

On the Inference of Collusion in Algorithmic Pricing: Lessons From Cornish-Adebiyi V. Caesars

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I. Distinguishing Information Effects from Collusive Coordination

The growing use of common pricing algorithms (hub-and-spoke systems) has generated an important question for antitrust law: when competing firms transmit commercially sensitive information to a common pricing platform and subsequently exhibit higher prices and lower output, what inference should be drawn from those outcomes regarding collusion?

That question is particularly salient after the Third Circuit's recent opinion in *Cornish-Adebiyi v. Caesars Entertainment, Inc.* ("the Opinion").¹ The plaintiffs (casino-hotel guests) alleged that competing Atlantic City casino-hotels supplied non-public pricing and occupancy information to a common algorithmic pricing provider, *Cendyn Group LLC's Rainmaker software*, which used those data in generating pricing recommendations to each hotel. The Third Circuit held that the allegations were sufficient to plausibly allege

concerted action under Section 1 of the Sherman Act.

Of particular interest from an economic perspective is the Third Circuit's discussion of prices and occupancy. According to the court's description of the allegations, collective room occupancy declined while room revenue increased during the class Period (June 28, 2018-present). The court reasoned that the alleged arrangement could succeed only if hotels could maintain higher prices without fearing that rivals would undercut them, concluding that this "certainly supports an inference of collusion; indeed, we can think of no other explanation" (p.35).

In principle, the observed combination of declining quantities and increasing prices and revenues is economically consistent with an output-restricting collusive equilibrium, although the pattern is not uniquely diagnostic of collusion and must be evaluated against alternative supply- and demand-side explanations. For example, if, over time, maybe thanks to algorithmic software, firms become increasingly successful at attracting, identifying, or retaining consumers with higher willingness to pay ("WTP") and less elastic demand, while lower-WTP/more price-sensitive consumers leave the market (so that the inverse demand curve has a higher intercept and a steeper slope), then exactly the same aggregate pattern can be observed. Similarly, an input price increase can cause price and *revenue* increases when demand is sufficiently inelastic. But

¹ *Cornish-Adebiyi v. Caesars Entertainment, Inc.*, No. 24-3006 (3d Cir. 2026).

in this article, we focus on the information-sharing aspect of the case, as the Opinion does, and propose an empirical test to distinguish whether information sharing drives coordinated activity or merely supports decision-making under unilateral incentives. Specifically, the court also concludes that “...taking Plaintiffs’ allegations as true, the software is, in effect, facilitating collusive conduct by receiving from each client non-public commercial information, and in return, giving each client the benefit of their competitors’ non-public data in formulating a price recommendation which Defendants purportedly agreed to comply with.”(p.39)

To address this possibility, we present a simple model of an information-sharing practice that could produce the observed pattern without taking a stance on the anti-competitiveness of agreeing to such information sharing or on awareness of its potential to increase prices. We use the same economic mechanism as in Garcia, Janssen, & Shopova (2023), but rather than characterizing a broad dynamic pricing environment, we construct a minimal example designed to isolate the possibility that revealing residual capacity can increase prices and reduce occupancy.² We note, however, that the firms do not have to *agree* to comply with price recommendations in our model, they each have the unilateral *incentive* to do so. We hence exhibit an equilibrium in which **occupancy falls, and revenue rises solely because the information regime becomes**

transparent, while there is no agreement, punishment strategy, or commitment not to undercut. Then, the mechanism is purely informational rather than collusive. When a firm (e.g. a hotel) knows that its rival has exhausted its capacity, it recognizes that it is the residual monopolist and may raise its price.

Thus, the model predicts that this price effect should be concentrated when information reveals that residual competition has become weak: dates with scarce remaining inventory, late booking horizons, sellouts by competing properties, high-demand event dates, etc. In contrast, a genuine broad “don’t undercut” coordination story predicts something different: elevated pricing should not require the particular state in which competitors have exhausted or nearly exhausted capacity. Then, an empirical test could interact algorithm adoption/information availability with measures of rival residual capacity, booking horizon, or market tightness. If the price increase appears specifically when competitors’ residual capacity disappears, that is more consistent with **information changing unilateral incentives than with collusive conduct**. We also show that even such information sharing does not necessarily imply higher prices and lower occupancy. Its effects depend on the underlying demand and strategic parameters. The remainder of the paper

² Garcia, D., Janssen, M. C., & Shopova, R. (2023). Dynamic pricing with uncertain capacities. *Management Science*, 69(9), 5275-5297.

presents the model's mechanics and delves on sensitivities.

II. A Minimal Model

We now illustrate a deliberately minimal dynamic pricing model in which competing hotels possess perishable capacity and consumers arrive sequentially in two Periods. We compare two information regimes. Under **opacity**, a hotel with an unsold room does not know whether its rival has already sold its room. This game involves simultaneous-moves without the benefit of information. Under **transparency**, the hotel observes whether its rival remains active in the second Period and prices accordingly. The two information regimes differ only in information structures.

There are two symmetric firms represented by $i \in \{1, 2\}$. Each begins with one room for the same hotel night (or, airplane seat, concert ticket, etc.). There are two Periods representing the perishable (time-dated) nature of a hotel night capacity, represented by $t \in \{1, 2\}$. A room sold in Period 1 is unavailable in Period 2; an unsold room remaining after Period 2 expires. Marginal cost is zero for the sale of either room. Conditional on arrival, the willingness-to-pay (WTP) of the customer can also be low or high $v \in \{\$1, \$3\}$ with corresponding arrival probabilities of $3/5$ and $2/5$. In each Period t , every active firm i chooses from a low and a high price possibility, i.e., $p_i^t \in \{\$1, \$3\}$. Assume that a customer arrives in Period 1 with probability $1/2$ and in Period 2 with probability $1/4$. Arrival probabilities are chosen for numerical simplicity and are not

intended to capture a particular booking curve pattern. For many hotels, especially business or airport hotels, booking intensity may rise close to the stay date. Our results hold if we reverse these probabilities to accommodate that possibility. A consumer purchases from the lowest-priced available firm whenever their WTP is at least the posted price. Equal prices are resolved by uniform random allocation; hence, winning is with probability $1/2$.

We solve for the Perfect Bayesian Equilibrium ("PBE") of this game for each information regime and summarize it below. In this equilibrium, each hotel maximizes expected profit taking as given the other's pricing strategy and the information structure.

A. Equilibrium Prices, Profits, and Occupancy with Opacity

We show below that both hotels charging $(\$1, \$1)$ in both Periods is the PBE of this game with opacity. Rational players anticipate Period 2 outcomes in Period 1; hence, we first solve for Period 2. Given the symmetry of the model, it suffices to solve for the equilibrium from the perspective of hotel i .

Period 2

We assume Period 1 prices are $(\$1, \$1)$ as per the proposed equilibrium. Under opacity, hotel i does not observe whether hotel j remains active before setting its Period 2 price. It therefore forms a Bayesian belief, denoted by q , about the probability that hotel j

is still active conditional on hotel i being active:

$q = \text{Probability}(\text{hotel } j \text{ active} \mid \text{hotel } i \text{ active})$
 $= \text{Probability}(\text{both hotels active}) / \text{Probability}(\text{hotel } i \text{ active})$

given

$\text{Probability}(\text{both hotels active}) = \text{Probability}(\text{no arrival in Period 1}) = 1/2$

and

$\text{Probability}(\text{hotel } i \text{ active}) = \text{Probability}(\text{no arrival in Period 1}) + \text{Probability}(\text{arrived bought from competitor}) = 1/2 + 1/2 * 1/2 = 3/4,$

we have

$q = (1/2) / (3/4) = 2/3.$

Now, we test (\$1,\$1) as equilibrium in Period 2.

Thus, deviating to \$3

should not be profitable for hotel i.

Expected revenue for hotel i from charging \$1 when the hotel j is charging \$1 is
 $= \text{Probability of arrival} * [(1-q) * \$1 + q * \$1 * 1/2] + \text{Probability of not arrival} * \0

$= 1/4[(1/3) + (2/3)(1/2)]$

$= \$1/6$

Expected revenue for hotel i from charging \$3 when the hotel j is charging \$1 is
 $= \text{Probability of arrival} * [(1-q) * (2/5) * \$3 + q * 0] + \text{Probability of no arrival} * \0

$= 1/4[(1/3)(2/5) * \$3]$

$= \$1/10 < \$1/6.$

Showing that (\$3,\$3) is not an equilibrium is similar.

Now we move to Period 1.

Period 1

As (\$1,\$1) is the equilibrium in Period 2, rational players take it as given. Now we check if (\$1,\$1) is also an equilibrium in Period 1. Hotel i's expected revenue from continuation to Period 2 is \$1/6 and the probability of remaining active is 3/4 as shown, giving $(3/4) * (1/6) = \$1/8.$ We add this to the Period 1 expected revenue from the

play (\$1,\$1), which is given by

$$\begin{aligned} & \text{Probability(arrival in Period 1)} * \text{Probability(winning the customer)} * \$1 \\ &= (1/2) * (1/2) * \$1 \\ &= \$1/4 \end{aligned}$$

So, the payoff from playing \$1 in Period 1 is
 $\$1/8 + \$1/4 = \$3/8$

We compare \$3/8 with hotel i's deviation revenues from \$3: Hotel i cannot sell in Period 1 and is certainly active in Period 2. Hotel j is active in Period 2 only if there is no arrival in Period 1, that is, with probability $1 - 1/2 = 1/2 = q$. So, the expected revenues are

$$\begin{aligned} & \text{Probability(arrival in Period 2)} \\ & [(1-q) * \$1 + q * (1/2) * \$1] + \\ & \text{Probability(no arrival in Period 2)} * 0 \\ &= (1/4) * [(1/2) * \$1 + (1/2) * (1/2) * \$1] \\ &= \$3/16 < \$3/8 \end{aligned}$$

Showing that charging \$1 is not profitable when the rival charges \$3 and also that (\$3,\$3) is not an equilibrium are similar.

Now we find the expected number of rooms sold and the average transaction price to address the price-quantity

argument of the Third Circuit. The expected number of rooms sold is given by

$$\begin{aligned} \text{Expected rooms sold} &= \\ & P(\text{Period-1 arrival}) + \\ & P(\text{Period-2 arrival}) \\ &= 1/2 + 1/4 \\ &= 0.75. \end{aligned}$$

The expected occupancy rate is $0.75 / 2 = 37.5\%$ because there are initially two rooms. Because every transaction occurs at price \$1, the average transaction price is \$1. Expected revenue is \$0.75 because price is \$1 throughout. We next show how the change in the information structure may lead to a lower occupancy rate with a higher price.

B. Equilibrium Prices, Profits, and Occupancy with Transparency

We show below that both hotels charging (\$1,\$1) in Period 1 and charging \$3 in Period 2 when the rival hotel has sold out is the PBE of this game with transparency. If both hotels remain active in Period 2, both charge (\$1,\$1).

Period 2

Under transparency, hotel i observes whether hotel j is active in Period 2 so there is no need to form a belief q about whether the rival remains active. We therefore consider the two possible states separately. First, suppose hotel j has sold out and hotel i is the only active hotel.

Hotel i is then a monopolist. Expected revenue for hotel i from charging \$3 is

$$\begin{aligned}
 &= \text{Probability of arrival} * (2/5) * \$3 \\
 &+ \text{Probability of no arrival} * \$0 \\
 &= (1/4)(2/5)\$3 \\
 &= \$3/10.
 \end{aligned}$$

Expected revenue for hotel i when hotel i is a monopolist from charging \$1 is lower:

$$\begin{aligned}
 &= \text{Probability of arrival} * \$1 + \text{Probability of no arrival} * \$0 \\
 &= (1/4)\$1 \\
 &= \$1/4 < \$3/10.
 \end{aligned}$$

Thus, when hotel i observes that hotel j has sold out, charging \$3 is the unique optimal action. Now suppose both hotels remain active in Period 2. We test (\$1,\$1) as equilibrium. Thus, deviating to \$3 should not be profitable for hotel i.

$$\begin{aligned}
 &\text{Expected revenue for hotel i from charging \$1 when hotel j is charging \$1 is} \\
 &= \text{Probability of arrival} * \text{Probability of winning the customer} * \$1 + \text{Probability of no arrival} * \$0 \\
 &= (1/4)(1/2)\$1 \\
 &= \$1/8.
 \end{aligned}$$

Expected revenue for hotel i from charging \$3 when hotel j is charging \$1 is simply zero.

Showing that (\$3,\$3) is not an equilibrium when both hotels remain active is similar. Thus, in Period 2, an active hotel charges \$3 if it observes that its rival has sold out

and \$1 if it observes that its rival remains active. Now we move to Period 1.

Period 1

Rational players take these Period 2 strategies as given. Now we check if (\$1,\$1) is an equilibrium in Period 1. When hotel i charges \$1 and hotel j charges \$1, hotel i's expected Period 1 revenue is

$$\begin{aligned}
 &\text{Probability(arrival in Period 1)} \\
 &* \text{Probability(winning the customer)} * \$1 \\
 &= (1/2)(1/2)\$1 \\
 &= \$1/4.
 \end{aligned}$$

Now we consider Period 2 continuation revenues. If there is an arrival in Period 1 and the customer buys from hotel j, which occurs with probability $(1/2)*(1/2)=1/4$, hotel i remains active as a monopolist and earns expected Period 2 revenue of \$3/10 as shown above.

If there is no arrival in Period 1, which occurs with probability 1/2, both hotels remain active and hotel i earns expected Period 2 revenue of \$1/8 as shown above. If there is an arrival in Period 1 and the customer buys from hotel i, which occurs

with probability $(1/2)*(1/2)=1/4$, hotel i sells out and its continuation revenue is \$0.

Thus, hotel i's expected continuation revenue is

$$\begin{aligned} &= (1/4)\$3/10 + (1/2)\$1/8 \\ &+ (1/4)*\$0 \\ &= \$1/16 + \$3/40 \\ &= \$11/80. \end{aligned}$$

We add this to the Period 1 expected revenue, so the payoff from playing \$1 in Period 1 is

$$\begin{aligned} &= \$1/4 + \$11/80 \\ &= \$31/80. \end{aligned}$$

We compare \$31/80 with hotel i's deviation revenues from \$3. Hotel i cannot sell in Period 1 and is certainly active in Period 2. If there is no arrival in Period 1, which occurs with probability 1/2, hotel j remains active and hotel i earns expected Period 2 revenue of \$1/8. If there is an arrival in Period 1, which occurs with probability 1/2, the customer buys from hotel j, hotel j sells out, and hotel i becomes a monopolist and earns expected Period 2 revenue of \$3/10. Thus, the expected revenues from deviating to \$3 are lower

$$\begin{aligned} &= (1/2)\$1/8 + (1/2)\$3/10 \\ &= \$1/16 + \$3/20 \\ &= \$17/80 < \$31/80. \end{aligned}$$

Thus, deviating from \$1 to \$3 is not profitable for hotel i in Period 1. Showing that charging \$1 is not profitable when the

rival charges \$3 and also that (\$3,\$3) is not an equilibrium are similar.

Therefore, the PBE under transparency has both hotels charging (\$1,\$1) in Period 1. In Period 2, an active hotel charges \$3 when it observes that its rival has sold out and charges \$1 when it observes that its rival remains active.

Now we find the expected number of rooms sold and the average transaction price to address the price-quantity argument of the Third Circuit. The expected number of rooms sold reflects the sum of the possibilities that 1) one room is sold upon arrival in Period 2, 2) one room is sold upon no arrival in Period 1 but in Period 2, and 3) upon arrival in both Periods with the latter being a high value customer and is given by

Expected rooms sold =

$$\begin{aligned} &P(\text{Period-1 arrival}) + (1 - P(\text{Period-1 arrival})) P(\text{Period-2 arrival}) + \\ &P(\text{Period-1 arrival}) P(\text{Period-2 arrival}) P(\text{high WTP given Period-2 arrival}) \\ &= \frac{1}{2} + (1 - \frac{1}{2}) * \frac{1}{4} + \frac{1}{2} * \frac{1}{4} * \frac{2}{5} \\ &= 0.675 \end{aligned}$$

Then we have a lower expected occupancy rate of $.675/2 = 33.75\%$. Defining the average transaction price as expected revenue divided by expected rooms sold—the volume-weighted average across repeated markets—the price increases to $(31/40)/(27/40) = 31/27$, or approximately to \$1.15. The expected total revenue increases to $\frac{1}{2}*\$1 + \frac{1}{2}*\frac{1}{4}*\$1 +$

$$1/2 * 1/4 * 2/5 * \$3 = 31/40 = \$0.775.$$

Table 1. Effect of Information Transparency on Prices, Revenues, and Occupancy

Information regime	Expected rooms sold	Occupancy	Average transaction price	Expected total revenue
Opacity	0.750	37.50%	\$1.00	\$0.750
Transparency	0.675	33.75%	\$1.15	\$0.775

We present a sensitivity analysis in the next section.

III. When Does Transparency Increase Prices?

More generally, let H denote both the high valuation and the available high price, let h be the probability of a high-value customer, and let q be the perceived probability that the rival remains active conditional on both firms having charged \$1 in the first Period (in our example, $h=2/5$, $H=3$ and $q=2/3$). We show that (details are available upon request from the authors) the transparency effect that increases the price is unambiguous when $1 < hH < 1/(1-q/2)$. When this condition is violated because H or h is either too low or too high, or because q is too low, transparency *need not* increase transaction prices while decreasing occupancy rates.

These findings are intuitive. **If H is too low**, the extra revenue from charging H does not compensate for potentially losing low-value customers. If h is too low, high-value customers are too rare to charge a high price. If H is too high, the

payoff from the relatively few high-value customers becomes so large that H can be attractive even under opacity, despite uncertainty about continued competition. Thus, transparency is no longer necessary to induce high pricing. If h is too high, high-value customers are sufficiently common that H may already be attractive under opacity. Finally, under opacity, if the hotel already believes there is only a small probability q that its rival remains active, opacity provides relatively little competitive discipline, so revealing the rival's actual status has less scope to change pricing. Thus, as cited in the Opinion, "A number of factors including most prominently the structure of the industry involved and the nature of the information exchanged are generally considered in divining the procompetitive or anticompetitive effects of this type of interseller communication." *Todd v. Exxon Corp*) p.36

IV. Broader Implications for Algorithmic Pricing

The analysis suggests caution in drawing structural conclusions from reduced-form market outcomes. An observed combination of higher prices, higher firm profits, and lower occupancy is compatible both with collusion and, under some demand conditions, with independent dynamic pricing following improved information about residual capacity. This distinction does not imply that information

exchange among competitors is competitively benign.

Given variation in algorithm adoption and information availability, together with measures of rivals' residual capacity, an empirical test could examine whether observed price increases can be explained by the information mechanism alone. Under this mechanism, the effect of increased information should be state-dependent: prices should increase particularly when the information reveals diminished rival residual capacity, because a hotel can recognize that it faces less competition or has become a monopolist. Accordingly, price increases concentrated in such states would be consistent with the information mechanism. By contrast, price increases that persist more generally—including when rivals retain substantial residual capacity—would not be explained by this mechanism alone and could be more consistent with coordination or collusion. The analysis could further control for changes in demand conditions, including the prevalence of high-WTP customers and differences in willingness to pay across customer types, which may independently generate higher prices.

Finally, the nature of capacity matters. Froeb, Tschantz & Sokol (2026) study markets in which capacity turns over—such as rental housing and self-storage—rather than expires, as with a hotel room for a particular night. They find that sharing occupancy information can intensify competition by allowing firms to price based on realized market conditions rather than averages. Thus, greater occupancy transparency need not raise prices: its competitive effect depends

importantly on the underlying capacity technology and how information affects residual competitive constraints.

Taken together, these models suggest a broader proposition for algorithmic pricing: the competitive effect of information sharing is state-dependent and cannot be inferred from information sharing alone. Information may reveal that competitive constraints are weaker or stronger than firms otherwise perceive them to be, and prices may respond accordingly. The relevant question is therefore what the information reveals about residual demand and competition, and how firms optimally respond to that information.