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Imminent Entry and the Transition to Multimarket Rivalry in a Laboratory Setting*

by

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Abstract: In this paper we study the behavior of rivals when there is a known probability of imminent entry. Experimental markets are used to collect data on pre- and post-entry production when there is an announced time of possible entry; some markets experience entry and other do not. In all pre-entry markets competition is more intense. Post-entry behavior in all markets is more competitive compared to a baseline that had no threat. There is evidence that post-entry multimarket contact raises outputs in those markets that did not experience entry, behavior we generally refer to as a conduit effect.

Keywords: Entry, Rivalry, Market Experiments

JEL Classifications: L1, L4, C9

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I. Introduction

The potential threat of entry can influence the strategies of incumbent firms. Seemingly imminent entry changes both a pre-entry and a possible post-entry competitive landscape. How these landscapes change may depend as much on the entrant as the cast of current producers. The new firm can have little or no competitive market experience, or it can enter with a history of rivalry from other and perhaps related markets. The entrant can establish links to other markets if it operates in more than one market. It then becomes a conduit through which events in one market impact behavior in other markets. In general, learning in one market can be transferred to other markets through the conduit firm. A web of multimarket producers creates interacting market connections (Phillips and Mason 2001).

An example of entry combined with multi-market participation is provided by an antitrust case involving the Swedish packaging giant Tetra Pak. Known as a major global provider of aseptic packaging, in the late 1980s and early 1990s Tetra Pak acquired firms that allowed it to compete in the market for non-aseptic packaging. Prior to these acquisitions, the market for non-aseptic packaging was dominated by two firms, Elopak and PKL (García-Gallego and Georgantzís, 1999). Tertra Pak's entry plans were widely announced. These plans created a different set of behavioral incentives for the already existing firms in that market. Following the acquisitions, Elopak Italia complained that Tetra Pak's business practices brought economic harm to Elopak; an indication that post-merger rivalry was intense. The European Competition Commission ultimately decided against Tetra Pak.[1] While the competition authority's primary focus was on the post-event behavior, we maintain there were important implications for pre-merger behavior in the non-aseptic packaging market.

Imminent entry of the sort described above creates a transition to different market structures. There is a period of time during which the already-producing firms have a reasonable belief that another firm will enter the market. This may be known because capital is being put in place, or there has been an announcement that a new firm is planning to begin operations.[2] Also as communities develop, some firms have widely known business plans to extend operations as populations or household incomes reach a target level.[3] One can also think of a scenario in which entry is imminent once a patent expires.[4] Alternatively, one can imagine the appointment of a new anti-trust authority that takes a far more aggressive stance towards existing oligopolies, and takes actions that facilitate entry.[5] During this transition are incumbent firms more or less cooperative compared to the identical market structure without the threat of entry? How does behavior compare in the post-entry period to a market structure that has a long history with no threat of entry?

In this paper we study transitions before and after the time that entry may occur. Behavior can be modeled with firms using trigger strategies to punish non-cooperative actions. The repeated game has a known transition point at which the number of firms possibly increases by one. There may be no actual entry, but until the transition point there is a threat. If entry occurs, it is either from a newly formed firm entering, or an established firm extending its operations into another market. While the analytics suggest that rivals are less cooperative as a result of the threat of entry, it is difficult to predict behavior after the possible time of entry. In order to learn more about pre- and post-entry behavior we construct experimental duopoly and triopoly markets, where as a baseline, quantity choosers go for an indefinite period of time without any threat of entry. We compare this behavior to duopoly markets that have a threat of entry.

We construct two experimental market environments that involve potential entry. In one design the entrant is a new firm that has no other market contact. In a second design, when entry occurs it comes from a duopoly firm extending its operations into a second market. Here, the entrant becomes a multi-market firm; this allows strategic learning to be transferred across markets.

Our results show that potential entry inhibits collusive tendencies, as one would expect; this effect arises whether or not entry transpires.[6] Perhaps more surprisingly, this effect persists past the date of potential entry. Because there are a multiplicity of equilibrium strategy configurations in an indefinitely repeated game, such as the one we study, subjects may gravitate towards a less collusive regime when entry is more likely; this tendency then gets "locked in" and so survives past the date at which entry could occur, whether or not entry transpires. As such, the results suggest that public policy can measurably inhibit collusive behavior by more generally creating a probability of entry, which would include taking actions that reduce entry barriers.

II. Experimental Market Designs

A description of the experimental design will present a clearer picture of the market structures before and after the announced date of entry. Subjects make choices from a payoff table for an indefinite number of periods. In a duopoly game the row choice made by one subject is the column value of a rival. The intersection of the row and column in the payoff table shows earnings for the period. The payoff table represents the normal form of a stage game (Friedman, 1983). The use of payoff tables in experiments has a history that predates their description of oligopoly markets. Rapoport, Guyer and Gordon (1976) and Colman (1982), for instance, provide extensive surveys of literally hundreds of experiments that use payoff tables to generally learn more about rivalry and bargaining behavior. Surveys of how researchers have used payoff tables to study non-cooperative behavior are provided by Davis and Holt (1993, Chapter 2), Friedman and Sunder (1994, Chapter 9), Kagel and Roth (1995), and Plott (1989).

A schematic (Figure 1) of the experimental market structures before and after the period of potential entry is a helpful introduction to a description of the experimental design. Before entry there are six duopoly markets with 12 subjects choosing quantity from a payoff table. Figure 1 at the top illustrates the pre-entry configuration. There are 25 choice periods in the pre-entry market structure.

II.A. Treatment I: A Single Market Entrant

In this experimental design we recruit two additional subjects as potential entrants in the six duopoly markets. Altogether 14 subjects are recruited. After everyone is seated, two subjects are randomly designated as entrants. These people know that they will enter the game in period 26. They make no choices during the first 25 periods, though they are able to view the choices of earnings of the players in the market they will enter. Otherwise, these subjects have no market experience. Subject who are actively participating in a duopoly market during the first 25 periods of the game know that there is a 1/3 chance of entry. In the bottom half of Figure 1 we show subjects 13 and 14 entering markets 1 and 3, which then become triopolies for the remainder of the experiment. The other four markets continue to operate as duopolies.

II.B. Treatment II: A Multi-market Entrant

In this design, subjects who will become entrants actively make choices in a different market in all periods. Figure 1 at bottom illustrates the design. As in treatment I, the probability of entry into a duopoly market at the end of period 25 is 1/3. However, two of the duopoly markets became "conduit markets." They are connected to another market through subjects who participate in two markets (in Figure 1, these are subjects 9 and 11). The probability of a player becoming a multimarket operator, i.e. making choices from two tables, is 1/6. Subjects were informed of these probabilities.[7] Entry creates two triopoly markets (in Figure 1, these are markets 1 and 3). This design leaves two duopoly markets that had a threat of entry at the end of period 25, but into which no entry occurred (in Figure 1, these are markets 2 and 4). These markets are "siloed", because the duopoly firms do not participate in any other markets. Finally, the transition date creates two "connected" duopoly markets that had a threat of entry, but no entry in period 25, however one of the firms operates in two markets (markets 5 and 6). After the transition period subjects make choices for at least 25 more periods. Starting with period 50 in both treatments I and II, there is a 20% probability of stopping at the end of each period.[8]

II.C. Baseline Treatments

As baseline treatments, 18 duopoly markets in two experimental sessions operated for 50 periods with the same random end point; there was no possibility of entry, nor was there a threat of entry. Eight triopoly markets were conducted the same way during two sessions of 12 subjects each. These two baselines allow us to test for differences in behavior under treatment designs I and II before and after period 25. Altogether there are four experimental designs: the two entry designs described in Figure 1 (four sessions with 12 subjects each), and two baseline duopoly and triopoly markets.

II.D. Instructions and Basic Market Conditions

Subjects for all experimental sessions were recruited from upper level undergraduate economic classes. They reported to a reserved classroom with a personal computer at each seat. At the beginning of a session, instructions were read aloud as subjects followed along on their own copy. Questions were taken and one practice period was held with sample payoff tables different from those used in the experiment. The samples showed a table when two people made a row choice, and a table for which three people made a row choice. Several examples of row choices were covered in both a duopoly and triopoly game. Earnings were measured in a fictitious currency called tokens. At the end of the experiment, tokens were exchanged for cash at the rate of $1.00=1000 tokens.

In each market period subjects were instructed to type their row choices into their personal computer.[9] Subjects were anonymously matched for the duration of the experiment, and matched individuals were not seated close to each other. Once everyone had made their choices, the linked computer screens reported back to subjects their choices, earnings, and balance. Subjects kept track of this information and they always could check the computer's calculations from the payoff tables provided to them. Subjects were informed of the choices and earnings made by a rival or rivals. Finally, all participants knew that if there was some probability of entry, it would occur in period 26. The second part of treatments I and II would have at least 25 periods. Subjects were informed that there was an 80% chance of continuing after period 50. After period 50, the computer would randomly generate a number between 0 and 100, and the experiment would end in the period the random number did not exceed 20. Sessions generally ended between periods 50 and 55, and took about 2 hours; earnings averaged about $25 per subject.[10]

All of the experimental market designs described in Figure 1 are constructed as two or three person repeated games, where the payoff tables are derived from linear demand conditions. The inverse demand function in the market is $P(Q) = 60 - Q$ where $Q = \sum_{i=1}^{n} q_i, n = 2\, or\, 3$. There are no variable costs of production, though agents face fixed costs of 75. Reduced-in-size copies of the two and three person games are contained in Appendix A.[11]

Subjects were never told they were picking outputs, just that they were choosing values from a payoff table where the intersection of their row choice and the other player's column choice determined earnings for the period. In treatments I and II, subjects were told that in period 25 the tables may or may not change to a larger version with three people choosing row values. The instructions also informed all subjects that they could be making row choices from two tables in each period.

For reference, several possible equilibrium choices can be identified in the payoff tables. In the duopoly games the static Cournot/Nash quantities are $q_i = 20$. Complete symmetric collusion occurs at $q_i = 15$. In the triopoly games, the static Cournot/Nash quantity is at $q_i = 15$ and the complete symmetric collusive choice occurs at $q_i = 10$.

III. Hypotheses

Our experimental setting can be represented as a dynamic game in which there is a shock to the system. Players reach tacit agreement using trigger strategies,[12] but they must cope with a change in the market structure in which they are aware of the probability of change at a known point in time. Hence we discuss pre-entry and post-entry behavior.[13]

There are two critical points in time: the end of period 25, when the uncertainty regarding the potential entry is resolved, and the end of period 50, when the random termination commences. We use "epoch 1" to refer to periods 1 through 25 and "epoch 2" to refer to choice periods after period 25. During epoch 1 there are two players, 1 and 2, who simultaneously select outputs q_{1t} and q_{2t} in each period t. In epoch 2, the number of players either changes from 2 to 3, with probability 1-λ, or the number remains 2; this number applies for the remainder of the game. Whether or not entry occurred, all players choose outputs simultaneously in each period in epoch 2. Finally, starting with period 50, the game terminates at the end of each period with probability $1-\theta \in (0,1)$ (and so with probability θ the game continues to the next period).

The central question we study in this paper is: how does the threat of entry affect the ability to tacitly collude? Intuitively, the threat of entry reduces the value of continued cooperation, and so one expects to see larger outputs when there is a threat of entry than where no such threat exists. On the other hand, behavior in advance of entry must surely entail smaller outputs than would be observed in a 3-firm industry. Accordingly, there are two testable hypotheses associated with our experimental design during epoch 1:

Hypothesis 1: An experimental design with two firms and potential entry will have larger outputs than will an experimental design where the number of firms is fixed at 2;

and

Hypothesis 2: An experimental design with two firms and potential entry will have smaller outputs than will an experimental design where the number of firms is fixed at 3.

Notice that *Hypothesis 1* does not hold true in a standard Cournot/Nash framework: in such an environment, firms would produce the Cournot output with or without the threat of entry. It is only when there is a tendency to produce smaller outputs in a tacitly collusive environment for which the threat of entry will matter.

A natural way to model the post entry period is as an indefinitely repeated game with a fixed number of players, under which deviation from a cooperative regime induces perennial reversion to the one-shot Cournot/Nash equilibrium (Gibbons (1992), pp. 102-107). With this backdrop in mind, a natural expectation is that subjects in markets that did not experience entry at the end of the first phase will choose outputs that on average are more cooperative than the

Cournot/Nash duopoly level. But the nature of this strategy is such that firms maintain whatever level of cooperation they had achieved during the first epoch. That suggests a third hypothesis:

Hypothesis 3: In the experimental design with potential entry that does not materialize, behavior in epoch 2 will not differ from behavior in epoch 1.

In some of our experimental markets, subjects operate in two markets in epoch 2; these subjects make choices in a duopoly and a triopoly and so face two distinct incentive constraints. As we describe in Phillips and Mason (2001), it is likely one of these markets will be more cooperative than the other. Different degrees of cooperation could reflect different degrees of "rationality" among players that emerges from their history of play (Kreps (1990)). This potential heterogeneity motivates subjects to learn about their rival(s) mode of behavior, and may facilitate a similar level of cooperation in the two markets. One can think of learning as altering the incentive constraint(s), by changing the weight put on future returns, and this will change the quantities at which the incentive constraints bind.

It is possible that the multimarket producer, in order to interpret the actions of different rivals, treats all rivals as having a single common strategy. The multimarket producer therefore uses the same rule by which to adjust to the actions of different rivals. In turn, this strategy may force the X and Y market rivals to adjust quantities in different directions. The strategy of the multimarket agent may break "the constraint" in the Y market and crate slack in the X market. The conduit firm will generate market outcomes very similar to that of the same firms meeting in different markets.

The foregoing discussion suggests that behavior in experimental duopolies may differ when one compares regimes where both players operate in just the one market with regimes in which one player operates in both the duopoly and a second market. In our experimental design, this comparison is readily available in treatment II for epoch 2: of those pairs that did not experience entry (and so remain a duopoly), half of the pairs include a subject who has been placed in a second market while the other half included subjects that are participating in one market only. In the discussion below, we term the second cohort “no entry, no multi-market” and the first cohort “no entry, multi-market.” An interesting behavioral question addresses the comparison of these two cohorts.

IV. Econometric Model

We now turn to a rigorous analysis of choices in our pre-entry and post-entry experimental design. The goal is to estimate the equilibrium choice for a typical agent. We analyze the experimental data by treating each session as a pooled cross section time series.[14] In the sample, the cross-sectional element is given by the number of participants, with the number of observations per subject determined by the length of the session in which he or she participated.

The structural model we estimate to test these hypotheses is based on the relation

$$C_{it}= \alpha_i + \varepsilon_{it}, \tag{1}$$

where C_{it} represents the market output chosen by subject pair i in period t, α_i is the equilibrium or "steady-state" choice for pair i, and ε_{it} is a disturbance term. Because subjects’ decisions are simultaneous, an individual's choice can be influenced only by a counterpart's past choices. As an individual adjusts his or her choices in approaching equilibrium, the history of the game provides important information. This can occur either because agents are learning about their rival's rationality (Kalai and Lehrer, 1993) or because of signalling, aimed at coordinating on a more profitable regime (Shapiro, 1980). The implication is that the disturbance term in equation

(1) may contain subtle dynamic effects more than first-order ones. The most parsimonious time-series structure that includes such subtle effects is a second-order autoregressive process, which yields:

$$C_{it} = b_i + \rho_1 C_{it-1} + \rho_2 C_{it-2} + u_{it}, \qquad (2)$$

where $b_i = a_i(1 - \rho_1 - \rho_2)$, and we impose the regularity conditions $|\rho_1| < 1$, $|\rho_2| < 1$, and $|\rho_1 + \rho_2| < 1$ (Fomby, Hill and Johnson, 1988).

To estimate this regression model, we regard our dataset as a balanced panel; this requires the same number of observations for each element of the cross-section, i.e., each subject pair. In each case, we estimated the system of equations defined by equation (2) for all subject pairs, allowing intercepts to vary between subject pairs in a given treatment, and slopes to vary between different treatments.

We propose a fixed-effects approach to analyze choices. This approach assumes that variations between subjects within a given design can be captured through differences in the intercept term, b_i.[15] However, the dynamic adjustment terms, ρ_1 and ρ_2, as well as the variance of the disturbance term, u_{it}, are assumed equal for all pairs in a given design. Also, we assume no contemporaneous covariance between subject pairs and that u_{it} is serially uncorrelated:

$$E(u_{it}u_{jw}) = 0 \text{ if } i \neq j \text{ or } t \neq w,$$

where w is a time period different from t.

With this structure, it is straightforward to obtain asymptotically efficient, consistent estimates of the parameters b_i, ρ_1 and ρ_2. Once consistent and efficient estimates of these parameters are obtained, we construct the average intercept in design n as

$$\beta_n = \Sigma\, b_i / N_n, \qquad (3)$$

where N_n is the number of pairs in treatment n. We are interested in the equilibrium behavior of a typical subject in each of the treatments. If agents choose the steady-state value for several consecutive periods, then the deterministic version of equation (2) may be used to derive the equilibrium output for subject pair i in treatment n as

$$a_i = b_i/(1 - \rho_1 - \rho_2). \tag{4}$$

Because we are interested in the central tendency in each design, we then use these estimates of each pair's equilibrium to obtain the average choice for the design:

$$\alpha_n = \Sigma\, a_i / N_n = \beta_n/(1 - \rho_{1n} - \rho_{2n}). \tag{5}$$

Finally, we can use covariance information from the maximum-likelihood estimates of β_n, ρ_{1n} and ρ_{2n} to construct consistent estimates of the covariance structure for the steady-state values α_n for each treatment *n* (Fomby, Hill, and Johnson, 1988).

V. Results

We now turn to a discussion of our empirical analysis. We start by discussing the summary statistics, and then proceed to the formal econometric results from analysis of each of the two epochs.

V.1. Summary Statistics

Summary statistics for the baseline and treatment sessions are presented in Table 1. For each of the experimental designs, we list mean, standard error, minimum and maximum choices for the experimental markets. In the duopoly baseline treatment, three sessions with 6 subject pairs in each session participated, for a total of 18 markets. In the triopoly baseline treatment, two sessions with 4 subject groups each participated, for a total of 8 markets. In Treatment I, four sessions were conducted with 14 subjects in each session. In epoch 1 there were 6 duopoly markets in each session while in epoch 2 there were 4 duopoly markets (identified by the row "no entry") and 2 triopoly markets (identified by the row "entry"). In Treatment II, three sessions with 6 subject pairs in each session participated. Altogether, there were 18 pairs in epoch 1. At the end of epoch 1, two subjects from each session were randomly placed into a second market, so that 6 triopolies were formed. Throughout epoch 2, these six individuals participated in two markets, or had multi-market (MM) participation as illustrated in the second half of Figure 1. The same six subjects continued to make choices in their respective duopoly markets; the corresponding market choices are summarized in the Treatment II row labeled "no entry, MM". The other 12 subjects made choices during epoch 2 in duopolies where neither subject participated in more than one market; the data from these subjects is summarized in the row labeled "no entry, no MM."

The Table 1 summary shows that average duopoly market choices in the two treatment sessions increased relative to the baseline during epoch 1. Specifically, average duopoly choices are 38.42 in Treatment I and 38.06 in Treatment II, while average duopoly choices are 35.48 in the baseline.

With respect to epoch 2, in the treatment sessions where the potential entrant would only operate in the market under consideration (i.e., the entrant would not be multi-market), average choices are 37.69 (in Treatment I) and 41.29 (in Treatment II). By comparison, the average choices in the duopoly baseline are 37.84. Average choices in the Treatment sessions during epoch 2 where entry did occur are 41.19 (in Treatment I) and 44.61 (in Treatment II), which are larger than the average choices of 40.76 in the triopoly baseline in epoch 2.

Treatment I triopoly choices are less than choices of 42.75 during epoch 1 in the triopoly baseline, however average triopoly choices from both treatments are greater. The standard errors associated with these choices are fairly large, so determining the statistical importance of these effects requires a more thoughtful approach.

V.2 Data and Analysis: Epoch 1

We apply the regression model to each of four experimental designs. In Figure 2 average choices in the duopoly baseline, for which there is no threat of entry, are plotted as short-dashed lines and labelled “Baseline duopoly”. Choices as market output begin at about 35 units and fluctuate around this level for all periods during epoch 1. The Cournot/Nash quantity is 40 for the market, so there is a noticeable degree of tacit cooperation in the market that is sustained. The triopoly baseline, where there is no threat of entry and there are three players in each market throughout the experiment, is also graphed. Average choices are plotted in Figure 2 as the long-dashed line, which we label “Baseline triopoly”. Average combined market output is consistently about 40 units, ranging between 40 and 45 units for the duration of epoch 1. The Cournot/Nash quantity is 45 units. The experimental data exhibit a tendency to produce a few units below this level. Figure 2 also includes average choices from Treatment I, which we plot as the solid line, labelled “Treatment I.” These choices are generally greater than those in Baseline duopoly and smaller than those in Baseline triopoly.

Figure 3 contains the two baseline designs, along with average choices from Treatment II, which we plot as the solid line labelled “Treatment II.” As with the average choices in Treatment I shown in the preceding figure, these choices are consistently greater than average choices in the duopoly baseline., and smaller than average choices in the triopoly baseline (though they are closer to the Cournot/Nash choice of 40 than those in Treatment I).

The data summarized in Figures 2 and 3 are directly relevant to the two hypotheses we posed above. The results from our regression model, as applied to each of the two treatments, are provided in Table 2. In this table, parameter estimates for α_n, ρ_{1n} and ρ_{2n} are presented for all four experimental designs as labelled and described in Table 2.[16] The corresponding standard error is given, in parentheses, below the relevant point estimate. We also present the implied steady state choice, β_n, along with its standard error (in parentheses). Below these estimates we give the R^2 goodness of fit statistic for the regression, as well as the number of observations.

We note first that for all designs, the estimates of ρ_1 and ρ_2 are all less than one in magnitude, as is $|\rho_1 + \rho_2|$. Thus, the conditions for dynamic stability are satisfied, so we may properly regard the estimated value of β_n as the steady-state choices in each design *n*. Comparing the designs, we see that the estimated steady state choice in Treatment I (38.44) is virtually identical to the estimated steady state choice in Treatment II (38.31); the difference between these estimates is statistically insignificant.[17] For both treatments, the estimated steady state choice is significantly larger than the estimated steady state choice for the duopoly baseline, and significantly smaller than the estimated steady state choice for the triopoly baseline. All these differences are statistically different from 0 at better than the 1% confidence level, confirming our two propositions. This set of experiments confirms Hypothesis 1, that the threat of entry leads duopoly players to produce more during epoch 1.

V.3 Data and Analysis: Epoch 2

Figure 4 plots post entry duopoly choices from Treatments I and II, along with baseline choices from duopoly markets that had no threat of entry. These plots suggest that subjects in Treatment I behaved similarly to subjects in the duopoly baseline during epoch 2, where as subjects in Treatment II were significantly less cooperative. Choices in these latter sessions generally hover around the Cournot/Nash level of 40, but appear to increase with greater variance. These observations suggest the potential entry by a multi-market firm in Treatment II exerts a lingering effect upon any cooperative tendencies, even after the time at which entry could occur has passed – a theme we return to below.

Indeed as Table 3 reports, the difference between β_I, the estimated steady state choice level for subjects in the threatened duopoly Treatment I (which equals 37.60), and β_2, the estimated steady state choice level of subjects in the duopoly baseline session (which equals 37.65), is statistically insignificant. In contrast, the difference between β_2 and the estimated steady state choice level for subjects in the threatened duopoly Treatment II is significant. This is true both for subjects in markets where the potential entrant would make choices in multiple markets (β_{IIb} =40.13) and for subjects in markets where the potential entrant would only make choices in market facing potential entry (β_{IIa} = 41.22) is significant.[18] These latter estimated values, while significantly different from the estimated value for β_2, are not significantly different from the Cournot/Nash choice of 40, nor are they significantly different from each other. These observations suggest a role for the threatened entry via a multi-market firm during epoch 1. The comparison of β_I and β_2, on the other hand, suggests that once the threat of entry passes in Treatment I, subjects' cooperative tendencies are comparable to those in the duopoly baseline.

Figure 5 plots post entry triopoly choices from Treatments I and II, along with baseline choices from triopoly markets. The baseline is clearly more cooperative than the newly created triopolies through the middle periods, though the differences between the baseline and the triopoly choices from Treatment I tend to erode later in the sessions. As with the results illustrated in Figure 4, however, differences between average choices between epoch 2 in the Treatment II sessions and the baseline sessions persist through the end of the experiment.

Table 4 presents results for choices from epoch 2 for those experimental markets that have three participants in that epoch. The steady state choice level for the triopoly baseline (β_3 = 40.40) is not significantly different from the estimated steady state choice for subjects in Treatment I markets where entry occurred ($\beta_I = 41.30$). By contrast, steady state choices in for subjects in Treatment II markets where entry occurred ($\beta_{II} = 44.94$) are significantly different from both the triopoly baseline sessions and the sessions in Treatment I.

One possible explanation for the differences between Treatment II and the triopoly baseline is that once entry occurs all history is forgotten from the duopoly era, and players are working on tacit agreement with a clean slate. To get at this idea, we compare average choices in the triopoly baseline during epoch 1 against average choices in the newly formed triopolies in the treatment sessions during epoch 2. In Figure 6 we label the *x*-axis "round" to reflect the idea that any identified number *k* is the k^{th} choice period in the corresponding structure.[19] While there is considerable variance in choices, the three plots are roughly similar through round 21. After round 21, however, choices in the treatment triopolies diverge from choices in the baseline triopoly. Thus, while the conjecture that history is forgotten has some merit, for a while, this effect does not appear to persist.[20]

VII. Conclusion

Against the backdrop of duopoly and triopoly markets for which there is no threat of entry, we empirically investigate how firms behave in experimental markets when there is an imminent threat of entry. When duopolists are completely informed of the time and probability of entry they are significantly less cooperative than firms without such a random threat of entry. Imminent entry enhances competitive behavior in all markets in the pre-entry period.

Even if entry does not materialize, we find that compared to a baseline without a threat of entry, markets tend to be less cooperative in the post-entry period.[21] Players are unable to overcome their competitive history. An important element here is the multi-market presence for the potential entrant: the possibility for entry by such a player appears to mitigate cooperative tendencies in later periods. In the second epoch, after the date of potential entry has passed, duopolies in which the potential entrant would not have had a multi-market presence (Treatment I) chose significantly smaller outputs than conduit duopolies, in which the potential entrant would have had a multi-market presence (Treatment II). Triopolies where the entrant has a multi-market presence choose significantly greater quantities than triopolies where the entrant does not have a multi-market presence. For both the conduit duopoly and triopoly the difference is about 10%.

These experimental results expand our understanding of how the threat of entry in oligopoly markets affects competitive behavior. The threat posed as a randomized event independent of current output (and price) choices has the impact of making all markets in the threatened set of markets more competitive. Our experiments are showing a significant output increase of 10%, with subject choices moving close to the Cournot/Nash choice. We might expect that once the threat is past and agents are assured there is no further threat of entry that they would return to a level of tacit agreement described by baseline behavior that never had a threat of entry. However, the experimental data show there is a lasting legacy of the entry event that carries forward into the indefinite future. Markets that experience the random threat continue to be more competitive, continuing to behave as if they are Cournot/Nash players.

The econometric evidence in Table 2 suggests that public policies designed to make entry more likely can inhibit collusive tendencies, even if entry does not take place. Moreover, the evidence in Tables 3 and 4 indicates this welfare-enhancing effect is likely to persist beyond the point in time when entry may have occurred. In the context of former European state monopolies that have been privatized, for example, our results suggest that policies that create a chance of entry in the future may have pro-competitive impacts prior to the date of potential entry. It need not be the case that the path to entry is clear-cut or that a potential entrant is waiting in the wings if incumbent firms should raise price – the mere likelihood of such an event is sufficient to induce competitive behavior before and after the point in time possible entry can occur.

This work complements the contestable market arguments advanced by Baumol (1982) and others. In the contestability literature, hit-and-run entry forces firms in concentrated markets to keep prices competitive. There is always the understanding, however, that there are identifiable firms that will enter the market if monopoly profits are earned. We argue that even without a clearly identified entrant, some probability of entry is sufficient to induce competitive outcomes. Along this line, there clearly is room for more testing. There are a host of questions for further study. For example, how sensitive is competitive behavior in the pre-entry period to lower or higher probabilities of entry? More realistically would a series of probabilistic entry points affect behavior? Finally, how would the potential for future entry impact behavior in an environment where firms have established a collusive history prior to the announcement of potential entry? One imagines that having established this collusive tradition, the existing firms might be more inclined to continue colluding even in the face of newly announced imminent entry. This sort of scenario differs from the regime we have studied, where potential entry is made common knowledge at the outset.

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TABLE 1: Summary Statistics

		mean	s.d.	min	max	no. subjects	no. markets
Baseline duopoly							
	epoch 1	35.48	7.979	16	50	36	18
	epoch 2	37.84	6.046	25	50	36	18
Treatment I							
duopoly	epoch 1	38.42	6.803	16	50	48	24
no entry	epoch 2	37.69	6.081	20	50	32	16
entry	epoch 2	41.19	9.436	18	67	24	8
Treatment II							
duopoly	epoch 1	38.09	7.926	10	50	36	18
no entry, no MM	epoch 2	41.29	7.964	17	50	12	6
no entry, MM	epoch 2	40.01	5.073	29	50	12	6
entry	epoch 2	44.61	8.394	28	69	18	6
Baseline triopoly							
	epoch 1	42.75	9.131	24	69	24	8
	epoch 2	40.76	9.936	24	63	24	8

TABLE 2: Regression Results for Choices During Epoch 1

parameter	Baseline duopoly (n=2)	Treatment I (n=I)	Treatment II (n=II)	Baseline triopoly (n=3)
α_n	38.87	33.44	30.72	45.13
	(2.785)	(0.708)	(3.234)	(4.784)
ρ_{1n}	-0.0634	0.0467	-0.0952	0.0788
	(0.0486)	(0.0589)	(0.0545)	(0.0812)
ρ_{2n}	-0.0547	0.0834	0.2933	-0.1312
	(0.0482)	(0.0567)	(0.0502)	(0.0732)
β_n	34.76	38.44	38.31	42.88
	(0.250)	(0.270)	(0.344)	(0.599)
R^2	0.490	0.396	0.510	0.212
observations	460	552	414	184
design	duopoly baseline; two firms, no entry	single market potential entrant	multi-market potential entrant	triopoly baseline; three firms, no entry

Note: $\beta_I - \beta_2 = 3.68$; standard error = 0.657; t-statistic = 10.00

$\beta_3 - \beta_I = 4.44$; standard error = 0.692; t-statistic = 9.80

$\beta_{II} - \beta_2 = 3.55$; standard error = 0.427; t-statistic = 8.320

$\beta_3 - \beta_{II} = 4.58$; standard error = 0.692; t-statistic = 6.614

$\beta_I - \beta_{II} = 0.13$; standard error = 0.437; t-statistic = 0.297

TABLE 3: Regression Results for Choices During Epoch 2, Entry Does Not Occur

parameter	Baseline duopoly (n=2)	Treatment I (n=I)	Treatment IIa (n=IIa)	Treatment IIb (n=IIb)
α_n	18.65	25.84	21.8	26.23
	(1.082)	(0.998)	(5.109)	(3.003)
ρ_{1n}	0.248	0.302	0.508	0.151
	(0.07)	(0.07)	(0.17)	(0.10)
ρ_{2n}	0.257	0.0113	-0.0037	0.195
	(0.0740)	(0.0618)	(0.0970)	(0.0821)
β_n	37.65	37.60	41.22	40.12
	(0.510)	(0.271)	(0.803)	(0.540)
R^2	0.534	0.649	0.615	0.349
observations	276	384	150	138
design	duopoly baseline; two firms; no entry	no entry; single market potential entrant	no entry; neither firm is multi-market	no entry; one firm is multi-market

Note: $\beta_I - \beta_2 = -0.05$; standard error = 0.578; t-statistic = -0.087

$\beta_{IIa} - \beta_2 = 3.57$; standard error = 0.951; t-statistic = 3.753

$\beta_{IIb} - \beta_2 = 2.47$; standard error = 0.743; t-statistic = 3.325

$\beta_{IIa} - \beta_{IIb} = 1.10$; standard error = 0.968; t-statistic = 1.137

$\beta_I - \beta_{IIa} = -3.62$; standard error = 0.847; t-statistic = -4.271

TABLE 4: Regression Results for Choices During Epoch 2, Entry Does Occur

parameter	Treatment I	Treatment II	Baseline 3
α_n	36.85	43.13	24.2
	(1.67)	(2.30)	(1.69)
ρ_{1n}	0.141	0.065	0.298
	(0.08)	(0.09)	(0.09)
ρ_{2n}	-0.0329	-0.0246	0.103
	(0.0717)	(0.0801)	(0.0916)
β_n	41.30	44.94	40.40
	(0.548)	(0. 638)	(0.890)
R^2	0.527	0.245	0.479
observations	184	138	184
design	entry; no multi-market firms	entry; multi-market presence	three firms, no entry

Note: $\beta_1 - \beta_3$ = 0.900; standard error = 1.045; t-statistic = 0.861

$\beta_{II} - \beta_3$ = 4.540; standard error = 1.095; t-statistic = 4.146

$\beta_{II} - \beta_I$ = 3.640; standard error = 0.841; t-statistic = 4.328

Figure 1: Initial Market Structure: Six Duopoly Markets; 12 quantity-choosing subjects.

There are 25 choice periods in this part of the game.

Market	Subjects
1	1 ↔ 2
2	3 ↔ 4
3	5 ↔ 6
4	7 ↔ 8
5	9 ↔ 10
6	11 ↔ 12

Reconfigured Market Structure: There are at least 25 choice periods in this part of the game.

Market	Treatment I: New subjects 13 and 14 enter a market	Treatment II: Subjects 9 and 11 enter a second market
1	1 ↔ 2 ↔ 13	1 ↔ 2 ↔ 9
2	3 ↔ 4	3 ↔ 4
3	5 ↔ 4 ↔ 14	5 ↔ 6 ↔ 11
4	7 ↔ 8	7 ↔ 8
5	9 ↔ 10	9 ↔ 10
6	11 ↔ 12	11 ↔ 12

Figure 2: Average Choices in Epoch 1, Treatment I vs. Duopoly and Triopoly Baseline sessions

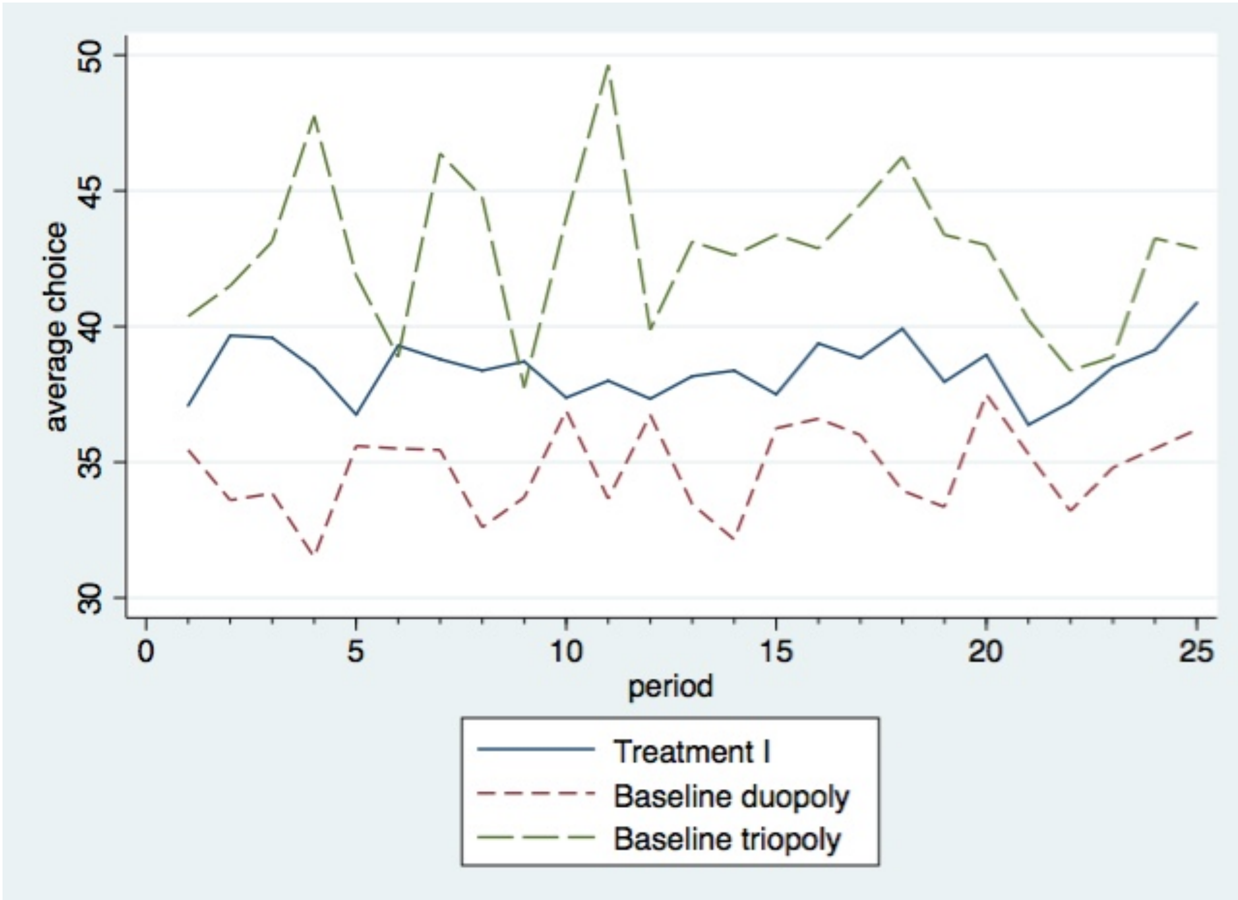


Figure 3: Average Choices in Epoch 1, Treatment II vs. Duopoly and Triopoly Baseline sessions

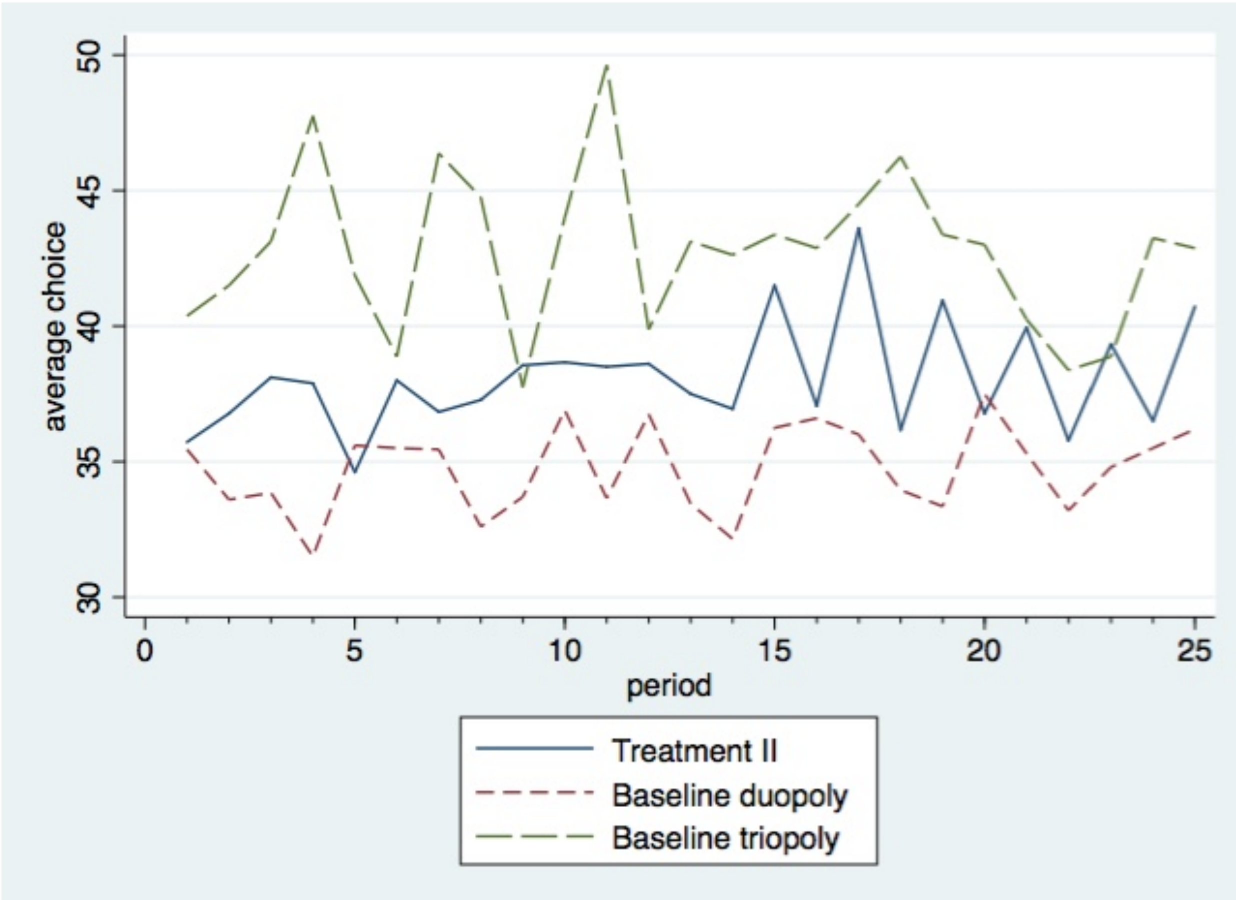


Figure 4: Choices in Epoch 2, Duopoly Baseline vs. Treatments with no Entry

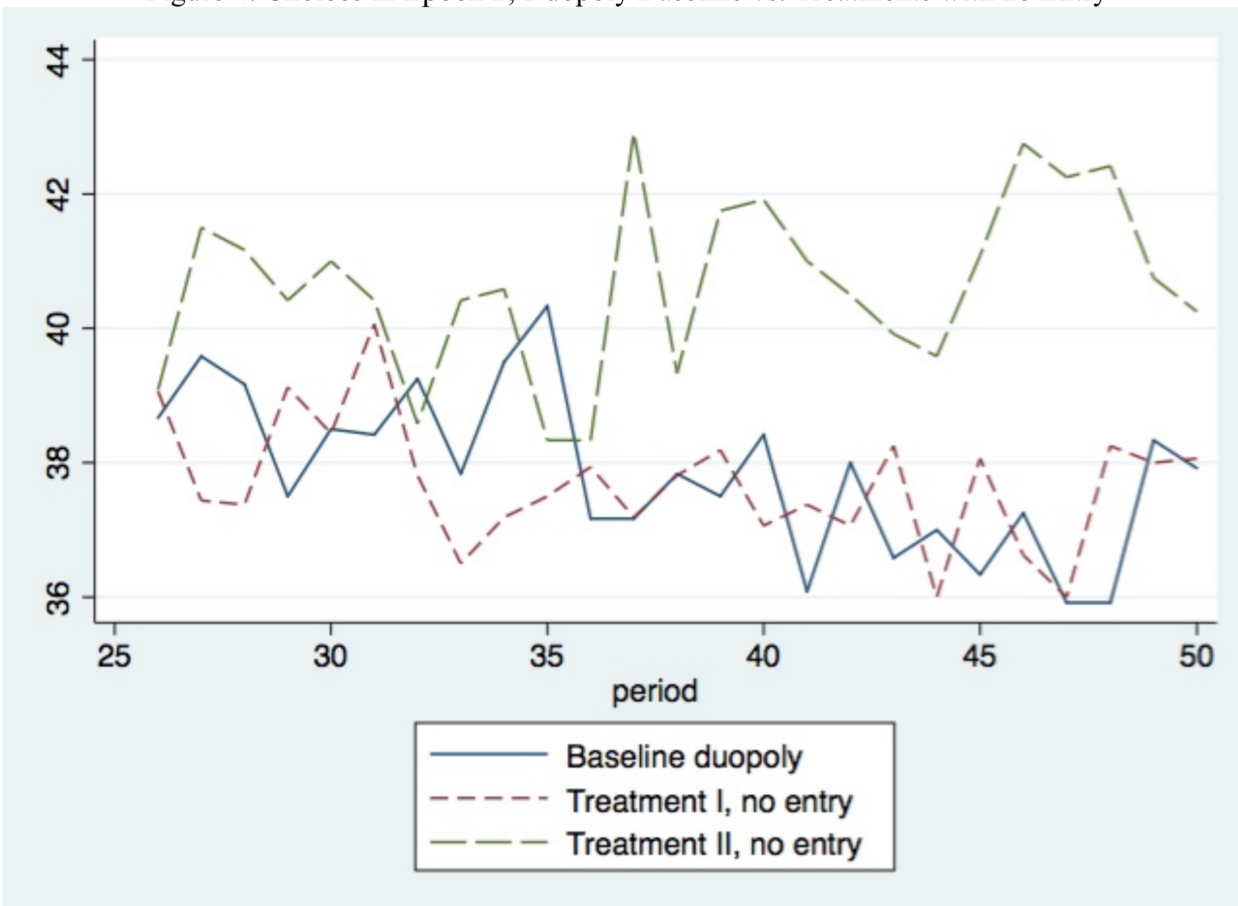


Figure 5: Triopoly Choices in Epoch 2 after Entry in Some Markets.

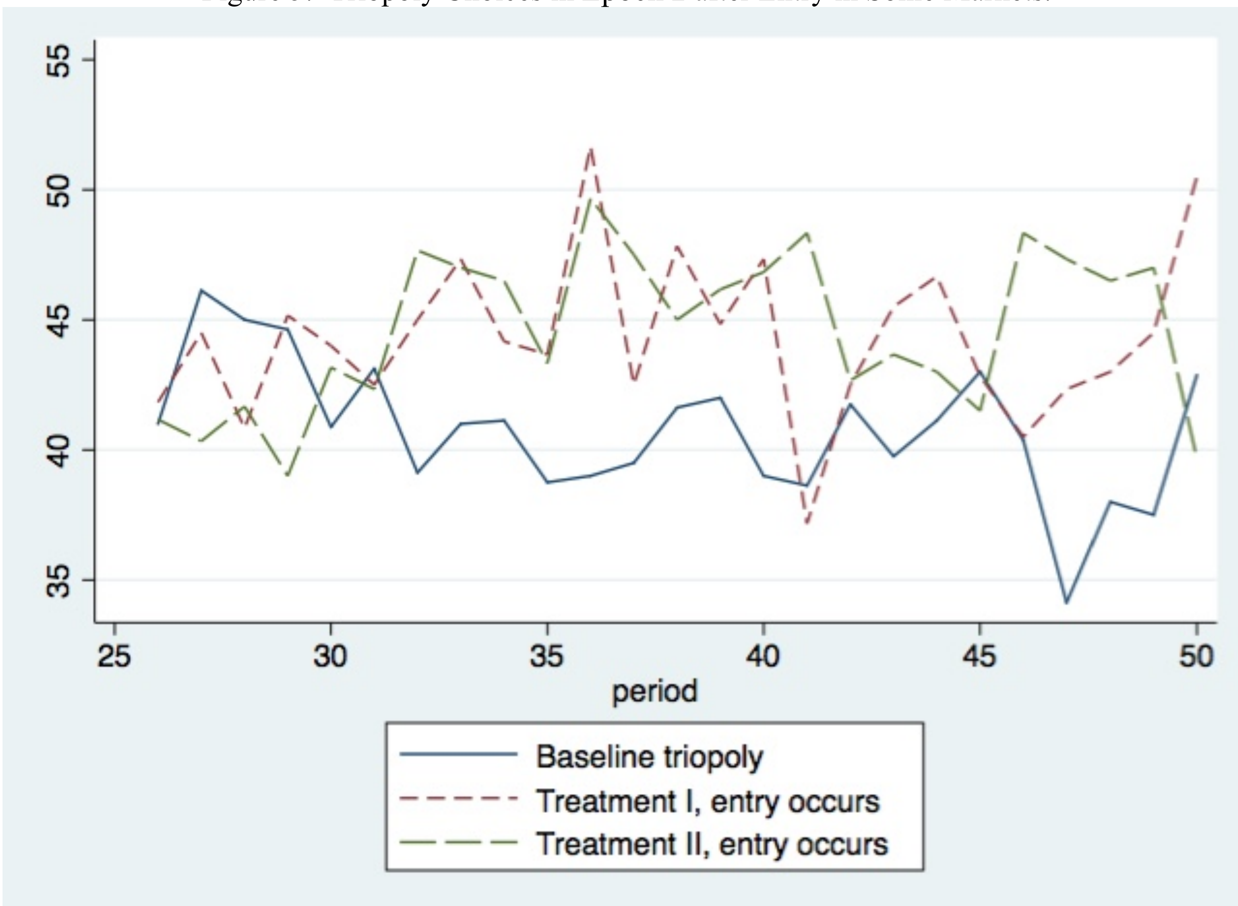
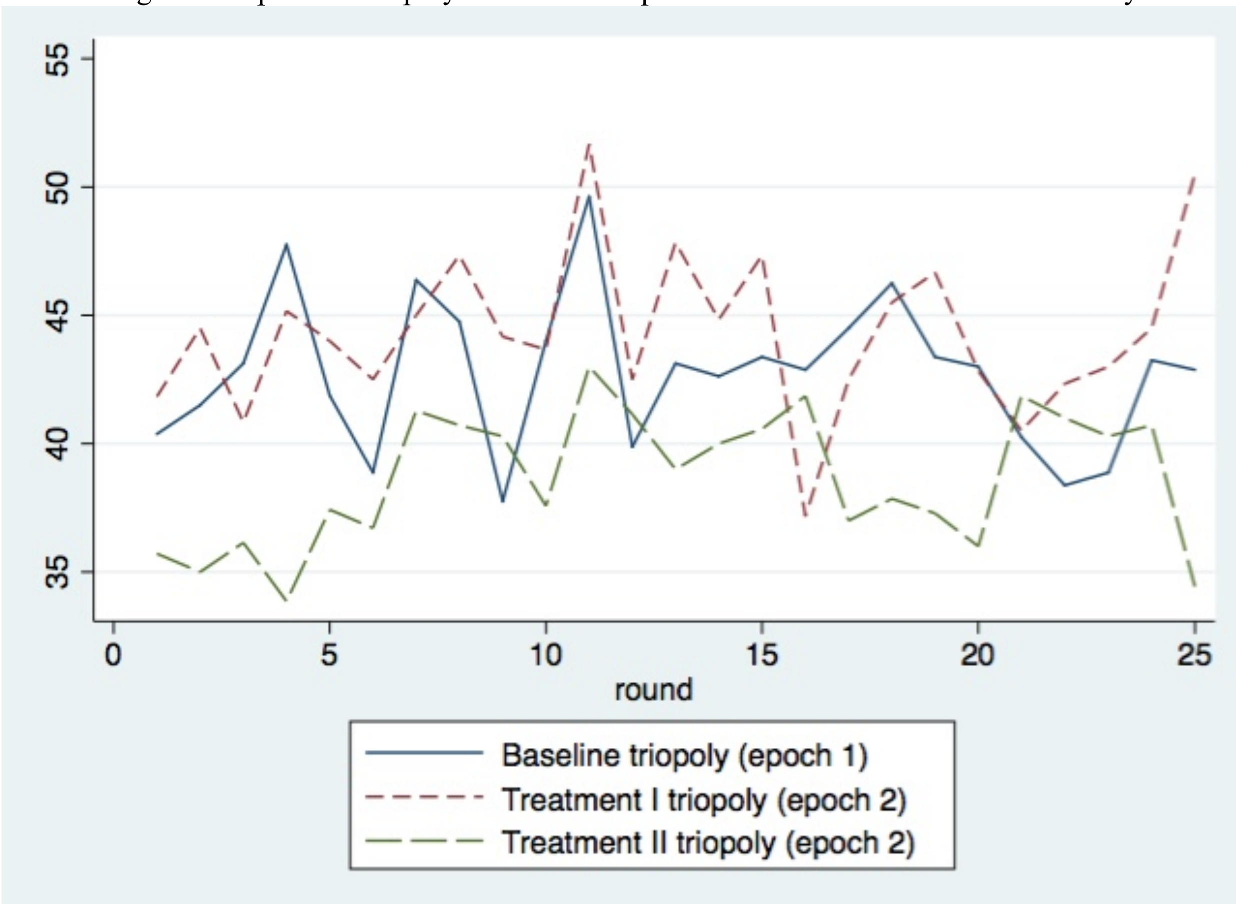


Figure 6: Epoch 1 Triopoly Baseline vs. Epoch 2 in Treatments I and II with Entry



Notes

[1] This decision was upheld in 1996 following an appeal. See Russo et al. (2010, pp. 153-158) for more discussion. Evidently Tetra Pak attempted to work around this decision by acquiring the Italian firm Italpak; this led to a second major finding against Tetra Pak in 2004 (Siragusa and Baretta, 2008).

[2] Cabela's, a large retailer of outdoor equipment and clothing, selects potential retail sites years in advance of building, and may choose not build a store after investing in a land site. Once the firm decides to go forward it will announce two or three years in advance that it is planning to open a new store, and begin construction. In this way, incumbent retailers have probabilistic signals that are directly linked to Cabela's decision to enter a geographic market (see, for example, http://phx.corporate-ir.net/phoenix.zhtml?c=177739&p=irol-newsArticle&ID=1990864; last accessed November 19, 2014).

[3] Yum! Brands Inc., owners of the restaurant chains KFC, Pizza Hut, and Taco Bell measures its growth opportunities in terms of restaurants/million people. In the United States it averages 58 restaurants per million people. In its top emerging markets, Yum! Brands has 2 restaurants per million (http://www.yum.com/annualreport/). It currently targets entry for its identified emerging markets: In the U.S., Yum! Seeks a minimum of 5,000 people in a trade area for a Pizza Hut franchise, and a minimum of 15,000 people in a trade area for KFC and Taco Bell restaurants (http://www.yum.com/company/realestate/documents/RealEstateContactsVisual.pdf). Once a community's population reaches one of these thresholds, entry may occur.

[4] For example, the effect of entry after a patent's expiration has been studied extensively in the pharmaceutical industry. See Berndt et al (2003). For discussion on behavior before entry see Ellison and Ellison (2011).

[5] Of course, existing firms may take actions that impede entry. Our focus abstracts from this possibility, and so is better viewed as a characterization of the potential effect of a shift in antitrust policy towards potentially collusive firms.

[6] An example of the sort of effect we have in mind here comes from the market for seamless carbon-steel pipes and tubes. During the latter part of the 20th century, a cooperative arrangement was promulgated between European and Japanese manufacturers (collectively known as the "Euro-Japan club") to rig prices. This arrangement was destabilized in 1993 in the face of imminent entry by Latin American manufacturers, ultimately collapsing in 1995 (Russo et al. (2010), p. 58).

[7] For each of the entry treatments, an equal number of sessions were conducted without informing subjects of the probabilities of these events.

[8] Accordingly, these experimental games are not stationary. The class of subgame-perfect equilibria that satisfy the incentive constraints in each period of the stationary game, as described in more detail below, also satisfy the incentive constraints in each period of nonstationary games such as these. In other work (Phillips and Mason (1996)) we have created stationary duopolies and have found behavior no different from behavior in the nonstationary structure.

[9] In later sessions subjects were instructed to highlight their row choice with their mouse and then click an "ok" tab on their screen. The instructions read to subjects for the design when there was a forthcoming threat of entry are provided in Appendix C, which is available online from the journal's website.

[10] In the three duopoly baseline sessions, the experiments lasted 50, 51 and 53 periods. In the two triopoly baseline sessions, the experiments lasted 50 and 51 periods. In the three treatment sessions, the experiments lasted 50, 51 and 52 periods.

[11] In order to avoid having a large number of negative payoffs in the first few rows of the triopoly table, we slightly increased payoffs for these rows. This adjustment did not change the symmetric joint profit-maximizing combination, nor did it affect the Cournot equilibrium.

[12] A representative sampling of discussions on the use of trigger strategies includes Marschak and Selten (1978), Spence (1978), Fudenberg and Maskin (1986), Fudenberg and Tirole (1989) and Segerstrom (1988). Papers that analyze the use of trigger strategies in an uncertain environment include Green and Porter (1984), Rotemberg and Saloner (1986) and Haltiwanger and Harrington (1991); these papers consider environments that are subject to stochastic influences in every period. By contrast, our problem is one where the uncertainty is resolved at a certain time, with the structure permanently settled after the shock occurs – which is equivalent to one with a sequence of perfectly correlated shocks.

[13] Details of such a model are relegated to Appendix B.

[14] Experimental economists have often analyzed mean choices over a subset of the play in similar settings. Such an approach is inferior to our procedure because it neglects learning and dynamic adjustments, which can distort the results (Alger, 1987).

[15] Essentially, this approach employs a regression model with pair-specific dummy variables; the coefficients on the dummies reflect the underlying parameters a_i. Alternatively, one can analyze the residuals from a regression with a common intercept, and allow for deviations from that intercept for pair i to arise through the average value of the residual for pair i.

[16] We use n to index the baselines and treatments, with n = 2 referring to the Baseline duopoly, n = 3 referring to the Baseline triopoly, n = I referring to the Treatment I and n = II referring to the Treatment II.

[17] The data for Treatment II include all subjects, both those who participate in markets for which there is no entry and markets for which there is entry (in which case the entrant is a multi-market player).

[18] Behavior also differs significantly between Treatment I and Treatment IIa, which again indicates the threat of entry by a player that participates in multiple markets exerts a different impact from the threat of entry by a player that only participates in the market where entry may occur.

[19] So, for example, $k = 5$ corresponds to period 5 in the triopoly baseline, but period 30 in the post-entry triopoly from a treatment session.

[20] A comparison of subject behavior in markets where entry occurred in Treatment II with subject behavior where entry occurred in Treatment I reveals a statistically important difference (as indicated in the notes at the bottom of Table 4). A comparison of the steady state choices in Treatment II across the structures (entry does not occur, no multi-market contact – IIa in Table 3; entry does not occur, multi-market contact – IIb in Table 3; entry does occur, multi-market contact – II in Table 4) also indicates post-entry behaviour is noticeably different when there is multi-market contact. In our earlier work (Phillips and Mason (2001)), where we observed that producers in conduit markets behave as if they have a pooled incentive constraint: Operation in two markets leads to higher outputs in one market and lower outputs in the other.

[21] Sonnemans, Schram and Offerman (1999) also find that the potential arrival of new competition can erode cooperation, albeit in a different economic setting. In their experiment, agents in a public goods contribution game are re-matched at regular intervals. They find that tendencies to contribute, which correspond mathematically to tendencies to restrict output in an oligopoly game, are reduced as the time of reorganization draws nigh.

APPENDIX A: Payoff Tables

PAYMENT TABLE

The Other Participant's Choice

Your Choice	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
8	227	269	261	253	245	237	229	221	213	205	197	189	181	173	165	157	149	141
9	312	303	294	285	276	267	258	249	240	231	222	213	204	195	186	177	168	159
10	345	335	325	315	305	295	258	275	265	255	245	235	225	215	205	195	185	175
11	376	365	354	343	332	321	310	299	288	277	366	255	244	233	222	211	200	189
12	405	393	381	369	357	345	333	321	309	297	285	273	261	249	237	225	213	201
13	432	419	406	393	380	367	354	341	328	315	302	289	276	263	250	23	224	211
14	457	443	429	415	401	387	373	348	345	331	317	303	289	275	261	247	233	219
15	480	465	450	435	420	405	390	375	360	345	330	315	300	285	270	255	240	225
16	501	485	469	453	437	421	405	389	373	357	341	325	309	293	277	261	245	229
17	520	503	486	469	452	435	418	401	384	367	350	333	316	299	282	265	248	231
18	537	519	501	483	465	447	429	411	393	375	357	339	321	303	285	267	249	231
19	552	533	514	495	476	457	438	419	400	381	362	343	324	305	286	267	248	229
20	565	545	525	505	485	465	445	425	405	385	365	345	325	305	285	265	245	225
21	576	555	534	513	492	471	450	429	408	387	366	345	324	303	285	261	240	219
22	585	563	541	519	497	475	453	431	409	387	365	343	321	299	277	255	233	211
23	592	569	546	523	500	477	454	431	408	385	362	339	316	293	270	247	224	201
24	597	573	549	525	501	477	453	429	405	381	357	333	309	285	261	237	213	189
25	600	575	550	525	500	475	450	425	400	375	350	325	300	275	250	225	200	175

		PAYMENT TABLE																																		
		Combined Choices of Other Participants																																		
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Your Choice	8	261	253	245	237	229	221	213	205	197	189	181	173	165	157	149	141	133	125	117	109	101	93	85	77	69	61	53	45	37	29	21	13	5	-3	-11
	9	294	285	276	267	258	249	240	231	222	213	204	195	186	177	168	159	150	141	132	123	114	105	96	8	78	69	60	51	42	33	24	15	6	-3	-12
	10	325	315	305	295	285	275	265	255	245	235	225	215	205	195	185	175	165	155	145	135	125	115	105	92	85	75	65	55	45	35	25	15	5	-5	-15
	11	288	277	266	255	244	233	222	211	200	189	178	167	156	145	134	123	112	101	90	79	68	57	46	35	24	12	2	-6	-20	-31	-42	-53	-64	-75	-86
	12	309	297	285	273	261	249	237	225	213	201	189	177	165	153	141	129	117	105	93	81	69	57	45	33	21	9	-3	-15	-27	-39	-51	-63	-75	-87	-99
	13	328	315	302	289	276	263	250	237	224	211	198	185	172	159	146	133	120	107	94	81	68	55	42	29	16	3	-12	-23	-36	-37	-62	-75	-88	-101	-114
	14	345	331	317	303	289	275	261	247	233	219	205	191	177	163	149	135	121	107	93	79	65	51	37	23	9	-5	-19	-33	-47	-61	-75	-89	-103	-117	-131
	15	360	345	330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60	45	30	15	0	-15	-30	-45	-60	-75	-90	-105	-120	-135	-150
	16	373	357	341	325	309	293	277	261	245	229	213	197	181	165	149	133	117	101	95	69	53	37	21	5	-11	-27	-43	-59	-75	-91	-107	-123	-139	-155	-171
	17	384	367	350	333	316	299	282	265	248	231	214	197	180	163	146	129	112	95	78	61	44	27	10	-7	-24	-41	-58	-75	-92	-109	-126	-143	-160	-177	-194
	18	393	375	357	339	321	303	285	267	249	231	243	195	177	159	141	123	105	87	69	51	33	15	-3	-21	-39	-57	-75	-93	-111	-129	-147	-165	-183	-201	-219
	19	400	381	362	343	324	305	286	267	248	229	210	191	172	153	134	115	96	77	68	39	20	1	-18	-37	-56	-75	-94	-113	-132	-151	-170	-189	-208	-227	-246
	20	405	385	365	345	325	305	285	265	245	225	205	185	165	145	125	105	85	65	45	25	5	-15	-35	-55	-75	-95	-115	-135	-155	-175	-195	-215	-235	-255	-275
	21	408	387	366	345	324	303	282	261	240	219	198	177	156	135	114	93	72	51	30	9	-12	-33	-54	-75	-96	-117	-138	-159	-180	-201	-222	-243	-264	-285	-306
	22	409	387	365	343	321	299	277	255	233	211	189	167	145	123	101	79	57	35	13	-9	-31	-53	-75	-97	-119	-141	-163	-185	-207	-229	-251	-273	-10	-317	-339
	23	408	385	362	339	316	293	270	247	224	201	178	155	132	109	86	63	40	17	-6	-25	-52	-75	-98	-121	-144	-167	-190	-213	-236	-259	-282	-305	-628	-351	-374
	24	405	384	357	333	309	285	261	237	213	189	165	141	117	93	69	45	21	-3	-27	-51	-75	-99	-123	-147	-171	-195	-219	-243	-267	-291	-363	-339	-363	-38	-411
	25	400	375	350	325	300	275	250	225	200	175	150	125	100	75	50	25	0	-25	-50	-75	-100	-125	-150	-175	-200	-225	-250	-275	-300	-325	-400	-375	-400	-425	-450

APPENDIX B: Details of the Model

In this Appendix, we describe the main elements of a game theoretic model that can be used to represent our experimental structure, and discuss conditions under which *Hypotheses 1* and *2* will hold.

As noted in the text, we use "epoch 1" to refer to periods $t = 1,\ldots,T_1$, where uncertainty regarding the potential entry is resolved at the end of T_1, and we use and "epoch 2" to refer to periods $t > T_1$. There are two players, 1 and 2, in epoch 1; at the end of epoch 1 the number of players either changes from 2 to 3, with probability $1-\lambda$, or the number remains 2; this number applies for the remainder of the game. Starting with period T_2, the game ends at the end of the current period with probability $1-\theta \in (0,1)$. In every period, all players choose outputs simultaneously; these outputs induce payoffs for player i by the stage-game payoff function $\pi(q_{it}, q_{It})$, where q_{It} is the sum of all other players' outputs. We adopt conventional assumptions governing the stage-game payoff function: that it is strictly concave in own output, i.e. $\partial^2\pi/\partial q_i^2 < 0$, and that both π and $\partial\pi/\partial q_i$ are decreasing in q_I (this latter assumption ensures reaction functions are downward-sloping). These assumptions hold true for the linear-quadratic payoff structure we employ in our experimental design. For later reference, we define the one-shot Cournot/Nash output when there are k (symmetric) players as q_k^N; the corresponding profits are π_k^N.

We propose the following strategy σ In epoch 1: choose q_2^{c1} if both players have played q_2^{c1} in all periods prior to period t; if either party deviated from q_2^{c1} in any period prior to period t, play q_2^N. If entry occurred at the end of period T_1 then play q_3^{c2} in period T_1+1 if both players 1 and 2 played q_2^{c1} in all periods of epoch 1, but play q_3^N if either player deviated from q_2^c in any period $t \leq T_1$; in any period $\tau > T_1+1$ play q_3^{c2} if both players 1 and 2 played q_2^{c1} in all periods of epoch 1 and all three players chose q_3^{c2} in all prior periods in epoch 2, but play q_3^N if either player 1 or 2 deviated from q_2^{c1} in any period of epoch 1 or if any player deviated from q_3^{c2} in any prior period of epoch 2. If entry did not occur at the end of period T_1 then play q_2^{c2} if both players 1 and 2 played q_2^{c1} in all periods of epoch 1 and both players 1 and 2 played q_2^{c2} in all prior periods of epoch 2; if either party deviated in any period prior to period t, play q_2^N.[1]

We denote the payoffs a player earns if all n players use the strategy σ in epoch m as π_n^{cm} Let us define q_n^{dm} as the Nash best response when the other n-1 players have chosen q_n^{cm}, n = 2 or 3, and m = 1 or 2. We write the corresponding payoffs as π_n^{dm}. We assume the quasi-cooperative outputs q_n^{cm} are such that the strategy σ can be part of a subgame-perfect equilibrium. This requires the one-time gains from deviation to not exceed the future discounted losses in the three time frames: epoch 1, epoch 2 prior to T_2, epoch 2 after T_2. Consider first values of $t \geq T_2$. In this time frame, the incentive constraints take the form

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[1] The strategy we propose is stationary, i.e. it is time-invariant. Because of the relatively complex structure of the game, it is conceivable that players could adopt time-varying strategies. Our view is that the most obvious manner in which strategies would change over time is linked to the potential for entry, which differentiates periods iin epoch 1 ($t \leq T_1$) from periods in epoch 2 ($t \geq T_1 + 1$). It is also true that periods in epoch 2 prior to T_2 differ from period T_2 and after, in that it is common knowledge the probability the game will terminate during the first set of dates is nil. The discussion in the text can be adapted to incorporate this additional complication, but at the cost of complicating the exposition.

$$\pi_n^{d2} + \theta\pi_n^N/(1-\theta) \le \pi_n^{c2}/(1-\theta) \Leftrightarrow \pi_n^{d2} - \pi_n^{c2} \le \theta(\pi_n^{d2} - \pi_n^N). \qquad \text{(A1)}$$

There are two versions of this constraint, one for n = 2 and one for n = 3. Next, consider values of t in epoch 2 prior to T_2. Here, the incentive constraints take the form

$$\pi_n^{d2} + (T_2\text{-}t\text{-}1)\pi_n^N + \pi_n^N/(1-\theta) \le \pi_n^{c2}(T_2 - t) + \pi_n^{c2}/(1-\theta)$$

$$\Leftrightarrow \pi_n^{d2} - \pi_n^{c2} \le (1-\theta)(T_2 - t)(\pi_n^{c2} - \pi_n^N) + \theta(\pi_n^{d2} - \pi_n^N), \qquad \text{(A2)}$$

Clearly, the right-hand side of (A2) is larger than the right-hand side of (A1) for any $t < T_2$. Accordingly, we can ignore this constraint. Finally, consider values of t in epoch 1 (i.e., $t \le T_1$). Here, the incentive constraints take the form

$$\pi_2^{d1} + (T_1\text{-}t)\pi_2^N + (T_2\text{-}T_1)E\pi^N + E\pi^N/(1\text{-}\theta) \le \pi_2^{c1} + (T_1\text{-}t)\pi_2^{c2} + (T_2\text{-}T_1)E\pi^{c2} + E\pi^{c2}/(1\text{-}\theta),$$

where $E\pi^N = \lambda\pi_2^N + (1\text{-}\lambda)\pi_3^N$ and $E\pi^{c2} = \lambda\pi_2^{c2} + (1\text{-}\lambda)\pi_3^{c2}$. This constraint is tightest at $t = T_1$, where it reduces to

$$(\pi_2^{d1} - \pi_2^{c1}) \le \{(1\text{-}\theta)(T_2\text{-}T_1) + 1\}(E\pi^{c2}\text{-}E\pi^N)/(1\text{-}\theta). \qquad \text{(A3)}$$

If the constraint in (A3) is not binding, then an increase in λ – for example, from 0 to some positive level – need not have any impact on $\pi_2^{d1} - \pi_2^{c1}$. But if the constraint is binding, so that full collusion is not feasible, then the impact of an increase in λ upon $\pi_2^{d1} - \pi_2^{c1}$ will be proportional to the impact of an increase in λ upon $E\pi^{c2}\text{-}E\pi^N$. Using the definitions of $E\pi^{c2}$ and $E\pi^N$ given above,

$$E\pi^{c2}\text{-}E\pi^N = \lambda[\pi_2^{c2} - \pi_2^N - (\pi_3^{c2} - \pi_3^N)] + \pi_3^{c2} - \pi_3^N.$$

It follows that

$$\partial(\pi_2^{d1} - \pi_2^{c1})/\partial\lambda \propto \pi_2^{c2} - \pi_3^{c2} - (\pi_2^N - \pi_3^N),$$

the difference between the reduction in cooperative profits and the reduction in Cournot profits as industry size increases from 2 to 3. If the drop in in Cournot profits exceeds the drop in in cooperative profits, then an increase in λ will induce less cooperative behaviour in epoch 1. This condition can hold for a variety of market structures, including the linear-quadratic framework we employ in our experimental design.[2] Thus, Hypothesis 1 can hold under the assumed condition that perfect collusion is not feasible and players adopt the strategy σ.

The potential for entry induces firms to increase output during epoch 1 because this threat lowers the expected reward from continued cooperation in epoch 2. But the resultant expected reward is surely larger than the actual reward that would obtain in a triopoly. Accordingly, the incentives to cooperate are larger in a design where entry is probabilistic than in a design where the industry size has already been set at 3. Thus, *Hypothesis 2* will hold so long as firms are not irrationally aggressive.

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[2] Let the cooperative profit π_n^{c2} be a convex combination of fully collusive profits π_n^M and the Cournot profits π_n^N, with weight γ placed on π_n^M. Suppose in contrast to the statement in the text that this weight does not change between n = 2 and 3. It is straightforward to show that the reduction in collusive profit when n increases from 2 to 3 equals 1/6 of monopoly profit, while the reduction in Cournot profit when n increases from 2 to 3 cooperative is 7/36 of monopoly profit. Thus, Cournot profits fall faster than collusive profits, as n increases from 2 to 3. We conclude that the constraint (A3) becomes tighter when n increases from 2 to 3.

APPENDIX A: Payoff Tables

PAYMENT TABLE

The Other Participant's Choice

Your Choice	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
8	227	269	261	253	245	237	229	221	213	205	197	189	181	173	165	157	149	141
9	312	303	294	285	276	267	258	249	240	231	222	213	204	195	186	177	168	159
10	345	335	325	315	305	295	258	275	265	255	245	235	225	215	205	195	185	175
11	376	365	354	343	332	321	310	299	288	277	366	255	244	233	222	211	200	189
12	405	393	381	369	357	345	333	321	309	297	285	273	261	249	237	225	213	201
13	432	419	406	393	380	367	354	341	328	315	302	289	276	263	250	23	224	211
14	457	443	429	415	401	387	373	348	345	331	317	303	289	275	261	247	233	219
15	480	465	450	435	420	405	390	375	360	345	330	315	300	285	270	255	240	225
16	501	485	469	453	437	421	405	389	373	357	341	325	309	293	277	261	245	229
17	520	503	486	469	452	435	418	401	384	367	350	333	316	299	282	265	248	231
18	537	519	501	483	465	447	429	411	393	375	357	339	321	303	285	267	249	231
19	552	533	514	495	476	457	438	419	400	381	362	343	324	305	286	267	248	229
20	565	545	525	505	485	465	445	425	405	385	365	345	325	305	285	265	245	225
21	576	555	534	513	492	471	450	429	408	387	366	345	324	303	285	261	240	219
22	585	563	541	519	497	475	453	431	409	387	365	343	321	299	277	255	233	211
23	592	569	546	523	500	477	454	431	408	385	362	339	316	293	270	247	224	201
24	597	573	549	525	501	477	453	429	405	381	357	333	309	285	261	237	213	189
25	600	575	550	525	500	475	450	425	400	375	350	325	300	275	250	225	200	175

PAYMENT TABLE

Combined Choices of Other Participants

Your Choice	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
8	261	253	245	237	229	221	213	205	197	189	181	173	165	157	149	141	133	125	117	109	101	93	85	77	69	61	53	45	37	29	21	13	5	-3	-11
9	294	285	276	267	258	249	240	231	222	213	204	195	186	177	168	159	150	141	132	123	114	105	96	8	78	69	60	51	42	33	24	15	6	-3	-12
10	325	315	305	295	285	275	265	255	245	235	225	215	205	195	185	175	165	155	145	135	125	115	105	92	85	75	65	55	45	35	25	15	5	-5	-15
11	288	277	266	255	244	233	222	211	200	189	178	167	156	145	134	123	112	101	90	79	68	57	46	35	24	12	2	-6	-20	-31	-42	-53	-64	-75	-86
12	309	297	285	273	261	249	237	225	213	201	189	177	165	153	141	129	117	105	93	81	69	57	45	33	21	9	-3	-15	-27	-39	-51	-63	-75	-87	-99
13	328	315	302	289	276	263	250	237	224	211	198	185	172	159	146	133	120	107	94	81	68	55	42	29	16	3	-12	-23	-36	-37	-62	-75	-88	-101	-114
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APPENDIX B: Details of the Model

In this Appendix, we describe the main elements of a game theoretic model that can be used to represent our experimental structure, and discuss conditions under which *Hypotheses 1* and *2* will hold.

As noted in the text, we use "epoch 1" to refer to periods $t = 1,\ldots,T_1$, where uncertainty regarding the potential entry is resolved at the end of T_1, and we use and "epoch 2" to refer to periods $t > T_1$. There are two players, 1 and 2, in epoch 1; at the end of epoch 1 the number of players either changes from 2 to 3, with probability $1-\lambda$, or the number remains 2; this number applies for the remainder of the game. Starting with period T_2, the game ends at the end of the current period with probability $1-\theta \in (0,1)$. In every period, all players choose outputs simultaneously; these outputs induce payoffs for player i by the stage-game payoff function $\pi(q_{it}, q_{It})$, where q_{It} is the sum of all other players' outputs. We adopt conventional assumptions governing the stage-game payoff function: that it is strictly concave in own output, i.e. $\partial^2\pi/\partial q_i^2 < 0$, and that both π and $\partial\pi/\partial q_i$ are decreasing in q_I (this latter assumption ensures reaction functions are downward-sloping). These assumptions hold true for the linear-quadratic payoff structure we employ in our experimental design. For later reference, we define the one-shot Cournot/Nash output when there are k (symmetric) players as q_k^N; the corresponding profits are π_k^N.

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$$\pi_n^{d2} + \theta\pi_n^N/(1-\theta) \le \pi_n^{c2}/(1-\theta) \Leftrightarrow \pi_n^{d2} - \pi_n^{c2} \le \theta(\pi_n^{d2} - \pi_n^N). \qquad \text{(A1)}$$

There are two versions of this constraint, one for n = 2 and one for n = 3. Next, consider values of t in epoch 2 prior to T_2. Here, the incentive constraints take the form

$$\pi_n^{d2} + (T_2\text{-}t\text{-}1)\pi_n^N + \pi_n^N/(1-\theta) \le \pi_n^{c2}(T_2 - t) + \pi_n^{c2}/(1-\theta)$$

$$\Leftrightarrow \pi_n^{d2} - \pi_n^{c2} \le (1-\theta)(T_2 - t)(\pi_n^{c2} - \pi_n^N) + \theta(\pi_n^{d2} - \pi_n^N), \qquad \text{(A2)}$$

Clearly, the right-hand side of (A2) is larger than the right-hand side of (A1) for any $t < T_2$. Accordingly, we can ignore this constraint. Finally, consider values of t in epoch 1 (i.e., $t \le T_1$). Here, the incentive constraints take the form

$$\pi_2^{d1} + (T_1\text{-}t)\pi_2^N + (T_2\text{-}T_1)E\pi^N + E\pi^N/(1\text{-}\theta) \le \pi_2^{c1} + (T_1\text{-}t)\pi_2^{c2} + (T_2\text{-}T_1)E\pi^{c2} + E\pi^{c2}/(1\text{-}\theta),$$

where $E\pi^N = \lambda\pi_2^N + (1\text{-}\lambda)\pi_3^N$ and $E\pi^{c2} = \lambda\pi_2^{c2} + (1\text{-}\lambda)\pi_3^{c2}$. This constraint is tightest at $t = T_1$, where it reduces to

$$(\pi_2^{d1} - \pi_2^{c1}) \le \{(1\text{-}\theta)(T_2\text{-}T_1) + 1\}(E\pi^{c2}\text{-}E\pi^N)/(1\text{-}\theta). \qquad \text{(A3)}$$

If the constraint in (A3) is not binding, then an increase in λ – for example, from 0 to some positive level – need not have any impact on $\pi_2^{d1} - \pi_2^{c1}$. But if the constraint is binding, so that full collusion is not feasible, then the impact of an increase in λ upon $\pi_2^{d1} - \pi_2^{c1}$ will be proportional to the impact of an increase in λ upon $E\pi^{c2}\text{-}E\pi^N$. Using the definitions of $E\pi^{c2}$ and $E\pi^N$ given above,

$$E\pi^{c2}\text{-}E\pi^N = \lambda[\pi_2^{c2} - \pi_2^N - (\pi_3^{c2} - \pi_3^N)] + \pi_3^{c2} - \pi_3^N.$$

It follows that

$$\partial(\pi_2^{d1} - \pi_2^{c1})/\partial\lambda \propto \pi_2^{c2} - \pi_3^{c2} - (\pi_2^N - \pi_3^N),$$

the difference between the reduction in cooperative profits and the reduction in Cournot profits as industry size increases from 2 to 3. If the drop in in Cournot profits exceeds the drop in in cooperative profits, then an increase in λ will induce less cooperative behaviour in epoch 1. This condition can hold for a variety of market structures, including the linear-quadratic framework we employ in our experimental design.[2] Thus, Hypothesis 1 can hold under the assumed condition that perfect collusion is not feasible and players adopt the strategy σ.

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[2] Let the cooperative profit π_n^{c2} be a convex combination of fully collusive profits π_n^M and the Cournot profits π_n^N, with weight γ placed on π_n^M. Suppose in contrast to the statement in the text that this weight does not change between n = 2 and 3. It is straightforward to show that the reduction in collusive profit when n increases from 2 to 3 equals 1/6 of monopoly profit, while the reduction in Cournot profit when n increases from 2 to 3 cooperative is 7/36 of monopoly profit. Thus, Cournot profits fall faster than collusive profits, as n increases from 2 to 3. We conclude that the constraint (A3) becomes tighter when n increases from 2 to 3.