Strategic Investment and Industry Risk Dynamics

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This paper characterizes how firms' strategic interaction in product markets affects the industry dynamics of investment and expected returns. In imperfectly competitive industries, a firm's exposure to systematic risk is affected by both its own investment strategy and the investment strategies of its peers, so that the dynamics of its expected returns depend on the intraindustry value spread. In the model and the data, firms' betas and returns correlate more positively in industries with low value spread, low dispersion in operating markups, and low concentration. (*JEL* G12, G31)

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In imperfectly competitive industries, the ability of firms to affect market prices induces them to invest strategically. The value of each firm depends not only on its own assets in place and investment opportunities but also on the ability of its competitors to expand capacity and reduce market prices. As a result, under imperfect competition, the dynamics of a firm's exposure to systematic risk is not only significantly explained by its own investment strategy but is also explained by the investment strategies of its industry peers.

The study of firms' intraindustry interactions is relevant in light of the empirical evidence that suggests that commonly studied asset pricing regularities are predominantly intraindustry (see, e.g., Cohen and Polk 1996; Moskowitz and Grimblatt 1999; Cohen, Polk, and Vuolteenaho 2003). The current production-based asset-pricing literature focuses on the impact of corporate investment on expected returns in perfectly competitive or in perfectly monopolistic industries (see, e.g., Berk,

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Green, and Naik 1999; Zhang 2005; Carlson, Fisher, and Giammarino 2004). We explore the intermediate case of imperfectly competitive industries, in which firms' strategic interaction affects the dynamics of investment and risk. Our analysis rationalizes existing findings on the cross-section of returns and provides additional testable predictions for which we find supporting evidence in our empirical section.

Our study is motivated by several research questions. How does a firm's relative position in its product market influence its investment decisions and the conditional dynamics of its expected returns? In which types of industries are the stylized predictions of investment-based asset pricers for monopolies or perfectly competitive industries still appropriate? And how does strategic interaction affect the intraindustry correlation of firms' investments and their exposure to systematic risk?

1. Basic Model

We begin by studying a tractable model of duopoly to characterize the effect of firms' strategic interaction on their risk exposure in the most simple way. In the following section, we elaborate on alternative specifications of the model and derive testable implications.

1.1 Main assumptions

We consider an industry with two firms $j=L,M$, in which each firm has assets in place and a single growth option to increase its capacity. Each firm is all-equity financed and run by a manager who is the single shareholder.

Firms compete in capacity and produce a homogeneous good that they sell in the market at a price p_t. Firms operate at full capacity at any point in time. The demand function requires that the product market price p_t equals

$$p_t = X_t Y_t^{-\frac{1}{\varepsilon}}, \tag{1}$$

where $\varepsilon > 1$ is the elasticity of demand, X_t is a systematic multiplicative shock, and the industry output Y_t is the sum of the production at time t.

The demand shock X_t follows a geometric Brownian motion with drift μ_x and volatility σ_x so that

$$dX_t = \mu_x X_t dt + \sigma_x X_t dz_t, \tag{2}$$

where z_t is a standard Wiener process, and X_0 is strictly positive. We further assume that X_0 is sufficiently low so that the growth options of all firms in the industry are strictly positive at $t=0$. Throughout the paper, we denote by $\mu_{\mathbf{y}t}$ and $\sigma_{\mathbf{y}t}$ the mean and standard deviation of any variable y at time t, and we omit the subscript t when $\mu_{\mathbf{y}}$ or $\sigma_{\mathbf{y}}$ are constant over time.

1.1.1 Equilibrium outcome. We obtain two types of subgame-perfect equilibria in pure strategies: a leader-follower equilibrium and multiple clustering equilibria. We denote by x_j^s the investment threshold of firm j in the leader-follower equilibrium, in which firms invest sequentially. We denote by x^c the investment threshold of any firm j in a given clustering equilibrium, in which firms invest simultaneously. We define x_L^{c*} as the optimal clustering equilibrium for firm L. The standard deviation of firms' scale of production after investment is given by $\sigma_\Lambda \equiv \frac{|\Lambda_L - \Lambda_M|}{2}$.

1.1.2 Equilibrium concept. The equilibrium concept is Bayes-Nash. The state of the industry is described by the history of the stochastic demands shocks X_t. At any point in time, a history is the collection of realizations of the stochastic process X_s, $s \leq t$, and the actions taken by all firms in the industry. The investment strategy maps the set of histories of the industry into the action x_j for each firm j. Before investment, firm j responds immediately to its competitor's investment decision. This yields Nash equilibria in state-dependent strategies of the closed-loop type.[1] Upon investment, firm j cannot take any other action.

Proposition 1 (Equilibrium investment dynamics). The subgame-perfect industry equilibria for $N = 2$ with $\Lambda_L > \Lambda_M$ are such that

- if $\sigma_\Lambda \geq \Theta_\Lambda$, firm L invests earlier than firm M so that $x_L^s < x_M^s$, and
- if $\sigma_\Lambda < \Theta_\Lambda$, the Pareto optimal equilibrium is so that both firms invest jointly at the threshold $x^c \equiv x_L^{c*}$,

where Θ_Λ is determined endogenously in equilibrium.

Proof. See Appendix B. ■

Proposition 1 states that the investment dynamics of any industry depend on the cross-sectional differences in firms' production technologies. When firms are distant competitors so that $\sigma_\Lambda \geq \Theta_\Lambda$, a leader-follower equilibrium arises, in which firm L invests first. The dynamics of firms' values are affected by their strategic interaction so that $\Delta\pi_{Lt}^{s+} < 0$ and $\Delta\pi_{Mt}^{s-} < 0$. By construction, it also holds that $\Delta\pi_{Lt}^{s-} = 0$ and $\Delta\pi_{Mt}^{s+} = 0$.

We solve for the optimal investment strategy that maximizes the value of firm L as a leader subject to the incentive compatibility constraint

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[1] A closed-loop equilibrium is a Nash equilibrium in state-dependent strategies. See Fudenberg and Tirole (1991), Weeds (2002), and Back and Paulsen (2009) for related discussions on closed-loop strategies.

(ICC) of firm M. The complementary slackness condition of the ICC of firm M is given by

$$\lambda^s \left[\widetilde{V_M^s} - V_M^s\right]\Big|_{X_t = x_L^s} = 0, \tag{3}$$

where the multiplier $\lambda^s \geq 0$ in Equation (3) relates to Posner (1975) and measures to which extent the contest for monopoly power between firms L and M hinders the value of firm L. $\widetilde{V_M^s}$ denotes the value of firm M when it deviates from its strategy as a follower and invests instead at the threshold x_L^s.

Proposition 2 (Leader-follower equilibrium strategies). The subgame-perfect strategies for $N=2$ with $\Lambda_L > \Lambda_M$, in which $x_L^s < x_M^s$ are so that the investment threshold of firm L equals

$$x_L^s = \frac{fK^{\frac{1}{\varepsilon}}(1-\lambda^s)\frac{\upsilon\delta}{\upsilon-1}}{\left[(\Lambda_L+1)^{-\frac{1}{\varepsilon}}\Lambda_L - 2^{-\frac{1}{\varepsilon}}\right] - \lambda^s\left[(\Lambda_M+1)^{-\frac{1}{\varepsilon}}\Lambda_M - (\Lambda_L+1)^{-\frac{1}{\varepsilon}}\right]}, \tag{4}$$

and the investment threshold of firm M equals

$$x_M^s = \frac{fK^{\frac{1}{\varepsilon}}\frac{\delta\upsilon}{\upsilon-1}}{(\Lambda_L+\Lambda_M)^{-\frac{1}{\varepsilon}}\Lambda_M - (\Lambda_L+1)^{-\frac{1}{\varepsilon}}}, \tag{5}$$

where $\lambda^s = 0$ if $\sigma_\Lambda > \overline{\sigma_\Lambda}$, and $\lambda^s \in (0,1)$ if $\sigma_\Lambda < \overline{\sigma_\Lambda}$.

Proof. See Appendix B. ■

Proposition 2 characterizes the leader-follower equilibrium strategies. We obtain two different types of leader-follower equilibria, depending on the strength of the preemptive motives of firm M. When $\sigma_\Lambda > \overline{\sigma_\Lambda}$, firm L invests at the Stackelberg threshold x_L^{s*} so that $x_L^{s*} \equiv x_L^s(\lambda^s = 0)$.

The upper charts of Figure 1 illustrate the leader-follower equilibrium strategies as a function of σ_Λ. The multiplier λ^s captures the shadow cost of preemption for firm L, and it is decreasing in σ_Λ. When firms are more distant competitors, the wedge between the equilibrium threshold x_L^s and the Stackelberg threshold x_L^{s*} decreases. It is less costly for firm L to lead if firm M is a weaker competitor.

Proposition 3 (Clustering equilibrium strategies). The subgame-perfect clustering equilibria for $N=2$ with $\Lambda_L > \Lambda_M$ are so that both firms invest at the same threshold $x^c \in [\underline{x}_L^c, x_L^{c*}]$. While there is a continuum of equilibrium thresholds over this interval, the Pareto optimal equilibrium threshold x_L^{c*} is given by

$$x_L^{c*} = \frac{fK^{\frac{1}{\varepsilon}}\frac{\delta\upsilon}{\upsilon-1}}{(\Lambda_L+\Lambda_M)^{-\frac{1}{\varepsilon}}\Lambda_L - 2^{-\frac{1}{\varepsilon}}}. \tag{6}$$

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Figure 1
Investment strategies as a function of σ_Λ
In panel A, the solid line relates to the leader equilibrium strategies x_L^s. The dashed line corresponds to the Stackelberg strategy x_j^{s*}, in which firm L leads by assumption. λ^s is the shadow cost of preemption in the leader-follower equilibrium. In panel B, the solid line relates to the Pareto optimal clustering equilibrium strategy x_L^{c*}. The dashed line corresponds to the minimum clustering equilibrium threshold $\underline{x}_L^c$. For the sake of comparison, the dotted line depicts the follower threshold in the leader-follower equilibrium $x_M^s < x^c$. The dash-dotted line represents the first-best joint-investment threshold of firm M, or $x_M^{c*} > x^c$.

Proof. See Appendix B. ■

Fudenberg and Tirole (1985) argue that if one equilibrium Pareto dominates all others, it is the most reasonable outcome to expect. We apply an equilibrium refinement to select the Pareto optimal clustering equilibrium as the joint-investment equilibrium of the model, and derive testable implications on industry dynamics in the next section.

Assumption 1 (Pareto dominance refinement). Given $V^s_{jt} \leq V^{c*}_{jt}$ for $j=L,M$, firm L rationally opts for the Pareto optimal clustering equilibrium strategy x^{c*}_L.

Assumption 1 arises naturally in our setting because firm L has the real option to become the industry leader. Given assumption 1, the clustering equilibrium outcome depends on the relative magnitudes of the value of firm L as a leader and the value of firm L when both firms delay their investment until the Pareto optimal clustering threshold x^{c*}_L. If V^s_{Lt} ever exceeds V^{c*}_{Lt}, preemption incentives are too strong for clustering to be an equilibrium, and the only possible outcome is the leader-follower equilibrium. Conversely, if V^s_{Lt} never exceeds V^{c*}_{Lt}, a clustering equilibrium may be sustained, although the leader-follower equilibrium outcome is also an equilibrium.

Proposition 4 (Intraindustry correlation of betas). Given $X_t < x^s_M$ and the refinement in assumption 1, the equilibrium dynamics of β_{jt} depend on σ_Λ so that

- if $\sigma_\Lambda < \Theta_\Lambda$, firms' betas correlate positively, and
- if $\sigma_\Lambda \geq \Theta_\Lambda$, the betas of leaders and followers correlate negatively.

2. Empirical Evidence

The theoretical framework described so far provides qualitative predictions on how firms' strategic interaction affects the intraindustry dynamics of investments and betas. A reasonable concern, however, is whether these effects are economically significant. We therefore assess whether the main testable implications of our model hold on average for the cross-section of U.S. industries. We find supporting empirical evidence on the following predictions.

- Firms' investment strategies are significantly related to the intraindustry value spread.
- Firms' betas and returns correlate more positively in industries with low intraindustry value spread.
- Firms' betas and returns correlate more positively in industries with low intraindustry standard deviation in markups and low HHI.

2.1 Data set and empirical approach

Our tests rely on similar data sets used in previous studies, such as those of Hoberg and Phillips (2010). We define an industry by its four-digit SIC code. This is the finest available industry classification that is available in our merged CRSP/Compustat data set.

Table 1
Working sample statistics

	Firm level			Industry level		
	Mean	SD	N	Mean	SD	N
$\frac{I}{K}$	0.360	0.520	113,007	0.324	0.293	14,745
β	1.102	0.947	115,702	1.040	0.547	15,014
R	0.082	0.564	115,765	0.073	0.366	15,077
$\frac{V}{K}$	1.477	0.826	110,355	1.407	0.525	14,931
$\frac{V-B}{K-B}$	2.085	1.543	109,797	1.985	1.050	14,836
$\frac{B}{K}$	0.526	0.230	115,702	0.544	0.145	15,014
$\frac{\pi}{K}$	0.082	0.219	115,633	0.110	0.099	15,013
m	0.144	0.110	115,419	0.129	0.075	14,779
$\sigma_{\frac{I}{K}}$				0.274	0.353	12,584
σ_β				0.635	0.417	12,815
σ_R				0.374	0.279	12,815
$\sigma_{\frac{V}{K}}$				0.530	0.394	12,693
$\sigma_{\frac{V-B}{K-B}}$				1.088	0.718	12,523
$\sigma_{\frac{B}{K}}$				0.178	0.081	12,815
$\sigma_{\frac{\pi}{K}}$				0.111	0.116	12,811
σ_m				0.058	0.047	12,782
lnHHI				5.645	1.185	8,539
lnCR4				3.583	0.642	8,539
lnCR8				3.917	0.555	8,539
$\omega_{\frac{I}{K}}$				0.031	0.066	14,812
ω_β				0.026	0.032	14,857
ω_R				0.016	0.012	14,857
$\omega_{\frac{V}{K}}$				0.107	0.213	14,849
$\omega_{\frac{V-B}{K-B}}$				0.178	0.201	14,244

This table reports the summary statistics of our working sample of U.S. public firms from 1968 to 2008. $\frac{I}{K}$ is the investment rate; β is the equity beta; R is the stock return in excess of the risk-free rate, which is annualized in this table, since all statistics are reported in annual terms; $\frac{V}{K}$ is the market-to-book asset ratio; $\frac{V-B}{K-B}$ is the market-to-book equity ratio; $\frac{B}{K}$ is the book leverage ratio; $\frac{\pi}{K}$ is operating cash flows to assets; m is the operating markup on profits; σ_x denotes the intraindustry standard deviation in variable x; lnHHI is the logarithm of the U.S. Census HHI; lnCR4 and lnCR8 are the logarithm of the U.S. Census concentration ratios CR4 and CR8; and ω_x denotes the intraindustry comovement in variable x.

We include all listed in firms in NYSE, AMEX, and Nasdaq. We merge the CRSP monthly returns file with the Compustat annual file between January 1968 and December 2008. We use data at annual frequency to run the tests on investment equations. We use data at monthly frequency to run the asset-pricing tests. We elaborate on the database construction in Appendix G. We report the summary statistics of the working sample in Table 1.

3. Conclusion

In this paper we study how strategic interaction affects the intraindustry dynamics of corporate investment and expected returns. Under imperfect competition, a firms' exposure to systematic risk or beta is affected significantly not only by its own investment decisions but also by the investment decisions of its industry peers.

In imperfectly competitive industries, we predict that the investment strategy and exposure to systematic risk of each firm is affected by the marginal product of capital of all its competitors; this suggests why the empirically observed value spread is predominantly intraindustry. In the model and in the data, we find that firms' betas and returns correlate more positively in industries with low value spread. We also show empirically and explain theoretically why firms' betas and returns correlate more positively in industries with low HHI, and low intraindustry standard deviation in markups.

To conclude, we note that the fundamental insight of our paper is that product markets have nontrivial effects on firms' investment decisions and their expected returns. In this context, dynamic models of strategic interaction typically studied in the industrial organization literature become a useful tool to explain empirical regularities in the cross-section of returns.

Appendix A. Firm Value

At the investment threshold $X_t = x_j$, the value-matching condition ensures that the firm can pay fK to increase the value of its assets in place from A^-_{jt} to A^+_{jt}. Given exercise at $X_t \geq x_j$, the value of the growth option to invest is calculated as a perpetual binary option with payoff $A^+_{jt} - A^-_{jt} - fK$. We then observe[2] that the expected value of the growth option to invest is given by $G_{jt} \equiv \left(A^+_{jt} - A^-_{jt} - fK\right)\left(\frac{X_t}{x_j}\right)^\upsilon$, where $\left(\frac{X_t}{x_j}\right)^\upsilon$ is the price of a contingent claim that pays one if the firm invests and zero otherwise, and the parameter $\upsilon > 1$ equals

$$\upsilon = \frac{1}{2} - \frac{r-\delta}{\sigma_x^2} + \left[\left(\frac{r-\delta}{\sigma_x^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma_x^2}\right]^{\frac{1}{2}}.$$

For any investment strategy x_j, we conclude that V_{jt} equals $A^-_{jt} + G_{jt}$ if $X_t < x_j$ and A^+_{jt} if $X_t \geq x_j$.

In what follows, we specify the functional form of firms' value functions when firms invest sequentially and simultaneously. In doing so, we do not characterize explicitly firms' investment strategies. We use these expressions in the derivation of the equilibrium outcome in Appendix B.

Consider first the values of firms L and M when both firms invest simultaneously at a given threshold x. For any value of X_t, the value of firm $j = L, M$ equals

$$V_{jt} = \begin{cases} (2K)^{-\frac{1}{\varepsilon}} \frac{K}{\delta} X_t + \left[(\Lambda_L K + \Lambda_M K)^{-\frac{1}{\varepsilon}} \Lambda_j \frac{K}{\delta} x - fK - (2K)^{-\frac{1}{\varepsilon}} \frac{K}{\delta} x\right] \left(\frac{X_t}{x}\right)^\upsilon & \text{if } X_t < x \\ (\Lambda_L K + \Lambda_M K)^{-\frac{1}{\varepsilon}} \Lambda_j K \frac{X_t}{\delta} & \text{if } X_t > x. \end{cases}$$

[2] See Dixit and Pindyck (1994). The details of the derivation of $\upsilon > 1$ are provided in Chapter 5.

Appendix B. Equilibrium Outcome of the Basic Model

We derive the proof of the equilibrium outcome in several steps. As a first step, we consider the sorting condition of the game, and we derive firms' leader-follower investment strategies $x_L^s < x_M^s$. The derivation relies on the premise that firm M must be indifferent between investing as a leader and as a follower. We then show that firm L has no incentive to deviate as a follower and that there exists no alternative leader-follower equilibrium in which firm M invests first.

As a second step, we characterize the clustering equilibria x^c. We prove that firm M has no incentives to deviate from the clustering equilibrium. We consider a refinement to select the Pareto optimal clustering equilibrium out of all possible clustering equilibria. We obtain a unique cutoff value Θ_Λ so that firm L has incentives to invest jointly with firm M at the Pareto optimal clustering equilibrium if $\sigma_\Lambda < \Theta_\Lambda$.

B.1 Sorting Condition

The strategy pursued by firm j is given by x_j. We denote by $X_t \widehat{Y}_j^{-\frac{1}{\varepsilon}}$ the expected price by firm j at time t. In equilibrium, $X_t \widehat{Y}_j^{-\frac{1}{\varepsilon}}$ is equal to the market price p_t when $\Delta\pi_{jt}^- = 0$ and $\Delta\pi_{jt}^+ = 0$; we use a more general notation, because the sorting conditions hold for any given investment strategy of firm j, conditional on any strategy of firm $-j$. Using this notation, the preinvestment value function V_{jt} defined in $X_t < x_j$ for any investment strategy x_j of firm j and taking as given the strategy of firm $-j$ equals

$$V_{jt} = \left(\widehat{Y}_j^-\right)^{-\frac{1}{\varepsilon}} K \frac{X_t}{\delta} + \left[\left(\widehat{Y}_j^+\right)^{-\frac{1}{\varepsilon}} \frac{x_j}{\delta} \Lambda_j K - \left(\widehat{Y}_j^-\right)^{-\frac{1}{\varepsilon}} \frac{x_j}{\delta} K - fK\right] \left(\frac{X_t}{x_j}\right)^{\upsilon}. \tag{B1}$$

B.2 Sufficient Conditions for Clustering Equilibria

Consistent with Weeds (2002), we predict multiple clustering equilibria $x^c \in [\underline{x}_L^c, x_L^{c*}]$, and we claim that the Pareto optimal equilibrium is given by $x^c = x_L^{*c}$. We denote by $\underline{x}_L^c$ the lowest clustering threshold that can be sustained as an equilibrium outcome, and is equal to the minimum joint-investment threshold of firm L so that its value-matching condition holds and $V_{Lt}^s \le V_{Lt}^c$. We denote by x_L^{c*} the highest clustering threshold that can be sustained in equilibrium, which is the optimal joint-investment threshold for firm L.

To prove these statements, we first analyze the conditions so that both firms expand capacity at some threshold x^c. Consider the incentives of firm L to deviate from the equilibrium threshold x^c. We assume for now and later verify that firm M has no unilateral incentives to deviate so that if firm L invests, then firm M invests immediately. Consider then the incentives of firm L to deviate from $x^c$and invest earlier at $X_t < x^c$. We require that $V_{Lt}^s \le V_{Lt}^c$ at any point in time, so that firm L has no unilateral incentive to invest as a leader. Given the definition of $\underline{x}_L^c$ in, this implies $x^c \ge \underline{x}_L^c$.

Consider the incentives of firm L to deviate from the equilibrium threshold x^c and invest later at $X_t > x^c$. Note that the minimum investment threshold at which firm L has a unilateral incentive to invest jointly with firm M is given by $\underline{x}_L^c$. Assuming that firm M has no unilateral incentive to deviate as a follower, firm M invests immediately if firm L invests, and hence it follows that $\underline{x}_L^c$ is a feasible joint-investment threshold as long as firm L believes that firm M will invest at $\underline{x}_L^c$. This argument applies to any investment threshold in the range $x^c \in (\underline{x}_L^c, x_L^{*c})$. At the optimal joint-investment threshold x_L^{c*}, it is a dominant strategy for firm L to invest regardless of the beliefs about firm M, and firm M invests immediately. Hence, $x^c \le x_L^{c*}$.

Consider the incentives of firm M to deviate from the equilibrium threshold x^c and invest later at $X_t > x^c$. For this sake, we take into account the optionality of investment: if firm M does not invest when firm L does, it will invest optimally in the future. The optimal threshold of firm M as a follower is given by x_L^s. Consistent with Pawlina and Kort (2006), we conjecture and later verify that a sufficient condition so that firm M has no incentives to delay its investment at x^c is given by $x_L^s \leq x^c$. Given $x_L^s \leq x^c$, and conditional on firm L investing at x^c, firm L invests immediately.

Last, consider the incentives of firm M to invest earlier than the joint-investment threshold for some $X_t < x^c$. Two alternative cases may arise. The first is that firm M deviates by investing earlier in the range $x_M^s < X_t < x^c$. In this range, firm M has no incentive to become a leader, because X_t is already above its optimal follower threshold; hence, if firm L invests at x^c, firm M will optimally invest at the same time. The second case is that firm M deviates in the range $X_t < x_M^s$. The value of firm M as a leader may be lower, equal, or higher than its value as a follower in the range $x_L^s \leq X_t < x_M^s$. If its value as a leader is lower than as a follower, then firm M optimally waits. If its value as a leader is higher than as a follower, the optimal threshold at which firm M should invest as a leader is equal to x_L^s; by construction, however, the threshold x_L^s is so that firm M is indifferent between investing as a follower and as a leader. Hence, firm M has no incentives to invest earlier than x^c at $X_t < x_M^s < x^c$.

Put together, the conditions so that neither firm L nor firm M deviate from the clustering threshold x^c are given by $V_{Lt}^s \leq V_{Lt}^c$ and $x_L^s \leq x^c$. Consistent with Pawlina and Kort (2006), we prove that if $V_{Lt}^s \leq V_{Lt}^c$, then $x_M^s < x^c$. Moreover, given that $\widetilde{x}_L < x_M^s$, it follows that $V_{Lt}^s \leq V_{Lt}^c$ also implies $x^c > \widetilde{x}_L$. Therefore, if firm M has no incentive to deviate as a follower, then neither does firm L. The only relevant condition for a clustering equilibrium to hold is $V_{Lt}^s \leq V_{Lt}^c$.

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