Product Market Competition and Corporate Real Estate Investment under Demand Uncertainty*

Brent Ambrose†
Moussa Diop‡
Jiro Yoshida§

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Abstract

This paper theoretically and empirically analyzes the interactions among corporate real estate investment, product market competition, and firm risk. In our model, firms own strategic real estate or lease generic real estate. Our model predicts that strategic real estate ownership is positively correlated with industry concentration and negatively related to demand uncertainty. Also, firm risk is higher for firms with more strategic real estate operating in a more concentrated market. This prediction arises because smaller investments induce greater market competition, which effectively eliminates the right tail of the firm’s profit distribution. We provide strong empirical support for our predictions. In particular, firm value is more volatile in less competitive markets for a given level of demand uncertainty.


Keywords: strategic investment, entry deterrence, real options, flexibility, firm risk

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†Smeal College of Business, The Pennsylvania State University, University Park, PA 16802-3306, Email: bwa10@psu.edu
‡Wisconsin School of Business, University of Wisconsin, Madison, WI 53706, Email: mdiop@bus.wisc.edu.
§Smeal College of Business, The Pennsylvania State University, University Park, PA 16802, Email: jiro@psu.edu.
Abstract

This paper theoretically and empirically analyzes the interactions among corporate real estate investment, product market competition, and firm risk. In our model, firms own strategic real estate or lease generic real estate. Our model predicts that strategic real estate ownership is positively correlated with industry concentration and negatively related to demand uncertainty. Also, firm risk is higher for firms with more strategic real estate operating in a more concentrated market. This prediction arises because smaller investments induce greater market competition, which effectively eliminates the right tail of the firm’s profit distribution. We provide strong empirical support for our predictions. In particular, firm value is more volatile in less competitive markets for a given level of demand uncertainty.

*JEL Classification:* R33, G31, L13.

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Introduction

Firms invest in real estate for various reasons. A firm may employ generic real estate when it does not play a special role in corporate activities. For example, generic office or storage space simply provides shelter and the user is generally indifferent between similar facilities; such space is a commodity that can be quickly reconfigured to meet a variety of space needs. Users typically lease generic space from tax-efficient property owners such as real estate investment trusts to make shelter as flexible and cheap as possible. Alternatively, a firm can strategically invest in real estate when it plays a special or irreplaceable role. Firms typically own such firm-specific facilities and acquire them through ground-up development or by renovating existing properties for a long-term use. For example, Apple, Inc. has proposed spending $5 billion to build a new, 2.8-million-square-foot, specialized headquarters facility with an R&D function.\(^1\) This firm-specific real estate located in the heart of Silicon Valley may bolster the firm’s competitive position by increasing employee loyalty and demonstrating the company’s commitment to research and development.

Our study centers on real estate investment decisions by firms whose core business activities are not directly related to the development, investment, management, or financing of real estate properties. For these firms, corporate real estate is a factor of production, similar to labor or other inputs (Tuzel, 2010). Typically, a firm’s capital investments consist of assets necessary for production, including physical capital as well as intangible capital such as patents and human capital (labor). Real estate (including manufacturing facilities, warehouses, office buildings, equipment, and retail outlets) represents one of the largest physical capital investment categories. Far from being marginal, real estate represents an important investment that corporations must make in order to competitively produce the goods and services required by their customers. To underscore its importance, we note that real estate owned by non-real estate, non-financial corporations was valued at $7.76 trillion in 2010, accounting for roughly 28% of total assets.\(^2\) However, its bulkiness, large and asymmetric adjustment costs, and relative illiquidity limit the ability to maintain an optimal level of real estate as demand fluctuates.\(^3\)

\(^1\)http://www.businessweek.com/articles/2013-04-04/apples-campus-2-shapes-up-as-an-investor-relations-nightmare
\(^2\)Source: http://www.federalreserve.gov/releases/z1/20110310/
\(^3\)Dixit and Pindyck (1994) note that real estate investments may provide firms with options to grow production.
Some firms hold greater amounts of corporate real estate than others (Liow, 2004; Brounen and Eichholtz, 2005). What creates this cross-sectional variation in corporate real estate investment? Moreover, do strategic corporate real estate investments make firms safer or riskier? Recent research has identified various channels through which capital investments affect the risk characteristics of stock returns. For example, corporate investments affect the risk of stock returns by changing financial and operating leverage, the proportion and type of growth options, and the ability to capture positive economic shocks (e.g., Berk et al., 1999; Carlson et al., 2004; Cooper, 2006; Tuzel, 2010; Kogan and Papanikolaou, 2013, 2014; Babenko et al., 2014). Furthermore, corporate investment decisions may reveal information regarding shifting investment opportunities (e.g., Cochrane, 1991; Liu et al., 2009). However, the analysis of how financial policy can affect firm risk is complicated by the need to recognize that managers must optimize among various forms of capital investments having differing degrees of flexibility and efficiency.\(^4\) In addition, capital investments can have significant implications on the firm’s product market. We argue that demand uncertainty and the entry deterrence effect of firm-specific corporate real estate critically affects the attractiveness of these investments, the competitive landscape, and ultimately the firm’s risk.

We emphasize the effect of strategic real estate investments on the product market structure. For example, in the retail industry, firms often make investments in multiple outlets in an effort to preempt entry of competitors (for example, see Igami and Yang, 2014). In view of broader corporate assets, industries with large fixed capital investments (such as aircraft, computer, and automobile manufactures) are often characterized by fewer competitors than industries without large capital investments (such as the legal profession, software developers, and service providers). The interaction between capital investments and product market competition has been intensively studied in the industrial organization literature (e.g., Spence, 1977; Dixit, 1980; Bulow et al., 1985; Allen et al., 2000, and many others.) However, these studies are often silent about the risk characteristics of stock returns.

In this study, we analyze the effect of corporate real estate holdings on product market competition and firm risk. To motivate our empirical analysis, we develop a model that allows us to study

\(^4\)For example, Rutherford (1990), Alayyay et al. (1995), Fisher (2004), and Benjamin et al. (2011) study impacts of sale and leaseback. Ambrose (1990) and Brounen et al. (2008) study the effect of corporate real estate ownership on takeovers.
how management decisions regarding corporate real estate investments affect competition within the firm’s product market. Most components of our model are straightforward and consistent with well-established results in the literature. Our contribution is to integrate the fragmented knowledge about corporate real estate investment, competitive industry structure, and firm value in a single model and derive new insights into the link between strategic real estate investments and firm risk. We then empirically test key predictions of the model by using U.S. corporate data. Without a model, one might casually conjecture that firms with significant real estate holdings that operate in less competitive industries would exhibit lower risk than firms in more competitive industries because firms with greater market power may be able to protect themselves from market risk. Contrary to this conjecture, our model and empirical analysis indicate that firms with strategic real estate investments in less competitive industries exhibit higher risk for a given level of demand uncertainty. This is an often overlooked cost in a market with limited competition.

Our model is based on the observation that real estate can be either strategic (and often owned), which may offer strategic advantages, or flexible (more often leased) that can be easily utilized by multiple firms. The inflexibility of corporate real estate may result from its fixed location or idiosyncratic physical characteristics while more flexible or generic corporate real estate, such as office space, can be quickly reconfigured to meet a variety of firms’ space needs. In our two-stage investment model, one of \( n + 1 \) ex-ante homogeneous firms precedes the other firms by acquiring inflexible but efficiency-improving real estate. We refer to this as a strategic real estate investment as it demonstrates the firm’s credible commitment to production. The other \( n \) firms can subsequently lease generic but less efficient real estate when the realized demand is sufficiently large. The generic real estate is also available for the leading firm for capacity expansion. To counter potential competition, the leading firm takes into consideration the entry deterrence effect of the initial strategic real estate investment. This leader-follower structure better captures the actual corporate behavior for many industries than a simultaneous-move structure. We solve a subgame-perfect Nash equilibrium and endogenously derive the firm’s optimal early investment in strategic real estate and subsequent investment in generic real estate, the resulting product market competition,

\[ \textit{Although our model is predicated on the observation that real estate investments can be firm-specific or generic, the recognition of heterogeneity in capital investments is not new. For example, Gersbach and Schmutzler (2012) derive a model that allows for strategic investments in labor that produces similar insights and He and Pindyck (1992) analyze flexible and inflexible capacity investment decisions.} \]
and the systematic risk of corporate assets for a given level of demand uncertainty.

Our primary result is that state-contingent competition makes firms less risky because other firms’ options to enter the market eliminate the right tail of the leading firm’s value distribution. Competitors can enter the market and take profits away from the leading firm when demand is high but stay away from the market if demand is low. However, without a competitor, the leading firm can earn large profits under high demand by expanding its production. Thus, both the expected value and the unconditional variance of the leading firm’s value is greater in a more concentrated market. This finding is closely related to the studies by Aguerrevere (2009), Novy-Marx (2007), and Babenko et al. (2014). In particular, Aguerrevere (2009) shows how an exogenously given market structure impacts the risk and returns on firm assets. The key insights from his model are that firms in concentrated markets are less risky when demand is low but they are riskier when demand is high and an option to expand is more valuable. His prediction under high demand agrees with ours. In deriving these insights, Aguerrevere’s model assumes a symmetric Nash equilibrium in a repeated Cournot competition among a given number of existing firms that invest in homogeneous capital. Babenko et al. (2014) also derive a lower firm risk under high demand although they do not take into account an entry deterrence effect of investment. Novy-Marx (2007) also recognizes a skewed return distribution but it is caused by asymmetric adjustment costs of capital for a given size of industry rather than state-contingent competition. Our analysis relaxes these assumptions and endogenizes the market structure to derive new insights concerning the role of strategic real estate investment.

Other results of our model establish two sources for the negative relation between market competition and corporate real estate investment. First, irreversible investments in strategic corporate real estate assets have a strong entry deterrence effect under small uncertainty (a causal relation). The causal relation suggests that the leading firm’s investment in strategic real estate indicates the firm’s commitment to production. As a result, other firms only enter or stay in the market when demand is sufficiently large to support the total production by the leading firm and all other competitors. Thus, a larger amount of strategic real estate investment increases the probability of monopolizing the market. It is an uncertainty-augmented version of an entry deterrence effect that was established in the industrial organization literature. Second, uncertainty regarding mar-
ket demand increases competition but decreases investment in corporate real estate (a confounding factor). On one hand, competition with other firms is more likely when demand uncertainty is high. This is because high levels of uncertainty imply a greater probability of experiencing a large positive demand shock that encourages entry. This is an extension of the results of Pindyck (1988) and Maskin (1999), who show that leading firms need to employ a larger amount of capital to deter entry when demand is more uncertain. On the other hand, when demand uncertainty is high, the leading firm employs a small amount of strategic real estate to avoid large losses under possible weak demand and thus relies more on leasing subsequent generic real estate if realized demand is strong. This arises as a consequence of the leading firm’s option to wait (e.g., Dixit and Pindyck, 1994). Thus, demand uncertainty is a confounding factor of a positive equilibrium relation between strategic corporate real estate investment and market concentration.

Our model provides a formal mechanism for answering a variety of questions concerning corporate real estate investment. For example, why are industries with large fixed investments in property, plant, and equipment characterized by few competitors? Similarly, why are industries without large capital investment (such as the legal profession, software developers, and service providers) characterized by having large numbers of competitors? A concrete example illustrating the potential effect of strategic corporate real estate investment on competition comes from the consolidation in the automobile manufacturing industry during the first part of the 20th Century. At the beginning of the 20th Century, the U.S. had several hundred small automobile manufacturers. However, by the 1930’s, the industry had consolidated into a handful of firms dominated by the “Big Three.” One of the factors leading to this consolidation was the Ford Motor Company’s investment in firm-specific capital in the form of the sprawling River Rouge manufacturing plant beginning in 1917. The massive River Rouge plant was capable of processing iron ore and other raw materials into finished products in a continuous production line, providing Ford with significant economies

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6 Although Grenadier (2002) demonstrates that competition erodes an option premium and makes the model equivalent to Tobin’s q model (e.g., Hayashi, 1982), a premium will be preserved under imperfect competition (Novy-Marx, 2007). This effect is also empirically confirmed (e.g., Holland et al., 2000; Ott et al., 2008).

7 We do not preclude alternative explanations such as shifting investment opportunities and technological changes. Our explanation is complementary to these existing explanations.

8 Estimates are that over 500 automobile manufacturers entered the U.S. market between 1902 and 1910. (Source: “The Automobile Industry, 1900-1909” accessed on June 1, 2014 at http://web.bryant.edu/~ehu/h364/materials/cars/cars_10.htm)
of scale.  

To empirically verify our model, our analysis uses data from Compustat on public, non-real estate firms for the period from 1984 to 2012. The results are consistent with all predictions. First, industry concentration is positively related to strategic corporate real estate assets and negatively related to demand uncertainty after controlling for industry characteristics and year fixed effects (Predictions 1 and 2). Approximately 27% of the total explanatory power comes from the factors captured by corporate real estate and demand uncertainty, and the remaining 73% comes from various industry characteristics that are uncorrelated with these factors. More specifically, strategic corporate real estate that was acquired several years before production has a larger impact on market concentration than more recently acquired real estate, implying a time lag for changes in market structure. Also, the market structure is affected by the demand uncertainty observed at the time of production rather than by previously made forecasts. We also find that these effects of corporate real estate and demand uncertainty are counter-cyclical. Second, demand uncertainty forecasts negatively affect the amount of corporate real estate (Prediction 3). Specifically, our result is robust to the use of 4, 8, and 12-quarter ahead forecasts of demand uncertainty and the use of 20 and 40-quarter rolling volatility measures. Finally, we report that the firm value volatility is higher in more concentrated markets for a given level of demand uncertainty. This relation holds during both high and low demand periods (Prediction 4).

Our paper proceeds as follows. Section gives a general presentation of the model, which is then restricted to the case of a linear demand curve. Section presents our empirical analysis with a description of the sample in section and a discussion of the main findings in section . Finally, section concludes.

Model

We develop a dynamic model of corporate real estate investment under demand uncertainty. Following Dixit (1980) and Bulow et al. (1985), we assume that firms make investment and production

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decisions in a two-period (i.e., three-date) setting. The model features a leader-follower structure with a focus on the leading firm’s strategic investment. Figure 1 outlines the time line. We first characterize an asymmetric Nash equilibrium in a general setting without specifying functional forms for demand or production cost. Next, we numerically analyze the model by specifying a linear demand function and a quadratic cost function.

To frame the basic problem and establish a benchmark, we begin by assuming a monopoly environment where a firm (Firm 1) produces a good during the second period to sell in the market at $t_2$. Using the results from this base case, we then consider a potentially oligopolistic market structure where the leading firm may compete with other firms (e.g., oligopoly with $n$ other firms and full competition with an infinite number of firms).

**Monopoly Case**

At $t_0$, the firm decides the initial size of production capital (e.g., amount of factories, equipment, and corporate real estate) and builds that capital during the first period by customizing it to an efficient production process. We refer to corporate real estate acquired during the first period as inflexible strategic real estate ($K_{s1}$) since the firm cannot reduce its initial capacity even if the realized demand shock is weak, and it potentially serves as an entry deterrent as we demonstrate in the following sections. As a result, strategic real estate incurs a high fixed cost and a low variable cost of production. The firm pays a one-time fixed cost at $t_0$ to enter the market and pays the costs of capital and depreciation at $t_2$.

At $t_1$, the firm observes a random demand shock ($\varepsilon$) revealing the price level. Based on this observation, it potentially revises its production plan upward by renting additional flexible (generic) corporate real estate, denoted as $K_{g1}$. Although the firm can choose either generic or strategic real estate for production, a key advantage of generic real estate is that it offers the firm flexibility in setting up its production process in the face of an uncertain demand shock. We assume that the rent payments for the generic real estate are due at $t_2$, and this rental rate, which is determined in a competitive rental market, is less than the cost of strategic real estate because of the higher resale

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10 This is the simplest form of multi-period models to analyze long-term commitments. Extending the production period does not change our result.
value associated with generic real estate. That is, generic real estate is not unique to the firm’s production process and thus could be utilized by firms in other markets with little redeployment costs. However, generic real estate entails a higher production cost because it is not customized to a specific production process. As a result, Firm 1 trades off production efficiencies (and their lower production costs) that accrue to investment in inflexible capital at $t_0$ with less efficient (higher cost) production associated with the more flexible, generic capital acquired at $t_1$.

The total amount of strategic and generic real estate represents the scale of production, $F(K_s, K_g) = K_s + K_g$, and the variable cost of production is increasing and convex in quantity:

$$C_1 = C_1(K_{s1}, K_{g1}) \quad s.t., \quad \frac{\partial C_1}{\partial K_{s1}} > 0, \quad \frac{\partial^2 C_1}{\partial K_{s1}^2} > 0, \quad \frac{\partial^2 C_1}{\partial K_{g1}^2} > 0, \quad \frac{\partial^2 C_1}{\partial K_{s1} \partial K_{g1}} > 0. \quad (1)$$

The existence of a fixed cost and a convex variable cost implies that average total cost is U-shaped, which is consistent with a production technology that exhibits first increasing returns to scale, then constant returns to scale, and eventually decreasing returns to scale. For example, at a low production level, optimal production can exhibit economies of scale as capital intensity increases. At a larger scale, limitations to some factor inputs create diseconomies of scale because other factors exhibit diminishing marginal products. Standard microeconomics textbooks regard this production function as the most realistic. We also assume the firm faces an inverse demand function $P$ with the following properties:

$$P = P(K_{s1}, K_{g1}, \varepsilon), \quad s.t., \quad \frac{\partial P}{\partial \varepsilon} > 0, \quad \frac{\partial^2 P}{\partial \varepsilon^2} = 0, \quad \frac{\partial P}{\partial K_{s1}} < 0, \quad \frac{\partial P}{\partial K_{g1}} < 0, \quad (2)$$

where $\varepsilon$ is a random variable that represents the demand shock. The realized value of the demand shock at $t_1$ is denoted by $\bar{\varepsilon}$. Solving the firm’s choices regarding real estate investment by backward induction, we note that Firm 1 chooses the amount of generic real estate ($K_{g1}$) at $t_1$, taking $K_{s1}$ and $\bar{\varepsilon}$ as given. Thus, at $t_1$ Firm 1 solves the following profit maximization problem

$$\max_{K_{g1}} \Pi_1 = P(K_{s1}, K_{g1}, \bar{\varepsilon}) \times (K_{s1} + K_{g1}) - C_1(K_{g1}). \quad (3)$$

$^{11}$He and Pindyck (1992) make the same assumption about the cost associated to flexible capital since it can interchangeably be used to produce either of two products whereas inflexible capital is product-specific in their model.
The first order condition (FOC) and second order condition (SOC) determine the optimal $K_{g1}$. If the optimal $K_{g1}$ is zero or negative, then Firm 1 does not employ generic real estate. Since the sign of the optimal $K_{g1}$ positively depends on the realized demand shock, this sign condition gives a threshold value of $\bar{\varepsilon}$. Thus, the solution is:

$$
K_{g1}^M(K_{s1}, \bar{\varepsilon}) \quad \text{if } \bar{\varepsilon} > \varepsilon^M
$$

$$
0 \quad \text{otherwise.}
$$

(4)

Because of this nonlinearity in the optimal amount of generic real estate, the maximized profit of Firm 1 is also a nonlinear function of the demand shock. This option-like feature creates the effect of demand volatility on the initial choice of the amount of strategic real estate investment. Furthermore, the threshold value $\varepsilon^M$ depends on the amount of $K_{s1}$ and thus, also affects the initial choice of strategic real estate investment.

At $t_0$, Firm 1 chooses $K_{s1}$ by maximizing its expected profit where the product price and $K_{g1}$ are uncertain because they depend on the random variable $\varepsilon$. Furthermore, $K_{g1}$ is a nonlinear function of $\varepsilon$ due to the state contingency exhibited in Equation (4). Thus, Firm 1 faces the following optimization:

$$
\max_{K_{s1}} E \left[ \Pi_1^M(K_{s1}, K_{g1}, \varepsilon) \right]
= E \left[ \Pi_1^M(K_{s1}, K_{g1}^M, \varepsilon) \mid \bar{\varepsilon} > \varepsilon^M(K_{s1}) \right] Pr(\bar{\varepsilon} > \varepsilon^M(K_{s1}))
+ E \left[ \Pi_1^M(K_{s1}, 0, \varepsilon) \mid \bar{\varepsilon} \leq \varepsilon^M(K_{s1}) \right] Pr(\bar{\varepsilon} \leq \varepsilon^M(K_{s1}))
$$

(5)

where $\Pi_1^M$ denotes Firm 1’s profit function and the superscript “M” denotes the monopoly market environment. $Pr(\mathcal{A})$ denotes the probability of event $\mathcal{A}$ and $E[\bullet \mid \mathcal{A}]$ denotes the expectation operator conditional on event $\mathcal{A}$. Equation (5) exhibits state contingency; the first term represents the profit generated by both strategic and generic real estate when the demand shock is large, and the second term represents the profit generated only by strategic real estate when the demand shock is small. Because Firm 1 produces at full capacity even if the demand level is low, the firm compares potential losses from too large an investment in strategic real estate in bad states with the extra costs of employing generic real estate in good states. We denote the solution to this
problem as
\[
\begin{cases}
K_{s1}^M & \text{if } E\left[\Pi_1^M(K_{s1}^M, K_{g1}^M, \varepsilon)\right] > 0 \\
0 & \text{otherwise.}
\end{cases}
\] (6)

By plugging Equations (4) and (6) back into the profit function and evaluating it on a distribution of \(\varepsilon\), we obtain the ex post distribution of firm profits. In our two period setting, the final profit is interpreted as the sum of all future discounted cash flows; i.e., the firm value. In particular, we are interested in the firm risk as defined by:

\[
Var\left[\Pi_1^M(K_{s1}^M, K_{g1}^M, \varepsilon)\right],
\] (7)

where \(Var[\cdot]\) denotes the variance.

**Case of Potential Oligopoly**

Having established the base conditions for the firm’s choice of strategic and generic real estate under the assumption of a monopoly environment, we now consider a subgame-perfect Nash equilibrium in an oligopoly market, in which one of \(n + 1\) ex-ante homogeneous firms (Firm 1) precedes the other firms by acquiring strategic real estate. Firm 1 is faced with potential competitions with \(n\) identical firms (Firm \(i, i = 2, \ldots, n + 1\) without coalitions) at \(t_1\). Firm \(i\) observes Firm 1’s strategic real estate investment and the realized demand shock before deciding whether to pay a one-time fixed cost and enter the market.\(^{12}\) The follower firms only employ generic real estate \((K_{gi})\) for production and face an increasing and convex cost function:

\[
C_i = C_i(K_{gi}), \quad \text{s.t.,} \quad \frac{\partial C_i}{\partial K_{gi}} > 0, \quad \frac{\partial^2 C_i}{\partial K_{gi}^2} > 0.
\] (8)

In a market characterized as an oligopoly, the inverse demand function \(P\) now has the following properties:

\[
P = P\left(K_{s1}, K_{g1}, \sum_{i=2}^{n+1} K_{gi}, \varepsilon\right), \quad \text{s.t.,} \quad \frac{\partial P}{\partial \varepsilon} > 0, \quad \frac{\partial^2 P}{\partial \varepsilon^2} = 0, \quad \frac{\partial P}{\partial K_{s1}} < 0, \quad \frac{\partial P}{\partial K_{g1}} < 0, \quad \frac{\partial P}{\partial K_{gi}} < 0.
\] (9)

\(^{12}\) No entry and the resulting monopoly can also be interpreted as the exit of existing competitors.
As in the monopoly case, the demand curve is downward sloping.

In this market environment, firms compete in the product market at \( t_2 \). Thus, taking the competitive environment into account, each firm chooses the amount of generic real estate at \( t_1 \). Firm 1 also chooses the amount of strategic real estate at \( t_0 \) by taking into account its effect on the competitive environment of the product market. For example, as will be discussed below, a sufficiently large investment in \( K_{S1} \) by Firm 1 could serve as a deterrent to potential entrants, leading to a monopoly product market.

At \( t_1 \), each entrant chooses \( K_{gi} \), taking \( K_{s1}, K_{g1}, K_{gj} j \neq i \), and the realized value of demand shock \( \bar{\varepsilon} \) as given in order to solve the following profit maximization problem:

\[
\max_{K_{gi}} \Pi_i \equiv P \left( K_{s1}, K_{g1}, \sum_{i=2}^{n+1} K_{gi}, \bar{\varepsilon} \right) \times K_{gi} - C_i(K_{gi}).
\]  

where \( \Pi_i \) is the profit of Firm \( i \). The solution is:

\[
\begin{cases}
K^O_{gi}(K_{s1}, K_{g1}, K_{gj}; j \neq i, \bar{\varepsilon}) & \text{if } \max \Pi_i \geq 0 \\
0 & \text{otherwise}.
\end{cases}
\]

because the maximized profit can be negative due to the fixed cost of entry. This condition implicitly gives a lower bound of the demand shock \( \bar{\varepsilon} \) because \( \partial \Pi_i / \partial \bar{\varepsilon} > 0 \). Thus, the optimal \( K_{gi} \) is:

\[
\begin{cases}
K^O_{gi}(K_{s1}, K_{g1}, K_{gj}; j \neq i, \bar{\varepsilon}) & \text{if } \max \Pi_i \geq 0 \\
0 & \text{otherwise}.
\end{cases}
\]

where the “O” superscript denotes the oligopoly market environment. If Firm \( i \) decides not to enter the market due to a low demand level, then the market devolves to a monopoly of Firm 1.

Similar to Firm \( i \), Firm 1 also chooses \( K_{g1} \) at \( t_1 \), taking \( K_{s1}, K_{gi;j=i=2,...,n+1} \), and \( \bar{\varepsilon} \) as given by solving the problem that is equivalent to Equation (3) with the respective first and second order conditions. The solution is:

\[
\begin{cases}
K^O_{g1}(K_{s1}, K_{gi}; i=2,...,n+1, \bar{\varepsilon}) & \text{if } \bar{\varepsilon} > \varepsilon^O \\
0 & \text{otherwise}.
\end{cases}
\]
The threshold value $\varepsilon^O$ depends on $K_{gi}$ and $K_{s1}$ and thus, affects the initial choice of strategic real estate.

When both the leader and the follower firms employ positive amounts of generic real estate, the strategic environment in the second period becomes a Cournot competition. The Cournot Nash equilibrium is symmetric among the identical entrants and asymmetric between the leader and entrants. The Cournot Nash equilibrium levels of generic real estate, $K^E_{g1}$ and $K^E_{gi}$, are expressed as:

$$K^E_{g1} = K^O_{g1} \left( K_{s1}, \bar{\varepsilon} \right), \tag{14}$$

$$K^E_{gi} = K^O_{gi} \left( K_{s1}, K^E_{g1} \left( K_{s1}, \bar{\varepsilon} \right), \bar{\varepsilon} \right). \tag{15}$$

Firm $i$’s entry condition (11) gives a threshold value of demand shock $\varepsilon^*$ such that $\Pi_i(K_{gi}^{E}(K_{s1}, \varepsilon^*), \varepsilon^*) = 0$. Thus, Firm $i$ will enter the market if $\bar{\varepsilon} \geq \varepsilon^*$. We also define the threshold value for Firm 1’s expansion in this Cournot equilibrium, $\varepsilon^E$, which equals $\varepsilon^O$ evaluated at $K^E_{g1}$.

Therefore, we obtain the following entry deterrence effect of strategic real estate:

**Proposition 1.** When demand function is an affine function of price, Firm 1’s strategic real estate always has an entry deterrence effect:

$$\frac{d\varepsilon^*}{dK_{s1}} > 0. \tag{16}$$

*For more general demand functions, the existence of the entry deterrence effect depends on parameter values.*

**Proof.** Proof. See Appendix A.

Firm 1’s profit is affected by whether the market becomes a monopoly or oligopoly. Thus, there are three variations in Firm 1’s problem depending on the relation among the firms’ threshold values: (1) $\varepsilon^M < \varepsilon^E < \varepsilon^*$; (2) $\varepsilon^M < \varepsilon^* < \varepsilon^E$; and (3) $\varepsilon^* < \varepsilon^M < \varepsilon^E$. We present the second variation
below and other variations in Appendix C:

\[
\max_{K_{s1}} E [\Pi_1 (K_{s1}, K_{g1}, K_{gi}, \varepsilon)] \\
\equiv E [\Pi_1^O (K_{s1}, K_{g1}^E, K_{gi}^E, \varepsilon) | \bar{\varepsilon} > \varepsilon^E (K_{s1})] \Pr (\bar{\varepsilon} > \varepsilon^E (K_{s1})) \\
+ E [\Pi_1^O (K_{s1}, 0, K_{gi}^E, \varepsilon) | \varepsilon^* (K_{s1}) \leq \bar{\varepsilon} \leq \varepsilon^E (K_{s1})] \Pr (\varepsilon^* (K_{s1}) \leq \bar{\varepsilon} \leq \varepsilon^E (K_{s1})) \\
+ E [\Pi_1^M (K_{s1}, K_{g1}^M, \varepsilon) | \varepsilon^M (K_{s1}) < \bar{\varepsilon} < \varepsilon^* (K_{s1})] \Pr (\varepsilon^M (K_{s1}) < \bar{\varepsilon} < \varepsilon^* (K_{s1})) \\
+ E [\Pi_1^M (K_{s1}, 0, \varepsilon) | \bar{\varepsilon} \leq \varepsilon^M (K_{s1})] \Pr (\bar{\varepsilon} \leq \varepsilon^M (K_{s1}))
\] (17)

where \(\Pi_1^O\) denotes Firm 1’s profit function in the oligopoly market. In this problem, state contingency arises from both Firm 1’s own option to expand and Firms \(i\)’s option to enter the market. The four terms on the right hand side of Equation (17) corresponds to four possible types of market structures: (1) Both leader and followers employ generic real estate in a Cournot competition; (2) Only followers employs generic real estate and compete with the leader; (3) The leader monopolizes the market with both strategic and generic real estate; and (4) No firm employs generic real estate and the leading firm monopolizes the market with strategic real estate. We denote the solution to this problem as

\[
K_{s1}^O \quad \text{if } E [\Pi_1^O (K_{s1}^O, K_{g1}^E, K_{gi}^E, \varepsilon)] > 0 \\
0 \quad \text{otherwise.}
\] (18)

The solution is characterized in a usual way by FOC and SOC.\(^{13}\) Based on the equilibrium solution, we can analyze the expectation about the equilibrium market structure by the probability of monopoly:

\[
\Pr (\varepsilon < \varepsilon^* (K_{s1}^O)).
\] (19)

Finally, we obtain the firm risk by considering possibilities of both monopoly and oligopoly. In particular, we are interested in the ratio of the firm risk under potential oligopoly to the firm risk under monopoly when the distribution of \(\varepsilon\) is given: i.e.,

\[
\frac{\text{Var} [\Pi_1^O (K_{s1}^O, K_{g1}^E, K_{gi}^E, \varepsilon)]}{\text{Var} [\Pi_1^M (K_{s1}^M, K_{g1}^M, \varepsilon)]}.
\] (20)

\(^{13}\)Technically, the Leibniz integral rule is applied to conditional expectations to derive partial derivatives of the expected profit with respect to strategic real estate.
**Linear demand and quadratic cost function**

To illustrate more concrete predictions of the model, we specify simple functions for the demand and production costs. First, we set the inverse demand function as linear in quantity: \( P = A - BQ + \varepsilon \), where \( P \) is the product price, \( Q \) is the product quantity, \( A \) and \( B \) are non-negative constants, and \( \varepsilon \) is a random variable that represents demand shocks. \( \varepsilon \) is drawn from a uniform distribution \( U(-\sqrt{3}\sigma, \sqrt{3}\sigma) \) with \( \sigma > 0 \). Its mean and variance are \( E[\varepsilon] = 0 \) and \( Var[\varepsilon] = \sigma^2 \). This demand function is well-defined on \( \{ Q : Q > 0 \text{ and } BQ < A - \sqrt{3}\sigma \} \). In a competitive market, \( B = 0 \). In the monopoly market, \( Q = K_{s1} + K_{g1} \). For the oligopoly market, we focus on the case of one competitor \((n = 1)\): \( Q = K_{s1} + K_{g1} + K_{g2} \) because analyzing a larger number of competitors does not give additional insights (nevertheless, we provide solutions of the \( n \)-entrant case in Appendix D).

The marginal cost of production is linear in quantity:

\[
\begin{align*}
\text{Firm 1:} & \quad \begin{cases} 
\alpha K & \text{for } 0 \leq K \leq K_{s1}, \\
\alpha K_{s1} + \beta (K - K_{s1}) & \text{for } K > K_{s1}.
\end{cases} \\
\text{Firm 2:} & \quad \beta K,
\end{align*}
\]

where \( \beta > \alpha > 0 \). \( \alpha \) and \( \beta \) correspond to the slope of the marginal cost line for strategic and generic real estate, respectively. The user cost of real estate, which is paid at \( t_2 \), is \( sK_{s1} + gK_{g1} \) and \( gK_{g2} \) for Firms 1 and 2, respectively. The parameter \( s \) denotes the user cost of strategic real estate for two periods; i.e., \( s = r(1+r) + (r+\delta) \), where \( r(1+r) \) is the compounded interest cost for the first period, and \( r+\delta \) is the sum of interest and depreciation costs for the second period. The parameter \( g \) denotes the rental rate of generic real estate for one period, which compensates for the interest and depreciation costs for the lessor. The depreciation rate is smaller for generic real estate than for strategic real estate because the resale value of strategic real estate is low due to customization. Given these costs, the total cost functions for Firms 1 and 2 become quadratic
in quantity:

\[ C_1(K_{s1}, K_{g1}) = (1 + r)^2 f + sK_{s1} + gK_{g1} + \frac{\alpha}{2} K_{s1}^2 + \alpha K_{s1} K_{g1} + \frac{\beta}{2} K_{g1}^2, \quad (23) \]

\[ C_2(K_{g2}) = (1 + r)f + gK_{g2} + \frac{\beta}{2} K_{g2}^2, \quad (24) \]

where \( f \) is the fixed cost of entry. \( C_1 \) and \( C_2 \) satisfy the conditions specified in Equations (1) and (8).

The solutions are presented in Appendix D to both firms’ problems for each market structure; i.e., \( K^C_{g2} \) and \( K^O_{g2} \) for Firm 2, and \( K^C_{g1}, K^M_{g1}, K^O_{g1}, K^C_{s1}, K^M_{s1} \), and \( K^O_{g1} \) for Firm 1. Because these solutions are long polynomial equations, we specify a set of numerical parameter values that satisfies the regularity conditions for the demand function and probabilities in the case of Equation (C.1a): \( B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2, \) and \( f = 3.2 \). The demand level 4 is set at 4.3. We change demand uncertainty \( \sigma \) from 0.6 to 2 to obtain our theoretical predictions. These parameter values guarantee the existence of a unique equilibrium but are not intended to represent realistic values of an actual economy.

Figure 2 depicts the equilibrium outcome of the model for different levels of demand uncertainty. Panel (a) shows the equilibrium amount of strategic real estate as defined by Equation (18). We find a negative effect of demand uncertainty on strategic real estate investment, confirming a standard result in the real options literature. This effect is created by a trade-off for Firm 1 between an immediate investment in strategic real estate and the use of generic real estate after uncertainty is resolved. If the ex post market demand turns out to be strong, the firm benefits from a more efficient production by using strategic real estate than by expanding its operations with generic real estate. However, if the market demand is weak, strategic real estate result in losses. Thus, because potential losses increase with uncertainty, Firm 1 employs a smaller amount of strategic real estate when demand is more uncertain.

In addition, Firm 1 employs greater amounts of strategic real estate in the potential oligopoly market than in the monopoly market (see Figure 7b in Appendix E). This extra amount of investment in the potential oligopoly market is motivated by the additional desire of deterring entry of potential competitors. In a potential oligopoly market characterized by lower uncertainty, the excess
amount of strategic investment becomes smaller because Firm 1 can deter entry more successfully. Furthermore, Figure 3 plots the probability of monopoly against the optimal amount of strategic real estate. This figure indicates the role of strategic real estate in potential entry deterrence.

Panel (b) of Figure 2 depicts the probability that Firm 1 monopolizes the market by successfully deterring entry as measured by Equation (19). The entry deterrence is less effective when demand uncertainty is large. For example, when $\sigma = 0.6$, the probability of monopoly is 99.9%. In contrast, when $\sigma = 2.0$, the probability of monopoly declines to 63.7%. This is because the probability that the actual demand is greater than the entry threshold ($\varepsilon^*$) increases when demand uncertainty is larger (see Figure 8b in Appendix E).

As demand uncertainty increases, Firm 1 needs to increase strategic real estate to deter entry. However, a large investment is not optimal because it will cause a large loss under weak demand. In equilibrium, Firm 1 chooses a smaller amount of strategic real estate under larger uncertainty and accepts imperfect entry deterrence. This is a new finding that is not demonstrated in the existing studies. For example, Maskin (1999) only shows that uncertainty makes entry deterrence more difficult and necessitates a larger amount of capital for entry deterrence. We further demonstrate that complete entry deterrence is not only difficult but also suboptimal when losses from overcapacity arising from uncertainty are taken into account.

Panel (c) depicts the variance of Firm 1 value under potential oligopoly relative to the variance under perfect monopoly. Note that the volatility of firm value in this model represents the systematic risk (i.e., the market beta) of the firm value as in Aguerrevere (2009) because firm value is perfectly correlated with the sole uncertainty in the economy. The ratio slopes downward as demand uncertainty rises, indicating that firm risk under potential oligopoly does not increase as much as firm risk under monopoly.\(^{14}\) When the monopoly structure is imposed, the volatility of profits is almost directly proportional to demand volatility because the demand uncertainty is absorbed by one firm. In particular, the monopoly firm captures the entire profit arising from large demand by exercising the option to expand. In contrast, in the potential oligopoly market, the profit resulting from high demand must be shared with competitors that enter the market. Since a large upside potential is absent for the leading firm due to the endogenous change in market structure, the expected firm

\(^{14}\)This is explicitly shown in Figure 10 in Appendix E.
value is lower but at the same time firm risk is reduced.

**Empirical Predictions**

Our model generates four inter-related predictions. First, we expect a positive equilibrium relation between strategic corporate real estate and market concentration (see Figure 3).

**Prediction 1.** *Market concentration and strategic real estate are positively correlated in equilibrium.*

Second, as noted in Panel (b) of Figure 2, the probability of market competition increases as demand uncertainty increases. Our model suggests that when demand uncertainty is high, a firm’s ability to deter entry is smaller for a given amount of strategic real estate. Thus, our second prediction is:

**Prediction 2.** *Market concentration increases as demand uncertainty declines.*

Third, as seen in Panel (a) of Figure 2, greater demand uncertainty causes the firm’s option to expand to be more valuable. In addition, uncertainty makes strategic real estate less effective in entry deterrence. Thus, the firm employs a smaller amount of strategic real estate when faced with greater uncertainty. This observation leads to the third prediction:

**Prediction 3.** *The amount of strategic real estate utilized by firms is greater when demand uncertainty is smaller.*

Finally, from Figure 2 (and Figure 10 in Appendix E), we obtain the last prediction:

**Prediction 4.** *The volatility of firm value is less than directly proportional to the demand volatility and the slope is steeper in a more concentrated market.*

Our predictions concerning the interaction of competition and strategic real estate were generated from a stylized two-period model. Thus, in order to empirically test these predictions, we must adjust the stylized predictions to reflect a multi-period world. For example, the model does not differentiate between a stock or flow measure of strategic corporate real estate investment. However, empirically testing the predictions requires that we carefully consider the application of the model to whether the various predictions apply to a stock or flow measurement of strategic investment.
Empirical Analysis

In this section, we present the formal empirical analysis of the model’s predictions using a sample of public firms listed on NYSE, AMEX, and NASDAQ that have balance sheet and income statement data available on the Compustat annual and quarterly accounting databases and monthly stock returns reported on the Center for Research in Security Prices (CRSP) database. The sample comprises firms with two-digit SIC numbers between 01 and 87, excluding real estate investment trusts (REITs) and other public real estate firms, hotels and lodging, and investment holding companies.

We restrict our analysis to firms with information recorded in the Compustat dataset over the period 1984 to 2012 that have positive total assets (TA), property, plant and equipment (PPE), net sales (Sales), and real estate data reported on the balance sheet. Our final sample consists of 11,708 firms belonging to 65 two-digit SIC code industries. We also conduct robustness checks by excluding the utility industries, i.e., electric, gas, sanitary services, and water transportation industries. Table 1 shows the frequency distribution of firms and industries over the sample period. The sample contains an average of 3,993 firms per year, ranging from 2,874 firms in 2012 to 5,627 firms in 1997.

In the theoretical model, we characterize strategic, inflexible real estate as (1) taking time to build, (2) being fixed in size, (3) determining the production capacity, and (4) improving operational efficiency. Thus, in order to test the model’s predictions we use owned corporate real estate as a proxy for strategic real estate. Corporate real estate assets include factories, warehouses, offices, and retail facilities. Investing in real estate requires a significant amount of time. Real estate largely determines production capacity, and it is difficult to adjust its size once developed. Owned real estate that is tailored for a firm improves production efficiency (e.g., a factory designed for a particular production process). By contrast, short-term rental spaces are considered to be flexible capital because this real estate is relatively easy to adjust.

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15 Prior to 1984, PPE accounts were reported net of depreciations. Compustat switched to a cost basis reporting with accrued depreciation contra accounts from 1984 onward. For consistency purposes, we restrict our analyze to this period. However, reported tests based on the 40-year period from 1973 to 2012 show similar results.

16 Long-term leased real estate (e.g., a single-tenant warehouse that is designed specifically for the tenant firm) provides the same benefits and is therefore equivalent to owned real estate.
We construct real estate measures using the Compustat PPE account, which includes buildings, machinery and equipment, capitalized leases, land and improvements, construction in progress, natural resources, and other assets. Following the literature, we measure inflexible strategic real estate by adding buildings, land and improvements, and construction in progress in PPE (RE_Assets). Then we construct a normalized measure (SC) by taking the ratio of RE_Assets to PPE.  

We measure industry concentration using the Herfindahl-Hirschman Index (HHI) computed on the basis of net sales. To ensure that our results are not driven by the HHI measure, we also use industry concentrations based on the three largest firms in terms of net sales. Again, industry classifications are based on two-digit SICs, with industry concentrations computed every year using the annual net sales from Compustat. Finally, we also check the robustness of the results using three-digit SIC code industry groups.

In the theoretical model, the industry-wide demand shock is the sole source of uncertainty and affects the revenue and profits of both leading and following firms. To construct a proxy for the demand uncertainty, we use the year-on-year quarterly net sales growth from the Compustat data series. The sales growth is primarily driven by demand shocks rather than supply shocks because a demand shock changes price and quantity in the same direction whereas a supply shock changes price and quantity in the opposite directions. We first compute the time-series variance of the industry mean quarterly sales growth rate. The variance is measured on a rolling basis using 20- and 40-quarter look-back windows. Because this variance measure is biased due to the time-varying number of observations in an industry, we make a statistical adjustment as detailed in Appendix F to remove the effect of the number of observations. We use the standard deviation as the volatility measure.

The realized volatility at the time of production is suitable for studying the effect of volatility on HHI because the contemporaneous level of uncertainty affects firms’ entry decisions. However, this realized measure is not the best to study the effect of volatility on corporate investments because

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17 We could also use capital investment as a measure of inflexible capital because, in the theoretical model, capital investment is equivalent to the stock of capital. Our current stock measure is relevant as a proxy for capacity.

18 The HHI of an industry is the sum of the squares of the individual firms’ net sales to total industry net sales. The higher the number of firms in an industry is, the smaller the resulting industry’s HHI will be. The HHI is based on net sale because gross sales figures are not available on Compustat. Our industry concentration measure does not account the effect of imports from non-US listed firms. But since it omits exports by US firms, the net effect should be smaller.
firms make their investment decisions on the basis of forecasts of the future demand uncertainty that will affect their production. In the theoretical model, this timing gap is not an issue because the demand uncertainty is constant over time. In our empirical analysis, we mimic firms’ forecasts of the industry sales volatility by estimating an ARIMA(1,1,0) model on a 20- and 40-quarter rolling basis.\textsuperscript{19}

In addition, we compute the volatility of firm value to test Prediction 4. Because the theoretical model is a two-period model, firms’ profits are equivalent to the firm value. In the empirical test, periodic profits are not a good measure because profit growth is highly correlated with sales growth, which we use for demand uncertainty. Moreover, the gap between sales volatility and profit volatility is primarily determined by the operating leverage (i.e., the amount of fixed costs in production). Thus, we use the variance of quarterly changes in firm value based on the monthly CRSP data series.

\textit{Descriptive Statistics}

Table 2 presents the industry level descriptive statistics for the 29-year period from 1984 to 2012. The average industry contains 69 firms and has an HHI of 0.19 - the corresponding median values are 27 firms and an HHI of 0.14. The average level of concentration among the 65 industries varies considerably from 0.02, which is characteristic of a very competitive industry, to 0.83, indicating a highly concentrated industry - we impose a cutoff of three firms minimum per industry. The most competitive industry in our sample consists of 534 firms.

Also, average firm size (whether measured by market value, sales, or total assets in 2012 U.S. dollars) increases with industry concentration. The distribution of firm sizes in our sample is positively skewed with a mean and a median total assets per firm of $615 million and $64 million, respectively. Understandably, our sample is dominated by relatively small firms mostly operating in competitive industries. As expected, leverage and industry concentration are also positively related for good reasons. As noted in the introduction, the average amount of inflexible capital owned by firms in our sample is 27% of PPE. The average annual rent expense for our sample is roughly $2.3\textsuperscript{19}

\textsuperscript{19}The positive autocorrelations of our volatility measure almost completely disappear when we take the first difference. Thus, we estimate a simple AR(1) model for volatility changes.
million. The average stock of flexible capital derived from rent expenses is 46.6%, indicating that firms lease significant amounts of real estate as well.\footnote{Generic Real Estate Capital ($GC$) is the ratio of capitalized rent expenses (using corporate bond yields) to PPE plus capitalized rent expenses.}

The bottom section of Table 2 presents the summary statistics of our measures of sales volatility and firm value volatility computed on the rolling 20- and 40-quarter basis. The adjusted variance of sales growth sometimes exhibits negative values because of the adjustment outlined in Appendix F. However, this does not affect our results because the relative volatilities are what matters.

**Results**

**Predictions 1 and 2**

Prediction 1 concerns a causal relationship that the ownership of strategic real estate increases industry concentration (the entry deterrence effect). Prediction 2 indicates that demand uncertainty also affects industry concentration. To test these predictions, we estimate via ordinary least squares (OLS) the following industry-level panel regression model that controls for industry characteristics and year fixed effects:

\[
HHI_{it} = \beta_0 + \beta_1 SC_{it} + \beta_2 GC_{it} + \beta_3 VOL_{it} + X_i \gamma + y_t + \varepsilon_{it}. \tag{25}
\]

where \(HHI_{it}\) is the Herfindahl-Hirschman Index for industry \(i\) in year \(t\) and represents our proxy for market concentration; \(SC_{it}\) represents our proxy for strategic real estate ownership; \(GC_{it}\) represents our proxy for leased (generic) real estate; \(VOL_{it}\) represents our proxy for the industry demand uncertainty; and \(X_i\) represents industry characteristics.\footnote{\(HHI_{it}\) is bounded between 0 and 1, with monopoly industries having a value of 1 and perfectly competitive industries having a value of 0. \(SC_{it}\) is also bounded between 0 and 1 because it is the ratio to total PPE.} The industry characteristics include the mean growth rate of industry sales, industry age, mean leverage, the number of firms, the mean asset size of firms, and the return on asset (ROA).

Key challenges to this identification are potential reverse causality and the existence of a confounding factor. However, reverse causality is not a serious issue in our estimation method because our strategic real estate capital \((SC_{it})\) measure is based on the past accumulation of real
estate assets. Furthermore, with the use of year fixed effects, our estimation mainly relies on cross-sectional variations. Thus, persistent variables in time-series are not a serious issue, either. To clarify the causal effects of past strategic real estate investments, we decompose $SC_{it}$ into $SC_{i,t-3} + \Delta SC_{i,t-2} + \Delta SC_{i,t-1} + \Delta SC_{i,t}$, where $\Delta SC_{i,t}$ represents the change in real estate ownership between $t-1$ and $t$. Thus, the $\beta$ coefficient on the single current variable equals the weighted average of the coefficients on the decomposed terms. This decomposition also enables us to infer the time lag in the effect of strategic real estate investments on market concentration.

We control for demand uncertainty as a confounding factor because it is predicted to affect both industry concentration and the investment in strategic real estate. Although there are various methods to deal with confoundedness such as matching methods, there is no fundamental difference between regression methods and matching methods (see Angrist and Pischke, 2009, for detailed discussions). It is also important to note that strategic corporate real estate investment is not entirely driven by demand uncertainty; i.e., an entry deterrence effect exists even without demand uncertainty. Thus, it is necessary to include both $SC_{it}$ and $VOL_{it}$. The current level of uncertainty is our primary measure because the entry decision of a competitor is based on the current level of demand uncertainty. However, previous forecasts may affect the market concentration if the entry decision was made several years before production on the basis of volatility forecasts. Thus, we also include the 1, 2, and 3-year forecast errors of our ARIMA(1,1,0) model.

Table 3 reports the results, all of which are consistent with the predictions. When we impose $\beta_3 = 0$ to test Prediction 1 (column 1), the estimated $\beta_1$ for strategic real estate is 0.15 and statistically significant at the 1% level. Moreover, the coefficient is 55% larger for strategic real estate (0.15) than for generic flexible real estate (0.10), indicating the entry deterrence effect of inflexible capacity investments. Alternatively, when we impose $\beta_1 = \beta_2 = 0$ to test Prediction 2 (column 2), the estimated coefficient on the current sales volatility is $-0.20$ and statistically significant at the 1% level. Greater demand uncertainty makes the market more competitive. We report the result with the 20-quarter rolling volatility measure, but the 40-quarter rolling volatility gives a consistent result. Regarding the coefficients on industry characteristics, the average growth rate, leverage, and the average firm size do not exhibit significant effects on market concentration. The industry age has a profound positive effect but it disappears when we decompose strategic real
estate ownership by seniority.

The results are largely unchanged when we remove restrictions on $\beta_1$, $\beta_2$, and $\beta_3$ to estimate the causal effect of strategic real estate on the market concentration by controlling for sales volatility as a confounding factor. In column 3, the coefficient on strategic real estate is 0.15, which is statistically significant and greater than the coefficient on generic real estate (0.09). Thus, investment in strategic real estate has a positive causal effect on market concentration. The coefficients imply that, on average, a one standard deviation increase in strategic real estate ownership (from 26% to 38%) increases the average HHI by 0.018 points. A one standard deviation increase in demand uncertainty (from 3.9% to 13.9%) decreases the average HHI by 0.014 points. On the basis of the adjusted $R^2$, approximately 27% of the total explanatory power comes from the factors captured by the real estate variables and demand uncertainty, and the remaining 73% comes from various industry characteristics that are uncorrelated with these factors. Since our real estate and demand uncertainty variables are measured with errors, the proportion could increase by using more accurate measures.

When $SC_{it}$ is decomposed and past forecast errors in sales volatility are added (column 4), we see that the amount of strategic real estate that was in place 3-years before production makes the largest impact on market concentration (0.18). The impact monotonically decreases as the timing of investment becomes closer to production. However, all coefficients are positive and statistically significant at least at the 10% level. Thus, market concentration increases with several years of lags as strategic real estate increases. The estimated coefficient on the current sales volatility is $-0.12$, which is statistically significant at the 5% level. However, coefficients on the past forecast errors are not statistically significant. Thus, the demand volatility at the time of production negatively affects market concentration, which suggests a relatively quick response of entrants to the market condition.

In addition to the average relation, we also investigate the temporal variation in the effect of strategic real estate by estimating the following regression that allows for time-varying betas:

$$HHI_{it} = \beta_0 + \beta_t SC_{it} + y_t + \varepsilon_{it}.$$  (26)
Figure 4 plots the yearly estimated coefficients. We note that in all years, we obtain a positive coefficient, which is consistent with Prediction 1. Although cycles are observed, the year-specific coefficient appears stationary. Interestingly, the coefficient is larger during the recession periods of the early 1990’s, the early 2000’s, and the late 2000’s.

Similarly, for Prediction 2, we estimate the following model with time-varying beta:

$$HHI_{it} = \beta_0 + \beta_t VOL_{it} + y_t + \varepsilon_{it}. \quad (27)$$

Figure 5 plots the yearly estimated coefficients. The estimated coefficient is negative for 26 years during the 36-year sample period when we use 20-quarter volatility. The coefficient is negative for 25 years during the 32-year period when we use 40-quarter volatility. The mean coefficient is $-0.23$ and $-0.30$ for the 20- and 40-quarter measures, respectively. These mean values are consistent with the estimated coefficient from the constant-coefficient model.

**Prediction 3**

We now turn to the model’s prediction concerning the negative relation between the investment in strategic real estate and demand uncertainty. We note the timing gap between the initial investment and the demand uncertainty in the production phase. Thus, we use the ARIMA(1,1,0) volatility forecasts in the following panel regression model with year fixed effects:

$$SC_{it} = \beta_0 + \beta_1 E_t [VOL_{i,t+q}] + \beta_2 GC_{it} + X_i \gamma + y_t + \varepsilon_{it}, \quad (28)$$

where $E_t [VOL_{i,t+q}]$ is the $q$-quarter ahead forecast of industry $i$’s level of sales volatility. We compute the 20- and 40-quarter rolling volatility measures adjusted for the time-varying sample size as described in Appendix F. Then we construct the 4, 8, and 12-quarter ahead forecasts.

Table 4 reports the estimation result. Consistent with the theoretical prediction, the estimated coefficients on the expected volatility are negative and statistically significant at the 5% level or higher in all specifications. For the 40-quarter rolling volatility measure (columns 4, 5, and 6), the estimated coefficients are $-0.0956$, $-0.0778$, and $-0.0634$ when 4-, 8-, and 12-quarter ahead
forecasts are used, respectively. The effect of uncertainty is strongest when the 4-quarter forecasting horizon is used. Thus, firms own less real estate (employ a smaller amount of inflexible capacity) if they expect greater demand uncertainty for the next year. The effects are economically significant because a one percentage point change in the ratio requires a large change in real estate investment that increases the total PPE by more than one percent after depreciation. As expected, we also observe strong substitution between strategic and generic real estate use; the coefficient of $GC_{it}$ is $-0.21$ and statistically significant at the 1% level.

In addition to the average impact of demand uncertainty on real estate ownership, we also investigate the time variation in the parameter coefficient by estimating the following regression that allows for time-varying betas:

$$SC_{it} = \beta_0 + \beta_t E_t [VOL_{t+q}] + y_t + \varepsilon_{it}. \quad (29)$$

Figure 6 depicts the estimation result using the 8-quarter ahead forecasts of demand volatility. The estimated coefficient is negative for 17 years in the 29-year period when we use 20-quarter volatility, and for 19 years in the 27-year period when we use 40-quarter volatility. Interestingly, the coefficients are positive during recessions in the early 1990’s and early and late 2000’s especially when 20-quarter rolling volatility is used.

**Prediction 4**

Tables 5 and 6 report the result of the OLS estimation of panel regression model:

$$VOL_{it}^{value} = \beta_0 + (\beta_1 + \beta_2 HHI_{it}) VOL_{it}^{sales}$$
$$+ LD_t \{ (\beta_3 + (\beta_4 + \beta_5 HHI_{it}) VOL_{it}^{sales}) \}$$
$$+ X_t \gamma + y_t + \varepsilon_{it}, \quad (30)$$

where $VOL_{it}^{value}$ is industry $i$’s corporate value volatility at time $t$ and $LD_t$ is a dummy variable that represents the low demand state. We use two measures of $LD_t$: the NBER recession periods

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The results with other forecast horizons are almost identical.
and periods of low growth in aggregate sales. Our model’s predictions are: $\beta_1 \in (0, 1)$ and $\beta_2 > 0$. In addition we test Aguerrevere’s (2009) predictions: $\beta_5 < 0$, $\beta_2 + \beta_5 < 0$, $\beta_1 + \beta_4 > 0$, and $\beta_1 + \beta_2 + \beta_4 + \beta_5 > 0$.

Table 5 reports the results when we impose $\beta_3 = \beta_4 = \beta_5 = 0$. When $\beta_2 = \gamma = 0$ is further imposed (columns 1 and 3), the estimated value of $\beta_1$ is 0.22 and 0.31 when the 20- and 40-quarter rolling volatility measures are used, respectively. These coefficients represent the average slope for various concentration levels in both demand states. Both estimates are consistent with our model’s prediction. When the restriction on $\beta_2$ and $\gamma$ is relaxed in columns 2 and 4, the coefficient on the interaction term is positive and statistically significant. When the 40-quarter rolling volatility measure is used, the estimated slopes are 0.12 for a perfectly competitive market ($\beta_2$) and 0.81 for a monopoly market ($\beta_1 + \beta_2$). The estimated coefficients confirm that firm value volatility is greater in a more concentrated market. Regarding the coefficients on the control variables, firm value volatility is greater for an industry with a high sales growth rate, high leverage, a short history, smaller firms, and a lower yield.

Table 6 reports the results when we condition on the low demand state. Column 2 is for the NBER recession dummy and columns 3 and 4 are for aggregate low sales dummy. Column 4 reports the result with a nonlinear effect of a high HHI dummy. The main effects of sales volatility ($\beta_1$) and market concentration ($\beta_2$) are positive and statistically significant at the 1% level for all specifications. Firm value volatility is high during low demand states; $\beta_3$ is 0.01 for NBER recession periods and 0.02 for low growth periods. The estimate of $\beta_5$ on the product of volatility, HHI, and a low demand indicator is positive when NBER recession periods are used (0.06), but is negative when low sales growth measures are used ($-0.70$). Although this negative coefficient in column 3 is consistent with Aguerrevere’s (2009) model, the sum of $\beta_2$ (1.08) and $\beta_5$ ($-0.70$) is still positive. Thus, we find that firm value is riskier in more concentrated markets regardless of demand levels.

One possible explanation for this result is that the U.S. market since 1984 has been in a sufficiently high demand state where the option to expand has a large value.
Robustness Check

The model’s setup implies that the three main outputs (i.e., strategic real estate, industry concentration, and volatility of firm value) are jointly determined, conditional on demand shocks. Thus, to control for possible endogeneity among the outputs and recognize the implied joint determination, we simultaneously estimate the following system derived from Equations (25), (29), and (30):

\[ HHI_{it} = \beta_0 + \beta_1 SC_{it} + \beta_2 GC_{it} + \beta_3 VOL_{it} + X_1 \gamma_1 + y_t + \varepsilon_{it}. \]  
\[ SC_{it} = \beta_0 + \beta_4 E_t [VOL_{i,t+q}] + X_2 \gamma_2 + y_t + \zeta_{it}. \]  
\[ VOL_{it}^{value} = \beta_0 + (\beta_1 + \beta_2 HHI_{it}) VOL_{it}^{sales} + X_3 \gamma_3 + y_t + \xi_{it}. \]

The maximum likelihood estimation of this system allows for correlation between the error terms. To achieve identification, we exclude from \( X_{1i}, X_{2i}, \) and \( X_{3i} \) in Equations (25'), (28'), and (30') the set of industry characteristics (\( X_i \)) used in the estimations of Equations (25), (28), and (30) that have p-values greater than 5%. Thus, \( X_{1i} \) excludes average industry growth rate, leverage, average firm size, and industry profitability. \( X_{2i} \) excludes average industry growth rate, industry age, and leverage. Finally, \( X_{3i} \) includes all \( X_i \)’s variables since they are significant in the model explaining variations in the volatility of firm value. These variable exclusions allow identification of the model’s main output variables. Table 7 presents the results of the joint test of the predictions. In line with the previous results, industry concentration in column 1 is negatively correlated with demand volatility and positively correlated with capital investments as per predictions 1 and 2.\(^{23}\)

Strategic real estate remains negatively related to demand volatility in column 2 (prediction 3) and, as expected, negatively correlated with generic real estate. Also, the volatility of firm value in column 3 increases with both demand volatility and industry concentration, as expected and consistent with prediction 4.

Next, we check the robustness of our results by using an additional measure of industry concentration based on the market share of the three largest firms. Since the Compustat data do not include private or non-U.S. firms, the HHI that is based on the Compustat data may not accurately rep-

\(^{23}\) Though statistically insignificant (the p-value is 0.129), the coefficient of strategic real estate is 2.4 times larger than that of generic real estate.
resent the industry concentration of all firms. In contrast, the market share of three largest public firms is robust to this omission of private and non-U.S. firms because public firms are generally larger than private firms. Furthermore, this measure is consistent with the concept of early strategic real estate investment by leading firms, assuming that firm size is positively correlated with firm age. By using this alternative concentration measure, we test the effects of strategic real estate investment and demand volatility on industry concentration (Predictions 1 and 2) and the impact of industry concentration on firm risk (Prediction 4). Prediction 3 does not concern the industry structure. Tables G.1 and G.2 in Appendix G show that our findings are robust to this alternative measure of industry concentration.

We also test our model’s predictions using a more granular industry grouping based on three-digit SIC codes (see Tables G.3, G.4, and G.5 in Appendix G). The results of these tests unequivocally confirm predictions 1, 2, and 3. We also note that firm risk is also positively correlated with demand uncertainty as per prediction 4. Overall, these and previous robustness checks on industry grouping provide additional comfort that our main results are not driven by the use of HHI measure or 2-digit industry classification.

Conclusion

We study how corporate real estate investments may affect market structure and firm riskiness. In our model, which captures realistic features of investment and production, firms invest in inflexible, but strategic, real estate to take advantage of its effect on product market competition.

The main results of our analysis are that the use of strategic real estate investment is negatively related to market competition and that greater market competition results in a smaller risk in the firm value for a given level of demand uncertainty. These results do not depend on traditional leverage effects or asymmetric adjustment costs within a firm. Rather, our key insight is that the riskiness of a firm critically depends on the level of market competition that is contingent on the state of stochastic demand and the firm’s capital investments. This state-contingent competition with potential entrants is often implicit but relevant for most industries. The state-contingency

\[24\] We restrict the analysis to industries with a minimum of five firms.
arises from a combination of an entry deterrence effect of strategic real estate, the incumbent firm’s option to expand by using generic real estate, and potential competitors’ options to enter the market. Our findings are distinguished from the result of the extant studies that exogenously impose market competition.
References


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<th>Year</th>
<th>N. Firms</th>
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Table 1: Number of Firms and Industries. The total sample spanning 29 years from 1984 to 2012 comprises 11,708 firms belonging to 65 industries according to their 2-digit SIC numbers.
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<th>Variables</th>
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<th>Median</th>
<th>Std. Dev.</th>
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<th>Max.</th>
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<td>Number of Firms per industry</td>
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<td>HHI (Net Sales)</td>
<td>Industry Concentration Herfindahl based on Net Sales</td>
<td>0.187</td>
<td>0.142</td>
<td>0.150</td>
<td>0.017</td>
<td>0.825</td>
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<tr>
<td>HHI (Total Assets)</td>
<td>Industry Concentration Herfindahl based on Total Assets</td>
<td>0.193</td>
<td>0.157</td>
<td>0.143</td>
<td>0.017</td>
<td>0.737</td>
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<td>MV</td>
<td>Total Market Value of all Firms</td>
<td>$195,374</td>
<td>$50,141</td>
<td>$349,077</td>
<td>$349</td>
<td>$1,675,834</td>
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<td>TA</td>
<td>Total Assets</td>
<td>$614,940</td>
<td>$64,226</td>
<td>$1,977,151</td>
<td>$707</td>
<td>$14,777,544</td>
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<td>Sales</td>
<td>Total Net Sales</td>
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<td>$69,685</td>
<td>$336,656</td>
<td>$698</td>
<td>$1,639,086</td>
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<td>Sales Growth</td>
<td>Changes in Quarterly Sales</td>
<td>9.27%</td>
<td>9.22%</td>
<td>15.15%</td>
<td>-188.61%</td>
<td>263.85%</td>
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<td>LT_Dept</td>
<td>Long-Term Debt</td>
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<td>$11,609</td>
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<td>Earnings Before Interest and Depreciation</td>
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<td>$49,421</td>
<td>-$14</td>
<td>$278,668</td>
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<td>Net_Income</td>
<td>Annual Net Income</td>
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<td>$2,219</td>
<td>$16,227</td>
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<td>$88,430</td>
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<td>ROA</td>
<td>Ratio of Net Income to Total Assets</td>
<td>0.12%</td>
<td>0.96%</td>
<td>6.72%</td>
<td>-65.55%</td>
<td>35.45%</td>
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<td>Leverage</td>
<td>Ratio of Long-Term Debt to Equity (Total Assets - Total Liabilities)</td>
<td>1.53%</td>
<td>0.76%</td>
<td>7.61%</td>
<td>0.00</td>
<td>303.25</td>
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<td>Rent Expenses</td>
<td>Annual Rental Expenses</td>
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<td>$779</td>
<td>$3,615</td>
<td>$1</td>
<td>$21,194</td>
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<td>PPE</td>
<td>Gross Properties Plants and Equipment</td>
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<td>$153</td>
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<td>RE_Assets</td>
<td>Buildings, Construction in Progress, and Land and Improvements</td>
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<td>$2,905</td>
<td>$24,745</td>
<td>$57</td>
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<td>SC</td>
<td>Specific Real Estate Capital: Ratio of RE_Assets to PPE</td>
<td>27.43%</td>
<td>26.26%</td>
<td>11.72%</td>
<td>7.11%</td>
<td>62.88%</td>
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<td>GC</td>
<td>Generic Real Estate Capital: Ratio of capitalized rent expenses to PPE plus capitalized rent expenses</td>
<td>46.62%</td>
<td>46.32%</td>
<td>17.71%</td>
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<td>93.56%</td>
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Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Table 3: Test of Predictions 1 and 2. This table reports the result of the OLS estimation of the panel regression model (Equation (25)) with year fixed effects. The dependent variable is the Herfindahl-Hirschman Index for industries by the 2-digit SIC classification. White’s heteroskedasticity-consistent standard errors are also reported.
## VARIABLES

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<td>-0.0411**</td>
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<td>(0.0221)</td>
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<td>4-qtr. ahead forecast of sales volatility (40-qtr.)</td>
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<td>-0.0778***</td>
<td>-0.0634***</td>
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<td>(0.0308)</td>
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<tr>
<td>8-qtr. ahead forecast of sales volatility (40-qtr.)</td>
<td>-0.0778***</td>
<td>-0.0634***</td>
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<td>12-qtr. ahead forecast of sales volatility (40-qtr.)</td>
<td>-0.0634***</td>
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<tr>
<td></td>
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<td>Generic Real Estate</td>
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<td>-0.0138</td>
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</tr>
<tr>
<td></td>
<td>(0.0183)</td>
<td>(0.0182)</td>
<td>(0.0181)</td>
<td>(0.0182)</td>
<td>(0.0182)</td>
<td>(0.0182)</td>
</tr>
<tr>
<td>Industry age</td>
<td>0.5652</td>
<td>0.5589</td>
<td>0.5502</td>
<td>0.5621</td>
<td>0.5738</td>
<td>0.5785</td>
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<tr>
<td></td>
<td>(0.4337)</td>
<td>(0.4338)</td>
<td>(0.4342)</td>
<td>(0.4629)</td>
<td>(0.4607)</td>
<td>(0.4593)</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0000)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>No. of firms</td>
<td>-0.0003***</td>
<td>-0.0003***</td>
<td>-0.0003***</td>
<td>-0.0003***</td>
<td>-0.0003***</td>
<td>-0.0003***</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>Average firm size (Assets)</td>
<td>-0.0084***</td>
<td>-0.0085***</td>
<td>-0.0086***</td>
<td>-0.0065***</td>
<td>-0.0067***</td>
<td>-0.0068***</td>
</tr>
<tr>
<td></td>
<td>(0.0014)</td>
<td>(0.0014)</td>
<td>(0.0014)</td>
<td>(0.0015)</td>
<td>(0.0015)</td>
<td>(0.0015)</td>
</tr>
<tr>
<td>Profitability industry (ROA)</td>
<td>0.2134***</td>
<td>0.2135***</td>
<td>0.2137***</td>
<td>0.1972***</td>
<td>0.1975***</td>
<td>0.1978***</td>
</tr>
<tr>
<td></td>
<td>(0.0267)</td>
<td>(0.0267)</td>
<td>(0.0268)</td>
<td>(0.0291)</td>
<td>(0.0291)</td>
<td>(0.0291)</td>
</tr>
<tr>
<td></td>
<td>(3.2853)</td>
<td>(3.2860)</td>
<td>(3.2887)</td>
<td>(3.5058)</td>
<td>(3.4895)</td>
<td>(3.4789)</td>
</tr>
<tr>
<td>Year f.e.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>6,969</td>
<td>6,969</td>
<td>6,969</td>
<td>6,124</td>
<td>6,124</td>
<td>6,124</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.139</td>
<td>0.139</td>
<td>0.138</td>
<td>0.139</td>
<td>0.139</td>
<td>0.138</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Table 4: Test of Prediction 3. This table reports the result of the OLS estimation of the panel regression model (28) with year fixed effects. The dependent variable is the industry-average strategic real estate based on the 2-digit SIC classification. The explanatory variable is the 4, 8, and 12-quarter ahead forecasts of industry sales growth volatility. The sales growth volatility is measured on the basis of 20-quarter and 40-quarter rolling estimation. Forecasts are based on an ARIMA(1,1,0) model that is estimated with the previous 20 quarter observations. White’s heteroskedasticity-consistent standard errors are also reported.
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Model (1)</th>
<th>Model (2)</th>
<th>Model (3)</th>
<th>Model (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales volatility (20-qtr.)</td>
<td>0.2244***</td>
<td>0.1211***</td>
<td>(0.0289)</td>
<td>(0.0313)</td>
</tr>
<tr>
<td>Sales volatility (20-qtr.) × HHI</td>
<td>0.3455**</td>
<td></td>
<td>(0.1620)</td>
<td></td>
</tr>
<tr>
<td>Sales volatility (40-quarter)</td>
<td></td>
<td>0.3071***</td>
<td>0.1169***</td>
<td>(0.0277)</td>
</tr>
<tr>
<td>Sales volatility (40-quarter) × HHI</td>
<td></td>
<td></td>
<td>0.6951***</td>
<td>(0.1633)</td>
</tr>
<tr>
<td>Average growth rate industry</td>
<td>0.0413***</td>
<td>0.0424***</td>
<td>(0.0151)</td>
<td>(0.0147)</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.0014***</td>
<td>0.0014***</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>Industry age</td>
<td>-0.7641***</td>
<td>-0.9050***</td>
<td>(0.2238)</td>
<td>(0.2068)</td>
</tr>
<tr>
<td>No. of firms</td>
<td>0.0001***</td>
<td>0.0001***</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>Average firm size (Assets)</td>
<td>-0.0088***</td>
<td>-0.0087***</td>
<td>(0.0012)</td>
<td>(0.0010)</td>
</tr>
<tr>
<td>Profitability industry (ROA)</td>
<td>-0.0894***</td>
<td>-0.0751***</td>
<td>(0.0280)</td>
<td>(0.0256)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.1360***</td>
<td>6.0373***</td>
<td>0.1223***</td>
<td>7.1019***</td>
</tr>
<tr>
<td>Year f.e.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>7,109</td>
<td>6,989</td>
<td>6,989</td>
<td>6,989</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.154</td>
<td>0.182</td>
<td>0.142</td>
<td>0.209</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.1

Table 5: Test of Prediction 4. This table reports the result of the OLS estimation of regression equation (30). The dependent variable is the volatility of the average corporate value growth rates for each industry with the 2-digit SIC classification. The explanatory variables are the industry sales volatility and the interaction terms of the sales volatility and the Herfindahl-Hirschman Index. The low demand variables are also used as a conditioning variable. The volatility is measured on the basis of 40-quarter rolling estimation and adjusted for the number of observation as outlined in Appendix F. White’s heteroskedasticity-consistent standard errors are also reported.
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Model (1)</th>
<th>Model (2)</th>
<th>Model (3)</th>
<th>Model (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales volatility</td>
<td>0.1169***</td>
<td>0.1857***</td>
<td>0.1129**</td>
<td>0.2778***</td>
</tr>
<tr>
<td>(0.0316)</td>
<td>(0.0368)</td>
<td>(0.0526)</td>
<td>(0.0300)</td>
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</tr>
<tr>
<td>Sales volatility × NBER recession dummy</td>
<td>0.0108</td>
<td>0.0108</td>
<td>0.1315*</td>
<td>0.0389</td>
</tr>
<tr>
<td>(0.0892)</td>
<td>(0.0672)</td>
<td>(0.0437)</td>
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<td></td>
</tr>
<tr>
<td>Sales volatility × Aggregate low sales dummy</td>
<td>0.6951***</td>
<td>0.7042***</td>
<td>1.0847***</td>
<td></td>
</tr>
<tr>
<td>(0.1633)</td>
<td>(0.1915)</td>
<td>(0.2826)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales volatility × High HHI dummy</td>
<td></td>
<td></td>
<td>0.2023***</td>
<td></td>
</tr>
<tr>
<td>(0.0495)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sales volatility × HHI × NBER recession dummy</td>
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<td>0.0600</td>
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</tr>
<tr>
<td>(0.4566)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales volatility × HHI × Aggregate low sales dummy</td>
<td></td>
<td></td>
<td>-0.7024**</td>
<td></td>
</tr>
<tr>
<td>(0.3423)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBER recession dummy</td>
<td>0.0100**</td>
<td>0.0100**</td>
<td>0.0196***</td>
<td>0.0212***</td>
</tr>
<tr>
<td>(0.0050)</td>
<td>(0.0034)</td>
<td>(0.0035)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate low sales dummy</td>
<td>0.0424***</td>
<td>0.0120</td>
<td>0.0338**</td>
<td>0.0328**</td>
</tr>
<tr>
<td>(0.0147)</td>
<td>(0.0143)</td>
<td>(0.0143)</td>
<td>(0.0159)</td>
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</tr>
<tr>
<td>Average growth rate industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leverage</td>
<td>0.0014***</td>
<td>0.0014***</td>
<td>0.0001***</td>
<td></td>
</tr>
<tr>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry age</td>
<td>-0.9050***</td>
<td>-0.3724*</td>
<td>-0.3629*</td>
<td>-0.2996</td>
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<td>(0.2068)</td>
<td>(0.2181)</td>
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<td>No. of firms</td>
<td>0.0001***</td>
<td>0.0001***</td>
<td>0.0001***</td>
<td></td>
</tr>
<tr>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td>(0.0000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average firm size (Assets)</td>
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<td>-0.0087***</td>
<td>-0.0018***</td>
<td>-0.0020*</td>
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<td>(0.0010)</td>
<td>(0.0009)</td>
<td>(0.0008)</td>
<td>(0.0010)</td>
<td></td>
</tr>
<tr>
<td>Profitability industry (ROA)</td>
<td></td>
<td>-0.0751***</td>
<td>-0.0278</td>
<td>-0.0255</td>
</tr>
<tr>
<td>(0.0256)</td>
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<td>(0.0244)</td>
<td>(0.0262)</td>
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</tr>
<tr>
<td>Constant</td>
<td>7.1019***</td>
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<td>2.8741*</td>
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<td>(1.6580)</td>
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<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Observations</td>
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<td>6,989</td>
<td>6,989</td>
<td>6,989</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.209</td>
<td>0.112</td>
<td>0.126</td>
<td>0.108</td>
</tr>
</tbody>
</table>

Table 6: Test of Prediction 4. This table reports the result of the OLS estimation of regression equation (30). The dependent variable is the volatility of the average corporate value growth rates for each industry with the 2-digit SIC classification. The explanatory variables are the industry sales volatility and the interaction terms of the sales volatility and the Herfindahl-Hirschman Index. The low demand variables are also used as a conditioning variable. The volatility is measured on the basis of 40-quarter rolling estimation and adjusted for the number of observation as outlined in Appendix F. White’s heteroskedasticity-consistent standard errors are also reported.

Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1
Table 7: Simultaneous test of the four predictions using maximum likelihood taking the three variable outputs (i.e., industry concentration, strategic capital, and volatility of firm value) as endogenous. The dependent variables are the Herfindahl-Hirschman Index for industries by the 2-digit SIC classification in column 1, the industry-average firm-specific real estate in column 2, and volatility of the average corporate value growth rates for each industry in column 3. White's heteroskedasticity-consistent standard errors are also reported.
Figure 1: Time line

\[ t_0 \quad \text{Period 1} \quad t_1 \quad \text{Period 2} \quad t_2 \]

Demand shock is realized.

Firm 1: Chooses \( K_{s1} \), pays fixed cost. Chooses \( K_{s1} \), pays costs of capital & production. Chooses \( K_{s1} \), pays costs of capital & production.

Builds \( K_{s1} \)

Production

Firm \( i = 2, \ldots, n \): Chooses \( K_{p} \), pays fixed cost. Sells products, pays costs of capital & production.

Production
Figure 2: Equilibrium Outcome. This figure depicts the equilibrium amount of strategic real estate (Panel (a), Equation (6)), the probability that the market becomes monopoly (Panel (b), Equation (19)), and the ratio of the variance of firm value under potential oligopoly to the variance of firm value under monopoly (Panel (c), Equation (20)) when linear demand and quadratic cost functions are assumed. The demand uncertainty is on the horizontal axis. Parameter values are: $A = 4.3, B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2, f = 3.2$. 

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Figure 3: Strategic real estate and market structure. The amount of strategic real estate is on the horizontal axis. $A = 4.3, B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2, \text{and } f = 3.2$.

Figure 4: Relation between the Herfindahl-Hirschman Index and strategic real estate. This figure depicts the OLS estimation result of a regression equation (26), which corresponds to Prediction 1. White’s heteroskedasticity-consistent standard errors are also reported.
Figure 5: Relation between the Herfindahl-Hirschman Index and the industry volatility. This figure depicts the OLS estimation result of a regression equation (27), which corresponds to Prediction 2. White’s heteroskedasticity-consistent standard errors are also reported.
Figure 6: Relation between strategic real estate and the demand uncertainty. This figure depicts the OLS estimation result of a regression equation (29), which corresponds to Prediction 3. The 8-quarter ahead volatility forecast is used. White’s heteroskedasticity-consistent standard errors are also reported.
Appendix A  Proof of Proposition 1

Without loss of generality, consider the 2-firm Cournot equilibrium represented by Equations (14) and (15). When \( \varepsilon = \varepsilon^* \), Firm 2’s profit is zero:

\[
\Pi_2 = P (K_{s1}, K_{g1}^E (K_{s1}, \varepsilon^*), K_{g2}^E (K_{s1}, \varepsilon^*)) \times K_{g2} - C_2 (K_{g2}^E (K_{s1}, \varepsilon^*)) = 0 \quad (A.1)
\]

We rewrite Equation (A.1) by using Firm 2’s FOC:

\[
\Pi_2 = - \frac{\partial P (K_{s1}, K_{g1}^E (K_{s1}, \varepsilon^*), K_{g2}^E (K_{s1}, \varepsilon^*))}{\partial K_{g2}^E} \times K_{g2} - C_2 (K_{g2}^E (K_{s1}, \varepsilon^*)) = 0 \quad (A.2)
\]

By totally differentiating Equation (A.2), we obtain

\[
\begin{align*}
&- \frac{\partial^2 P}{\partial K_{g2}^E} K_{g2}^E \times \left( dK_{s1} + \frac{\partial K_{g1}^E}{\partial K_{s1}} dK_{s1} + \frac{\partial K_{g1}^E}{\partial \varepsilon^*} d\varepsilon^* + \frac{\partial K_{g2}^E}{\partial K_{s1}} dK_{s1} + \frac{\partial K_{g2}^E}{\partial \varepsilon^*} d\varepsilon^* + d\varepsilon^* \right) \\
&- 2 \frac{\partial P}{\partial K_{g2}^E} K_{g2}^E \times \left( \frac{\partial K_{g2}^E}{\partial K_{s1}} dK_{s1} + \frac{\partial K_{g2}^E}{\partial \varepsilon^*} d\varepsilon^* \right) + C'_2 K_{g2} \times \left( \frac{\partial K_{g2}^E}{\partial K_{s1}} dK_{s1} + \frac{\partial K_{g2}^E}{\partial \varepsilon^*} d\varepsilon^* \right) \\
&+ C'_2 \times \left( \frac{\partial K_{g2}^E}{\partial K_{s1}} dK_{s1} + \frac{\partial K_{g2}^E}{\partial \varepsilon^*} d\varepsilon^* \right) - C' \times \left( \frac{\partial K_{g2}^E}{\partial K_{s1}} dK_{s1} + \frac{\partial K_{g2}^E}{\partial \varepsilon^*} d\varepsilon^* \right) = 0. \\
\end{align*}
\]

(A.3)

By assuming an affine demand function, the first term is eliminated \( (\partial^2 P / \partial K_{g2}^E = 0) \). The last two terms cancel out. By rearranging the equation, we obtain:

\[
\frac{d\varepsilon^*}{dK_{s1}} = - \left( \frac{\partial K_{g2}^E}{\partial \varepsilon^*} \right)^{-1} \left( \frac{\partial K_{g2}^E}{\partial K_{s1}} \right). 
\]

(A.4)

Since Firm 2 chooses a larger amount of capital for a greater demand and a smaller amount of Firm 1’s inflexible capital, \( \partial K_{g2}^E / \partial \varepsilon^* > 0 \) and \( \partial K_{g2}^E / \partial K_{s1} < 0 \). As a result, we derive Equation (16) in Proposition 1:

\[
\frac{d\varepsilon^*}{dK_{s1}} > 0. 
\]

(A.5)
Appendix B  Full Competition Case

We can easily generalize the oligopoly case to a market characterized as perfectly competitive (with an infinite number of firms) by noting that the inverse demand function is horizontal:

\[ P = P(K_{s1}, K_{g1}, K_{gi}, \varepsilon), \quad \text{s.t., } \frac{\partial P}{\partial \varepsilon} > 0, \quad \frac{\partial^2 P}{\partial \varepsilon^2} = 0, \quad \frac{\partial P}{\partial K_{s1}} = \frac{\partial P}{\partial K_{g1}} = \frac{\partial P}{\partial K_{gi}} = 0. \quad (B.1) \]

In the competitive market, the solutions to the optimal generic real estate for Firm 1 \((K_{g1})\) becomes:

\[
\begin{cases} 
K_{g1}^C(K_{s1}, \bar{\varepsilon}) & \text{if } \bar{\varepsilon} > \varepsilon^C \\
0 & \text{otherwise}, 
\end{cases} \quad (B.2)
\]

where as before, the threshold value \(\varepsilon^C\) depends on the amount of \(K_{s1}\). As in the previous cases, Firm 1 chooses \(K_{s1}\) at \(t_0\) by maximizing its expected profit:

\[
\max_{K_{s1}} E \left[ \Pi_1^C(K_{s1}, K_{g1}, \varepsilon) \right] = E \left[ \Pi_1^C(K_{s1}, K_{g1}^C, \varepsilon) \mid \bar{\varepsilon} > \varepsilon^C(K_{s1}) \right] Pr(\bar{\varepsilon} > \varepsilon^C(K_{s1})) \\
+ E \left[ \Pi_1^C(K_{s1}, K_{g1}, \varepsilon) \mid \bar{\varepsilon} \leq \varepsilon^C(K_{s1}) \right] Pr(\bar{\varepsilon} \leq \varepsilon^C(K_{s1})), \quad (B.3)
\]

where \(\Pi_1^C\) denotes Firm 1’s profit function in the competitive market. The solution to this problem is given as

\[
\begin{cases} 
K_{s1}^C & \text{if } E \left[ \Pi_1^C(K_{s1}^C, K_{g1}, \varepsilon) \right] \geq 0 \\
0 & \text{otherwise}, 
\end{cases} \quad (B.4)
\]
Appendix C  Variations in Firm 1’s problem under potential oligopoly

Variation 1: If $\varepsilon^M < \varepsilon^E < \varepsilon^*$,

$$
\max_{K_s} E \left[ \Pi_1(K_{s1}, K_{g1}, K_{g2}, \varepsilon) \right]
$$

$$
\equiv E \left[ \Pi_1^O(K_{s1}, K_{g1}, K_{g2}^E; \varepsilon) \mid \varepsilon \geq \varepsilon^*(K_{s1}) \right] Pr \left( \varepsilon \geq \varepsilon^*(K_{s1}) \right)
$$

$$
+ E \left[ \Pi_1^M(K_{s1}, K_{g1}^M, \varepsilon) \mid \varepsilon^*(K_{s1}) > \varepsilon > \varepsilon^M(K_{s1}) \right] Pr \left( \varepsilon^*(K_{s1}) > \varepsilon > \varepsilon^M(K_{s1}) \right)
$$

$$
+ E \left[ \Pi_1^M(K_{s1}, 0, \varepsilon) \mid \varepsilon \leq \varepsilon^M(K_{s1}) \right] Pr \left( \varepsilon \leq \varepsilon^M(K_{s1}) \right).
$$

(C.1a)

Variation 2: If $\varepsilon^M < \varepsilon^* < \varepsilon^E$, Equation (17)

Variation 3: If $\varepsilon^* < \varepsilon^M < \varepsilon^E$,

$$
\max_{K_s} E \left[ \Pi_1(K_{s1}, K_{g1}, K_{g2}, \varepsilon) \right]
$$

$$
\equiv E \left[ \Pi_1^O(K_{s1}, K_{g1}, K_{g2}^E; \varepsilon) \mid \varepsilon > \varepsilon^E(K_{s1}) \right] Pr \left( \varepsilon > \varepsilon^E(K_{s1}) \right)
$$

$$
+ E \left[ \Pi_1^O(K_{s1}, 0, K_{g2}^E, \varepsilon) \mid \varepsilon^*(K_{s1}) \leq \varepsilon \leq \varepsilon^E(K_{s1}) \right] Pr \left( \varepsilon^*(K_{s1}) \leq \varepsilon \leq \varepsilon^E(K_{s1}) \right)
$$

$$
+ E \left[ \Pi_1^M(K_{s1}, 0, \varepsilon) \mid \varepsilon < \varepsilon^*(K_{s1}) \right] Pr \left( \varepsilon < \varepsilon^*(K_{s1}) \right),
$$

(C.1b)
Appendix D  Solution of the model

Firms’ Decision for the second period

Firm 1.

At $t_1$, Firm 1 solves the problem specified in Equation (3), taking $K_{s1}$, $K_{g2}$, and $\bar{\epsilon}$ as given. Since the objective function is quadratic, SOC is readily satisfied. From FOC and the sign condition on $K_{g1}$, the optimal choice of $K_{g1}$ is:\(^{25}\)

Monopoly:

\[
\begin{cases}
  K_{g1}^M &= \frac{A - g - (2B + \alpha)K_{s1} + \bar{\epsilon}}{2B + \beta} & \text{if } \bar{\epsilon} > g - A + (2B + \alpha)K_{s1} \equiv \epsilon^M \\
  0 & \text{otherwise.}
\end{cases}
\]  

(D.1)

Oligopoly:

\[
\begin{cases}
  K_{g1}^O &= \frac{A - g - (2B + \alpha)K_{s1} - BK_{g2} + \bar{\epsilon}}{2B + \beta} & \text{if } \bar{\epsilon} > g - A + (2B + \alpha)K_{s1} + BK_{g2} \equiv \epsilon^O \\
  0 & \text{otherwise.}
\end{cases}
\]  

(D.2)

Competitive:

\[
\begin{cases}
  K_{g1}^C &= \frac{A - g + \bar{\epsilon} - \alpha K_{s1}}{\beta} & \text{if } \bar{\epsilon} > g - A + \alpha K_{s1} \equiv \epsilon^C \\
  0 & \text{otherwise.}
\end{cases}
\]  

(D.3)

Firm 2.

At $t_1$, Firm 2 solves the problem specified in Equation (10), taking $K_{s1}$, $K_{g1}$, and $\bar{\epsilon}$ as given. Since the objective function is quadratic, SOC is readily satisfied. From FOC and the entry condition

\(^{25}\)When there are $n$ entrants, $K_{g2}$ is simply replaced with $\sum_{i=2}^{n+1} K_{gi}$ in Equations (D.2) and (D.4).
the optimal choice of $K_{g2}$ is

**Oligopoly:**

$$
\begin{cases}
K_{g2}^O = \frac{A - g - B(K_{s1} + K_{g1}) + \bar{\varepsilon}}{2B + \beta} & \text{if } \bar{\varepsilon} \geq g - A + B(K_{s1} + K_{g1}) \\
0 & \text{otherwise}.
\end{cases}
$$

(D.4)

**Competitive:**

$$
\begin{cases}
K_{g2}^C = \frac{A - g + \bar{\varepsilon}}{\beta} & \text{if } \bar{\varepsilon} \geq g - A + \sqrt{2\beta(1+r)f} \\
0 & \text{otherwise}.
\end{cases}
$$

(D.5)

**Cournot Nash Equilibrium in the second period**

When both firms employ positive amounts of flexible capital, the Cournot Nash equilibrium levels of flexible capital, Equations (14) and (15), are expressed as:

$$
\begin{align*}
K_{g1}^E &= L - (1 - M)K_{s1}, \\
K_{g2}^E &= L - NK_{s1},
\end{align*}
$$

(D.6) (D.7)

where

$$
\begin{align*}
L &\equiv \frac{A - g + \bar{\varepsilon}}{3B + \beta} > 0, \\
M &\equiv \frac{(\beta - \alpha)(2B + \beta)}{(3B + \beta)(B + \beta)} \in (0,1), \\
N &\equiv \frac{B(\beta - \alpha)}{(3B + \beta)(B + \beta)} > 0.
\end{align*}
$$

Firm 2’s entry condition (11) gives the threshold value of demand shock $\bar{\varepsilon}^*$:

$$
\bar{\varepsilon}^*(K_{s1}) \equiv g - A + \sqrt{\frac{2(3B + \beta)^2(1+r)f}{2B + \beta} + \frac{B(\beta - \alpha)}{B + \beta}K_{s1}}.
$$

(D.8)

\[^{26}\text{When there are } n \text{ entrants, } L = \frac{A - g + \bar{\varepsilon}}{(n+1)B + \beta}, \quad M = \frac{2B + \alpha}{2B + \beta} - \frac{(n-1)B^2(\beta - \alpha)}{((n+1)B + \beta)(B + \beta)(2B + \beta)}\text{, and } N = \frac{B(\beta - \alpha)}{((n+1)B + \beta)(B + \beta)} > 0.\]
We confirm the entry deterrence effect (16); i.e., a larger inflexible capital of Firm 1 makes it less unlikely for Firm 2 to enter the market. We can also rewrite Firm 1’s expansion condition (D.2) for this Cournot equilibrium:

\[
\bar{\epsilon} > g - A + \left(3B + \beta - \frac{(\beta - \alpha)(2B + \beta)}{B + \beta}\right)K_s^1 \equiv \epsilon^E(K_s^1). \tag{D.9}
\]

**Initial choice of inflexible capital**

At \( t_0 \), Firm 1 solves the problems specified in Equations (5), (17), and (B.3). In this appendix, we solve for the optimal choice of inflexible capital for each market structure.

**Monopoly Market.**

In the monopoly market, Firm 1’s problem is:

\[
\max_{K_{s1}} \mathbb{E} \left[ \Pi^M_1(K_{s1}, K_{g1}, \epsilon) \right] \\
= \mathbb{E} \left[ \Pi^M_1(K_{s1}, K_{g1}^M, \epsilon) \mid \bar{\epsilon} > \epsilon^M(K_{s1}) \right] Pr(\bar{\epsilon} > \epsilon^M(K_{s1})) \\
+ \mathbb{E} \left[ \Pi^M_1(K_{s1}, 0, \epsilon) \mid \bar{\epsilon} \leq \epsilon^M(K_{s1}) \right] Pr(\bar{\epsilon} \leq \epsilon^M(K_{s1})), \tag{D.10a}
\]

\[
\Pi^M_1(K_{s1}, 0, \epsilon) = -(1 + r)^2 f + \epsilon K_{s1} + (A - s)K_{s1} - \left(B + \frac{\alpha}{2}\right)K_{s1}^2, \tag{D.10b}
\]

\[
\Pi^M_1(K_{s1}, K_{g1}^M, \epsilon) = R^M + S^M \epsilon^2 + T^M \epsilon + U^M \epsilon K_{s1} + V^M K_{s1} + W^M K_{s1}^2, \tag{D.10c}
\]

\[
R^M \equiv -(1 + r)^2 f + \frac{(A - g)^2}{2(2B + \beta)}, \tag{D.10d}
\]

\[
S^M \equiv \frac{1}{2(2B + \beta)}, \tag{D.10e}
\]

\[
T^M \equiv \frac{A - g}{2B + \beta}, \tag{D.10f}
\]

\[
U^M \equiv \frac{\beta - \alpha}{2B + \beta}, \tag{D.10g}
\]

\[
V^M \equiv \frac{A(\beta - \alpha) + g(2B + \alpha)}{2B + \beta} - s, \tag{D.10h}
\]

\[
W^M \equiv -\frac{\alpha}{2} - \frac{B(\beta - \alpha)^2}{(2B + \beta)^2} + \frac{\alpha(2B + \alpha)}{2B + \beta} - \beta(2B + \alpha)^2 - \frac{\beta(2B + \alpha)^2}{2(2B + \beta)^2}. \tag{D.10i}
\]
The specific expression for each of eight elements is as follows.

\[
\begin{align*}
\Pr (\bar{\varepsilon} > \varepsilon^M (K_{s1})) & = \frac{\sqrt{3} \sigma - \varepsilon^M}{2 \sqrt{3} \sigma} = \frac{1}{2} + \frac{A - g}{2 \sqrt{3} \sigma} - \frac{2B + \alpha}{2 \sqrt{3} \sigma} K_{s1}, \quad \text{(D.12)} \\
\frac{d\Pr (\bar{\varepsilon} > \varepsilon^M (K_{s1}))}{dK_{s1}} & = -\frac{2B + \alpha}{2 \sqrt{3} \sigma}, \quad \text{(D.13)} \\
\Pr (\bar{\varepsilon} \leq \varepsilon^M (K_{s1})) & = \frac{1}{2} + \frac{-A + g}{2 \sqrt{3} \sigma} + \frac{2B + \alpha}{2 \sqrt{3} \sigma} K_{s1}, \quad \text{(D.14)} \\
\frac{d\Pr (\bar{\varepsilon} \leq \varepsilon^M (K_{s1}))}{dK_{s1}} & = \frac{2B + \alpha}{2 \sqrt{3} \sigma}, \quad \text{(D.15)} \\
E \left[ \Pi^M_1 (K_{s1}, K^M_{g1}, \varepsilon) \mid \bar{\varepsilon} > \varepsilon^M (K_{s1}) \right] & = \int_{\varepsilon^M (K_{s1})}^{\sqrt{3} \sigma} \left( R^M + S^M \varepsilon^2 + T^M \varepsilon + U^M \varepsilon K_{s1} + V^M K_{s1} + W^M K^2_{s1} \right) \frac{1}{2 \sqrt{3} \sigma} d\bar{\varepsilon} \\
& = \frac{(R^M + V^M K_{s1} + W^M K^2_{s1}) \left( \sqrt{3} \sigma - \varepsilon^M \right)}{2 \sqrt{3} \sigma} + \frac{(T^M + U^M K_{s1}) \left( 3\sigma^2 - \varepsilon^M \right)}{4 \sqrt{3} \sigma} \right) \\
& + \frac{S^M \left( 3\sqrt{3} \sigma^3 - \varepsilon^M \right)}{6 \sqrt{3} \sigma}, \quad \text{(D.16)} \\
E \left[ \Pi^M_1 (K_{s1}, 0, \varepsilon) \mid \bar{\varepsilon} \leq \varepsilon^M (K_{s1}) \right] & = \int_{-\sqrt{3} \sigma}^{\varepsilon^M (K_{s1})} \left( -(1 + r)^2 f + \varepsilon K_{s1} + (A - s) K_{s1} - \left( B + \frac{\alpha}{2} \right) K^2_{s1} \right) \frac{1}{2 \sqrt{3} \sigma} d\bar{\varepsilon} \\
& = \frac{\left( -(1 + r)^2 f + (A - s) K_{s1} - \left( B + \frac{\alpha}{2} \right) K^2_{s1} \right) \left( \varepsilon^M + \sqrt{3} \sigma \right)}{2 \sqrt{3} \sigma} + \frac{K_{s1} \left( \varepsilon^M - \sigma^2 \right)}{4 \sqrt{3} \sigma}. \quad \text{(D.17)}
\end{align*}
\]
By using Leibniz rule of integration,

\[
\frac{dE}{dK_{s1}} \left[ \Pi^M_{1}(K_{s1}, K_{q1}^M, \varepsilon) \right]_{|\varepsilon > \varepsilon^M(K_{s1})} = \left( \frac{\sigma}{\sqrt{3}} \right)^{\frac{1}{2}} \left( \frac{\sigma}{\sqrt{3}} - \varepsilon^M \right) + \left( \frac{\sigma}{\sqrt{3}} + \varepsilon^M \right) \left( \frac{\sigma}{\sqrt{3}} - \varepsilon^M \right) \right]
\]

\[
- \frac{(2B + \alpha)}{2\sqrt{3}\sigma} \left( R^M + S^M \varepsilon^M \sigma^2 + T^M \varepsilon^M + U^M \varepsilon^M K_{s1} + V^M K_{s1} + W^M K_{s1}^2 \right), \quad (D.18)
\]

\[
\frac{dE}{dK_{s1}} \left[ \Pi^M_{1}(K_{s1}, 0, \varepsilon) \right]_{|\bar{\varepsilon} \leq \varepsilon^M(K_{s1})} = \left[ A - s - (2B + \alpha) K_{s1} \right] \left( \varepsilon^M + \sqrt{3}\sigma \right) + \left( \frac{\sigma}{\sqrt{3}} \right)^{\frac{1}{2}} \left( \frac{\sigma}{\sqrt{3}} - \varepsilon^M \right) \right]
\]

\[
+ \frac{(2B + \alpha)}{2\sqrt{3}\sigma} \left[ -(1 + r)^2 f + \varepsilon^M K_{s1} + (A - s) K_{s1} - \left( \frac{B + \alpha}{2} \right) K_{s1}^2 \right]. \quad (D.19)
\]

The first order condition (D.11) is a cubic function of \(K_{s1}\). The solution needs to satisfy non-negativity conditions on quantity and price and regularity conditions on probabilities. The existence and uniqueness of the solution depends on specific parameter values. In our numerical exercise, a unique solution exists after applying regularity conditions.
Potential Oligopoly Market.

In our numerical analysis, we focus on the first variation \( \varepsilon^M < \varepsilon^E < \varepsilon^* \) of Firm 1’s problem (C.1a) as a reasonable case:

\[
\begin{align*}
\max_{K_{s1}} E \left[ \Pi_1^O(K_{s1}, K_{g1}, K_{g2}, \varepsilon) \right] \\
= E \left[ \Pi_1^O(K_{s1}, K_{g1}^E, K_{g2}^E, \varepsilon) \mid \varepsilon \geq \varepsilon^*(K_{s1}) \right] \Pr(\varepsilon \geq \varepsilon^*(K_{s1})) \\
+ E \left[ \Pi_1^M(K_{s1}, K_{g1}^M, \varepsilon) \mid \varepsilon^*(K_{s1}) > \varepsilon > \varepsilon^M(K_{s1}) \right] \times \Pr(\varepsilon^*(K_{s1}) > \varepsilon > \varepsilon^M(K_{s1})) \\
+ E \left[ \Pi_1^M(K_{s1}, 0, \varepsilon) \mid \varepsilon \leq \varepsilon^M(K_{s1}) \right] \Pr(\varepsilon \leq \varepsilon^M(K_{s1})),
\end{align*}
\]

\( \Pi_1^O(K_{s1}, K_{g1}^E, K_{g2}^E, \varepsilon) = R^O + S^O \varepsilon^2 + T^O \varepsilon + U^O \varepsilon K_{s1} + V^O K_{s1} + W^O K_{s1}^2, \)  

\( R^O \equiv -(1+r)^2 f + \frac{(A-g)^2(2B+\beta)}{2(3B+\beta)^2}, \)

\( S^O \equiv \frac{2B+\beta}{2(3B+\beta)^2}, \)

\( T^O \equiv \frac{(A-g)(2B+\beta)}{(3B+\beta)^2}, \)

\( U^O \equiv \frac{BN+\beta-\alpha}{3B+\beta}, \)

\( V^O \equiv g-s + \frac{(A-g)(BN+\beta-\alpha)}{3B+\beta}, \)

\( W^O \equiv BMN + (\beta-\alpha)(M-\frac{1}{2}) - \frac{M^2}{2}(2B+\beta). \)
The first-order condition is:

\[
\begin{align*}
\frac{dE \left[ \Pi_1^K (K_{s1}, K_{g1}^E, K_{g2}^E, \varepsilon) \right]}{dK_{s1}} &= \frac{dE \left[ \Pi_1^K (K_{s1}, K_{g1}^E, K_{g2}^E, \varepsilon) \right] \mid \varepsilon \geq \varepsilon^*(K_{s1})}{dK_{s1}} \times Pr (\varepsilon \geq \varepsilon^*(K_{s1})) \\
&+ E \left[ \Pi_1^K (K_{s1}, K_{g1}^E, K_{g2}^E, \varepsilon) \right] \times \frac{dPr (\varepsilon \geq \varepsilon^*(K_{s1}))}{dK_{s1}} \\
&+ \frac{dE \left[ \Pi_1^M (K_{s1}, K_{g1}^M, \varepsilon) \right] \mid \varepsilon^M(K_{s1}) < \varepsilon < \varepsilon^*(K_{s1})}{dK_{s1}} \times Pr (\varepsilon^M(K_{s1}) < \varepsilon < \varepsilon^*(K_{s1})) \\
&+ E \left[ \Pi_1^M (K_{s1}, K_{g1}^M, \varepsilon) \right] \times \frac{dPr (\varepsilon^M(K_{s1}) < \varepsilon < \varepsilon^*(K_{s1}))}{dK_{s1}} \\
&+ \frac{dE \left[ \Pi_1^M (K_{s1}, 0, \varepsilon) \right] \mid \varepsilon \leq \varepsilon^M(K_{s1})}{dK_{s1}} \times Pr (\varepsilon \leq \varepsilon^M(K_{s1})) \\
&+ E \left[ \Pi_1^M (K_{s1}, 0, \varepsilon) \right] \times \frac{dPr (\varepsilon \leq \varepsilon^M(K_{s1}))}{dK_{s1}} \\
&= 0. \tag{D.21}
\end{align*}
\]
The specific expression for each of twelve elements is as follows.

\[ Pr(\bar{\varepsilon} \geq \varepsilon^*(K_{s1})) = \frac{\sqrt{3\sigma - \varepsilon^*}}{2\sqrt{3\sigma}} = \frac{1}{2} + \frac{1}{2\sqrt{3\sigma}} \left( A - g - \sqrt{\frac{2(3B + \beta)^2(1 + r)f}{2B + \beta}} \right) - \frac{1}{2\sqrt{3\sigma}} \frac{B(\beta - \alpha)}{(B + \beta) K_{s1}}, \]  
\[ (D.22) \]

\[ \frac{dPr(\bar{\varepsilon} \geq \varepsilon^*(K_{s1}))}{dK_{s1}} = -\frac{1}{2\sqrt{3\sigma}} \frac{B(\beta - \alpha)}{(B + \beta)}, \]  
\[ (D.23) \]

\[ Pr(\varepsilon^M(K_{s1}) < \bar{\varepsilon} < \varepsilon^*(K_{s1})) = \frac{\varepsilon^* - \varepsilon^M}{2\sqrt{3\sigma}} = \frac{1}{2 \sqrt{3\sigma}} \left( A - g - \sqrt{\frac{2(3B + \beta)^2(1 + r)f}{2B + \beta}} \right) - \frac{1}{2\sqrt{3\sigma}} \frac{(2B + \beta)(B + \alpha)}{(B + \beta) K_{s1}}, \]  
\[ (D.24) \]

\[ \frac{dPr(\varepsilon^M(K_{s1}) < \bar{\varepsilon} < \varepsilon^*(K_{s1}))}{dK_{s1}} = -\frac{1}{2\sqrt{3\sigma}} \frac{(2B + \beta)(B + \alpha)}{(B + \beta)}, \]  
\[ (D.25) \]

\[ Pr(\bar{\varepsilon} \leq \varepsilon^M(K_{s1})) = \frac{1}{2} - \frac{A - g}{2\sqrt{3\sigma}} + \frac{2B + \alpha}{2\sqrt{3\sigma}} K_{s1}, \]  
\[ (D.26) \]

\[ \frac{dPr(\bar{\varepsilon} \leq \varepsilon^*(K_{s1}))}{dK_{s1}} = \frac{2B + \alpha}{2\sqrt{3\sigma}}, \]  
\[ (D.27) \]

\[ E \left[ \Pi_1^O(K_{s1}, K_{s1}^E, K_{s2}^E, \varepsilon) | \bar{\varepsilon} \geq \varepsilon^*(K_{s1}) \right] = \int_{\varepsilon^*(K_{s1})}^{\sqrt{3\sigma}} \left( R^O + S^O \varepsilon^2 + T^O \varepsilon + U^O \varepsilon K_{s1} + V^O K_{s1} + W^O K_{s1}^2 \right) \frac{1}{2\sqrt{3\sigma}} d\bar{\varepsilon} \]
\[ = \frac{R^O + V^O K_{s1} + W^O K_{s1}^2}{2\sqrt{3\sigma}} \left( \sqrt{3\sigma - \varepsilon^*} \right) + \frac{(T^O + U^O K_{s1}) (3\sigma^2 - \varepsilon^*^2)}{4\sqrt{3\sigma}} \]
\[ + \frac{S^O (3\sqrt{3\sigma^3} - \varepsilon^*^3)}{6\sqrt{3\sigma}}, \]  
\[ (D.28) \]

\[ E \left[ \Pi_1^M(K_{s1}, K_{s1}^M, \varepsilon) | \varepsilon^M(K_{s1}) < \bar{\varepsilon} < \varepsilon^*(K_{s1}) \right] = \int_{\varepsilon^M(K_{s1})}^{\varepsilon^*(K_{s1})} \left( R^M + S^M \varepsilon^2 + T^M \varepsilon + U^M \varepsilon K_{s1} + V^M K_{s1} + W^M K_{s1}^2 \right) \frac{1}{2\sqrt{3\sigma}} d\bar{\varepsilon} \]
\[ = \frac{R^M + V^M K_{s1} + W^M K_{s1}^2}{2\sqrt{3\sigma}} \left( \varepsilon^* - \varepsilon^M \right) + \frac{(T^M + U^M K_{s1}) (\varepsilon^* - \varepsilon^M^2)}{4\sqrt{3\sigma}} \]
\[ + \frac{S^M (\varepsilon^*^3 - \varepsilon^M^3)}{6\sqrt{3\sigma}}, \]  
\[ (D.29) \]

\[ E \left[ \Pi_1^M(K_{s1}, 0, \varepsilon) | \bar{\varepsilon} < \varepsilon^M(K_{s1}) \right] = \frac{-(1 + r)^2 f + (A - s) K_{s1} - (B + \frac{2}{3}) K_{s1}^2}{2\sqrt{3\sigma}} \left( \varepsilon^M + \sqrt{3\sigma} \right) + \frac{K_{s1} (\varepsilon^M^2 - 3\sigma^2)}{4\sqrt{3\sigma}}. \]  
\[ (D.30) \]
By using Leibniz rule of integration,

\[
\frac{dE}{dK_{s1}} \left[ \Pi^O(K_{s1}, K_{g1}^E, K_{g2}^E, \varepsilon) \middle| \varepsilon \geq \varepsilon^M(K_{s1}) \right] = \frac{(V^O + 2W^O K_{s1}) (\sqrt{3} \sigma - \varepsilon^*) + U^O (3\sigma^2 - \varepsilon^*^2)}{4\sqrt{3} \sigma} \\
- \frac{(B(\beta - \alpha))}{2\sqrt{3} \sigma (B + \beta)} \left( R^O + S^O \varepsilon^*^2 + T^O \varepsilon^* + U^O \varepsilon^* K_{s1} + V^O K_{s1} + W^O K_{s1}^2 \right), \quad (D.31)
\]

\[
\frac{dE}{dK_{s1}} \left[ \Pi^M(K_{s1}, K_{g1}^M, \varepsilon) \middle| \varepsilon^M(K_{s1}) < \varepsilon < \varepsilon^*(K_{s1}) \right] = \frac{(V^M + 2W^M K_{s1}) (\varepsilon^* - \varepsilon^M)}{2\sqrt{3} \sigma} + \frac{U^M (\varepsilon^*^2 - \varepsilon^M^2)}{4\sqrt{3} \sigma} \\
+ \frac{(B(\beta - \alpha))}{2\sqrt{3} \sigma (B + \beta)} \left( R^M + S^M \varepsilon^*^2 + T^M \varepsilon^* + U^M \varepsilon^* K_{s1} + V^M K_{s1} + W^M K_{s1}^2 \right), \quad (D.32)
\]

\[
\frac{dE}{dK_{s1}} \left[ \Pi^M(K_{s1}, 0, \varepsilon) \middle| \varepsilon < \varepsilon^M(K_{s1}) \right] = \frac{[A - s - (2B + \alpha) K_{s1}] (\varepsilon^M + \sqrt{3} \sigma) + \varepsilon^M^2 - 3\sigma^2}{2\sqrt{3} \sigma} \\
+ \frac{(2B + \alpha)}{2\sqrt{3} \sigma} \left[ -(1 + r)^2 f + \varepsilon^M K_{s1} + (A - s) K_{s1} - \left( B + \frac{\alpha}{2} \right) K_{s1}^2 \right]. \quad (D.33)
\]

The first order condition (D.21) is also a cubic function of $K_{s1}$. 

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Competitive Market.

In the competitive market, Firm 1’s problem is:

\[
\max_{K_{s1}} E \left[ \Pi^C_1 (K_{s1}, K_{g1}, \varepsilon) \right]
\]

\[
= E \left[ \Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon > \varepsilon^C (K_{s1}) \right] Pr (\varepsilon > \varepsilon^C (K_{s1}))
+ E \left[ \Pi^C_1 (K_{s1}, 0, \varepsilon) \mid \varepsilon \leq \varepsilon^C (K_{s1}) \right] Pr (\varepsilon \leq \varepsilon^C (K_{s1}))
\]

(D.34a)

\[
\Pi^C_1 (K_{s1}, 0, \varepsilon) = -(1 + r)^2 f + \varepsilon K_{s1} + (A - s)K_{s1} - \frac{\alpha}{2} K_{s1}^2,
\]

(D.34b)

\[
\Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) = R^C + S^C \varepsilon^2 + T^C \varepsilon + U^C \varepsilon K_{s1} + V^C K_{s1} + W^C K_{s1}^2,
\]

(D.34c)

\[
R^C \equiv -(1 + r)^2 f + \frac{(A - g)^2}{2 \beta},
\]

(D.34d)

\[
S^C \equiv \frac{1}{2 \beta},
\]

(D.34e)

\[
T^C \equiv \frac{A - g}{\beta},
\]

(D.34f)

\[
U^C \equiv 1 - \frac{\alpha}{\beta}
\]

(D.34g)

\[
V^C \equiv A - s - \frac{\alpha (A - g)}{\beta},
\]

(D.34h)

\[
W^C \equiv -\frac{\alpha (\beta - \alpha)}{2 \beta}.
\]

(D.34i)

The first-order condition is

\[
\frac{d}{dK_{s1}} E \left[ \Pi^C_1 (K_{s1}, K_{g1}, \varepsilon) \right]
\]

\[
= \frac{d}{dK_{s1}} E \left[ \Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon > \varepsilon^C (K_{s1}) \right] \times Pr (\varepsilon > \varepsilon^C (K_{s1}))
+ E \left[ \Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon > \varepsilon^C (K_{s1}) \right] \times \frac{dPr (\varepsilon > \varepsilon^C (K_{s1}))}{dK_{s1}}
+ \frac{d}{dK_{s1}} E \left[ \Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon \leq \varepsilon^C (K_{s1}) \right] \times Pr (\varepsilon \leq \varepsilon^C (K_{s1}))
+ E \left[ \Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon \leq \varepsilon^C (K_{s1}) \right] \times \frac{dPr (\varepsilon \leq \varepsilon^C (K_{s1}))}{dK_{s1}}
+ E \left[ \Pi^C_1 (K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon \leq \varepsilon^C (K_{s1}) \right] \times \frac{dPr (\varepsilon \leq \varepsilon^C (K_{s1}))}{dK_{s1}}
= 0.
\]

(D.35)
For each element of Equation (D.35), the specific expression is as follows.

\[
Pr \left( \varepsilon > \varepsilon^C(K_{s1}) \right) = \frac{\sqrt{3} \sigma - \varepsilon^C}{2\sqrt{3} \sigma} = \frac{1}{2} + \frac{A - g}{2\sqrt{3} \sigma} - \frac{\alpha}{2\sqrt{3} \sigma} K_{s1},
\]

(D.36)

\[
\frac{dPr \left( \varepsilon > \varepsilon^C(K_{s1}) \right)}{dK_{s1}} = -\frac{\alpha}{2\sqrt{3} \sigma},
\]

(D.37)

\[
E \left[ \Pi^C_1(K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon > \varepsilon^C(K_{s1}) \right] = \int_{\sqrt{3} \sigma}^{\varepsilon^C(K_{s1})} \left( R^C + S^C \varepsilon^2 + T^C \varepsilon + U^C \varepsilon K_{s1} + V^C K_{s1} + W^C K_{s1}^2 \right) \frac{1}{2\sqrt{3} \sigma} \, d\varepsilon
\]

\[
= R^C + V^C K_{s1} + W^C K_{s1}^2 + \frac{3\sigma(T^C + U^C K_{s1})}{4\sqrt{3}} + \frac{\sigma^2}{2}
\]

\[
- \frac{(R^C + V^C K_{s1} + W^C K_{s1}^2)(\alpha K_{s1} - A + g)}{2\sqrt{3} \sigma}
\]

\[
- \frac{(T^C \varepsilon + U^C \varepsilon K_{s1})(\alpha K_{s1} - A + g)^2}{4\sqrt{3} \sigma}
\]

\[
- \frac{S^C(\alpha K_{s1} - A + g)^3}{6\sqrt{3} \sigma}.
\]

(D.38)

\[
E \left[ \Pi^C_1(K_{s1}, K_{g1}^C, \varepsilon) \mid \varepsilon \leq \varepsilon^C(K_{s1}) \right] = \int_{-\sqrt{3} \sigma}^{\varepsilon^C(K_{s1})} \left( -(1 + r)^2 f + \varepsilon K_{s1} + (A - s)K_{s1} - \frac{\alpha}{2} K_{s1}^2 \right) \frac{1}{2\sqrt{3} \sigma} \, d\varepsilon
\]

\[
= \frac{(-(1 + r)^2 f + (A - s)K_{s1} - \frac{\alpha}{2} K_{s1}^2)(\alpha K_{s1} - A + g)}{2}
\]

\[
+ \frac{(\alpha K_{s1} - A + g)^2 K_{s1}}{3\sqrt{3} \sigma}
\]

\[
- \frac{-(1 + r)^2 f + (A - s)K_{s1} - \frac{\alpha}{2} K_{s1}^2}{2}
\]

\[
- \frac{3\sigma}{4\sqrt{3}} K_{s1}.
\]

(D.39)
By using Leibniz rule of integration,

\[
\frac{dE \left[ \Pi_1^C (K_{s1}, K_{g1}, \varepsilon) | \varepsilon > \varepsilon^C (K_{s1}) \right]}{dK_{s1}} = \frac{V^C}{2} + W^C K_{s1} + \frac{3\sigma U^C}{4\sqrt{3}} - \frac{U^C (\varepsilon^C)^2}{4\sqrt{3}\sigma} - \frac{(V^C + 2W^C K_{s1}) \varepsilon^C}{2\sqrt{3}\sigma} - \frac{R^C + S^C \varepsilon^2 + T^C \varepsilon K_{s1} + V^C K_{s1} + W^C K_{s1}^2}{4\sqrt{3}\sigma}.
\]

(D.40)

\[
\frac{dE \left[ \Pi_1^C (K_{s1}, K_{g1}, \varepsilon) | \varepsilon \leq \varepsilon^C (K_{s1}) \right]}{dK_{s1}} = \frac{(A - s - \alpha K_{s1}) \varepsilon^C}{2\sqrt{3}\sigma} + \frac{(\varepsilon^C)^2}{4\sqrt{3}\sigma} + \frac{(A - s - \alpha K_{s1})}{2} - \frac{3\sigma}{4\sqrt{3}} + \frac{\alpha}{2\sqrt{3}\sigma} \left(- (1 + r)^2 f + \varepsilon^C K_{s1} + (A - s) K_{s1} - \frac{\alpha}{2} K_{s1}^2 \right).
\]

(D.41)

The first order condition (D.35) is also a cubic function of \( K_{s1} \).
Appendix E  Detailed results of a model with Linear demand and quadratic cost function

In this section, we discuss in detail the result of the model with linear demand and quadratic cost functions that we develop in Section . Figure 7a depicts the optimal amount of strategic real estate for various levels of demand uncertainty in the competitive market. For each level of demand uncertainty, we set the price level $A$ such that the entrant’s expected profit becomes zero. The price levels vary between 3.9 and 4.3 in this exercise. Figure 7b depicts strategic real estate in the monopoly market and the potential oligopoly market. The demand level $A$ is fixed at 4.3. We find a negative effect of demand uncertainty on strategic real estate in all market structures.

This negative effect is created by a trade-off between efficiency and inflexibility of strategic real estate. Firm 1 compares the efficiency gain and potential loss from holding a strategic real estate. By using strategic real estate, Firm 1 benefits from a more efficient production than by expanding its operations with generic real estate. Thus, strategic real estate is advantageous in a strong market to the extent of the efficiency gap between the two. However, in a weak market, greater amounts of strategic real estate result in larger losses. Because potential losses increase with uncertainty, Firm 1 employs a smaller amount of strategic real estate when demand is more uncertain.

Figure 7b also exhibits greater amounts of strategic real estate in the potential oligopoly market than in the monopoly market. This gap represents Firm 1’s motive to deter entry of a potential competitor. In the low end of the uncertainty range, the gap is smaller because Firm 1 can successfully deter entry with a smaller amount of extra real estate.

Figure 8a demonstrates how the probability of deterring entry changes by uncertainty when Firm 1 adopts the optimal investment strategy. When $\sigma = 0.6$, the probability of oligopoly (i.e., entry) is only 0.1%, and Firm 1 is likely to monopolize the market. When $\sigma = 2.0$, the probability of oligopoly becomes 36.3%. Thus, the probability of monopoly is negatively related with uncertainty. Under high uncertainty, a large amount of strategic real estate is needed to completely deter entry. However, such a large investment is not optimal because it will cause a large loss under weak demand. This is a novel finding. As demonstrated in the literature, uncertainty makes entry deterrence more difficult (e.g., Maskin, 1999). We further demonstrate that complete entry
deterrence is not only difficult but also suboptimal under uncertainty when losses from overcapacity are taken into account.

Figure 8b exhibits these probabilities in terms of the ranges of $\varepsilon$ that are defined by the threshold values $\varepsilon^*$ and $\varepsilon^M$. The upper range ($\varepsilon \geq \varepsilon^*$) corresponds to an oligopoly when entries are accommodated. As $\sigma$ increases, the probability of entry increases and approaches 0.5 because a mean-preserving spread brings greater probability mass to the range above the threshold value $\varepsilon^*$. The middle range ($\varepsilon \in (\varepsilon^M, \varepsilon^*)$) and the lower range ($\varepsilon \leq \varepsilon^M$) correspond to a monopoly with and without expansion, respectively.

Figures 9 depicts distributions of Firm 1’s realized profits for different values of demand uncertainty $\varepsilon$ based on 5,000 simulations. Figures 9a is for the monopoly market and 9b is for the potential oligopoly market. Note that the profit in our single-period production model represents periodic profits as well as the total firm value. When demand uncertainty is small, both distributions are relatively symmetric and similar to each other. However, when demand uncertainty is large, then the monopoly profit distribution exhibits positive skewness. This positive skewness is a result of exercising the expansion option; the firm earns profits from high demand while limiting losses from weak demand. In contrast, the distribution in the potential oligopoly market is bi-modal and narrower than in the monopoly case. When demand is high, the second firm enters the market and eliminates Firm 1’s opportunities to earn high profits. The downward shift of profits forms the second peak around the value of 3 in profits.

Figure 10 plots relative volatility of profits against relative volatility of demand ($\sigma$) for three market structures. The smallest volatility is normalized to unity. Note that the correlation coefficient between demand shocks and the firm value is one because the demand is the sole source of uncertainty in this economy. Thus, as Aguerrevere (2009) defines, the elasticity of the firm value with respect to demand shocks represents the systematic risk (i.e., the market beta) of the firm value.

When the monopoly structure is imposed, the volatility of profits is almost directly proportional to demand volatility because the demand uncertainty is absorbed by one firm. In particular, the monopoly firm captures the entire profit from large demand by exercising the option to expand. In contrast, the slope is much flatter in the potential oligopoly market. In this market, the profit
must be shared with a competitor that enters the market when demand is large. The large upside potential is absent for the leading firm due to the endogenous change in market structure. This limited upside potential is the reason why the value uncertainty is reduced. Finally, in the competitive market, the line is flat because profits are always zero. In summary, greater competition reduces the systematic risk of firm value. On one hand, competition decreases the expected firm value, but on the other hand, competition creates a benefit of decreasing the systematic risk.
Figure 7: Firm-specific capital and demand uncertainty. The demand uncertainty $\sigma$ is on the horizontal axis. For a competitive market, the price level $A$ is adjusted for each value of $\sigma$ so that an entrant earns zero profit. Parameter values are: $B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2,$ and $f = 7$. For monopoly and potential oligopoly markets, parameter values are: $A = 4.3, B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2, f = 3.2$. 
Figure 8: Comparative statics in a potential oligopoly market. The demand uncertainty $\sigma$ is on the horizontal axis. Parameter values are: $A = 4.3, B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2$, and $f = 3.2$. 
Figure 9: Distribution of Firm 1’s realized profits for different values of $\sigma$. Parameter values are: $A = 4.3$, $B = 0.5$, $\alpha = 0.8$, $\beta = 1.4$, $r = 0.05$, $s = 0.3$, $g = 0.2$, and $f = 3.2$. 
Figure 10: Relative volatilities of demand and profits. \( A = 4.3, B = 0.5, \alpha = 0.8, \beta = 1.4, r = 0.05, s = 0.3, g = 0.2, \) and \( f = 3.2. \)
Appendix F  Adjusted measure of industry sales volatility

We use the following method to estimate the industry demand volatility. A measure of demand volatility is the time-series variance of the mean sales growth rates. However, the variance of sample mean depends on the sample size (i.e., the number of firms in an industry), which varies by industry and changes over time in the Compustat data. Thus, we remove the effect of the sample size on our measure of demand volatility by the following method.

The sales growth rate $x_{it}$ for firm $i$ in quarter $t$ can be decomposed into the industry common factor and the inflexible factor: $x_{it} = c_t + f_i$, where $c_t$ is the latent industry common factor and $f_i$ is the firm specific disturbance. We assume homoskedasticity: $c_t \sim N(C, \sigma_c^2)$ and $f_i \sim i.i.d. N(0, \sigma_f^2)$, where $\sigma_c^2$ is the constant time-series variance of $c_t$ and $\sigma_f^2$ is the constant cross-sectional variance of $f_i$. Since $f_i$ is independent random variable, $cov[c_t, f_i] = 0$. At time $t$, there are $n_t$ observations of firms.

We can compute the empirical average of $x_{it}$ for each $t$:

$$\bar{x}_t \equiv \frac{1}{n_t} \sum_{i=1}^{n_t} x_{it} = \frac{1}{n_t} \left( n_t c_t + \sum_{i=1}^{n_t} f_{it} \right) = c_t + \frac{1}{n_t} \sum_{i=1}^{n_t} f_{it}. \quad \text{(F.1)}$$

An unbiased estimator of $c_t$ is the mean sales growth rate $\bar{x}_t$ because

$$E[c_t] = E\left[ \bar{x}_t - \frac{1}{n_t} \sum_{i=1}^{n_t} f_{it} \right] = E[\bar{x}_t]. \quad \text{(F.2)}$$

For each $t$, we can also estimate cross-sectional variance $\sigma_f^2$ by $s_t^2 = \frac{1}{n_t-1} \sum_{i=1}^{n_t} (x_{it} - \bar{x}_t)^2$, which depends on the sample size $n_t$. The time-series variance of the mean sales growth rate is:

$$\text{var}_t[\bar{x}_t] = \text{var}_t\left[ c_t + \frac{1}{n_t} \sum_{i=1}^{n_t} f_{it} \right] = E_t\left[ \left( c_t + \frac{1}{n_t} \sum_{i=1}^{n_t} f_{it} - C \right)^2 \right] = \sigma_c^2 + E_t\left[ \left( \frac{1}{n_t} \sum_{i=1}^{n_t} f_{it} \right)^2 \right], \quad \text{(F.3)}$$

where $E_t$ is the expectation operator over time. In the last equality, we also assume that $cov(c_t, n_t) = \sigma_c^2$. 

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0. If \( n_t = n \) (constant), Equation (F.3) becomes

\[
\text{var}_t [\bar{x}_t] = \sigma^2_c + \frac{1}{n^2} E_t \left[ \sum_{i=1}^{n_t} \sum_{j=1}^{n_t} f_{it} f_{jt} \right] = \sigma^2_c + \frac{1}{n^2} \sum_{i=1}^{n_t} E_t [f^2_{it}] = \sigma^2_c + \frac{\sigma^2}{n}. \tag{F.4}
\]

Then, an unbiased estimator of \( \sigma^2_c \) is \( \text{var}_t [\bar{x}_t] - \frac{s^2}{n} \), assuming \( s^2_t = s^2 \) (constant). However, if \( n_t \) changes over time, we need to evaluate \( E_t \left[ \frac{1}{n_t} \left( \sum_{i=1}^{n_t} f_{it} \right)^2 \right] \). An approximation is \( \frac{1}{T} \sum_{t=1}^{T} \frac{s^2_t}{n_t} \).

In our empirical tests, for each \( t \), we compute the adjusted rolling volatility over the length of \( T_r \):

\[
\bar{\sigma}_{c,t} = \left[ \frac{1}{T_r} \sum_{u=t-T_r}^{t} \left\{ \left( \bar{x}_u - \frac{1}{T_r} \sum_{v=t-T_r}^{t} \bar{x}_v \right)^2 - \frac{s^2_u}{n_u} \right\} \right]^{1/2}. \tag{F.5}
\]
## Appendix G  Additional Tables

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Year f.e.                                        Yes  Yes  Yes  Yes
Observations                                    7047  7204  7031  6143
Adjusted R-squared                              0.247  0.249  0.253  0.260

Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Table G.1: Test of Predictions 1 and 2. This table reports the result of the OLS estimation of the panel regression model (Equation (25)) with year fixed effects. The dependent variable is the combined market share of the three largest firms for industries based on 2-digit SIC classification. White’s heteroskedasticity-consistent standard errors are also reported.
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Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Table G.2: Test of Prediction 4. This table reports the result of the OLS estimation of regression equation (30). The dependent variable is the volatility of the average corporate value growth rates for each industry with the 2-digit SIC classification. The explanatory variables are the industry sales volatility and the interaction terms of the sales volatility and industry concentration (I.C. Index) measured by the combined market share of the three largest firms in each industry. The low demand variables are also used as a conditioning variable. The volatility is measured on the basis of 40-quarter rolling estimation and adjusted for the number of observation as outlined in Appendix F. White’s heteroskedasticity-consistent standard errors are also reported.
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<tr>
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Table G.3: Test of Predictions 1 and 2 Using 3-Digit SIC Industries. This table reports the result of the OLS estimation of the panel regression model (Equation (25)) with year fixed effects. The dependent variable is the Herfindahl-Hirschman Index for industries by the 3-digit SIC classification. White’s heteroskedasticity-consistent standard errors are also reported.
<table>
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<td>(0.0061)</td>
<td>(0.0063)</td>
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<td>(0.0003)</td>
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<td>0.2134***</td>
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<td>0.3913***</td>
<td>0.3716***</td>
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<td>(0.0062)</td>
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Table G.4: Test of Prediction 3 Using 3-Digit SIC Industries. This table reports the result of the OLS estimation of the panel regression model (28) with year fixed effects. The dependent variable is the industry-average strategic real estate based on the 3-digit SIC classification. The sales growth volatility is measured on the basis of 20-quarter and 40-quarter rolling estimation. White’s heteroskedasticity-consistent standard errors are also reported.
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</table>

Table G.5: Test of Prediction 4 Using 3-Digit SIC Industries. This table reports the result of the OLS estimation of regression equation (30). The dependent variable is the volatility of the average corporate value growth rates for each industry with the 3-digit SIC classification. The volatility is measured on a rolling basis and adjusted for the number of observation as outlined in Appendix F. White’s heteroskedasticity-consistent standard errors are also reported.