Over-Competition and Market Volatility: A Theory of the Desire to Win

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Abstract

Empirical industrial organization studies document frequent instances of over-competition and market volatility. This paper provides a new perspective on this phenomenon by introducing a psychological motive, the desire to win, defined as an extra utility received when an individual's profit exceeds that of rivals. I show that under plausible conditions, no pure-strategy Nash equilibrium exists. Additionally, in a Cournot setting, when the desire to win is moderate, no pure-strategy equilibrium arises; when it is large, the Cournot outcome coincides with the Bertrand outcome, and the mixed strategy equilibrium still leads to overproduction. Then, I estimate the desire to win coefficient by structural estimation using maximum likelihood on experimental data. The results have practical implications for incentive design and policy, such as rank-based bonuses that offer a direct incentive to adjust competitive intensity and market volatility to maximize social welfare or firm productivity.

Keywords: Discontinuous utility; Cournot Competition; Social Preference Utility

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1 Introduction

A growing empirical literature in industrial organization documents that market equilibria sometimes diverge from theoretical predictions, such as excessive entry and over-competition, as well as market volatility. Hsieh and Moretti (2003) showed that fixed commissions in real estate induced socially excessive entry of brokers, with little improvement in matching efficiency. Similar phenomena arose in healthcare: Kessler and McClellan (2000) found that increased hospital competition in the 1980s led to higher expenditures without improving patient outcomes. In transportation markets, Mayer and Sinai (2003) documented that airlines overscheduled flights at congested hubs, creating delays that individual carriers did not internalize, and Holmes (2011) found that Wal-Mart's dense rollout strategy led to costly cannibalization across outlets. Overinvestment has also emerged in dynamic settings: Greenwood and Hanson (2015) showed that shipping firms engaged in boom-time overbuilding of fleets, followed by predictably low subsequent returns. Beyond overinvestment and overproduction, overadvertising is likewise well documented. For example, Sinkinson and Starc (2019) demonstrated that pharmaceutical advertising primarily reallocated demand across brands without generating clear increased profits. As for the phenomenon of excessive market volatility, Eichenbaum et al. (2011) showed that actual transaction prices change very often, even when reference prices and measured costs are inert, implying substantial short-run volatility. In online electronics, Ellison and Ellison (2009) documented obfuscation and rapid repricing around price search engines that sustain sharp, frequent price movements. In secondary ticket markets, prices typically fall 40 percent as events approach, producing pronounced within-market volatility consistent with dynamic pricing under competition (Sweeting, 2012). Taken together, these studies provide abundant empirical evidence across different industries that competition exceeds the efficient level for producers and that market volatility is also excessively high.

While the evidence shows that excessive competition is common, current theory does not fully explain why market participants continue to engage in such wasteful rivalries. One well-known explanation is the sunk cost channel: once firms have already spent money that cannot be recovered, they may keep competing even when quitting would be better. In incentivized penny auction settings, Augenblick (2016) demonstrated that earlier bids lead players to continue bidding in aggressive ways that lead to profit loss. But sunk cost effects depend on context: a large field experiment finds that higher payments mostly affect who participates and does not show a clear sunk cost effect (Ashraf et al., 2010). Another explanation points to information-driven congestion: when firms cannot fully observe or react to rivals' simultaneous choices, they rely on shared signals or simple rules of thumb, which can lead to clustering, contests, and too much investment compared to what would be socially optimal. Theory highlights welfare losses from public signals in market games, greater waste in large contests, and crowding of research directions (Hopenhayn & Squintani, 2021; Olszewski & Siegel, 2016). Still, these explanations do not solve the puzzle that even in markets with low fixed costs and high transparency, over-competition remains. For example, modern electronic equity markets show wasteful speed races despite almost complete price transparency (Budish et al., 2015).

Motivated by this gap, this paper offers a psychology-based explanation: a non-monetary "desire to win" that helps explain why firms compete too aggressively and why the market is excessively volatile. Psychological research provides strong evidence that individuals often exhibit this motive, which can lead them to prioritize relative success over absolute outcomes. Classic work on social value orientation by Messick and McClintock (1968) demonstrated that many individuals displayed a competitive preference structure, willing to sacrifice absolute gains to outperform others. Subsequent psychometric advances, such as the Competitiveness Index developed by Houston et al. (2002) and the Hypercompetitive Attitude Scale of Ryckman et al. (1990), confirmed the existence of stable individual differences in the motivation to win at any cost. In sport psychology, Gill and Deeter (1988) distinguished between win orientation and goal orientation, showing that the drive to defeat opponents is separable from the motive of self-improvement, while Vealey (1986) further conceptualized competitive orientation as the lens through which individuals define success. Experimental work also highlighted how the desire to win can distort decision making: Ku et al. (2005) documented "auction fever," where participants escalated bids beyond item value to secure victory, and Malhotra (2010) showed how rivalry and time pressure amplified a win goal over payoff maximization. Relatedly, Kilduff et al. (2010) demonstrated that rivalry heightened motivation and effort independent of economic incentives, while Garcia and Tor (2009) provided evidence that performance intensified as competitive set size changed, consistent with a socially comparative drive to win. These findings collectively establish that the urge to win is a fundamental psychological motive with significant behavioral implications, and they suggest that the over-competition observed in markets may in part be rooted in this deeper psychological drive.

Since over-competition directly affects social welfare and economic growth, it is important to study how the desire to win influences over-competition. Existing literature shows both the benefits and the costs of intense rivalry. On the one hand, several studies highlight positive effects: Petrin (2002) showed that the introduction of the minivan generated large consumer welfare gains, and Goolsbee and Petrin (2004) found that competition between satellite and cable television significantly reduced prices and expanded consumer choice. On the other hand, a number of papers identified important inefficiencies when competition went too far. For example, Aghion et al. (2005) documented an inverted U relationship between product market competition and innovation, with moderate rivalry spurring firms to innovate. In addition, Hsieh and Moretti (2003) demonstrated that free entry of real estate agents led to socially excessive duplication with little efficiency gain. In healthcare, Kessler and McClellan (2000) provided evidence of a costly "medical arms race," where hospital competition raised expenditures without improving outcomes. In transportation, Mayer and Sinai (2003) showed that airline hub scheduling generated congestion externalities, while Greenwood and Hanson (2015) found that shipping firms overinvested in fleet capacity during booms, leading to predictably low returns. Finally, Ellison and Ellison (2009) showed that online retailers engaged in obfuscation strategies that reduced price transparency and increased search costs. Taken together, these studies suggest that while competition can deliver important benefits in terms of innovation, variety, and lower prices, it can also lead to over-competition that dissipates surplus through excessive entry, strategic waste, and congestion externalities. When the benefits of rivalry outweigh the costs, policymakers might intensify competition by leveraging the desire to win, for example, by creating public rankings among firms or awarding bonuses to top performers. Conversely, when the costs of over-competition dominate, policymakers might limit competitive pressures by withholding ranking information or providing financial support to lagging firms.

This paper makes several contributions. First, it provides a new explanation for a widely observed phenomenon in industrial organization: over-competition and market volatility. Using a desire to win framework, I show that the equilibrium under Cournot competition is no longer stable and shifts to a mixed-strategy equilibrium, where the probability of overproduction (about 95 percent) is much larger than the probability of underproduction (about 5 percent), compared to the benchmark with standard utility. Second, the paper studies a discontinuous utility function, which is rarely examined in the literature. I show that when utility is discontinuous, pure-strategy Nash equilibria typically do not exist, as players have strong incentives to deviate to capture the discontinuous utility gain. I further characterize the mixed-strategy equilibrium in this setting. Third, I provide empirical evidence of the desire to win using existing experimental data. Although the experiments did not explicitly study the desire to win, I show that reinterpreting them through my model reveals a statistically significant effect.

The remainder of the paper is organized as follows. Section 2 defines and demonstrates the desire to win utility. Section 3 integrates this utility into the Cournot model and characterizes the mixed-strategy equilibrium. Section 4 uses existing experiments to provide evidence on the statistical significance of the desire to win parameter via structural estimation. Section 5 concludes.

2 Model of Desire to Win

To study how the desire to win shapes Nash equilibrium outcomes in competition, I formally incorporate this motive into the utility function. I define the desire to win as the positive utility an individual derives simply from earning a higher monetary payoff than their peers. I use monetary payoff instead of utility to define winning status because payoffs are observable and have been used in prior behavioral literature (e.g., Fehr and Schmidt, 1999). The desire to win concerns ordinal ranking rather than the magnitude of the difference. It represents a status-seeking or competitive motive, in which utility is gained from outperforming another individual.

DEFINITION 1. Consider a set of n players indexed by $i \in \{1, \ldots, n\}$, and let $x = (x_1, \ldots, x_n)$ denote the vector of monetary payoffs. The utility function of player i motivated by a desire to win is given by:

$$U_i(x) = x_i + \frac{1}{n-1} \sum_{j \neq i} \gamma_{ij} \, \mathbb{1}_{\{x_i > x_j\}} - \frac{1}{n-1} \sum_{j \neq i} \kappa_{ij} \, \mathbb{1}_{\{x_i < x_j\}} \tag{2.1}$$

where $\mathbb{1}_{\{x_i > x_j\}}$ equals 1 if player i's payoff strictly exceeds player j's payoff, and 0 otherwise. The parameter $\gamma_{ij} \geq 0$ measures the strength of player i's desire to win against player j, while $\kappa_{ij} \geq 0$ captures the reluctance to lose. I separate the two terms because it is plausible that the joy of winning and the pain of losing differ in intensity. In addition, I assume players gain no utility if the result is a tie.[1] The subscript j allows for heterogeneity in these motives across opponents. A larger γ_{ij} indicates a more competitive individual, and if $\gamma_{ij} = \kappa_{ij} = 0$ for all j, player i behaves as a standard, purely self-interested agent.

For simplicity, I will refer to the utility defined above as "DTW," to the second term as the desire to win component, and to the third term as the reluctance to lose component. The normalization by $n-1$ ensures that the total potential utility from the desire to win is independent of group size, making comparisons across different n meaningful, again in line with previous literature (Fehr & Schmidt, 1999). This formulation captures the idea that utility consists of one's own monetary payoff, plus a bonus for each competitor one "beats," and a penalty for each competitor one loses to.

To characterize the properties of the desire to win, I first establish two conditions. I then prove that under these conditions, no pure-strategy equilibrium exists. This result indicates

[1] It can be shown that this assumption does not reduce the generality of the model. Let the utility for a tie be η. $U_i(x) = x_i + \frac{1}{n-1} \sum_{j \neq i} \gamma_{ij} \, \mathbb{1}_{\{x_i > x_j\}} - \frac{1}{n-1} \sum_{j \neq i} \kappa_{ij} \, \mathbb{1}_{\{x_i < x_j\}} + \frac{1}{n-1} \sum_{j \neq i} \eta_{ij} \, \mathbb{1}_{\{x_i = x_j\}}$ can be written as $U_i(x) = x_i + \frac{1}{n-1} \sum_{j \neq i} (\gamma_{ij} - \eta_{ij}) \, \mathbb{1}_{\{x_i > x_j\}} - \frac{1}{n-1} \sum_{j \neq i} (\kappa_{ij} - \eta_{ij}) \, \mathbb{1}_{\{x_i < x_j\}}$, which can be incorporated into the model without explicitly modeling tie utility.

that competition under the desire to win is generally unstable, explaining the observed market volatility.

CONDITION 1 (LOCAL RELATIVE RESPONSIVENESS). For every player i and every (s_i, s_{-i}) with $s_i \in S_i$ (where s_i denotes player i's strategy), for any x_j, there exist sequences $s_i^n \to s_i \in S_i$ such that the monetary payoff x_i satisfies

$$x_i(s_i^n, s_{-i}) - x_j(s_j, s_i^n, s_{-i,j}) > x_i(s_i, s_{-i}) - x_j(s_j, s_{-j})$$

When the payoff function is differentiable and S is open and connected, it is equivalent to

$$\frac{\partial[x_i(s_i, s_{-i}) - x_j(s_j, s_{-j})]}{\partial s_i} \neq 0 \text{ for all } i, j$$

Intuitively, the assumption requires that a player can always slightly adjust her action to improve relative performance to any other player.

Condition 1 is plausible in real-world environments such as the Cournot setting when price exceeds marginal cost. When a firm adjusts its decision marginally (price, quality, effort, capacity), it improves its performance relative to competitors, which will be discussed in detail in the next section. It should be noted that with only this assumption, a pure-strategy Nash equilibrium may still exist: although a deviation can improve performance relative to rivals, it can also reduce the deviator's own profit (i.e., making rivals lose more while the deviator also incurs a loss).

CONDITION 2 (CLOSENESS BETWEEN TOP PLAYERS). If no pure Nash equilibrium exists in the standard utility, this condition is automatically met. If it exists, let s^* denote a pure Nash equilibrium without the desire to win component, and $x_i(s_i^*, s_{-i}^*)$ denotes player i's monetary payoff. For every profile $s \in S$ and every player with the highest monetary payoff $k \in \arg\max_j x_j(s)$, there exists some follower $i \neq k$ such that

$$T = \{t \in S_i | \{x_i(t, s_{-i}^*) - x_k(s_{-i}^*, t) \geq 0\}\} \neq \varnothing \quad \text{and} \quad \sup_{h \in T} x_i(h, s_{-i}^*) - x_i(s_i^*, s_{-i}^*) < \gamma_i.$$

Where γ_i is the desire to win parameter defined previously. Intuitively, the assumption requires that at least one follower can (i) tie or overtake the current leader's monetary payoff holding others' actions fixed and (ii) do so without suffering a huge loss.

Condition 2 depends on market structure. It holds when one follower's feasible set and technology allow them to match the leader's realized profitability. In concentrated industries with a dominant firm possessing insurmountable advantages, Condition 2 may fail because no follower can reach the leader's profit level. In some markets where top firms are close in scale or efficiency, the condition is natural.

THEOREM 1 (Nonexistence of pure Nash equilibrium under desire to win). Let $N = \{1, \ldots, n\}$. For each player $i \in N$, let $S_i \subset \mathbb{R}$, and let $S = \prod_{i \in N} S_i$. If (i) each S_i is nonempty, compact, and convex; (ii) each payoff function $x_i : S \to \mathbb{R}$ is continuous; (iii) $\gamma_i > 0$ for all i; and (iv) Conditions 1–2 hold, then the game $(S, \{U_i\}_{i \in N})$ does not have a pure-strategy Nash equilibrium.

Proof: See Appendix A1

Theorem 1 shows that, under economically reasonable conditions, introducing a discrete bonus for "being ahead" eliminates pure-strategy Nash equilibria, explaining market volatility, since mixed strategies indicate randomized decisions. To intuitively understand this result, a pure profile either features a tie at the top, at which point a tied leader can make an arbitrarily small move to become the unique leader and gain a strictly positive rank bonus, or features a unique leader, at which point some follower can at least tie and then slightly overtake the leader to gain a strictly positive rank bonus. The resulting profitable deviations arise because the rank component is discontinuous at ties, destabilizing the equilibrium.

It should be noted that although Condition 1 may be violated at some zero measure points, for example, in Cournot competition when both firms produce at the level where price equals cost (see the details in the next section), it still helps eliminate most of the support of the action set and allows verification of the point at which Condition 1 is violated.

To show the distinctive role of the desire to win motive, it is useful to compare it to inequity-aversion as in Fehr and Schmidt (1999).

DEFINITION 2. Consider a set of n players indexed by $i \in \{1, \ldots, n\}$, and let $x = (x_1, \ldots, x_n)$ denote the vector of monetary payoffs. The utility function of player i motivated by inequity-aversion is given by:

$$U_i(x) = x_i - \alpha_i \frac{1}{n-1} \sum_{j \neq i} \max\{x_j - x_i, 0\} - \beta_i \frac{1}{n-1} \sum_{j \neq i} \max\{x_i - x_j, 0\}, \tag{2.2}$$

where $\alpha_i \geq \beta_i \geq 0$ and $\beta_i < 1$. Although both specifications involve comparisons of payoffs, they differ fundamentally. The desire to win utility exhibits a discontinuous jump when one's payoff just exceeds another's, whereas the inequity-aversion utility decreases continuously with the size of any payoff difference.

Most importantly, inequity-aversion seeks to minimize payoff disparities, while the desire to win seeks to maximize one's ordinal rank. Consequently, the desire to win can destabilize the original equilibrium and intensify competition, whereas inequity-aversion can stabilize the equilibrium and reduce competitive intensity.

These motives need not be mutually exclusive. An individual may feel envy when behind, guilt when far ahead, and joy from the status of being ahead. With all three motives, a player's emotional utility (beyond monetary payoff) could exhibit (i) a continuous rise as one approaches a competitor when trailing, (ii) a discontinuous gain when one's payoff just surpasses another's, and (iii) a decreasing return from larger leads due to guilt. Figure 1 illustrates how a player's emotional utility varies under envy, guilt, and the desire to win.

I formalize this by constructing a unified utility function that incorporates all three motives: envy, guilt, and the desire to win.

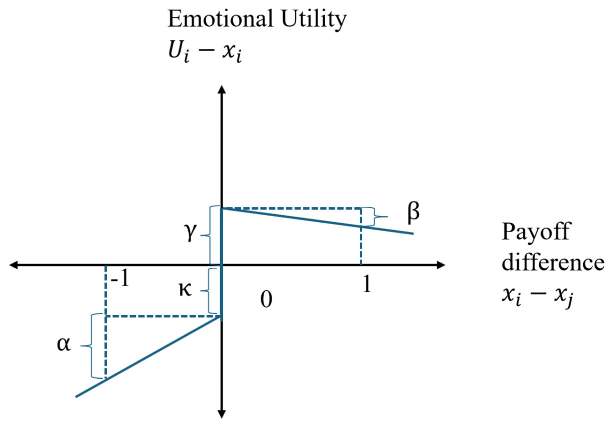


Figure 1: Illustration of emotional utility change

A player i's utility can be expressed as:

$$\begin{aligned} U_i(x) = x_i &- \alpha_i \frac{1}{n-1} \sum_{j \neq i} \max\{x_j - x_i, 0\} \\ &- \beta_i \frac{1}{n-1} \sum_{j \neq i} \max\{x_i - x_j, 0\} \\ &+ \frac{1}{n-1} \sum_{j \neq i} \gamma_{ij}\, \mathbb{1}_{\{x_i > x_j\}} - \frac{1}{n-1} \sum_{j \neq i} \kappa_{ij}\, \mathbb{1}_{\{x_i < x_j\}} \end{aligned} \tag{2.3}$$

(i) Purely Self-Interested: $\alpha_i = \beta_i = \gamma_{ij} = \kappa_{ij} = 0$. The utility reduces to $U_i(x) = x_i$.

(ii) Purely Competitive (Desire to Win only): $\alpha_i = \beta_i = 0$, $\gamma_{ij} > 0$, $\kappa_{ij} > 0$. The player cares only about their own payoff and the bonus from outperforming others, as in equation (DTW).

(iii) Fair Minded (Inequity Averse only): $\gamma_{ij} = \kappa_{ij} = 0$, $\alpha_i \geq \beta_i > 0$. This is the classic Fehr-Schmidt specification.

(iv) All Motives Present: $\gamma_{ij} > 0$, $\kappa_{ij} > 0$, $\alpha_i > 0$, $\beta_i > 0$. When $x_i > x_j$, the player gains from the desire to win (γ_{ij} term) but loses utility from guilt (β_i term), potentially favoring a small winning margin.

All of the above specifications can be incorporated into the model. In the next section, I will analyze how these motives affect the equilibrium. In summary, this section shows that the desire to win preference destabilizes the standard Cournot equilibrium. With strong reluctance to lose, even a small win motive drives firms to the Bertrand outcome, while weak reluctance to lose eliminates pure-strategy equilibria and induces mixed strategies skewed toward overproduction. When inequity-aversion is added, the discontinuous win motive dominates the continuous effects of envy and guilt, reinforcing aggressive behavior. With different costs, small gaps induce instability as high cost firms sacrifice profit to win, whereas large gaps restore the standard Cournot outcome, since the high cost firm either cannot be the winner or cannot afford the cost of deviation from the standard utility Cournot equilibrium.

3 Desire to Win in Cournot Competition

To illustrate how the desire to win motive reshapes equilibrium outcomes, I analyze a two-player Cournot model under four utility specifications: standard profit maximization, inequity-aversion (envy and guilt), desire to win (DTW), and a combination of DTW with inequity-aversion. When both firms have identical constant marginal costs, the inequity-aversion specification reproduces the classical Cournot equilibrium. Under the DTW specification, if each firm's reluctance to lose parameter is sufficiently large, it drives the outcome to the Bertrand benchmark. Conversely, when the reluctance to lose is small, no pure-strategy Nash equilibrium exists; instead, a mixed strategy equilibrium arises in which each firm chooses to overproduce (exceed Cournot production) with probability approximately 95.06%, independent of parameter values. Intuitively, when firms are motivated by a desire to win, they face uncertainty about whether to exert full effort to outcompete the rival or yield. If both firms compete aggressively, profits decline substantially; if both yield, either firm could profitably deviate by producing more, thereby both winning and earning higher profits, which compels firms to randomize. The intuition behind overproduction is that underproducing leads to both a penalty from losing and lower profits, whereas overproducing increases the probability of winning and may yield higher profits if the opponent happens to yield. When both DTW and inequity-aversion are present, the equilibrium resembles that under DTW alone because the desire to win is a discontinuous utility, which renders the continuous part of the utility function of second-order importance "near ties".

3.1 Model Setup

Consider a Cournot duopoly with firms $i \in \{1, 2\}$ producing a homogeneous good. Firm i has constant marginal cost $c_i > 0$. The inverse demand function is

$$P(Q) = a - Q, \qquad Q = q_1 + q_2, \quad a > \max\{c_1, c_2\}.$$

Hence, firm i's profit is

$$\pi_i(q_i, q_j) = \big(P(Q) - c_i\big)\, q_i = (a - q_i - q_j - c_i)\, q_i. \tag{3.1}$$

I compare four utility specifications incorporating desire to win (DTW) and inequity-aversion (IA):

(i) Standard: $U_i^S = \pi_i$.

(ii) IA: $U_i^I = \pi_i - \alpha_i \max\{\pi_j - \pi_i, 0\} - \beta_i \max\{\pi_i - \pi_j, 0\}$.

(iii) DTW: $U_i^D = \pi_i + \gamma_i\, \mathbb{1}_{\{\pi_i > \pi_j\}} - \kappa_i\, \mathbb{1}_{\{\pi_i < \pi_j\}}$.

(iv) Full model: $U_i^F = \pi_i + \gamma_i\, \mathbb{1}_{\{\pi_i > \pi_j\}} - \kappa_i\, \mathbb{1}_{\{\pi_i < \pi_j\}} - \alpha_i \max\{\pi_j - \pi_i, 0\} - \beta_i \max\{\pi_i - \pi_j, 0\}$.

where $\gamma_i, \kappa_i \geq 0$ and $1 > \alpha_i > \beta_i \geq 0$.

3.2 When Marginal Costs Are the Same

(i) *Standard Utility:*

Under standard profit maximization, the Nash equilibrium is familiar and provides a useful benchmark. Solving the first-order conditions yields

$$q_1^S = q_2^S = \frac{a-c}{3}, \quad P^S = \frac{a+2c}{3}, \quad \pi_1^S = \pi_2^S = \frac{(a-c)^2}{9}.$$

(ii) *IA Only Utility:*

PROPOSITION 1. Under the inequity-aversion specification, the Cournot competition defined in (3.1), when marginal costs are the same, has the same Nash equilibrium as the standard utility model.

Proof. See Appendix A2.

Conceptually, the classic Cournot outcome is already symmetric and stable, so there is no incentive to deviate. Any deviation would not only result in a monetary loss, since the benchmark equilibrium already maximizes profit, but would also generate disutility from envy or guilt. Hence, incorporating inequity-aversion merely reinforces the existing symmetry, and each firm maintains the same optimal output, which mitigates competition.

(iii) *DTW Only Utility:*

I characterize both pure-strategy and mixed-strategy Nash equilibria under the discontinuous DTW utility.

Part A: pure-strategy Nash Equilibrium:

To establish this formally, it is necessary to derive explicit conditions under which a pure-strategy equilibrium arises. Because the DTW utility is discontinuous, deriving best response functions directly is difficult. I therefore examine symmetric and asymmetric production scenarios, rule out the latter, and derive the symmetric equilibrium. Since Condition 2 is satisfied (See Appendix A4), by applying Theorem 1 to the interval that satisfies Condition 1, and verifying separately the point that violates Assumption 1.

LEMMA 1. Under the desire to win utility in the Cournot setting (3.1), when costs are the same, no asymmetric pure-strategy Nash equilibrium exists.

Proof. See Appendix A3.

This lemma is intuitively straightforward: any asymmetric output profile designates one firm as the winner and the other as the loser. For such a profile to constitute an equilibrium, neither the winner nor the loser should have an incentive to deviate. However, with identical costs, once the winner and loser are determined, each firm optimizes only its monetary payoff. This reduces the problem to the standard Cournot competition, in which both firms produce the same output, thereby contradicting the possibility of asymmetry.

THEOREM 2. Under the desire to win utility in the Cournot setting (3.1), when the marginal costs are the same, if the parameters κ and γ satisfy

$$\kappa_i, \kappa_j \geq \frac{(a-c)^2}{16}, \quad \gamma_i, \gamma_j > 0$$

Then the pure-strategy Nash equilibrium occurs where price equals marginal cost, matching the Bertrand outcome. Otherwise, no pure-strategy equilibrium exists.

Proof. See Appendix A4.

Intuitively, when the desire to win exists (i.e., $\gamma > 0$), a firm will deviate from the benchmark equilibrium to obtain the discontinuous utility gain γ at the cost of an infinitesimal monetary loss. When the reluctance to lose parameter κ is large, no firm wants to yield because of the severe penalty. At the same time, firms also prefer not to remain in a "tie," since deviating upward provides the additional discontinuous utility gain. However, when price equals marginal cost, firms no longer have an incentive to produce slightly more: in this case, increasing output generates negative profits, as price falls below cost, and the deviating firm becomes the loser. Thus, producing more results in both a monetary loss and the penalty

κ, eliminating the incentive to deviate. Likewise, no firm has an incentive to produce less, given the large penalty from losing. Therefore, in this case, the only pure-strategy equilibrium occurs when the price equals marginal cost.

When κ is small, firms still deviate from the benchmark equilibrium to secure the utility gain γ. At some point, the monetary payoff from producing less outweighs the small reluctance to lose penalty, and a firm deviates downward. Once one firm reduces output, the other responds by also producing less but slightly more than its rival, thereby increasing its monetary payoff while still capturing the desire to win utility γ. In this environment, no pure-strategy Nash equilibrium can exist.

It is worth noting that the conditions for a pure-strategy equilibrium are extremely restrictive: both firms' reluctance to lose parameters would need to be very large, approximately half of the Cournot profit, which is not realistic. This makes the study of mixed strategy equilibria essential.

Part B: Mixed Strategy Nash Equilibrium:

Because the decision variable is continuous, the equilibrium must feature mixing according to a distribution $f(q_i)$ that satisfies the equilibrium condition.

$$\mathbb{E}\big[U_i(q_i, f(q_j))\big] = \int_L^U f(q_j)\, U_i(q_i, q_j)\, \mathrm{d}q_j = \mathrm{C}(\theta), \tag{3.2}$$

where $C(\theta)$ is a constant (a function of $a, \kappa_1, \kappa_2, \gamma_1, \gamma_2$) that does not depend on q_i. Here, L and U denote the lower and upper bounds of the support of the probability distribution, respectively.

Without loss of generality, set $c = 0$. Solving equation (3.2) is equivalent to solving

$$\int_{\mathrm{L}}^{q_i} \left[f(q_j)\big((a-q_i-q_j)q_i+\gamma_i\big)\right] \mathrm{d}q_j + \int_{q_i}^{\mathrm{U}} \left[f(q_j)\big((a-q_i-q_j)q_i-\kappa_i\big)\right] \mathrm{d}q_j = \mathrm{C}(\theta).$$

Finding a closed-form expression for the full distribution is intractable; instead, I employ a simulation-based approximation to determine the function form, then solve for the parameter analytically. Using best response updating algorithms (see Appendix for details), which converge to the true mixed strategy distribution (Perkins & Leslie, 2014), I find that the equilibrium distribution is triangular.

$$f(q_j) = \frac{2}{(U-L)^2}(q_j - L), \quad q_j \in [L, U].$$

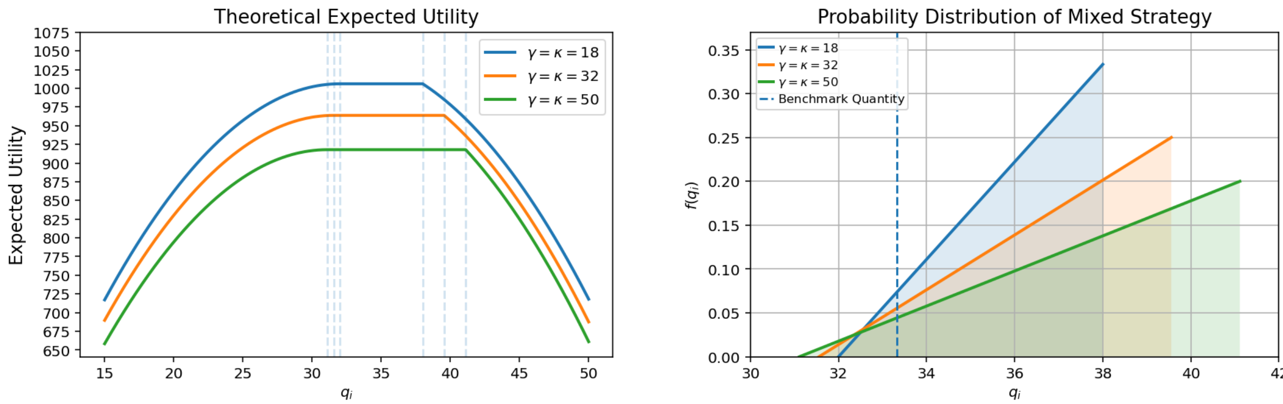
Solving (3.2) (details in Appendix B1) yields

$$(L_i, U_i) = \Big(\frac{3a - 2\sqrt{\gamma_i + \kappa_i}}{9}, \frac{3a + 7\sqrt{\gamma_i + \kappa_i}}{9}\Big).$$

When no pure-strategy equilibrium exists, firms randomize around the standard Cournot output: approximately 95% (77/81) of the probability mass lies above the Cournot quantity, while only about 5% (4/81) lies below it, irrespective of the desire to win parameter. It should be noted that this result holds when γ and κ are not too large; otherwise, the lower bound would be smaller than 0, which is infeasible.

To illustrate, let $a = 100$, $c = 0$, and $\kappa_1 = \kappa_2 = \gamma_1 = \gamma_2 \in \{18, 32, 50\}$. In these cases, the desire to win and the reluctance to lose are the parameters correspond to only 1.6%, 2.9%, and 4.5% of the standard Cournot profit, yet their impact on the equilibrium is substantial. Figure 2 shows the mixed strategy distribution and its expected utility:

Thus, under desire to win preferences, aggregate output becomes unstable: firms are likely



(a) Expected Utility

(b) Distribution

Figure 2: Mixed strategy with desire to win equal to 1.6%, 2.9%, and 4.5% of profit

to overproduce, with a small chance of underproduction. A larger desire to win parameter implies a wider possible range of production levels and a lower expected utility.

To build intuition, when a firm produces more, its probability of winning increases, and it may further benefit if the opponent produces less. By contrast, producing less makes winning unlikely and yields a low monetary payoff when the opponent produces more. Thus, higher output is generally more attractive. However, a mixed-strategy equilibrium cannot place all probability on overproduction: if both firms always produced high quantities, aggregate output would rise and profits would fall, so neither firm would be willing to stay at that level. Some probability of lower output must therefore be in the support for the equilibrium to be sustainable.

(iv) DTW and IA Combined Utility

COROLLARY 1. When both the desire to win and inequity-aversion are present in the Cournot setting (3.1), if the reluctance-to-lose parameters and envy are small, $\frac{(a-c)^2}{16}\alpha_i + \kappa_i < \frac{(a-c)^2}{16}$ for $i = 1, 2$, then the pure-strategy Nash equilibrium coincides with that under the DTW-only utility. Otherwise, no pure-strategy equilibrium exists.

Proof. See Appendix A5.

In this case, the desire to win motive dominates any inequity-aversion effects. Intuitively, when envy and guilt are present, firms can still produce slightly more to obtain a discontinuous utility gain at an infinitesimally small cost in terms of profit and guilt. Under envy and guilt, it becomes even easier to sustain a pure-strategy Nash equilibrium at the Bertrand level, because firms are more reluctant to yield. Yielding would impose a double penalty: the loss itself and the disutility from envy. In other words, inequity-aversion reinforces the effect of the desire to win motive.

3.3 When Marginal Costs Differ

Without loss of generality, assume $0 < c_1 < c_2 < a$. To ensure both firms produce a positive output, also require

$$a - 2c_1 + c_2 > 0 \quad \text{and} \quad a - 2c_2 + c_1 > 0.$$

(i) *Standard Utility:*

The standard profit maximization case is straightforward and serves as a benchmark. Solving

$$q_1 = \mathrm{BR}_1^S(q_2), \quad q_2 = \mathrm{BR}_2^S(q_1)$$

yields

$$q_1^S = \frac{a - 2c_1 + c_2}{3}, \quad q_2^S = \frac{a - 2c_2 + c_1}{3}, \tag{3.3}$$

So total output is

$$Q^S = q_1^S + q_2^S = \frac{2a - c_1 - c_2}{3}.$$

(ii) *IA Only Utility:*

PROPOSITION 2. Under inequity-aversion in the Cournot setting (3.1), the Nash equilibrium shifts relative to the standard model. Moreover, if

$$4(1 - \beta)(1 + \alpha) - 1 > 0,$$

then, the lower-cost firm reduces its output, while the higher-cost firm increases its output, compared to the standard equilibrium.

Proof. See Appendix A6.

Conceptually, the lower-cost firm, enjoying higher profits, experiences guilt and cuts back on production, while the higher-cost firm, earning less profit, feels envy and expands output, which shifts the equilibrium profile and mitigates competition.

(iii) *DTW Only Utility:*

When the marginal costs are different, the condition 2 (closeness between top players) might be violated when the marginal cost differences are large. To find the pure-strategy Nash equilibrium, I analyze two cases: (i) the outcome is a tie, $\pi_i = \pi_j$, and (ii) one firm is the winner and the other is the loser, i.e., $\pi_i > \pi_j$ or $\pi_i < \pi_j$. I first prove that no Nash equilibrium exists when the outcome is a tie, and then I derive the condition under which a pure-strategy Nash equilibrium exists.

LEMMA 2. In the Cournot setting (3.1) with desire to win preferences and different marginal costs, no pure-strategy Nash equilibrium exists where the outcome is a tie.

Proof. See Appendix A7.

Intuitively, a tie with unequal costs requires the high-cost firm to increase output or the low-cost firm to reduce just enough to equalize profits. Precisely at a tie, the low-cost firm can always reclaim the lead with an arbitrarily small output increase: the discrete win bonus outweighs the negligible profit change at the margin. Therefore, ties cannot be sustained in pure strategies when costs differ.

THEOREM 3. In the Cournot setting (3.1) with desire to win preferences and different marginal costs, no pure-strategy Nash equilibrium exists if and only if the following two conditions hold:

$$a > -10c_1 + 11c_2 + 6\sqrt{3}\,(c_2 - c_1) \tag{a}$$

$$\gamma_2 + \kappa_2 > \frac{1}{36}\Big(3\sqrt{(a-c_2)^2 - \tfrac{4}{9}(a-2c_1+c_2)(2a-c_1-c_2)} - (a-2c_1+c_2)\Big)^2 \tag{b}$$

Otherwise, the equilibrium coincides with that under standard profit maximization.

Proof. See Appendix A8.

To build intuition, condition (a) states that the higher cost firm can profitably deviate from the benchmark (the standard Cournot equilibrium under conventional utility) to exceed the lower cost firm's profit. This condition is independent of the intensity of the desire to win. When cost differences are large, the higher cost firm always loses. Condition (b) states that the desire to win outweighs the profit loss from deviating from the benchmark. Put differently, when cost differences are small or the desire to win is strong, the higher cost firm is willing to accept a monetary sacrifice to secure the winner's bonus, precluding a pure-strategy equilibrium. If the cost gap is large, however, the lower cost firm always wins, and the standard Cournot equilibrium remains the same as the benchmark.

The mixed strategy solution when costs differ is similar to the case where marginal costs are the same. Simply solving the equation presented in (3.2) yields the mixed strategy Nash equilibrium.

In summary, this section shows that the desire to win preference destabilizes the standard Cournot equilibrium and pushes firms to overproduce. With strong reluctance to lose, even a small win motive drives firms to the Bertrand outcome, while weak reluctance to lose eliminates pure-strategy equilibria and induces mixed strategies skewed toward overproduction. When inequity-aversion is added, the discontinuous win motive dominates the continuous effects of envy and guilt, reinforcing aggressive behavior. With different costs, small gaps induce instability as high cost firms sacrifice profit to win, whereas large gaps restore the standard Cournot outcome, since the high cost firm either cannot be the winner or cannot afford the cost of deviation from the standard utility Cournot equilibrium.

4 Experimental Evidence

In this section, I draw on two existing experimental datasets Carpenter et al. (2010) and Dal Bó and Fréchette (2011) to demonstrate that the psychological "desire to win" is statistically significant. The first study provides clear evidence of a desire to win, but it cannot estimate its coefficient directly since the only cost is moral cost, and it is not observable. The second study allows estimation of that coefficient, but the estimation method is more complicated. From both studies, I find that the desire to win is large and statistically significant.

4.1 Evidence from a Real Effort Tournament with Sabotage

4.1.1 Experimental Design

The first dataset is drawn from the real effort tournament experiment in Carpenter et al. (2010). Although the study's primary objective was to measure the impact of sabotage on effort, its design also allows me to disentangle pecuniary incentives, emotional motivations, and the pure desire to win.

Carpenter et al. (2010) implemented a real effort tournament with 224 student participants across 28 sessions (8 participants per session). Each subject devoted 30 minutes to a computer task that involved preparing form letters: printing, hand-addressing envelopes, stuffing them, and placing them in an output box.

After the production phase, each participant and a designated supervisor independently counted and quality-rated every peer's output on a 0 to 1 scale. An independent USPS letter carrier subsequently provided an objective deliverability rating. Finally, subjects completed a survey capturing demographics, risk attitudes (on the Weber et al. scale), and beliefs about peers' honesty in reporting.

Treatment	Payment rule
Piece Rate (P)	receiving dollar amount equal to supervisor's count × quality.
Tournament (T)	Same as Piece Rate, plus a $25 bonus awarded to the top performer.
Piece Rate & Sabotage (P+S)	As in Piece Rate, but payment is based on the average of supervisor and peer evaluations.
Tournament & Sabotage (T+S)	As in Tournament, but quality-adjusted output is averaged across supervisor and peer evaluations.

Even in treatments without a sabotage manipulation, participants were required to report their peers' counts and quality ratings; however, they were informed that these peer reports would not affect their own payments.

It is important to note that sabotage itself does not have a monetary cost: underreporting others' output or quality has no negative effect on one's own earnings. However, people may incur a moral cost from sabotaging, since it resembles cheating (Carpenter et al., 2010).

4.1.2 Evidence of the Desire to Win

Table 1 presents the summary statistics for the tournament experiment. The average sabotage in both output and quality is positive, indicating that participants tend to underreport their peers' performance. Here, quality sabotage is defined as the difference between the reported quality and the postal officer's objective rating: positive sabotage means the peer's report is lower than the officer's rating, while negative sabotage means the peer's report is higher than the officer's rating. Output sabotage is defined analogously.

Grouped summary statistics reveal that under tournament incentives, both output and quality sabotage are positive, whereas in non-tournament treatments these measures are negative, indicating overreporting of peers' effort. This pattern reflects both monetary and psychological

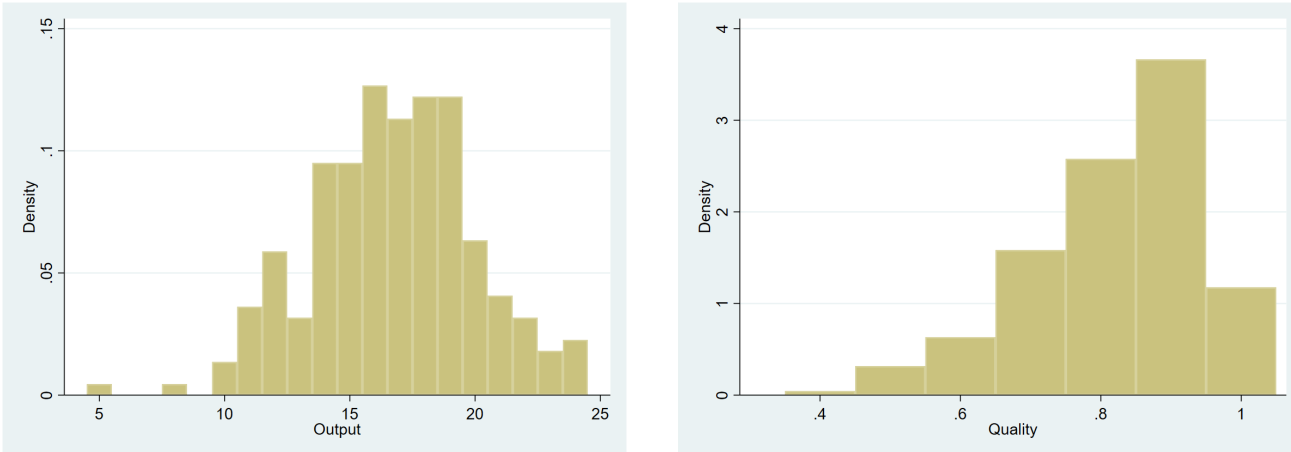
Table 1: Summary Statistics

Variable	N	Mean	Std.	Min	Max
Output Sabotage	1561	0.36	2.03	-9.00	20.00
Quality Sabotage	1563	0.08	0.27	-0.60	1.00
True_output	1792	12.84	3.43	1.00	24.00
True_quality	1792	0.82	0.13	0.40	1.00
male	1792	0.47	0.50	0.00	1.00
GPA	1776	3.49	0.28	2.55	4.00
International_Student	1792	0.15	0.36	0.00	1.00
First_Born	1792	0.58	0.49	0.00	1.00
Num_Siblings	1792	1.51	1.11	0.00	7.00
Bathrooms_in_house	1792	3.02	1.44	0.00	9.00
Car_on_Campus	1792	0.39	0.49	0.00	1.00
Risk_Scale	1792	127.67	23.65	0.00	203.00
Tournament					
Output Sabotage	385	0.11	1.41	-7.00	5.00
Quality Sabotage	387	0.10	0.24	-0.40	1.00
Tournament with Sabotage					
Output Sabotage	392	1.50	3.35	-3.00	20.00
Quality Sabotage	392	0.26	0.32	-0.60	1.00
Piece Rate					
Output Sabotage	392	-0.07	1.03	-9.00	7.00
Quality Sabotage	392	-0.03	0.18	-0.50	0.70
Piece Rate with Sabotage					
Output Sabotage	392	-0.11	0.68	-3.00	3.00
Quality Sabotage	392	-0.02	0.20	-0.50	0.80

motivations to win.

In the Tournament & Sabotage treatment, sabotage is significantly larger than in the other treatments. Notably, even in the pure Tournament treatment, where peer reports do not affect payoffs, sabotage remains positive, suggesting a purely psychological desire to win in the absence of additional monetary incentives.

Figure 3 shows the histogram of output and quality in the tournament setting. Both distributions are left-skewed, meaning that most participants' output and quality are concentrated



(a) Histogram of true output (b) Histogram of true quality

Figure 3: Distribution of output and quality when tournament exists (T & T+S)

at the higher end of the distribution. Thus, competition among the top performers is more intense (Carpenter et al., 2010).

4.1.3 Separating Desire to Win and inequity-aversion

While grouped statistics suggest the presence of a desire to win, they cannot rule out envy (inequity-aversion) as an alternative explanation. To disentangle these motives, I estimate the following OLS specification:

$$\text{Sabotage}_i = \beta_0 + \beta_1 \,\text{Group}_i + \boldsymbol{\beta}\,\text{Controls}_i + \varepsilon_i, \tag{4.1}$$

where i indexes an individual rating (i.e., a subject's rating of another group member). Sabotage includes both output and quality sabotage measures. Group is a vector of treatment dummies (Piece Rate, Tournament, Piece Rate+Sabotage, Tournament+Sabotage), and Controls include demographic and baseline characteristics (e.g., gender, GPA).

I also estimate:

$$\text{Sabotage}_i = \beta_0 + \beta_1 \,\text{eff\_output\_rater}_i + \boldsymbol{\beta}\,\text{Controls}_i + \varepsilon_i, \tag{4.2}$$

where eff_output_rater$_i$ denotes the rater's effective output (count $\times$ quality). Since the distributions of output and quality are both left-skewed, competition among the top players is more intense. Although sabotage increases the chance of winning for every player, top players are affected to a greater extent than bottom players. Therefore, a positive β_1 implies that higher performing raters engage in more sabotage, consistent with the desire to win dominating envy, whereas a negative β_1 would indicate that envy (inequity-aversion) prevails.

Table 2: OLS Regression Results

			Tournament		T+S	
	(1)	(2)	(3)	(4)	(5)	(6)
	Q_{Sab}	O_{Sab}	Q_{Sab}	O_{Sab}	Q_{Sab}	O_{Sab}
Tournament	0.126***	0.196				
	(0.0177)	(0.142)				
Tournament_sabotage	0.296***	1.568***				
	(0.0176)	(0.140)				
Piece_rate_sabotage	0.0190	-0.0430				
	(0.0180)	(0.144)				
eff_output_rater			0.0141**	0.138***	0.0274***	0.236***
			(0.00436)	(0.0264)	(0.00513)	(0.0539)
Observations	1549	1547	380	378	392	392
Adjusted R^2	0.191	0.112	0.045	0.060	0.117	0.106
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors are robust and reported in parentheses; Q_{sab} means quality sabotage; O_{sab} means output sabotage; `eff_output_rater` means the rater's true quality times true quantity.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2 reports the OLS estimates. Columns (1) and (2) show that sabotage is highest in the Tournament & Sabotage treatment. Importantly, even in the pure Tournament treatment, where sabotage does not affect payoffs, participants underreport quality by 12.6%, significant at the 1% level, indicating a psychological desire to win absent monetary stakes. The coefficient on sabotage is insignificant for the Tournament only group; this is understandable because quality is subjective, whereas count is objective, so the moral cost of sabotaging count is higher than sabotaging quality (Carpenter et al., 2010).

Columns (3) to (6) distinguish between the desire to win and inequity-aversion. Columns (3) and (4) are Tournament only, and Columns (5) and (6) are Tournament & Sabotage. In both treatments, the coefficient on `eff_output_rater` is positive and significant at the 1% level, indicating that sabotage increases with the rater's own output. This result contradicts envy and guilt-based predictions[2] and supports the hypothesis that the desire to win is the primary driver of sabotage.

4.2 Evidence from repeated cooperation game experiment

4.2.1 Experiment Design

The second experiment by Dal Bó and Fréchette (2011) was a laboratory study of infinitely repeated Prisoner's Dilemma games. Because the game structure is straightforward, it provides a suitable setting for testing the desire to win theory.

	C	D
C	(R, R)	$(12, 50)$
D	$(50, 12)$	$(25, 25)$

Table 3: Payoff matrix for experiment 2

In each round, participants simultaneously chose either cooperation or defection. The payoff matrix in Table 3 is parameterized by $R \in \{32, 40, 48\}$. If both cooperated, each received R experimental points; if one defected while the other cooperated, the defector received 50 points and the cooperator 12 points; if both defected, each earned 25 points. Participants remained matched with the same opponent until the game terminated probabilistically at the end of each round with probability $1 - \delta$. The continuation probability δ took values in $\{1/2, 3/4\}$, yielding an expected interaction length of $1/(1 - \delta)$. Both the payoff matrix and the value of δ were common knowledge; participants knew that play continued probabilistically and did not know the exact number of rounds in advance.

[2] Using envy-based predictions, top players are less likely to sabotage others, as they may feel guilt given that they already earn more than bottom players. Conversely, bottom players are more likely to sabotage others out of envy, since their payoffs are lower than those of others.

A total of 266 undergraduate students from New York University participated in multiple sessions, each accommodating 12 to 20 subjects. After each repeated interaction ended, subjects were randomly re-matched for a new infinitely repeated Prisoner's Dilemma. Each session comprised 50 minutes of active play. Because the realized number of rounds per repeated game varied stochastically, subjects experienced 23 to 77 repeated games per session, depending on δ and the random draws. When $\delta = 1/2$, the mean number of rounds per game was approximately 1.96 (maximum of nine); when $\delta = 3/4$, it was approximately 4.42 (maximum of 23).

In each round, subjects observed their own and their opponent's actions and payoffs, but did not know the total number of rounds in advance. The experimenters recorded each subject's action (cooperate or defect), the opponent's action, both players' payoffs (in points), and the outcome of the continuation draw. This round-by-round dataset enables reconstruction of the entire sequence of choices and payoffs for each subject across all matches.

To allow for players who are not fully rational, I estimate the desire to win utility using the discrete choice model of McFadden (1981), which is widely applied in experimental economics (e.g., Arcidiacono and Miller, 2011, Abaluck and Gruber, 2011):

$$\mathbb{P}(\text{Action C}) = \frac{e^{\lambda \mathbb{E}[U(\text{C})]}}{e^{\lambda \mathbb{E}[U(\text{C})]} + e^{\lambda \mathbb{E}[U(\text{D})]}}.$$

Since players do not observe their opponent's action before making a choice, I cannot directly compute $\mathbb{E}[U(\text{C})]$ and $\mathbb{E}[U(\text{D})]$. Instead, I follow two approaches from the literature to estimate these expected utilities.

The first approach uses observed data to estimate the probability of opponent cooperation, following Costa-Gomes et al. (2001). A drawback is that players do not see others' actions before play, so initial beliefs about cooperation probabilities are uninformed. However, given the large number of matches, after several rounds, players can form a reasonable estimate of their opponent's cooperation probability.

The second approach employs the Quantal Response Equilibrium (QRE) framework of

McKelvey and Palfrey (1995), which has been widely applied in estimating behavioral parameters (e.g., Hoppe and Schmitz, 2013):

$$\mathbb{P}(\text{Action C}) = \frac{e^{\lambda \mathbb{E}[U(\text{C}|\mathbb{P})]}}{e^{\lambda \mathbb{E}[U(\text{C}|\mathbb{P})]} + e^{\lambda \mathbb{E}[U(\text{D}|\mathbb{P})]}}.$$

Because this is an infinitely repeated game with probabilistic termination and decisions affecting future payoffs, to compute the expected utilities, it is necessary to restrict the strategy sets. In their experiment, 85.6% of matches[3] use either the always defect strategy or the grim trigger strategy. Therefore, I assume that each player randomly chooses between these two strategies,[4] and I calculate utility under two assumed strategies: grim trigger and always defect.

Since decisions after the first round are history dependent and thereby confound parameter identification, I include only the first round in the estimation. I estimate the desire to win parameter using maximum likelihood estimation (MLE).

Since the first round outcome under the grim trigger is cooperation, let U_C denote the grim trigger utility, U_D the always defect utility, δ the discount factor, and p the probability that the opponent adopts a grim trigger strategy. The probability p is obtained either directly from the data or via QRE.[5]

Next, for four utility models: standard utility, inequity-aversion only utility, desire to win only utility, and desire to win combined with inequity-aversion utility, I compute the corresponding expected utilities. To avoid multicollinearity, I include only the parameter γ for desire to win and α for inequity-aversion, since guilt-related parameters are typically weak or insignificant in

[3]Calculated at the match player level: with two players per match, if only one always adopts defect (or grim trigger), the match counts as 50%, and if both do, it counts as 100%. Thus, 85.6% means that 85.6 out of 100 match players (from 50 matches) used one of these strategies.

[4]Different individuals have different probabilities of choosing grim trigger versus always defect because they differ in their levels of desire to win, envy, and guilt.

[5]For QRE estimates, see Appendix C.

empirical studies (e.g., Engelmann and Strobel, 2006).

$$\begin{aligned}\text{Grim trigger: } \mathbb{E}(U_C) &= p\sum_{t=0}^{\infty}\delta^t\, u_{CC} + (1-p)\Big[u_{CD} + \sum_{t=1}^{\infty}\delta^t\, u_{DD}\Big] \\ &= p\,\frac{r}{1-\delta} + (1-p)\Big[(12-38\alpha) + \frac{\delta\cdot 25}{1-\delta}\Big].\end{aligned}$$

$$\begin{aligned}\text{Always defect: } \mathbb{E}(U_D) &= p\Big[u_{DC} + \sum_{t=1}^{\infty}\delta^t\, u_{DD}\Big] + (1-p)\sum_{t=0}^{\infty}\delta^t\, u_{DD} \\ &= p\Big[(50+\gamma) + \frac{\delta\cdot 25}{1-\delta}\Big] + (1-p)\,\frac{25}{1-\delta}.\end{aligned}$$

Under these specifications, the probability that i cooperates is

$$P_i(\boldsymbol{\theta}) = \frac{\exp\big(\lambda\, U_i^C\big)}{\exp\big(\lambda\, U_i^C\big) + \exp\big(\lambda\, U_i^D\big)},$$

where $\boldsymbol{\theta} = (\gamma, \kappa, \alpha, \beta, \lambda)$. The joint likelihood across all observations is

$$L(\boldsymbol{\theta}) = \prod_{i=1}^{N} P_i(\boldsymbol{\theta})^{\,a_i}\,\big[1 - P_i(\boldsymbol{\theta})\big]^{\,1-a_i},$$

where a_i denotes the cooperation indicator.

The maximum likelihood estimator is then

$$\widehat{\boldsymbol{\theta}} = \arg\max_{\boldsymbol{\theta}} L(\boldsymbol{\theta}).$$

Table 4 reports the MLE estimates using the group mean as the perceived probability of opponent cooperation. All parameters of interest are significant at the 1% level. Under the inequity-aversion–only specification, α is 0.36, consistent with existing literature (e.g. Charness and Rabin (2002)). Under the desire to win specification, γ is large in magnitude (5.560), exceeding 10% of the expected payoff, showing a substantial competitive motive. In the full model, γ remains large (3.829), demonstrating that the desire to win effect remains quantitatively

Table 4: MLE Estimates of Utility Parameters by Group Mean ($N = 13{,}888$)

Model	Restrictions	λ	α	γ	LL
Standard	$\alpha = \gamma = 0$	0.070***	—	—	-8082.50
		(8.92)			
IA (α)	$\gamma = 0$	0.042***	0.360***	—	-7409.21
		(9.27)	(12.39)		
DTW (γ)	$\alpha = 0$	0.084***	—	5.560***	-7454.69
		(11.31)		(7.93)	
Full (α, γ)	none	0.080***	0.244***	3.829**	-7157.60
		(10.78)	(5.08)	(2.81)	

Notes: t-statistics in parentheses. LL is the likelihood function, λ is the rationality parameter in the discrete choice model $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.

important even after controlling for inequity-aversion.

5 Conclusion

The desire to win framework helps explain the phenomenon of over-competition and market volatility. When firms derive utility from outperforming rivals, the standard Cournot equilibrium can become unstable. With similar marginal costs, the pure-strategy Nash equilibrium disappears, and firms adopt mixed strategies that lead to aggressive overproduction. Although inequity-aversion preferences alone tend to soften competition, their effect is dominated once the discontinuous desire to win motive is introduced. The desire to win is both psychologically plausible and empirically relevant, as shown by experimental evidence from real-effort tournaments with sabotage and repeated Prisoner's Dilemma games. Since over-competition can generate both benefits and costs for welfare, understanding how desire to win motives operate may guide policymakers in designing interventions that either mitigate or harness such motives to improve market outcomes.

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Appendix A: Proofs

A1 Proof of Theorem 1

Statement: For each player $i \in \{1, \dots, n\}$ let $S_i \subset \mathbb{R}$ be nonempty, compact, and convex. Let $S = \prod_i S_i$. Monetary payoffs $x_i : S \to \mathbb{R}$ are continuous. If all players have a strict positive desire to win $\gamma_i > 0$ and conditions 1 and 2 (C1, C2) hold, then the game $(S, \{U_i\})$ admits no pure-strategy Nash equilibrium.

Proof. Assume toward a contradiction that $s^* \in S$ is a pure-strategy Nash equilibrium in utilities U.

Case 1: A tie at the top.

Suppose there are distinct i, j with $x_i(s^*) = x_j(s^*) = \max_k x_k(s^*)$. Pick a tied player, w.l.o.g. i, with $s_i^* \in S_i$. By C1, local Relative Responsiveness, choose s_i' arbitrarily close to s_i^* with $x_i(s_i', s_{-i}^*) - x_j(s_j^*, s_{-j}^*) > x_i(s_i^*, s_{-i}^*) - x_j(s_j^*, s_{-j}^*) = 0$, so i becomes strictly top in x. By continuity, for any ε, there exists s_i' such that $|x_i(s_i', s_{-i}^*) - x_i(s^*)| < |\varepsilon|$. Hence, there exist s_i' such that:

$$U_i(s_i', s_{-i}^*) - U_i(s^*) = \underbrace{x_i(s_i', s_{-i}^*) - x_i(s^*)}_{>-|\varepsilon|} + \gamma_i > 0,$$

a profitable deviation, contradiction.

Case 2: A unique leader.

Let $s^* \in S$ be the candidate pure profile and suppose k is the unique maximizer of the monetary-payoff vector at s^*, so $x_k(s^*) > x_j(s^*)$ for all $j \neq k$. By the C2, closeness of top player, there exists a follower $i \neq k$ and a nonempty set

$$T = \left\{t \in S_i : x_i(t, s_{-i}^*) - x_k(s^*) \geq 0\right\}$$

such that $\sup_{h \in T} \big(x_i(h, s^*_{-i}) - x_i(s^*_i, s^*_{-i}) \big) < \gamma_i$. Since $T \neq \varnothing$ and S_i is compact, choose $t_i \in T$ that attains the supremum on T.

(i) *Strict overtake.* If $x_i(t_i, s^*_{-i}) > x_k(s^*)$, then by deviating to t_i, player i becomes the unique monetary leader. Because no other player's monetary payoff decreases when i moves (we hold opponents' actions fixed), i incurs no additional loss-indicator penalties, and she gains the rank bonus associated with being strictly ahead. Hence

$$U_i(t_i, s^*_{-i}) - U_i(s^*) \geq \big[x_i(t_i, s^*_{-i}) - x_i(s^*)\big] + \bar{\gamma}_i > 0,$$

thus i has a profitable deviation.

(ii) *Tie with the leader.* If $x_i(t_i, s^*_{-i}) = x_k(s^*)$, then t_i ties i with the leader in monetary payoff. If $t_i \in S_i$, Local relative responsiveness guarantees the existence of a nearby $t'_i \in S_i$ with $x_i(t'_i, s^*_{-i}) > x_k(s^*)$. By taking t'_i arbitrarily close to t_i, other players' monetary payoffs remain unchanged, and the argument in (i) applies: i can strictly overtake and secure a profitable deviation.

Both cases are impossible, hence no pure-strategy Nash equilibrium exists. ■

A2 Proof of Proposition 1

Statement: Under the inequity-aversion specification, the Cournot competition defined in (3.1) has the same Nash equilibrium as the standard utility model.

Proof: First, I show that no asymmetric equilibrium can arise.

Without loss of generality, suppose $\pi_1 > \pi_2$.

The first-order conditions are

$$\frac{\partial U_1^I}{\partial q_1} = (1-\beta_1)\,(a - 2q_1 - q_2 - c_1) - \beta_1\, q_2 = 0,$$
$$\frac{\partial U_2^I}{\partial q_2} = (1+\alpha_2)\,(a - q_1 - 2q_2 - c_2) + \alpha_2\, q_1 = 0,$$

which yield the best response functions:

$$\mathrm{BR}_1^I(q_2) = \frac{(1-\beta_1)(a-c_1) - q_2}{2(1-\beta_1)},$$
$$\mathrm{BR}_2^I(q_1) = \frac{(1+\alpha_2)(a-c_2) - q_1}{2(1+\alpha_2)}.$$

Solving the fixed point yields:

$$q_1^I = \frac{2(1-\beta_1)(1+\alpha_2)(a-c) - (1+\alpha_2)(a-c)}{4(1-\beta_1)(1+\alpha_2) - 1},$$

$$q_2^I = \frac{2(1-\beta_1)(1+\alpha_2)(a-c) - (1-\beta_1)(a-c)}{4(1-\beta_1)(1+\alpha_2) - 1}.$$

If $4(1-\beta_1)(1+\alpha_2) - 1 \leq 0$, the output is negative or infinite, which is impossible; hence the assumption is invalid. If $4(1-\beta_1)(1+\alpha_2) - 1 >= 0$, then $q_1^I < q_2^I$ and $p > c$, hence $\pi_1 < \pi_2$, contradicting the assumption $\pi_1 > \pi_2$.

Hence, the equilibrium must be symmetric, implying $\pi_i = \pi_j$, which contradicts the assumption. Therefore, no pure-strategy Nash equilibrium exists with asymmetric outputs.

Next, I show that the symmetric outcome $q_i = q_j = \frac{a-c}{3}$ is the unique Nash equilibrium. At the symmetric point, each firm's utility reduces to the standard profit function, which has a unique maximizer:

$$q_1^I = q_2^I = \frac{a-c}{3}.$$

Any deviation from this quantity reduces both monetary profit (since this is the optimal output in the standard model) and, by creating a profit difference, reduces the inequity-aversion utility.

Thus, there are no profitable deviations.

Therefore, the unique Nash equilibrium under inequity-aversion coincides with the standard Cournot equilibrium. ■

A3 Proof of Lemma 1

Statement: Under the desire to win utility in the Cournot setting (3.1), when costs are identical, no asymmetric pure-strategy Nash equilibrium exists.

Proof: Toward a contradiction, without loss of generality, suppose $q_1 > q_2$.

Case 1: $p > c$, price higher than the marginal cost. Then $\pi_1 > \pi_2$, firm 1 "wins," and firm 2 "loses." Each firm's best response thus maximizes monetary profit alone (the win/lose status is fixed). However, in the standard Cournot model with identical costs, the unique equilibrium is symmetric, contradicting $q_1 > q_2$.

Case 2: $p = c$, price equal to the marginal cost. The two firms' profits are equal, $\pi_1 = \pi_2 = 0$. By continuity, there exists $\varepsilon > 0$ such that $q_1 - \varepsilon > q_2$. Under the new quantity, price is higher than the marginal cost; firm 1 gains positive profit and $\pi_1' > \pi_2'$, implying a profitable deviation.

Case 3: $p < c$, price lower than the marginal cost. Then $\pi_1 < \pi_2 < 0$, firm 1 "loses," and firm 2 "wins." By continuity, there exists $\varepsilon > 0$ such that $q_1 - \varepsilon > q_2$, and the price remains below marginal cost. The winning status does not change, while firm 1 strictly increases its profit, a profitable deviation.

Since none of these cases is possible, no asymmetric pure-strategy Nash equilibrium exists. ■

A4 Proof of Theorem 2

Statement: Under the desire to win utility in the Cournot setting (3.1), when marginal costs are identical, if the parameters κ and γ satisfy

$$\kappa_i, \kappa_j \geq \frac{(a-c)^2}{16}, \quad \gamma_i, \gamma_j > 0,$$

then the pure-strategy Nash equilibrium occurs where price equals marginal cost. Otherwise, no pure-strategy equilibrium exists.

Proof: By Lemma 1, the only possible Nash equilibrium occurs when $q_1 = q_2$. Next, we check the two conditions of Theorem 1.

For C1 (local relative responsiveness), take the difference between the two firms:

$$\Delta(q_1, q_2) = \pi_1(q_1, q_2) - \pi_2(q_1, q_2).$$

$$\frac{\partial \Delta(q_1, q_2)}{\partial q_1} = \frac{\partial p}{\partial q_1} q_1 + p - c - \frac{\partial p}{\partial q_1} q_2 = a - c - 2(q_1 + q_2)$$

Since $q_1 = q_2$, the only case where C1 is violated ($\frac{\partial \Delta(q_1,q_2)}{\partial q_1} = 0$) is when $q_1 = q_2 = \frac{a-c}{2}$, $p = c$.

For C2 (closeness between top players), the profits are the same under the Nash equilibrium without the desire to win component. By applying Theorem 1, there is no pure-strategy Nash equilibrium when $p \neq c$.

To check whether a Nash equilibrium exists when $p = c$, in this case $q_1 = q_2 = \frac{a-c}{2}$. Without loss of generality, consider whether firm 1 has an incentive to deviate. Clearly, if firm 1 increases its output, it will incur negative profit; meanwhile, since $\pi_1 < \pi_2$, firm 1 will suffer an additional loss of κ_1. Hence, there is no profitable deviation from increasing output. When firm 1 decreases output, $q_1' < q_1$, the price will be higher than the marginal cost. Since firm 1's output is now lower than firm 2's, it will incur a loss of reluctance-to-lose κ_1. To maximize monetary profit,

$q_1' = \frac{a-c}{4}$, yielding $\pi = \frac{(a-c)^2}{16}$.

Therefore, the only pure-strategy equilibrium is

$$\big((a-c)/2,\,(a-c)/2\big),$$

and it exists if and only if

$$\kappa_1, \kappa_2 \geq \frac{(a-c)^2}{16}.$$

Otherwise, no pure-strategy equilibrium exists. ■

A5 Proof of Corollary 1

Statement: When both desire to win and inequity-aversion are present in the Cournot setting (3.1), if the reluctance-to-lose parameters and envy are small, $\frac{(a-c)^2}{16}\alpha_i + \kappa_i < \frac{(a-c)^2}{16}$ for $i = 1, 2$, the pure-strategy Nash equilibrium coincides with that under DTW-only utility. Otherwise, no pure-strategy equilibrium exists.

Proof: By analogy, it is easy to verify that condition C1 is violated only when $q_1 = q_2 = \frac{a-c}{2}$, and C2 is still satisfied. By applying Theorem 1, there is no pure-strategy Nash equilibrium when $p \neq c$.

To check the case when $p = c$, similarly, if firm 1 increases its output, it will incur negative profit; meanwhile, since $\pi_1 < \pi_2$, firm 1 will suffer an additional loss of κ_1. Hence, there is no profitable deviation from increasing output. When firm 1 decreases output, $q_1' < q_1$, the price will be higher than the marginal cost. Since firm 1's output is now lower than firm 2's, it will incur a loss of reluctance-to-lose κ_1 and a loss from envy. To maximize monetary profit, $q_1' = \frac{a-c}{4}$, yielding $\pi = \frac{(a-c)^2}{16}$.

Therefore, the only pure-strategy equilibrium is

$$\big((a-c)/2,\,(a-c)/2\big),$$

and it exists if and only if

$$\frac{(a-c)^2}{16}\alpha_i + \kappa_i < \frac{(a-c)^2}{16} \text{ for } i = 1, 2.$$

Otherwise, no pure-strategy equilibrium exists.

■

A6 Proof of Proposition 2

Statement: Under inequity-aversion in the Cournot setting (3.1), the Nash equilibrium shifts relative to the standard model. Moreover, if

$$4(1-\beta)(1+\alpha) - 1 > 0,$$

Then the lower-cost firm reduces its output while the higher-cost firm increases its output compared to the standard equilibrium.

Proof: First, suppose $\pi_1 \geq \pi_2$. I will then discuss the case $\pi_1 < \pi_2$.

When the lower-cost firm earns at least as much profit as the higher-cost firm, its utility becomes

$$U_i^I = (1-\beta_i)\,\pi_i + \beta_i\,\pi_j.$$

The first-order conditions are

$$\frac{\partial U_1^I}{\partial q_1} = (1-\beta_1)\,(a - 2q_1 - q_2 - c_1) - \beta_1\,q_2 = 0,$$
$$\frac{\partial U_2^I}{\partial q_2} = (1+\alpha_2)\,(a - q_1 - 2q_2 - c_2) + \alpha_2\,q_1 = 0,$$

which yield the best response functions

$$\mathrm{BR}_1^I(q_2) = \frac{(1-\beta_1)(a-c_1)-q_2}{2(1-\beta_1)},$$
$$\mathrm{BR}_2^I(q_1) = \frac{(1+\alpha_2)(a-c_2)-q_1}{2(1+\alpha_2)}.$$

Solving for the fixed point gives

$$q_1^I = \frac{2(1-\beta_1)(1+\alpha_2)(a-c_1)-(1+\alpha_2)(a-c_2)}{4(1-\beta_1)(1+\alpha_2)-1},$$

$$q_2^I = \frac{2(1+\alpha_2)(1-\beta_1)(a-c_2)-(1-\beta_1)(a-c_1)}{4(1+\alpha_2)(1-\beta_1)-1}.$$

Under this quantity, $\pi_1 > \pi_2$.

Now consider the case $\pi_1 < \pi_2$. Using a similar argument, compute the quantity and profit, and find that $\pi_1 > \pi_2$, contradicting the assumption $\pi_1 < \pi_2$. Therefore, the profit of firm 1 is always higher than that of firm 2.

Next, compare this with the standard Cournot equilibrium $q_i^S = \frac{a-2c_i+c_j}{3}$. Under the assumptions

$$0 < c_1 < c_2 < a, \quad 0 \le \beta_1 < \alpha_2 < 1, \quad 4(1-\beta_1)(1+\alpha_2)-1 > 0,$$

and

$$a-2c_1+c_2 > 0, \quad a+c_1-2c_2 > 0,$$

let $\Delta = q_1^S - q_1^I$. Since both denominators are positive, let the multiplication of denominators be C:

$$C = 3\big(4(1-\beta_1)(1+\alpha_2)-1\big),$$

and compute

$$C\,\Delta = (a-2c_1+c_2)\big(4(1-\beta_1)(1+\alpha_2)-1\big) - 3(1+\alpha_2)\big(2(1-\beta_1)(a-c_1)-(a-c_2)\big),$$

which simplifies to

$$C\,\Delta = \alpha_2\,(a - 2c_1 + c_2) + 2(1+\alpha_2)\,\beta_1\,(a + c_1 - 2c_2).$$

All terms on the right are nonnegative, with at least one strictly positive, so $\Delta > 0$. Hence

$$q_1^I \leq \frac{a - 2c_1 + c_2}{3} = q_1^S,$$

and by an analogous argument

$$q_2^I \geq \frac{a - 2c_2 + c_1}{3} = q_2^S.$$

■

A7 Proof of Lemma 2

Statement: In the Cournot setting (3.1) with desire to win preferences and different marginal costs, no pure-strategy Nash equilibrium exists if the outcome is a tie.

Proof: Suppose, toward a contradiction, that a tie $\pi_1 = \pi_2 > 0$ occurs in equilibrium. Define

$$D = \pi_1 - \pi_2 = (a - q_1 - q_2 - c_1)\,q_1 - (a - q_1 - q_2 - c_2)\,q_2.$$

Let (q_1^*, q_2^*) satisfy $D = 0$, i.e.

$$(a - q_1^* - q_2^* - c_1)\,q_1^* = (a - q_1^* - q_2^* - c_2)\,q_2^*. \tag{a}$$

A necessary condition for no profitable deviation by firm 1 is that the derivative of D with respect to q_1 is zero; otherwise, firm 1 could produce slightly more or slightly less to gain γ_1 with an arbitrarily small loss.

$$\left.\frac{\partial D}{\partial q_1}\right|_{q_1^*} = a - c_1 - 2q_1^* = 0 \Longrightarrow q_1^* = \frac{a - c_1}{2}.$$

Similarly, for firm 2 we require $q_2^* = \frac{a-c_2}{2}$. Substituting into (a) gives

$$(a - c_1)^2 = (a - c_2)^2,$$

contradicting $c_1 < c_2$.

Therefore, no pure-strategy equilibrium can involve a tie.

For $\pi_1 = \pi_2 < 0$, by the same method, it also leads to a contradiction.

For $\pi_1 = \pi_2 = 0$, this is impossible: if firm 1 has zero profit, then $p = c_1$ and $p = c_2$, but $c_1 \neq c_2$, a contradiction. ■

A8 Proof of Theorem 3

Statement: In the Cournot setting (3.1) with desire-to-win preferences and different marginal costs, no pure-strategy Nash equilibrium exists if both conditions hold:

$$a > -10c_1 + 11c_2 + 6\sqrt{3}\,(c_2 - c_1), \tag{a}$$

$$\gamma_2 + \kappa_2 > \frac{1}{36}\Big(3\sqrt{(a-c_2)^2 - \tfrac{4}{9}(a - 2c_1 + c_2)(2a - c_1 - c_2)} - (a - 2c_1 + c_2)\Big)^2. \tag{b}$$

Otherwise, the equilibrium coincides with that under standard profit maximization.

Proof: By Lemma 2, no equilibrium can be a tie. In equilibrium, firms maximize their profits without considering the desire to win or the reluctance to lose. Hence, the only possible equilibrium is:

$$q_1^D = \frac{a - 2c_1 + c_2}{3}, \qquad q_2^D = \frac{a - 2c_2 + c_1}{3}.$$

Firm 1, having maximized profit and won, has no incentive to deviate. I need to check whether firm 2 has any profitable deviation.

First, check whether firm 2 can increase its profit above firm 1's when $q_1 = \frac{a-2c_1+c_2}{3}$. Let

$$D(q_2) = \pi_1 - \pi_2 = q_2^2 - (a - c_2)\, q_2 + \frac{(a - 2c_1 + c_2)(2a - c_1 - c_2)}{9}.$$

Solving $D(q_2) = 0$ for q_2 and imposing $\pi_2 > 0$ yields the necessary condition for firm 2 to have an incentive to deviate:

$$a > -10c_1 + 11c_2 + 6\sqrt{3}\,(c_2 - c_1).$$

Second, ensure that any deviation yielding $\pi_2 = \pi_1$ fails to increase firm 2's total utility. Writing π_2^* for firm 2's profit in the standard equilibrium and $\pi_2(D = 0)$ for its profit at the tie, I require

$$\gamma_2 + \kappa_2 > \pi_2^* - \pi_2(D = 0).$$

Hence, the second necessary condition for firm 2 to have an incentive to deviate is

$$\gamma_2 + \kappa_2 > \frac{1}{36}\Big(3\sqrt{(a - c_2)^2 - \tfrac{4}{9}(a - 2c_1 + c_2)(2a - c_1 - c_2)} - (a - 2c_1 + c_2)\Big)^2.$$

If either condition fails, firm 2 cannot profitably deviate, and the unique pure-strategy equilibrium coincides with the standard Cournot outcome. If both conditions hold, no pure-strategy equilibrium exists. When either condition is violated, neither firm has the incentive or ability to deviate from the Nash equilibrium under the standard utility function.

■

Appendix B: Finding Mixed Strategy

B1 Steps to Finding the Theoretical Distribution

First, compute the integral and require that the following expression be constant:

$$E(q_i) = -\frac{A^3}{6}\,q_i + \frac{A^2 a}{2}\,q_i + \frac{A^2\gamma}{2} - \frac{A^2}{2}\,q_i^2 + \frac{AB^2}{2}\,q_i - AB\,a\,q_i + AB\,\kappa + AB\,q_i^2$$
$$- A\gamma\,q_i - A\kappa\,q_i - \frac{B^3}{3}\,q_i + \frac{B^2 a}{2}\,q_i - \frac{B^2\kappa}{2} - \frac{B^2}{2}\,q_i^2 + \frac{\gamma}{2}\,q_i^2 + \frac{\kappa}{2}\,q_i^2.$$

Next, collect terms by powers of q_i:

1. Coefficient of q_i^2:

$$C_2 = -\frac{A^2}{2} + AB - \frac{B^2}{2} + \frac{\gamma}{2} + \frac{\kappa}{2} = \frac{-(A-B)^2 + (\gamma+\kappa)}{2}.$$

2. Coefficient of q_i:

$$C_1 = -\frac{A^3}{6} + \frac{A^2 a}{2} + \frac{AB^2}{2} - AB\,a - A\gamma - A\kappa - \frac{B^3}{3} + \frac{B^2 a}{2}.$$

3. Constant term:

$$C_0 = \frac{A^2\gamma}{2} + AB\,\kappa - \frac{B^2\kappa}{2}.$$

Hence

$$E(q_i) = C_2\,q_i^2 + C_1\,q_i + C_0,$$

and I solve the system

$$C_2 = 0, \qquad C_1 = 0.$$

1. From $C_2 = 0$:

$$-(A-B)^2 + (\gamma+\kappa) = 0 \quad\Longrightarrow\quad (A-B)^2 = \gamma+\kappa.$$

Set $s = \sqrt{\gamma + \kappa}$. Since B is the upper bound, take $B = A + s$.

2. From $C_1 = 0$, substitute $B = A \pm s$ and solve for A. One obtains

$$-9A + 3a \pm 2s = 0 \quad \Longrightarrow \quad A = \frac{3a - 2s}{9} \; (\frac{3a + 2s}{9} \text{ ruled out})$$

Then

$$B = A + s = \frac{3a - 2s}{9} + s = \frac{3a - 2s + 9s}{9} = \frac{3a + 7s}{9},$$

which yields the solution.

Substituting back $s = \sqrt{\gamma + \kappa}$, the solutions are

$$(A, B) = \left(\tfrac{3a - 2\sqrt{\gamma+\kappa}}{9}, \tfrac{3a + 7\sqrt{\gamma+\kappa}}{9} \right)$$

B2 Finding the Distribution by Simulation

To approximate the mixed strategy distribution, I use the following steps:

1. Choose an initial support $[0, 50]$ since $a = 100$.
2. Discretize this interval with step size 0.05, yielding 1000 points.
3. Initialize the probability distribution uniformly over these points.
4. At each iteration, compute each action's expected utility, identify the best response, increase its probability by a small increment (e.g. 0.1%), and renormalize the distribution.
5. Repeat step 4 for 10,000 iterations.
6. Plot a histogram of the best response choices.

To improve efficiency, after a few initial iterations, I remove actions with the lowest expected utility, provided every remaining action has been a best response at least once.

Figure 4 shows the resulting simulated density of the mixed strategy Nash equilibrium.

Figure 4: Simulated density of the mixed strategy equilibrium

Appendix C: Robustness Check for Experimental Data Estimation

Table 5: MLE Estimates of Utility Parameters by Quantal Response Equilibrium ($N = 13{,}888$)

Model	Restrictions	λ	α	γ	LL
Standard	$\alpha = \gamma = 0$	0.067***	—	—	-8209.59
		(9.88)			
IA (α)	$\gamma = 0$	0.062***	0.262***	—	-7343.37
		(10.09)	(7.52)		
DTW (γ)	$\alpha = 0$	0.088***	—	4.723***	-7534.69
		(13.21)		(8.87)	
Full (α, γ)	none	0.093***	0.287***	2.873*	-6964.79
		(9.93)	(5.26)	(2.30)	

Notes: t-statistics in parentheses. LL is the likelihood function, λ is the rationality parameter in the discrete choice model $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.