.1076	1.1888	0.1134**	(2.09)
4	1.1667	1.1942	1.2025	1.2377	1.3336	0.1669*	(1.92)
INFLEX(high)	1.2061	1.1916	1.2452	1.2275	1.3913	0.1852***	(2.95)

Table 11
Beta Regression.
The table shows the results of regressions of stock beta on the inflexibility measure, the quasi-fixed cost over sales, their interaction term, and the beta in the previous year. The measure of scale inflexibility is constructed as the historical range of aggregate, standardized operating costs over sales scaled by the residual standard deviation from a regression of operating costs on contemporaneous sales and four lags of operating cost over sales and a constant. We compute industry aggregate cost, sales, and assets by summing over all quarterly firm observations in COMPUSTAT, with each calendar quarter using any available firm reported during that quarter. Industry operating costs and industry sales are standardized by industry assets. Firm-level estimates of QFC is obtained by running five-year, rolling-window regressions of operating costs on its first lag and contemporaneous sales. The measure of QFC in the year following the 5-year estimation period equals the sum of regression intercept and predicted operating costs, scaled by sales. The stock beta is constructed by regressing monthly stock returns on the value-weighted market return over the previous 36 months. In columns (1) and (2), we use the baseline definition of quasi-fixed cost over sales. In columns (3) and (4), we use the alternative definition of quasi-fixed cost over sales. R^2 reported is the average value of R^2 from all monthly regressions. The sample period ranges from January 1980 to December 2013. t-statistics are reported in parentheses under the estimation coefficient. The significance level 0.1%, 5%, and 1% are denoted by ***, **, and *, respectively.

Variable:	(1)	(2)	(3)	(4)
QFC	0.2032***	0.0649***	0.1084***	0.0334***
	(13.98)	(9.26)	(8.95)	(5.44)
Inflexibility	0.1079***	0.0275***	0.1802***	0.0459***
	(12.92)	(5.51)	(19.07)	(9.19)
Interaction term	0.1946***	0.0419***	0.1094***	0.0200**
	(8.62)	(3.74)	(6.75)	(2.14)
Lagged Beta		0.6495***		0.6509***
		(57.72)		(57.55)
R^2	0.036	0.509	0.025	0.510