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Development Strategies in a Market of High Vacancies and Sticky Rates – The Case of the Hotel Industry

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This paper discusses the concurrence of vacancy and ongoing construction under inflexible rents, taking the hotel industry as an area of application. The prevalent modest occupancy in the hotel industry of the United States has led to questions about the ongoing construction of hotels, even if average daily rates (ADRs) have not been reduced to eliminate the excess supply. By constructing a framework based on a game theory approach in market equilibrium, developers can determine the optimal timing to construct the development. Given this option to build, both profit and a double-digit vacancy rate can coexist with inflexible ADRs that exceed the market equilibrium threshold. The option framework also allows the management to project occupancy rates and profits of their existing premises before entering price wars even if their rivals build new projects.

Keywords:

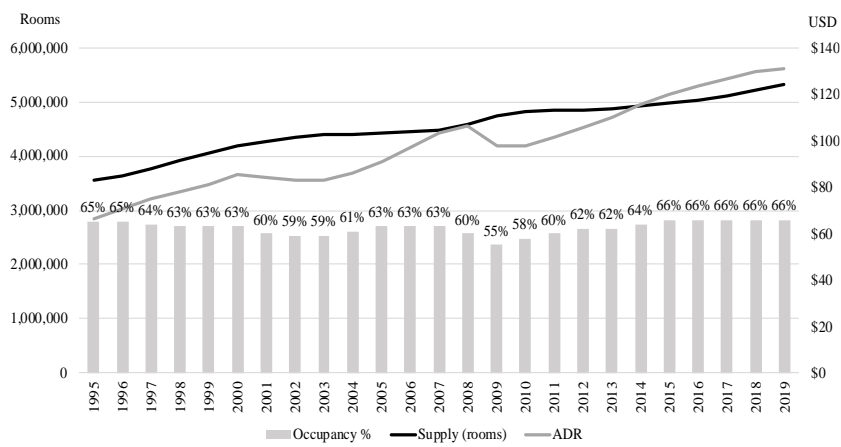
Oversupply, sticky rent, real options, game theory, hotel construction

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1. Introduction

This paper is about modeling the concurrence of vacancy and ongoing construction under inflexible rents. We pick the hotel industry as the area of application because it is more prone to oversupply than other industries, which is an issue in various regions of the world. The U.S. has continuously experienced a hotel oversupply in the last three decades (Dev and Hubbard, 1989; Lee and Jang, 2012). Figure 1 shows that the occupancy rate remained modest (below 70%) over the period of 1995-2019. Although hotel occupancy can be attributed to multiple factors, such as the existence of low-quality hotels, fluctuations in daily hotel occupancy, seasonal fluctuation, and variation in demand by market segment, the rate was still probably too low to conclude that the rooms were optimally utilized.

Figure 1 Room Occupancy Rate Versus Number of Rooms Supplied and Average Daily Rate: 1995 - 2019



Source: Cushman and Wakefield (2020)

Given oversupply, the average daily rates (ADRs) (also known as the rental rate per hotel room per day) should have been reduced to eliminate the excess capacity of rooms. However, Figure 1 exhibits an upward trend in ADRs. The recorded average annual percentage change of ADRs was 2.9% during the period (Cushman and Wakefield, 2020). At the same time, there have been continuous constructions of hotels. For instance, as of the end of 2019, the increase in hotel projects is 6%, which represents an increase in rooms by 8%, even though occupancy rates have been flat or dropping.¹ The sudden hit by the

¹ From “Top Hotel Construction Trends in 2020” by Russell and Dawson, available on <https://www.rdaep.com/blogs/hotel-construction-trends-usa-2020/>, and Major (2019).

COVID-19 pandemic in the first half of 2020 did not stop hotels from being built. One comment is that construction often lags behind the market mechanism, which would result in the coexistence of continued construction and poor market. Nevertheless, even in recession periods, hotel construction did not seem to have come to a halt easily because developers preferred to begin construction in slow periods when construction costs were lower (Major, 2019). To what extent is it profitable for developers to over-supply by constructing more, and when should they stop?

Numerous studies have discussed the issue of hotel overbuilding. O'Neill (2011) suggests the incorporation of multiple factors such as stabilized occupancy level in studying the feasibility of building a hotel. Gallagher and Mansour (2001) conclude that one of the primary reasons for overbuilding is the lagged response of hotel supply. They also find that allowing for some level of vacancy to price-discriminate higher-rate guests who are less responsive to price changes does not work in competitive markets and therefore is not the reason for high vacancy rates. Wheaton and Rossoff (1998) find that it takes 6 to 7 years for rental rates to adjust to changes in occupancy and another 2 to 3 years for new construction to react. However, this lag in rental rate adjustment and the long delivery lags in supply cannot fully explain why hoteliers tolerate a modest occupancy rate. The literature states that there is always incentive to build hotels as long as there is support from zoning and financing sources (for example, Johnson, 1998, Fickes, 2001, and McAneny, Han and Gallagher, 2001). In other words, when the construction cost is low relative to demand, there will be a greater tendency to overbuild. However, these studies do not take into account the stochasticity of ADRs and construction costs or, explicitly, game strategy by hoteliers, such as whether and when one hotelier should build if another one has started.

In this paper, we provide an alternative explanation for hotel overbuilding by using a real options modeling framework whereby developers are essentially in a game when they make their decisions. Decisions to construct hotels as a type of investment and opportunity for development can be considered as real options. Investment as a real option has been extensively studied in the literature. For instance, natural-resource investments and offshore petroleum leases (Brennan and Schwartz, 1985; Paddock, Siegel and Smith, 1988), as well as capital investment decisions (Ingersoll and Ross, 1992; Majd and Pindyck, 1987; McDonald and Siegel, 1986) can all be evaluated as real options. Grenadier (1995) and Grenadier and Weiss (1997) focus on lease contracts and investments in technological innovations. Titman (1985) and Williams (1991) study the value of development options in partial equilibrium, and Williams (1993) and Grenadier (1996) address the equilibrium option value and equilibrium option-exercise strategies of developers in real estate markets. Quigg (1993) and Holland, Ott, and Riddiough (2000) provide empirical evidence that supports the use of option-based models in making investment decisions. More recent studies on the timing of developments include Lai,

Wang, and Zhou (2004), Lai, Wang, and Yang (2007), and Chan, Wang, and Yang (2012).

This study contributes by drawing insights from oversupply by using a game theory approach in market equilibrium, which is particularly applicable to the hotel industry that is frequently prone to oversupply, a phenomenon that has not previously been theoretically explained. Our point of departure is that hotel developers make the choice of how much to build, having prepared for vacancies afterwards. We first determine the market equilibrium strategies that hotel developers can adopt to exercise their construction options optimally subject to the games played among them. We then use the strategies to examine the situation in which it is still profitable to maintain rental rates higher than that in equilibrium, coupled with oversupply, similar to the tacit collusion explanation in Horstmann et al. (2018). Our model is different from the games such as those in Ruiz-Aliseda (2019) because developers do not necessarily supply at the same time. We provide numerical examples to show when and how the strategies would work. Our analysis will benefit not only hotel developers in the U.S. but also their counterparts in other countries and regions, including China (Gu, 2003; Wang, Dai, and Xu, 2018) and Hong Kong (Tsai and Gu, 2012), which have experienced the concurrence of hotel oversupply and ongoing construction over the years. Our study is applicable not only to the hotel industry, but any other development opportunities with a similar setting.

The remainder of this paper is organized as follows. The following section shows the construction strategy model framework for hotel developers in a duopoly market. Comparison of scenarios for the model framework are provided in Section 3. We then offer an explanation of how construction strategies lead to hotel overbuilding in Section 4, illustrate the model with a numerical example in Section 5, and conclude the paper in Section 6.

2. Developers Price Game

In a dynamic market, the ADRs, or rental rates, will depend on random demand, which in turn depends on the market situation, consumer taste, and other factors that affect demand. In addition, ADRs tend to be lower when more developers are suppliers than when there is only one supplier in market equilibrium. Hence, sequential construction should provide more room revenue for at least a short period of time for the developer that takes the construction lead than simultaneous construction. Any rational developer will only build a hotel when the ADR could cover construction cost and generate a handsome payoff, or when the construction cost is sufficiently low. Otherwise, the developer would wait for more information. In this paper, we derive the development strategies in equilibrium that would maximize the allowable payoffs for both types of developers. Any deviation from the proposed strategies will result in sub-optimal payoffs.

Similar to previous studies on development opportunities as real options, we consider the opportunity of developing the hotel as a real option, with which the hotel is the underlying asset, and the continuous room revenue generated after the completion of the hotel is the underlying asset value. The option is said to be exercised once construction takes place such that the construction and development cost is the exercise price of the option. We begin by applying standard assumptions for financial options such as a complete market, non-satiated investors, a price process that follows a random walk in which the growth rate and variance are known, and a risk-free rate that is constant and known. Next, we consider a simple duopoly market with two hotel developers, each of whom owns an identical piece of land for hotel construction. We note that any difference in the land, such as size or location, can easily be adjusted in the model.

The use of a duopoly market serves only as a means of illustration. In the case of a competitive market, as long as one (or a group) of the developers (i.e. the “leader”) moves first, the rest would be “followers”, similar to a two-player market. Note in the case of real options, construction might require several years and room revenue would only be generated thereafter.

Suppose that room revenue can be generated soon after construction is completed, and the ADRs would follow an inverse demand function and be subject to continuous demand shocks, due to, for example, changes in the number of tourists. The volatility of such shocks would affect the demand for the use of hotel rooms or space. Mathematically, the price function that developers face when adding supply to the market is

$$R(t) = X(t)D[Q(t)] \quad (1)$$

where $R(t)$ is the ADR at time t , $Q(t)$ is the supply of hotel rooms at time t , $D(\cdot)$ is a standard differentiable inverse demand function with $D'(\cdot) < 0$ and $D''(\cdot) > 0$. $X(t)$ is a multiplicative demand shock that follows a geometric Wiener process:

$$dX = \mu_X X dt + \sigma_X X dw_X \quad (2)$$

where w is the Wiener process drawn from a normal distribution with $E(dw_X) = 0$, and $Var(dw_X) = dt$. μ_X is the constant instantaneous growth rate of the demand shock per unit time and σ_X is the constant instantaneous standard deviation per unit time with respect to w_X . Equation (2) shows the instantaneous change in demand shocks that govern ADRs, as represented by Equation (1). Thus, given any hotel room supply, $Q(t)$, at any time t , the ADR, $R(t)$, changes because of the demand shock $X(t)$, which could be due to change in economic conditions. Any differences in the ADR due to differences in hotel quality can easily be incorporated into the model by adding a coefficient proportional to quality, say, k , to adjust for quality (as in Stigler, 1964). For instance, $k > 1$ for a hotel with higher quality and therefore a higher room rate.

Construction cost is another source of stochasticity and can fluctuate substantially depending on the economic conditions, such as building booms, when construction workers and raw materials are both very expensive. Let I be the stochastic construction cost. Its instantaneous change becomes

$$dI = \mu_I I dt + \sigma_I I dw_I \quad (3)$$

where μ_I is the constant instantaneous growth rate of the construction cost per unit time and σ_I is the constant instantaneous standard deviation per unit time with respect to the Wiener process w_I . The instantaneous correlation coefficient ω between dw_X and dw_I is

$$dw_X dw_I = \omega dt \quad (4)$$

Consider the development time of the hotel to be δ years. The developer who decides at time $t = 0$ to build the hotel at time $t = \tau$ will receive room revenue only after time $\tau + \delta$. Here, the developer who decides to build the hotel first is labeled the Leader, while the developer who follows suit will be labeled the Follower. The Leader begins construction first, pays the construction cost and, when the building is completed, receives the room revenue. For simplicity, we assume that the existing supply before the Leader enters the market, Q_M , is zero so that we can focus on the new supply from the Leader and the Follower. Because the new market supply is restricted to only the supply from the Leader, the Leader is able to enjoy an ADR of

$$R(t) = X(t)D(1) \quad (5)$$

where we assume that the Leader supplies only 1 unit of room service for illustrative purposes. This can be easily relaxed to cater to any number of units permitted by the structure. If the Follower also decides to build 1 unit of room service some time later, there will be an increase in supply that drives down the ADR with

$$R(t) = X(t)D(2) \quad (6)$$

after δ years. The Follower experiences only one demand function (Equation 6), while the Leader experiences demand functions Equations (5) and (6) sequentially. Thus, the strategy of the Leader includes that of the Follower. This interactive decision chain is a game played by both developers in equilibrium.

2.1 Strategy of the Follower

Following Dutta and Rustichini (1993) and Grenadier (1996), we obtain the strategy of the Follower for market equilibrium before that of the Leader. Continuing with the assumption that both the Leader and the Follower supply one hotel unit respectively, the value of the option to build the hotel for the Follower at the time of decision-making is the lowered room revenue received after the hotel is built; that is,

$$F(t, X, I) = \sup_{\tau} E^{(t, X, I)} \left\{ e^{-r\tau} \left[e^{-(r-\mu_X)\delta} \frac{X(\tau)D(2)}{r - \mu_X} - I(\tau) \right] \right\} \quad (7)$$

where r is the risk-free rate and τ is the date that the construction begins. The first term inside the second set of parentheses in Equation (7) represents the constant flow of room revenue that follows the inverse demand function discounted to τ , while the second term is the construction cost that is assumed to have been paid all at once at τ . Applying Itô's lemma, the option value before implementation has an instantaneous rate of change of

$$\begin{aligned} dF = & \left(\frac{1}{2} \sigma_X^2 X^2 \frac{\partial^2 F}{\partial X^2} + \mu_X X \frac{\partial F}{\partial X} \right) dt + \partial X \frac{\partial F}{\partial X} dw_X + \sigma_X \sigma_I \omega XI \frac{\partial^2 F}{\partial X \partial I} \\ & + \left(\frac{1}{2} \sigma_I^2 I^2 \frac{\partial^2 F}{\partial I^2} + \mu_I I \frac{\partial F}{\partial I} \right) dt + \partial I \frac{\partial F}{\partial I} dw_I + \frac{\partial F}{\partial t} dt \end{aligned} \quad (8)$$

If the payoff function is valued today ($\tau = 0$), it would be invariant with time and would just be $F(X)$. Following Cox and Ross (1976) and Merton (1975), the expected rate of return from holding the development option should be equal to the risk-free rate according to the risk neutrality argument because neither income nor cost will be generated from the undeveloped land before construction. Hence, taking the expectation on Equation (8), letting $y = \frac{X}{I}$, and equating it to the risk-free rate, the equation that governs the flow of the room revenue of the Follower becomes

$$\left(\frac{1}{2} \sigma_X^2 + \frac{1}{2} \sigma_I^2 - \sigma_X \sigma_I \omega \right) y^2 f'' + (\mu_X - \mu_I) y f' + (\mu_I - r) f = 0 \quad (9)$$

To solve Equation (9), $f(y)$ must satisfy the following boundary conditions (see Dixit and Pindyck, 1994):

$$f(0) = 0 \quad (10a)$$

$$f(y_F) = e^{-(r-\mu_X)\delta} \frac{D(2)}{r - \mu_X} y_F - 1 \quad (10b)$$

$$f'(y_F) = e^{-(r-\mu_X)\delta} \frac{D(2)}{r - \mu_X} \quad (10c)$$

where y_F , the “trigger point,” is the ratio of the demand shock to the construction cost, based on which the Follower should start construction. The absorbing barrier condition (Equation 10a) specifies that the hotel development option has no value and will remain zero forever if the ADR ever goes to zero. The “value-matching condition” (Equation 10b) states the payoff at the time of

exercising the option. The last “smooth-pasting condition” (Equation 10c), also known as the “high-contact condition”, ensures an optimal value for $F(X)$ at X_F .

Suppose the solution to Equation (9) takes the form $f(y) = Ay^\beta$, and subject to Equations (10a) to (10c), the value of the hotel development opportunity is

$$F(X, I) = \begin{cases} \left(\frac{e^{-(r-\mu_X)\delta} D(2)}{r - \mu_X} \right)^\beta \left(\frac{\beta - 1}{I} \right)^{\beta-1} \left(\frac{X}{\beta} \right)^\beta & \text{if } \frac{X}{I} < y_F \\ e^{-(r-\mu)\delta} \frac{XD(2)}{r - \mu_X} - I & \text{if } \frac{X}{I} \geq y_F \end{cases} \quad (11)$$

where $y_F = e^{(r-\mu_X)\delta} \frac{(r-\mu_X)\beta}{D(2)(\beta-1)}$ and

$$\beta = \frac{1}{2} - \frac{\mu_X - \mu_I}{2\Sigma} + \sqrt{\left(\frac{\mu_X - \mu_I}{2\Sigma} - \frac{1}{2} \right)^2 + \frac{r - \mu_X}{\Sigma}},$$

$$\Sigma = \frac{1}{2} \sigma_X^2 + \frac{1}{2} \sigma_I^2 - \sigma_X \sigma_I \omega$$

Equation (11) shows that the Follower should start building the hotel only when the ratio of the demand shock to the construction cost reaches a value of at least y_F . Otherwise, the Follower should wait for more favorable market conditions rather than squandering the opportunity for optimal development. In a simplified situation where the construction cost is quite stable, Equation (11) will depend on the stochasticity of demand with a trigger value of only X_F , and

a much simpler $\beta = \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2}}$ where μ is the growth rate and σ is the standard deviation of the demand shock respectively.

2.2 Strategy of the Leader

The Leader can enjoy a monopoly before the Follower offers hotel rooms with a continuous room revenue of

$$L_1(t, X, I) = e^{-(r-\mu_X)\delta} \frac{X(t)D(1)}{r - \mu_X} - I(t) \quad (12a)$$

After the Follower supplies rooms for some time unknown to the Leader, the Leader faces a stochastically reduced room revenue, $L_2(t, X, I)$, which displays behavior similar to that of the Follower in Equation (7), that is,

$$\begin{aligned} & \frac{1}{2} \sigma_X^2 X^2 \frac{\partial^2 L_2}{\partial X^2} + \frac{1}{2} \sigma_I^2 I^2 \frac{\partial^2 L_2}{\partial I^2} + \sigma_X \sigma_I \omega X I \frac{\partial^2 L_2}{\partial X \partial I} + \mu_X X \frac{\partial L_2}{\partial X} \\ & + \mu_I I \frac{\partial L_2}{\partial I} + \frac{\partial L_2}{\partial t} - r L_2 = 0 \end{aligned} \quad (13)$$

When the Follower supplies the hotel because y_F is reached, the Leader loses the higher room revenue with the quantity demanded of $D(1)$ and earns a presumably lower continuous room revenue:

$$e^{-(r-\mu_X)\delta} \frac{[D(2) - D(1)]y_F}{r - \mu_X} I(t)$$

with a quantity demanded of $D(2)$ from then onward. This is the boundary condition for Equation (11), which, by also adopting a solution form $L_2(X, I) = Ay^\beta$, produces

$$L_2(X, I) = \beta \frac{D(2) - D(1)}{D(2)} \left(\frac{e^{-(r-\mu_X)\delta} D(2)}{r - \mu_X} \right)^\beta \left(\frac{\beta - 1}{I} \right)^{\beta-1} \left(\frac{X}{\beta} \right)^\beta \quad (12b)$$

Should the ratio between the demand shock and the construction cost reach y_F before construction commences, both developers will start to build their hotels at the same time (the minimal time lag between the onset of the two construction projects, if any, can be neglected). Thus, combining Equation (12b) with the monopoly room revenue flow in Equation (12a), the value of the hotel investment opportunity of the Leader is as follows:

$$L(X, I) = \quad (14)$$

$$\begin{cases} \frac{e^{-(r-\mu_X)\delta} D(1)X}{r - \mu_X} + \beta \frac{D(2) - D(1)}{D(2)} \left(\frac{e^{-(r-\mu_X)\delta} D(2)}{r - \mu_X} \right)^\beta \left(\frac{\beta - 1}{I} \right)^{\beta-1} \left(\frac{X}{\beta} \right)^\beta - I & \text{if } \frac{X}{I} < y_F \\ \frac{e^{-(r-\mu_X)\delta} D(2)X}{r - \mu_X} - I & \text{if } \frac{X}{I} \geq y_F \end{cases}$$

The goal is to determine the best time for the Leader to start the hotel construction. In market equilibrium, the value of the opportunity for the Follower to construct cannot be contingent on that for the Leader, who starts construction and subsequently enjoys an income earlier. Otherwise, both developers will try to “lead” the market as soon as possible. As both demand shock and construction costs follow growth processes, there is a y_L that is less than y_F at which the Leader should start construction, the value of opportunity of which can be determined with the following equation:

$$\begin{aligned} & \frac{D(1)e^{-(r-u_X)\delta}y_L}{r-\mu_X} + \left(\frac{D(2)e^{-(r-\mu_X)\delta}}{r-\mu_X} \right)^\beta (\beta \\ & - 1)^{\beta-1} \beta^{-\beta} y_L^\beta \left(\beta \frac{D(2)-D(1)}{D(2)} - 1 \right) - 1 = 0 \end{aligned} \quad (15)$$

To prove that y_L is a “trigger point” for the Leader to construct a hotel, recall that both developers need to be indifferent between being the Leader and the Follower in market equilibrium. Then, equating the first formulas in Equations (11) and (14), when $\frac{X}{I}$ has not reached y_F (but y_L may be found because $y_L < y_F$) and dividing by I , we obtain

$$\begin{aligned} & \frac{D(1)e^{-(r-u_X)\delta}y}{r-\mu_X} + \left(\frac{D(2)e^{-(r-\mu_X)\delta}}{r-\mu_X} \right)^\beta (\beta \\ & - 1)^{\beta-1} \beta^{-\beta} y^\beta \left(\beta \frac{D(2)-D(1)}{D(2)} - 1 \right) - 1 = 0 \end{aligned}$$

Let $\chi(y)$ be the left-hand side of the above equation. The root of this function is y_L . Another root is obviously y_F . To show their uniqueness, first note that because $\frac{D(2)-D(1)}{D(2)} < 0$, $\chi(y)$ is negative as y approaches 0. Next, $\chi''(y) < 0$ implies that there is a maximum point between y_L and y_F . Therefore, there is a unique $y_L \in (0, y_F)$ such that $\chi(y_L) = 0$.

To summarize, the value of opportunity for both developers to develop a hotel is such that

$$L(X, I) < F(X, I) \text{ if } \frac{X}{I} < y_L$$

$$L(X, I) = F(X, I) \text{ if } \frac{X}{I} = y_L$$

$$L(X, I) > F(X, I) \text{ if } y_L < \frac{X}{I} < y_F$$

$$L(X, I) = F(X, I) \text{ if } \frac{X}{I} \geq y_F$$

In sum, market equilibrium is attained either when there is sequential construction of the hotels when the demand shock–construction cost ratios reach $\frac{X}{I} = y_L$ and $\frac{X}{I} = y_F$, or when there is simultaneous construction when the

initial value of the ratio $\frac{x}{I}$ is more than y_L and increases to equal y_F . These are the ratios that trigger construction.

3. Comparative Static Analyses

Since the hotel industry is highly volatile, construction decisions are sensitive to changes in the market conditions (Overstreet, 1989). We examine the extent and effects of the changes in some of the relatively stable parameters, such as price elasticity and the risk-free rate, and more dynamic parameters such as demand and construction cost volatility, on the construction strategies in this section. We follow a similar approach as that in Cushman and Wakefield (2020) in the following comparative static analysis and illustrations. The chosen parameters are $\mu_X = 2.8\%$, $\mu_I = 8\%$, $I = \$125,000$ (taken as the average construction cost of an economy hotel room and a midscale hotel room (Major, 2019)), $\sigma_X = 0.1$, $\sigma_I = 0.4$, $\omega = 0.4$, and $\delta = 3$ years. Note that we assume a high risk-free rate of 10% to emphasize its effect in a high interest rate environment versus a relatively lower one at 4% (we do not adopt the low risk-free rate in the low interest rate period following the 2008 Global Financial Crisis because it was an unusual period with low interest rates).

Table 1 provides the trigger values of both developers, y_L and y_F , with different supply levels, price elasticities, and risk-free rates and a demand function of $D(t) = Q(t)^{\frac{1}{\gamma}}$, where γ represents the price elasticity of demand. Panel A provides the values for developers with equal supply, while Panel B shows the values for developers who have varying supply with a constant total supply. In general, when demand is elastic ($\gamma = 10$), the Follower will tend to start construction shortly after the Leader has started the work. Simultaneous construction is highly probable if both developers have little to supply while demand is very elastic. When demand becomes less elastic, the difference between the trigger point values becomes more pronounced, and even more so when developers have more units to offer.

Intuitively, when a developer with relatively few hotel units commences construction first, the other developer with more to offer will wait for better market conditions (i.e., much higher demand and/or lower construction costs) before commencing construction. However, if the developer with more supply becomes the Leader, the Follower will follow shortly afterward. These phenomena suggest that developers with more units to supply will be motivated to build only if market conditions are relatively favorable. Furthermore, as demand becomes inelastic, a slight increase in supply could significantly reduce the market price. Hence, the developer who becomes the Follower will not begin construction unless market demand increases or construction costs decrease substantially.

Table 1 **Trigger Point Values of Hotel Construction for Leader and Follower Developers**

<i>Panel A: Same Level of Supply by Both Developers</i>								
Individual Supply	Interest Rate = 10%				Interest Rate = 4%			
	$\gamma = 10$		$\gamma = 2$		$\gamma = 10$		$\gamma = 2$	
	y_F	y_L	y_F	y_L	y_F	y_L	y_F	y_L
100	<i>0.2906</i>	<i>0.2906</i>	2.4197	1.3411	0.0623	0.0545	0.5187	0.2831
200	<i>0.3115</i>	<i>0.3115</i>	3.4220	1.8966	0.0668	0.0584	0.7335	0.4003
300	0.3244	0.2839	4.1911	2.3228	0.0695	0.0608	0.8984	0.4903
400	0.3339	0.2922	4.8394	2.6821	0.0716	0.0626	1.0373	0.5661
500	0.3414	0.2988	5.4107	2.9987	0.0732	0.0640	1.1598	0.6329
<i>Panel B: Fixed Total Supply of 600 Units, with Varying Supply from the Leader Developer</i>								
Leader Supply	Interest Rate = 10%				Interest Rate = 4%			
	$\gamma = 10$		$\gamma = 2$		$\gamma = 10$		$\gamma = 2$	
	y_F	y_L	y_F	y_L	y_F	y_L	y_F	y_L
100	<i>0.3244</i>	<i>0.3244</i>	4.1911	1.1244	<i>0.0695</i>	<i>0.0695</i>	0.8984	0.2286
200	0.3244	0.2638	4.1911	1.7442	0.0695	0.0564	0.8984	0.3631
300	0.3244	0.2839	4.1911	2.3228	0.0695	0.0608	0.8984	0.4903
400	0.3244	0.2997	4.1911	2.9080	0.0695	0.0642	0.8984	0.6192
500	0.3244	0.3129	4.1911	3.5243	0.0695	0.0671	0.8984	0.7542

Note: 1. Numbers in bold and italics denote simultaneous construction. “Interest Rate” refers to the annual risk-free rate.
2. $\mu_X = 2.8\%$, $\mu_I = 8\%$, $I = \$125,000$, $\sigma_X = 0.1$, $\sigma_I = 0.4$, $\omega = 0.4$, and $\delta = 3$ years.

Panel B also shows an interesting circumstance of market equilibrium. For instance, when the developers supply 200 and 400 units as in the second and fourth rows, the developer with 200 units can choose to be the Leader at $y_L = 0.2638$ or the Follower at $y_F = 0.3244$. Both parties have equal payoffs under either market equilibrium strategy. Finally, the risk-free rate also plays a role in decision-making. When the discounted risk-free rate is high, delaying the payment of costs is a good idea. Construction is favored only if growth in demand is significantly higher than growth in construction cost when the risk-free rate is high. Otherwise, the costs for construction will be less detrimental. Therefore, the trigger point values shown in Table 1 where $r = 4\%$ are significantly lower than those where $r = 10\%$.

The next concern is the effects from more dynamic issues, namely, the volatilities of the random shocks (σ_I and σ_X) on the development strategy. It is easy to see from Equation (11) that β decreases as σ_I and/or σ_X increases and ω decreases. Differentiating y_F in Equation (11) with respect to β , we obtain:

$$\frac{dy_F}{d\beta} = e^{(r-\mu_X)\delta} \frac{(r-\mu_X)}{D(2)} \left(\frac{-1}{(\beta-1)^2} \right)$$

It is obviously negative, which implies that y_F increases with increases in σ_I and/or σ_X and decreases in ω . Moreover, Equation (15) shows that y_L is increasing in σ_I and/or σ_X . Hence, in general, a more fluctuating demand for hotel services or higher volatility in the cost of constructing a hotel will result in higher trigger values for both the Leader and the Follower. This is essentially the value of real options: given increased uncertainty, developers will wait for more favorable market situations before exercising the options.

Alternatively, developers will be more inclined to delay hotel construction and wait for more information in market situations with relatively more volatile demand. They will be reluctant to take the risk of beginning construction unless they are confident that it is the optimal time to build. In contrast, higher volatility in construction cost compels commencement of construction because developers can take advantage of the opportunity to develop if they believe that the future cost movement could be volatile. To see this, note that the anticipated commencements of hotel construction for both the Leader and the Follower from the current date t_0 are, respectively,

$$E(t_L) = \frac{\ln(y_L) - \ln\left(\frac{X(t_0)}{I(t_0)}\right)}{\mu_X - \mu_I - \frac{1}{2}(\sigma_X^2 - \sigma_I^2)} \quad \text{and}$$

$$E(t_F) = \frac{\ln(y_F) - \ln\left(\frac{X(t_0)}{I(t_0)}\right)}{\mu_X - \mu_I - \frac{1}{2}(\sigma_X^2 - \sigma_I^2)},$$

which are determined based on Dynkin's formula (see Øksendal 1998, p. 62). Recall that both y_L and y_F increase with increases in σ_X ; $E(t_L)$ and $E(t_F)$ are thus increasing with increases in σ_X and/or decreases in σ_I , which validates the argument. Furthermore, because the expected time lag between the commencement of the construction of the two hotels is

$$E(\tau_{LF}) = \frac{\ln(y_F) - \ln(y_L)}{\mu_X - \mu_I - \frac{1}{2}(\sigma_X^2 - \sigma_I^2)},$$

it follows that for a sufficient β value (e.g., $\beta > 1$), $E(\tau_{LF})$ is directly proportional to σ_I and inversely proportional to σ_X . As $y_L < y_F$, the directly proportional effect of σ_I is greater in $E(t_F)$ than $E(t_L)$. Intuitively, while the increasingly fluctuating cost of construction reduces the waiting time of both developers, the fluctuations tend to compel the Leader to commence construction at an even

earlier date, thus increasing the time lag between the two developers. Similarly, while a more volatile demand shock series delays construction decisions, it also tends to have a more pronounced effect on the Leader, thus reducing the gap between $E(t_L)$ and $E(t_F)$.

4. Overbuilding of Hotels

Section 2 shows the market equilibrium strategies adopted by both developers in which ADRs adjust to demand shocks immediately in accordance with the demand function so that there is no excess supply. In reality, there is continuous oversupply in hotel markets, and hotel ADRs are often sticky. We show in this section that the strategies thus derived are robust in generating profits even if developers do not reduce the ADR to eliminate the excess supply.

Suppose that developers are unwilling to lower ADRs to eliminate excess supply from the excessive construction of hotels. Let \bar{R}_t be the sticky ADR per unit of hotel service at time t and \bar{D} be the projected demand level for each unit of demand shock at the time. It follows that $X(t)\bar{D}$ is the total demand at time t and $X(t)\bar{R}_t\bar{D}$ is the aggregate room revenue of the industry to be shared by all developers. Given M existing inventory and $Q(t) = 2$ newly completed hotel units (recall that each developer arbitrarily supplies one hotel unit for illustrative purposes), each unit of hotel service at time t will generate a room revenue flow of

$$R(t) = \frac{X(t)\bar{R}_t\bar{D}}{M + Q(t)} \quad (16)$$

Oversupply occurs when the quantity demanded is less than the quantity supplied, or $X(t)\bar{D} < M + Q(t)$. By equating Equations (6) and (16) to obtain $D(Q(t)) = \frac{\bar{R}_t\bar{D}}{M+Q(t)}$, which is substituted for y_F in Equation (11) to obtain $X(t) = I(t)y_F$, we can conclude that the decision of the Follower to construct is considered to be overbuilding (where the supply would be realized only δ years after the construction is completed) if

$$\frac{I(t)(r - \mu_X)e^{(r - \mu_X)\delta}\beta}{(\beta - 1)\bar{R}_t} < 1 \quad (17)$$

Equation (17) holds for a smaller δ value (i.e., a shorter construction period), lower construction cost, and higher β (which implies less volatility in demand and/or the construction cost).

Hence, overbuilding is not necessarily the result of the lagged response of hotel supply. Rather, developers may prefer to overbuild more frequently in market recessions when lower construction costs facilitate more timely construction,

especially with anticipated high demand growth, μ_X . Furthermore, given that the ADR is inflexible, the excess supply from the Follower will be eliminated only with a higher demand shock. Thus, the average time required to absorb the excess supply, T , is

$$E(T) = \frac{\ln(1) - \ln\left(\frac{I(t)(r - u_X)e^{(r - u_X)\delta}\beta}{(\beta - 1)\bar{R}_t}\right)}{\mu_X - \frac{1}{2}\sigma_X^2} \quad (18)$$

$$= \frac{\ln\left(\frac{(\beta - 1)\bar{R}_te^{-(r - \mu_X)\delta}}{I(t)(r - \mu_X)\beta}\right)}{\mu_X - \frac{1}{2}\sigma_X^2}$$

Equation (18) shows that a longer construction time and higher construction cost will reduce the expected time for the absorption of the excess supply from the Follower. The construction time and cost are the same factors that inhibit overbuilding. As β decreases as σ_I and σ_X increase and ω decreases, the expected time for the market to absorb the excess supply is shorter, with greater fluctuation in construction costs. However, the effect of the volatility in the demand shock is less obvious because σ_X appears in both β and the denominator of Equation (18). Nevertheless, we find a positive relationship by differentiating Equation (18) with respect to σ_X . Hence, increased demand volatility or decreased construction cost volatility will not only delay the decision of developers to commence construction but increase the expected time for the market to absorb the excess supply. In general, a longer time is necessary to absorb the oversupply when it is economical, less uncertain, and requires less time to build hotels.

In a similar fashion, the Leader will overbuild if $X(t)\bar{D} < M + Q(t)$. Note that this $Q(t)$, which represents only the supply of the Leader, is different from the $Q(t)$ in Equation (16), which represents the aggregate supply of both developers. With $y_L = \frac{X}{I}$, we have

$$I < \frac{M + Q(t)}{\bar{D}y_L} \quad (19)$$

which is more likely to be sustained for small values of I and/or small y_L because of the small values of σ_I and σ_X . The result indicates that the Leader will overbuild if either the construction cost is sufficiently low or there are small fluctuations in the demand or construction costs.

From the analyses throughout this paper, our general model consistently shows the same inferences whether the hotel market readily adjusts the ADRs to eliminate overbuilding or simply adheres to current ADRs. First, both the Follower and Leader developers tend to overbuild when construction costs are

low, a phenomenon found in periods of recession. More volatility in the demand for hotel services and/or more volatility in hotel construction costs will result in higher “trigger points”, y_L and y_F , for construction but a reduced likelihood of overbuilding. Furthermore, higher volatility in demand increases the expected building time of the two developers, while the volatility of a higher construction cost produces the opposite result.

5. Model Applied in Practice

In this section, we show how our model framework can be used by the two hotel developers in a duopoly. Following Table 1, the growth rate, standard deviation, and correlation coefficients of demand and construction costs are $\mu_X = 0.023$, $\mu_I = 0.08$, $\sigma_X = 0.1$, $\sigma_I = 0.4$, and $\omega = 0.4$, respectively. Furthermore, we assume a risk-free rate of $r = 10\%$, construction cost per unit of hotel service as $I = \$125,000$, price elasticity of $\gamma = 2$, and construction period of 3 years for high-rise hotels in which each developer plans to supply 200 units of hotel service. Substituting these values into Equation (11), we obtain the following:

$$F(X, I) = \begin{cases} 0.099246 \frac{X^{2.309321}}{I^{1.309321}} & \text{if } \frac{X}{I} < 2.41973 \\ 0.728907X - I & \text{if } \frac{X}{I} \geq 2.41973 \end{cases}$$

where $y_F = 2.41973$ and $\beta = 2.309321$ with $\Sigma = 0.069$. In other words, the Follower should start hotel construction once the ratio of the demand shock to the construction cost reaches 2.41973. Otherwise, the Follower should wait. The value of holding this construction option can be calculated by using Equation 1.

Similarly, the value of the option of the Leader to commence building by using Equation (14) is

$$L(X, I) = \begin{cases} 1.03083X - 0.09493 \frac{X^{2.309321}}{I^{2.309321}} - I & \text{if } \frac{X}{I} < 2.41973 \\ 0.728907X - I & \text{if } \frac{X}{I} \geq 2.41973 \end{cases}$$

Note that both will build at the same time when the ratio hits 2.41973 from below, and will enjoy identical payoffs per unit of hotel service. Before the ratio reaches this value, however, the Leader will enjoy a monopoly, and the development opportunity gives the Leader a value that is equal to the first formula above. The Leader can optimally build the hotel when the demand shock/construction ratio reaches $y_L = 1.341063$. This is also the case when both developers are indifferent in being the Leader or Follower.

Excess supply will emerge if the developers adopt an inflexible ADR that exceeds the equilibrium rate. To see this, the market equilibrium strategies thus calculated reflect the equilibrium room revenue per annum of $R_F = X_F D(200) = \$21,387.55$, where X_F is the level of demand shock such that y_F is reached and both developers start building. Suppose that there are currently 1,000 existing hotel units. The new construction will increase the total supply to $M + Q(t) = 1,200$. With Equation (16) and $R(t) = R_F = \bar{R}_t$, we have $X(t)\bar{D} = M + Q(t) = 1,200$. If the developers wish to maintain an inflexible room revenue of, say, $\bar{R}_t = \$29,200$, the total demand will then decrease to $X(t)\bar{D} = 878.94$. The figures represent an occupancy rate of $878.94/1,200 = 73.25\%$. Developers can still earn a profit even when overcapacity exists, as long as the total revenue from inflexible ADR and current demand is maintained as if there is market equilibrium (that is, $\bar{R}_t X(t)\bar{D} = R_F [M + Q(t)]$). Note that the sticky ADRs of hotels can be reached not only because of greater demand but also when the volatility of either demand or construction cost (or both) is low, and demand and construction cost are more correlated, which are the conditions for a lower trigger value, y_F . As long as y_F is reached, the resulting equilibrium ADR per annum will be the minimum room rate that guarantees breaking even (at least on the construction cost) for developers, albeit with a lower occupancy rate. Interestingly, this is plausible not only during periods of high economic growth as usual, but also in periods of low economic growth as long as the construction costs are low and closely correlated with demand for hotel rooms.

6. Conclusion

The prevalence of modest occupancy in the U.S. hotel industry has led to questions about the ongoing construction of hotels, which causes volatile business cycles. Although the occupancy of hotels is far below 100%, investors are still able to increase room rates to sustain their profit. Several attempts have been made in the literature to explain the causal factors. This study deviates from other research by incorporating both stochastic revenue and construction costs and offering a closed-form solution to the general market equilibrium problem by using the game theory.

Our model framework suggests that hotel developers should consider whether they want to be leader or follower in the market, and the conditions of when they should start the development. More importantly, this study contributes to the literature by offering an alternative explanation for the coexistence of sticky room rates and the oversupply of hotels, which tend to be prominent not only in times of market booms but also in recessions when construction costs are low. We recommend that hotel developers can proactively determine their supply by following our framework for optimal decisions, as illustrated in Section 5, limit the range of ADRs so that the inflexibility of the ADR can still generate more profit, and determine the vacancy rate in market equilibrium. Our explanation of coexistence of oversupply and rigid pricing is applicable

not only to hotels, but any development that can be considered as real options in a similar game setting with which developers have the option to wait. We note of course that shocks like the COVID-19 pandemic cannot be incorporated in our framework without a much more complicated mathematical setup to cater to the extreme uncertainty, which could be an extension for future research.

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