# Demand Shocks, Capacity Coordination and Industry Performance: Lessons from an Economic Laboratory

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**Abstract**

Antitrust exemptions granted to businesses under extenuating circumstances are often justified by the argument that they benefit the public by helping producers adjust to otherwise difficult economic circumstances. Such exemptions may allow firms to coordinate their capacities, as was the case of post-September 11, 2001 antitrust immunity granted to Aloha and Hawaiian Airlines. We conduct economic laboratory experiments to determine the effects of explicit capacity coordination on oligopoly firms' abilities to adjust to negative demand shocks and on industry prices. The results suggest that capacity coordination speeds the adjustment process, but also has a clear pro-collusive effect on firm behavior.

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# 1 Introduction

It is not unusual for firms in distressed industries to seek government assistance. In industries experiencing a sharp and sudden decrease in demand, firms may request help in coordinating a capacity reduction. In the years following World War II, many of Japan's large industrial firms faced the task of reducing their wartime capacity and encountered the difficult strategic situation of making unilateral reductions. This prompted the creation of an industrial policy to facilitate the structured and balanced reduction of capacity across all firms in the industry (Peck et al. 1987). In Europe, competition law may allow firms in a distressed industry to form "crisis cartels," or agreements to systematically restrict output or reduce capacity in response to a crisis in the industry. Indeed, crisis cartels were formed in the European synthetic fiber industry in the 1980's and in the Dutch brick industry in the 1990's. In each case, the agreements provided for specific capacity reductions by individual producers in response to structural excess capacities in the corresponding industries (Fiebig, 1999; Simpson, 2004). A similar attempt to balance capacity reduction in the face of decreased demand took place recently in the United States. In 2002, the U.S. Department of Transportation granted antitrust immunity to Aloha and Hawaiian Airlines in order to facilitate a bilateral reduction in inter-island flight capacity in Hawaii after a reduction in demand following the September 11, 2001 terrorist attacks. Beyond merely permitting the two companies to coordinate their capacity reduction, the immunity agreement created a mechanism for revenue transfers designed to punish either company if they deviated from the agreed-upon capacity reduction.[1]

In this study, we use economic experiments to examine the effects of capacity coordination on industry performance in response to a negative demand shock. One could argue that explicit coordination by firms is critical in the face of a challenging reduction in demand. But coordination may also encourage anti-competitive behavior by participating firms. Proponents of the Aloha-Hawaiian antitrust immunity agreement argued that it was impossible for the two airlines to unilaterally reduce their capacity enough to avoid bankruptcy in reaction to a post-9/11 reduction in air travel (Aloha Airlines and Hawaiian Airlines, 2002).[2] The U.S. Department of Justice, in opposing the anti-trust exemption, claimed that the agreement would undermine consumer welfare by allowing the airlines market power sufficient to reduce service and raise prices well above the competitive level. Inter-island airfares did rise dramatically following the inception of the agree-

[1] An earlier case of coordinated capacity reduction in the U.S. airline industry took place in 1971, when the Civil Aeronautics Board approved a capacity limitations agreement among three airline carriers (Eads, 1974). In other historical circumstances producers were granted government permission to coordinate a variety of strategic economic variables, as was the case under the National Industrial Recovery Act of 1933 (e.g., Alexander, 1994). More recently, newspaper companies in the U.S. have proposed the need for an anti-trust exemption that would allow them to jointly set prices for their Web content (Los Angeles Times, February 4, 2009.)

[2] Aloha Airlines declared bankruptcy and went out of business in Spring 2008 despite the immunity agreement. Arguably, however, the primary reason for Aloha's going out of business was entry by a competitor airline *go!*, not the 2001 demand shock.

ment in 2002 (Blair et al., 2007; Kamita, 2010).[3] Yet, it is difficult to conclude, based on mere field data analysis, whether these price increases were necessarily due to capacity coordination. Further, it is difficult to determine whether or not explicit coordination was necessary for the firms to reduce their capacity in the face of decreased demand. Experimental methods have the advantage of permitting researchers to isolate effects of specific institutional features (Plott, 1989). Economic experiments have proven increasingly useful both in detecting anti-competitive effects of various industry practices (Grether and Plott, 1984; Offerman and Potters, 2006; Deck and Wilson, 2008), and in evaluating techniques used by antitrust authorities to hinder collusion (Apesteguia et al., 2007; Hinloopen and Soetevent, 2008).

There are theoretical and empirical arguments in the literature both for and against antitrust authorities allowing explicit capacity coordination. Capacity coordination in response to an unexpected negative demand shock in the airline industry may be justified by its cost structure, which includes large sunk costs (e.g., the cost of acquiring an aircraft) and large costs that can be avoided by not flying the aircraft but become fixed once the flight is scheduled (e.g., the cost for fuel and crew). As the scheduling of flights takes place before the seats are booked, the airlines run the risk of not covering their total costs unless they can predict the demand accurately and are able to set prices at levels above their marginal costs. This accounts for the necessity of above-marginal-cost pricing by firms in industries with large sunk and avoidable costs (Sjostrom, 1989; Durham et al, 2004; see also Van Boening and Wilcox, 1996). Kreps and Sheinkman (1983) develop a two-stage oligopoly model where firms first set their capacities, and then engage in price competition. They demonstrate that in this setting, Cournot-level above-marginal-cost pricing will emerge even without explicit capacity coordination, provided that the firms observe each other's capacity choices prior to setting their prices. This model appears appropriate for the airline industry, where capacities (flight schedules) are set before tickets are sold and companies may observe each other's capacities though publicly announced flight schedules. However, firms' knowledge of demand is an essential assumption in the Kreps and Scheinkman model. An unexpected demand shock may lead to over-investment in capacity and losses either from unsold seats, or from marginal cost pricing.[4] Further, it may be unrealistic to expect firms to adjust to new demand conditions instantaneously. If explicit capacity coordination allows firms to adjust to these new conditions faster, then it may help the firms avoid losses and stay in business. This could yield an argument for the antitrust exemption, provided that welfare gains from doing so outweigh potential costs to consumers.

The argument against explicit capacity coordination is backed by a large theoretical, empirical

[3] Kamita (2010) reports not only that prices rose during the period of coordination, but that they remained high until the entry of a new competitor, two and a half years after the antitrust immunity expired.

[4] If the demand shock is unanticipated, then capacities set before the shock become exogenous. Depending on the level of capacity set, the subsequent price competition may result in either marginal cost pricing, or in price instability due to the non-existence of a pure strategy equilibrium in prices (Osborne and Pitchik, 1986; see also Kruse et al., 1994).

and experimental literature on collusion in oligopoly. Both game-theoretical (Tirole, 1988) and experimental research (Fouraker and Siegel, 1963; Dufwenberg and Gneezy, 2000; Huck et al., 2004) indicates that industries with a small number of firms with symmetric cost structures, who interact repeatedly under known and stable demand conditions,[5] are prone to tacit collusion in the form of above-competitive pricing. Empirical evidence of collusion in oligopolies, especially duopolies, is also quite rich (Rees, 1993; Levenstein and Suslow, 2006). Though it is plausible that duopolists in an industry with stable demand could achieve above-competitive pricing, an unexpected negative demand shock would constitute a major challenge (Levenstein and Suslow, 2006; Staiger and Wolak, 1992).[6] An antitrust immunity agreement that allows firms to explicitly coordinate and enforce capacity reductions could help firms establish or re-establish collusive pricing in a new environment and in this way have a detrimental effect on consumer welfare.

There are several cases detailed in the literature where government authorities have unintentionally helped firms to collude (Albaek et al., 1997); and other cases where explicit coordination helped firms to avoid bankruptcy (Sjostrom, 1989). In this view, consideration of the effect of capacity coordination on competition and overall outcomes in an industry experiencing an unexpected demand shocks is of particular interest.

In this article we report on an economic laboratory experiment that was conducted to evaluate effects of capacity coordination on oligopolistic industry performance. We recreate the Kreps and Sheinkman (1983) two-stage capacity and price setting duopoly game in the economic laboratory, but with repeated play in order to model firms who interact with each other for a long time under known and stable demand conditions. This allows us to establish, as a baseline, whether firms are likely to engage in above-marginal-cost pricing even without explicit coordination. We then institute a negative demand shock halfway through each experimental session, in order to investigate its effect on firm behavior. By then varying regulatory regimes after the demand shock (allowing or not allowing capacity coordination, and enforcing or not enforcing the agreed-upon capacity restrictions), we further examine how different capacity coordination regimes affect post-shock industry outcomes. This method allows us to evaluate whether capacity coordination agreements are likely to facilitate capacity reduction and to what extent these agreements are anti-competitive.

[5]Blair et al. (2007) report that at the time of September 11th attacks, Hawaii's inter-island airline industry was largely dominated by two main providers, Aloha and Hawaiian airlines. These two providers had symmetric cost structures, near equal market shares, provided homogeneous product, and had been operating in this industry for a long time, with only occasional and largely unsuccessful entry. See also Kamita (2010).

[6]Reviewing the empirical literature on collusion, Levenstein and Suslow (2006) write: "Cartels break down occasionally because of cheating and lack of effective monitoring, but the biggest challenge cartels face are entry and adjustment of collusive agreement in response to changing economic conditions. Cartels that develop organizational structures that allow them the flexibility to respond to changing economic conditions are more likely to survive" (p. 43). Even though Levenstein and Suslow focus their analysis on the "hard-core" cartels, their arguments fully apply to tacit collusion where collusive outcomes may be supported by a repeated game-theoretic argument. Theoretical models, such as Staiger and Wolak (1992), also predict that periods of low demand will lead, through the emergence of excess capacity, to a breakdown of collusive pricing.

Davis (1999) and Muren (2000) study experimental triopoly markets in repeated settings in the framework of the Kreps and Sheinkman (1983) two-stage capacity and price setting game. Davis finds that capacity pre-setting raises prices and reduces capacity, though with substantial variation across markets. Muren reports that capacity choices for inexperienced subjects are higher (more competitive) than the Kreps and Sheinkman (1983) model predicts. Goodwin and Mestelman (2010) also report that inexperienced subjects over-invest in capacities in Kreps and Sheinkman duopolies, but that capacities converge to the Cournot prediction as subjects gain experience. However, these papers do not consider demand changes, which is the main focus of our study. Other experimental studies analyze the ability of market institutions to adjust to supply and demand shifts (Williams and Smith, 1984; Davis et al., 1993). Still others consider the effects of certain industrial practices or government programs on market outcomes (Grether and Plott, 1984; Hinloopen and Soetevent, 2008), but under stable economic conditions. Many experiments investigate collusion in a variety of market settings, but only a few (e.g., Brown et. al., 2009) explore the robustness of established collusive practices under changing conditions. The unique contribution of this article is two-fold. First, we study the effect of a negative demand shock on firms' abilities to sustain above-marginal-cost pricing in the Kreps and Sheinkman (1983) two-stage capacity and price competition framework. This setting is arguably more complex than simple quantity- or price- oligopoly competition; therefore it may be more challenging for firms to adjust to changes in demand. Second, we focus on the effects of regulatory measures that may be instituted in response to sudden negative changes in economic conditions. Our experimental evidence adds to and complements the scarce empirical literature (e.g., Kamita 2010) on the effect of capacity coordination on firms' abilities to both reduce capacities and engage in tacit collusion.

Our key experimental findings are as follows. First, we observed that explicit capacity coordination helped firms quickly adjust their capacities when demand conditions changed. Yet, most firms reduced capacity immediately after the demand shock even in markets where no explicit coordination was allowed. The demand shock did not result in persistent losses or firm bankruptcies in any of the markets.[7] Further, we obtained strong evidence that in many experimental markets, capacity coordination had a pronounced pro-collusive effect on firm behavior. Whereas prices fell and remained low after the demand shock in markets without capacity coordination, prices quickly recovered and even increased in markets with coordination. This is quite remarkable because, in our experiment, sellers coordinated capacities in settings more restrictive than real-world capacity negotiations. Negotiations in our experiment were computer-mediated, and were restricted to alternating capacity proposals, with the additional ability, in some treatments, to engage in mod-

[7] In fact, the only two markets where the sellers experienced on-going losses and went bankrupt were in the treatments allowing for coordination; see table 1. These losses were most likely attributable to the seller's lack of understanding of the market, rather than the demand shock, as these losses started in the initial periods of the experiment and persisted through most periods before the shock.

erated online chats.[8] Next, we observed that whereas the ability to coordinate capacity levels had a significant effect on reducing capacities and increasing prices immediately after the negotiations started, explicit agreement enforcement was not always necessary to establish and maintain successful coordination. Finally, we find that supplementary free-style communication enhanced firm abilities to sustain capacity agreements and ultimately resulted in the highest share of perfectly collusive markets among all institutions considered.

The rest of the article is organized as follows. Research objectives, design and procedures are given in Section 2. Section 3 presents the results, and Section 4 concludes.

## 2 Research objectives and experimental design

The experiment is designed to explore the effects of capacity coordination in an oligopoly industry experiencing a sudden negative demand shock. Specific research objectives are the following. First, as a benchmark, we explore firms' abilities to avoid excess capacities and achieve and sustain above-marginal-cost pricing without explicit coordination in a repeated two-stage capacity-price-setting duopoly. Second, we study the effects of a negative demand shock on industry outcomes in this environment, and on producers' abilities to adjust to the new demand conditions without explicit coordination. Third, we examine the ability of several capacity coordination institutions to help producers adjust to a negative demand shock. We compare the speed and the extent of capacity reduction under each institution, and the effects of the institutions on firm profits as a proxy for producer welfare. Finally, we investigate whether capacity coordination has a pro-collusive effect on firm behavior, leading to higher industry prices.

**Experimental Design** The basic design mirrors the Kreps and Sheinkman (1983; hereafter KS 1983) two-stage capacity-price duopoly model, except similar to many market experiments, we add a repeated setting as this is more appropriate in modeling most real-world oligopolies. Each market is conducted as a series of trading periods in which two subjects in the roles of sellers compete to sell units of a fictitious good to a simulated buyer with a known linear demand. In line with KS (1983), the institution is a modified posted offer market, where subjects specify production and observe the production level of their counterpart prior to setting a price in each period. The capacity setting is simultaneous and - in the first part of each experimental session - is undertaken without communication between the sellers. Sellers incur costs on each unit of capacity produced regardless of how many units they actually sell. The capacities set by each seller are then revealed

[8] In reality, capacity coordination between firms may take place under more pro-collusive conditions. The 2002 Aloha-Hawaiian anti-trust exemption allowed representatives of both airlines to meet every 30 days to agree on flight capacities for the next month. The meetings took place behind closed doors, with apparently no direct oversight from the Attorney General's office. Experimental research shows that face-to-face communication has a strong positive effect on cooperation (e.g., Crawford, 1998).

to the other seller in the market, after which the sellers simultaneously and privately specify an asking price for the goods they have produced. After that, the simulated buyer purchases units from the sellers, buying from the lower priced seller first.[9] At the end of each trading period, sales and the corresponding profits or losses are reported to the sellers along with the posted price and the sales of the other seller.

**Parameters** Each seller faces a constant marginal cost of 10 experimental dollars per unit and no fixed costs. We abstract from a more realistic setting of large fixed costs and non-constant marginal cost to focus on the issue of capacity coordination and its effect on the prices in a relatively simple environment. Each seller makes their capacity and pricing decisions in light of a known continuous linear demand function, which was set to be $Q = 304 - 4(p)$ for the first 21 trading periods.

In the 22nd period, a demand shock is induced by a decrease in the intercept of the demand function. The post-shock demand that persists for the remainder of the session is then $Q = 256 - 4(p)$.

This decrease in demand occurs in the course of a period (referred to as the "shock period") after the capacity-setting stage has elapsed. Subjects are made aware of the change at that time and post their price in light of the new demand information. Subjects are warned during the instructions that a change in the demand is possible.

These supply and demand conditions imply a market price and quantity combination associated with each of three plausible theoretical benchmarks: Bertrand equilibrium (which would imply marginal cost pricing of $10 and outcomes identical to perfect competition); Cournot outcome (as predicted by KS, 1983), and Monopoly outcome (which may be supported by repeated play and possibly enhanced by explicit capacity coordination). The demand parameters are chosen so that the pre-shock Cournot price ($32 experimental) is below the post-shock monopoly price ($37 experimental), allowing for the replication of the post-shock price increase observed after the inception of the anti-trust exemption agreement between Aloha and Hawaiian airlines.

**Treatments** The experiment consists of four main treatments and two additional treatments. The main treatments are designed to investigate the effects of capacity-coordination institutions established in response to a negative demand shock. The additional treatments are added to separate the effects of capacity coordination from the effects of demand shock, and consider markets where coordination starts prior to the demand shock. We introduce the four main treatments

[9] Given the capacities and prices, the sales are determined exactly as specified in the KS (1983) model. See Experimental Instructions, included in Appendix A. We do not explore alternative models of advanced capacity setting (e.g., Davidson and Deneckere 1986; Moreno and Ubeda 2006), as we believe the KS model most accurately describes the real-world market outcomes preceding the demand shock: two producers with symmetric market shares and with some price-setting power (see footnote 5). In comparison, Davidson and Deneckere (1986) predict a tendency towards asymmetric firm sizes, assuming an alternative to KS demand rationing rule. Moreno and Ubeda (2006) assume that firms do not have price-setting power after choosing capacities, but set reserve prices instead.

next. The additional treatments will be introduced and discussed later, in the subsection "Early coordination and enforcement" of Section 3.

For the four main treatments, the before-shock trading periods are conducted identically under all treatments, with no capacity coordination. The demand shock is then instituted in period 22, followed by three transition periods (periods 22-24, which we call the "shock periods") with no coordination. This short span of shock periods allows us to assess whether the subjects attempt to unilaterally adjust to the new demand conditions immediately after the shock before any coordination takes place. Starting from period 25, we vary capacity coordination and enforcement institutions across sessions, giving rise to four distinct treatments:

Treatment "No Negotiations, No Punishment" (NoNegNoPun). In this baseline treatment, the demand shock is followed by 14-16 additional periods under the new demand conditions with no explicit capacity coordination. The institution is the same as in the pre-shock periods.

Treatment "Negotiations, Punishment" (NegPun) is modeled after the 2002 Hawaiian - Aloha airlines anti-trust exemption. Following the three shock periods, the capacity coordination mechanism is imposed and persists for the remainder of the session. In an additional stage at the beginning of each period, sellers negotiate and agree upon a per capacity per seller prior to setting own capacity. In the event that either seller chooses to produce more than the agreed amount that period, the offender is penalized seven experimental dollars per unit produced over the agreed capacity, an amount chosen to exceed any potential gains that might accrue to the seller who broke the agreement. This penalty is transferred to the other seller. In the event that both exceed the agreed upon amount, the penalty is accrued to each with the net balance determined by the relative size of the divergence of each seller. This setting is designed to mimic the actual revenue transfer clause of the Aloha-Hawaiian airlines agreement.[10]

The negotiation stage takes the form of a real-time bargaining session. Each seller can propose a per-seller capacity. During this negotiation stage, a seller can change their proposal at any time as many times as they wish. Each seller, seeing the current proposal of the other seller, can choose to propose a different capacity, accept the proposal of the other seller, or do nothing at all. Upon either seller accepting the proposal of another, the negotiations end immediately and the sellers proceed to the capacity-setting stage. If no proposal is accepted in the time allotted for negotiations (90 seconds), there is no agreement in place for that period.

Treatment "Negotiations, No Punishment" (NegNoPun) is identical to the NegPun treatment described above, except that there is no penalty for breaking the capacity agreement.

[10] In setting the penalty level, we assumed that explicit capacity coordination may lead to the perfectly collusive monopoly outcome. Using the best response analysis, we then calculated the highest gain from deviation that a firm could obtain assuming the other firm sticks to the agreement. We then set the penalty per each unit of capacity excess at about 60% of possible per unit gain from deviation. Blair et al (2007) report that the revenue transfer clause of the actual Aloha-Hawaiian agreement set the penalty at the level corresponding to around 60-100% of extra revenue that a deviating party could obtain from each unit exceeding the agreed capacity level.

This treatment is designed to isolate the effects of the enforcement (in the form of the revenue transfer clause) on the effectiveness of the agreement.

Treatment "Negotiations, No Punishment, Chat" (NegChat) replicates the NegNoPun treatment but allows, in parallel with structured negotiations, free form communication between the subjects in a chat window. This treatment is motivated by a large body of existing literature on non-binding communication in experimental markets and games (e.g., Holt, 1995; Crawford, 1998). It aims to investigate whether free-style non-binding communication could lead to better coordination than the structured negotiations alone, and whether it may substitute for an explicit punishment clause in promoting and maintaining capacity reductions. Chats are monitored and subjects are warned not to discuss price in their chats, with the threat of removal from the experiment if they do not comply.

**Procedures** 41 two-person markets were conducted under the four main treatments over the course of 13 experimental sessions. Eight sessions were conducted at the University of Hawaii at Manoa (UHM hereafter) and five sessions were conducted at the University of Alaska Anchorage (UAA hereafter). Table 1 provides a summary of the experimental sessions.[11]

TABLE 1 AROUND HERE

Each session began with an oral reading of the instructions, a quiz confirming the subjects' understanding of the instructions (see Appendix A)[12] and a trial period. The experiment was computerized using the z-tree software (Fischbacher 2007). Subjects were seated at visually isolated computer terminals with communication limited to the experiment interface. In treatments with capacity coordination, further instructions on coordination were given in unpaid trial period 25, which preceded the paid negotiations periods. A market typically consisted of 39 paid periods, with the number of periods unknown to the subject beforehand.[13] All markets were conducted with the subjects' full and common information of the demand and cost conditions. Demand conditions were presented to the subjects in tabular form and in the form of an on-screen calculator. The calculator allowed the subjects to evaluate their own and the other seller's earnings for each capacity and price combination before making actual capacity and price choices. See Appendix B for a screen shot of subject decision screen with built-in calculator. Session length ranged between 2 and 3 hours.

[11] Experimental sessions for the additional treatments are also included, to be discussed in Section 3 below.

[12] The first three sessions conducted at UH did not have a quiz. The main instructions, which were identical for all sessions, contained many hypothetical examples to ensure subject understanding. The quiz was later included to facilitate subject understanding of the instructions. The pre-shock market capacities, prices and earnings in markets in Sessions 1-3 were no different from those in the remainder of the sessions (Mann-Whitney test, two-sided). We therefore include Sessions 1-3 in the analysis.

[13] Sessions 1 and 7 were cut short due to time constraint with the shortest ending after 35 paid periods. See Table 1.

Subjects were selected from the general undergraduate population at the two universities. No subject participated in more than one experimental session. Subjects received $5 for showing up on time. They were provided an initial budget of 7500 experimental dollars, and were also given a small per period endowment of 50 experimental dollars in each trading period, to offset any losses incurred early in the session.[14] Conversion rate was 1750 experimental dollars per U.S. dollar. The overwhelming majority of the subjects earned between US $11 and $47, including show-up fees, with the average of US $31.46.[15]

# 3 Results

The analysis is organized in three subsections. First, we look at the aggregate results in the main treatments, focusing on treatment effects. Next, we introduce two additional treatments with pre-shock capacity coordination, and take a closer look at capacity-setting and enforcement strategies used by the sellers. Finally, we study long-term convergence properties of each market, allowing for market heterogeneity within and across treatments.

### Aggregate results and cross-treatment comparisons

The data from the experimental sessions are presented in Tables 2-4 and Figures 1-2. The data analysis revealed no significant differences in market performances between the UHM and UAA subject pools; thus we present the statistics by treatment pooled across both locations. Tables 2-4 display the theoretical benchmarks (Monoply, Cournot and Bertrand predictions), along with descriptive statistics by treatment, with independent markets as the units of observation. The tables report the total capacities (Table 2) produced in each market, in physical units; the average selling price of the goods weighted by the number of sales at each price (Table 3), and the average subject earnings per period in experimental dollars (Table 4). We report the descriptive statistics for the span of periods prior to the demand shock ("before shock" periods); for the short span between the demand shock and the period when the coordination mechanism is imposed in the corresponding treatments ("shock" periods 22-24); and the periods following the imposition of the treatments ("after shock" periods). Before and after shock data are organized into seven-period intervals: very early periods (periods 1-7); early periods before the demand shock (periods 8-14); later periods before the shock (periods 15-21); "early" after-shock periods, which are seven periods

[14] A positive per period endowment, in addition to the start-up budget, was given to subjects to help avoid losses which we considered likely in the first few periods. This endowment, however, accounted to only about 3 cents US and never had a decisive effect on subjects in avoiding bankruptcies.

[15] Sessions 1 and 2 had a higher exchange rate of 1000 experimental dollars per U.S. dollar, resulting in much higher dollar earnings. The behavior in these sessions was no different that the behavior in the remainder of the sessions. One outlier subject in Session 10 received $75 by earning nearly all monopoly profits in the market, while their competitor earned only $14. In another market in Session 10, both subjects went bankrupt; the latter market is excluded from the analysis.

right after the capacity coordination institutions in the corresponding treatments were imposed (periods 25-31); and "late" after-shock periods, from period 32 till the end of the experiment (up to period 40).[16] To account for subject learning in early periods before the shock, we use the later periods before the demand change (periods 15-21), rather than the earlier periods, as a benchmark for comparison with the shock and after-shock periods. Further, we will compare market characteristics in the early after-shock periods (periods 25-31) with those in the later after-shock periods (periods 32-end) to evaluate if the speed of adjustment to the demand change varied across treatments.

Figures 1 and 2 display time-series data for capacities, prices and profit medians, as well as market sales. We display the medians, rather than the means, to reduce the effect of the outliers (e.g., very high capacities) that are occasionally observed in the data. The gap in period 25 in capacity coordination treatments corresponds to an instruction period. Figure 1 compares No Negotiations markets with all Negotiations markets pooled, whereas Figure 2 shows the medians for all four treatments separately. We also display the benchmark theoretical predictions for Monopoly, Cournot, and Bertrand equilibrium market dynamics. Note the shift in these curves that occurs in period 22 representing the demand shock imposed at that time.

TABLES 2-4 AND FIGURES 1-2 AROUND HERE

Large standard deviations of the variables, reported in Tables 2-4, indicate substantial variations in the data across markets in every treatment. In addition, prices and capacities varied within each market across time periods. The large variations observed in the data are consistent with findings by Davis (1999), who posits that it is the specific nature of the two-step task in this environment that makes it challenging for subjects. The Kreps and Sheinkman (1983) model requires each seller to perform sophisticated backward induction in order to determine the predicted capacity setting. However, the variations narrowed over the course of each session in all treatments[17] suggesting substantial learning effects in the course of the session. More importantly, despite the noise in the data, the results below clearly demonstrate that experimental subject behavior was sensitive to both changes in the demand conditions, and to variations in institutions.

We start by documenting the performance of experimental markets in the periods before the shock. Note that our main treatments are all identical up to period 24 (i.e., until institutional arrangements to coordinate capacities are put in place in the corresponding treatments). Therefore, we pool the data across treatments in the pre-shock and shock periods.

[16] For markets with capacity coordination, period 25 was instructional. The corresponding seven-period intervals after the shock are periods 26-32 ("early") and periods 33-end ("late").

[17] The average standard deviation of market capacity within a market was 59.71 in the periods before the shock, but it decreased to 35.42 in the periods after the shock. This decrease in variations in capacities over the course of the sessions occurred in each treatment.

**Result 1** *Prior to the demand shock, subjects often set capacities well in excess of those predicted by Kreps and Sheinkman (1983), but below the Bertrand equilibrium benchmark. Likewise, prices exceeded those predicted by Bertrand equilibrium, but were below the Cournot level. Consistent with Kreps and Sheinkman (1983) prediction, markets with lower capacities were characterized by higher prices.*

*Support:* Figures 1-2, Tables 2-3. Based on periods 15-21, the average (as well as the median; see Figure 2) market capacities before the shock were between the Cournot and Bertrand theoretical benchmarks in all treatments, with the overall mean of 231.59 (seven-period average before the shock) as compared to the Cournot capacity of 176 and the Bertrand capacity of 264. The mean price before the shock was 25.54 experimental dollars, as compared to the Cournot prediction of 32 and the Bertrand prediction of 10 experimental dollars. Comparing prices and capacities across markets, the market trading price was negatively related to market capacity. In markets with average capacity exceeding the Bertrand prediction, the average trading price was 17.48 experimental dollars, as compared to the average price of 25.39 in the markets with capacities averaging between the Bertrand and Cournot predictions, and compared to the average price of 39.66 in the markets with capacities at or below the Cournot level. We further analyzed whether the subjects, having set the capacities, made pricing decisions in accordance with the KS predictions. Whereas the prices in the pricing subgame fell within the exact theoretical bounds only in 40% of the cases before the shock, they were within 5 experimental dollars from the theoretical predictions in 81% of the cases. The average price deviation from the theoretically predicted price (or the range of prices, if the equilibrium prediction in the pricing subgame involved mixed strategies) was only 0.96 experimental dollars. □

We conclude that advanced capacity setting allowed our experimental subjects to achieve below Bertrand production levels and above marginal cost prices even without explicit coordination. This confirms the findings by Davis (1999) on super-competitive pricing, in a quite different market setting. Yet, the observed market outcomes were, on average, characterized by higher capacities and lower prices than the KS (1983) model predicts. Given capacities, the sellers in our experiment charged prices that were, on average, slightly above the theoretically predicted prices. As a consequence, some capacities were not fully utilized. Comparing market capacities with sales (see Figures 1-2), the markets before the shock were characterized by an average excess capacity of 52.11 units, which was reduced to 38.34 units in the seven periods immediately preceding the shock. Informal post-experiment debriefing suggested that some subjects were averse to exhausting their entire capacity and allowing their counterpart to serve a portion of the demand at a higher price.

We now turn to the effects of the unexpected demand change on market performance. We rely on non-parametric tests to evaluate the differences across time intervals (Wilcoxon signed ranks test) and across treatments (Wilcoxon-Mann-Whitney rank sum test; WMW hereafter), with individual market averages used as the units of observation. The reported p-values are for one-sided tests when the underlying hypotheses are directional; that is, when comparing market characteristics before and after the shock, and when comparing the negotiations and the no negotiations markets. In all other cases, the reported p-values are for two-sided tests.

**Result 2** *Substantial reductions in capacities, prices and seller profits occurred immediately following the demand shock.*

*Support:* Figures 1-2, Tables 2-4. Comparing market capacity levels between the pre-shock periods (periods 15-21) and shock periods (periods 22-24), capacities fell significantly immediately following the shock (p-value is 0.0008, Wilcoxon signed ranks test, one-sided). On average, capacity decreased by 24.78 units in the shock periods as compared to seven periods before the shock. The prices and seller profits also fell immediately following the shock; the corresponding p-values are 0.0001 for trading prices and 0.0000 for seller profits. The average trading price decreased by 3.79 experimental dollars, which is not significantly different from the decrease of 4 experimental dollars that would occur under Cournot-level equilibrium pricing (p-value is 0.9638). Seller profits decreased, on average, by 596.96 experimental dollars, which again is not significantly different from a decrease of 640 experimental dollars that would occur following the shift to the new equilibrium in the KS model (p-value is 0.8005). □

The above result clearly demonstrates that the sellers in our experimental markets started adjusting their behavior immediately in response to the change in market conditions. This presents evidence that cost-cutting capacity reduction in industries in crisis can occur even if firms are unable to coordinate the reductions explicitly.[18] However, capacity coordination did allow for a larger and faster decrease in excess capacities, as we demonstrate below.

We now compare the ability of different capacity coordination institutions to help producers to adjust to new demand conditions, as well as to raise prices and profits. In analyzing treatment effects, we focus on comparing the changes in key variables, rather than their absolute values, across the multi-period intervals defined above as "before shock," "shock," and "after shock." This allows us to directly compare the treatment effects while controlling for naturally occurring variation in the baseline (before-shock and shock) values.[19]

[18] The media also present ample evidence of unilateral capacity reductions in industries in crises; e.g., "Airlines Cut Long Flights To Save Fuel Costs," *Wall Street Journal,* July 8, 2008; "*Continental* to cut 3,000 jobs, slash capacity, flights," marketwatch.com, June 5, 2008; "*Alcoa* to Reduce Capacity By 18%, Cut 13,500 Workers," bloomberg.com, January 9, 2009.

[19] We also conducted difference-in-differences estimations of treatment effects using panel regressions. The results, reported in Table 7 in Appendix C, were overwhelmingly the same as those based on the non-parametric tests.

**Result 3** *Capacity coordination resulted in a larger and faster reduction of excess market capacity following the demand shock.*

*Support:* Figures 1-2, Table 2. The capacity decreased, on average, from the shock periods to the seven periods after the shock (periods 25-31) by 51.3 units in the markets with capacity coordination, but only decreased by 21.3 units in markets without capacity coordination; the difference is statistically significant (p-value is .0124, WMW test). Considering the data for each coordination treatment separately, the reduction in capacities was significantly larger in two out of the three capacity coordination treatments as compared to the baseline NoNegNoPun treatment (NegNoPun: p-value is 0.0144; NegPun: p-value is 0.0173). As evident in Table 2, the average after-shock capacities in coordination treatments NegNoPun and NegPun were below that in the baseline NoPunNoNeg treatment, and near the Cournot prediction in the first seven periods following the demand shock (periods 25-31). While capacity reduction continued in the NoNegNoPun treatment in the late after-shock periods (periods 32-end), the overall capacity decrease from the shock periods to the late after-shock periods remained larger is the markets with coordination (56.81 units) than in the markets without coordination (35.6 units). □

**Result 4** *In the absence of explicit capacity coordination, prices did not significantly change in the periods after the demand shock. In contrast, with capacity coordination, prices increased in the after-shock periods, reaching or exceeding the after-shock Cournot level. The differences in price dynamics between the no coordination and coordination treatments are significant.*

*Support:* Figures 1-2, Table 3. Comparing the prices in the shock and after-shock periods, in the baseline NoNegNoPun treatment, the prices decreased in the first seven periods after the shock by an average of 1.25 experimental dollars, and then increased by 1.76 experimental dollars in the following periods; neither the initial decrease nor the subsequent increase are statistically significant (the corresponding p-values are 0.9218 and 0.4316, sign rank test.) In contrast, prices increased from the shock to the after-shock periods in all negotiation treatments by an overall average of 7.48 experimental dollars by the early periods after the shock, and by the overall average of 8.30 experimental dollars by the late periods; the increase is statistically significant (p-value is 0.0000 for comparison between both time intervals). The difference in price changes between the no negotiations and the negotiations treatments is highly significant for the early after-shock periods ($p = 0.0016$, WMW test), and is still significant for the late after-shock periods ($p = 0.0733$).

It is also instructive to compare price changes between pre-shock and after-shock periods. Given either Cournot or Monopoly benchmark predictions, a negative demand shock would be expected to reduce prices in after-shock periods. Indeed, the average price decreased from the seven periods before the shock to the seven periods after the shock in the baseline NoNegNoPun treatment (p-value is 0.0137, sign rank test). In contrast, the average price in the negotiations markets *increased* from before to after the shock (p-value is 0.0456). The average price was below the Cournot prediction in the seven periods after the shock in the NoNegNoPun treatment (p-value is 0.0367), but it was not statistically different from the Cournot prediction in the negotiation treatments (p=0.3779). Even though the average price in the no negotiations treatment reached the pre-shock level in the late periods after the shock, it was still below the average prices in each of the negotiations treatments. □

From Figures 1-2, one can clearly recognize that in the capacity coordination treatments, prices return to and then exceed pre-shock levels despite a reduction in demand. This mirrors the post-exemption price increases for inter-island travel in Hawaii documented in Blair et al. (2007) and Kamita (2010). This finding suggests the potential for consumer-welfare reducing collusion beyond that which would occur in the absence of explicit coordination across sellers.

**Result 5** *Without negotiations, profits stayed at low shock-period levels for many periods after the demand shock and did not start recovering until later in the sessions. In contrast, with explicit capacity coordination, the after-shock profits quickly recovered to pre-shock levels.*

*Support:* Figures 1-2, Table 4. Looking at the baseline NoNegNoPun treatment, the seller profits did not change significantly from the shock periods in the first seven periods after the shock (p-value is 0.6250). Consequently, the after-shock profits stayed significantly below the before-shock profits in the first seven periods following the demand shock (p=0.0136). Even though the profits started to increase in the late after-shock periods, they stayed, on average, below pre-shock levels. The picture is quite different for two of the three negotiations treatments. The profits increased significantly from the shock periods to the seven periods after the shock in both NegNoPun and NegPun treatments; p-values are: 0.0274 for NegNoPun and 0.0010 for NegPun. Further, profits reached the pre-shock levels in the seven periods after the shock: p-values for the differences between the pre-shock profits and the after-shock profits are 0.8992 for NegNoPun and 0.3652 for NegPun. In the third negotiations treatment, NegChat, the profits took longer to recover, but they did experience strong recovery to almost exactly the pre-shock levels in the later periods (see Figure 2). □

Note that in the absence of any capacity coordination, a demand reduction would be expected to reduce the earnings of the sellers in the market, unless the earnings were already zero (as under perfect competition). Again, the above finding suggests the potential for consumer-welfare reducing collusion in markets where explicit capacity coordination is allowed. Of course, if the policy goal is to maintain the solvency of firms in the face of losses from a demand shock, these findings suggest the potential of capacity coordination to reduce losses and increase profitability to firms.[20]

[20]Results 2-5 are confirmed if we group the data into five-period or ten-period averages, instead of seven-period

We now turn to a comparison of treatments that allow for explicit capacity coordination. We consider the effect of the agreement enforcement first, by comparing NegNoPun and NegPun treatments.

**Result 6** *Punishment for non-compliance in capacity coordination treatments had little effect on performance in the early periods after the negotiations started, as compared to negotiations without punishment. In later periods, markets with punishment maintained Cournot-level capacities and high profits, while markets without punishment exhibited more variable capacities and a drop in profits.*

*Support:* Figure 2, Tables 2-4. Average market capacities, prices and subject profits were virtually identical between the NegNoPun and the NegPun treatments in the first seven periods after the negotiations started (periods 25-31). The average capacities and prices were exactly at the Cournot prediction, with profits not significantly different from the Cournot level. In later periods (periods 32-end), average capacities, prices and profits stayed unchanged in the NegPun treatment, whereas in the NegNoPun treatment, the average market capacity increased from 146.64 units to 161.19 units, and average subject profit decreased from 1021.18 to 855.34 experimental dollars. The decrease in profits from early to late after-shock periods was marginally significantly larger in NegNoPun treatment than in the NegPun treatment (p=0.0905, WMW test). In addition, capacities in NegNoPun became more variable: the standard deviation of average market capacity across markets increased from 38.68 units in the early after-shock periods to 68.35 units in the late periods. At the same time, the standard deviation of capacity in the NegPun markets remained unchanged at about 33 units between these two time intervals. □

The apparent inefficacy of the punishment mechanism in the early after-shock periods may be explained by subjects setting less stringent capacity agreements in the presence of punishment. The average agreed-upon capacity was marginally significantly higher in the NegPun markets as compared to NegNoPun markets: 78.67 in NegPun as compared to 65.64 in NegNoPun (p-value 0.1053); see Table 8 in Appendix C. Nevertheless, the punishment did play a role, as capacity agreements were followed through more carefully in the markets with punishment. The average deviation from agreed-upon capacity in the early negotiations periods in NegPun markets was -6.89, which was significantly different (lower) than the average deviation of 6.23 in NegNoPun markets

averages, before and after the shock. In line with Result 3, the after-shock differences in capacity adjustments between coordination and no coordination treatments are more pronounced for shorter time spans than for longer time spans. For markets with no capacity coordination, the capacity decrease from the the shock periods (periods 22-24) to the early after-shock periods is only significant at the 10% level based on five-period averages after the shock (periods 25-29; p=0.0967), but becomes significant at the 1% level based on ten-period averages after the shock (periods 25-34; p=0.0068). In comparison, in two treatments out of three with capacity coordination, and overall, capacities drop significantly (p<0.01) from the shock periods to early after-shock periods based on either five-, seven- or ten-period averages after the shock.

(p-value is 0.0112). This led, in the late periods, to more stable agreements and higher profits in the NegPun markets. In the markets without agreement enforcement, sellers tended to deviate from agreed-upon capacities more with time, undermining the advantages of capacity coordination in the late periods.

We next consider the effect of adding free-style communication on sellers' ability to increase price and earnings.

**Result 7** *Free-style communication (chat) had a significant effect on the dynamics of capacities and prices in late negotiations periods.*

*Support:* Figure 2, Tables 2-4. In the early negotiations periods (periods 25-31), the market prices, capacities and earnings in the NegChat treatment experienced the same or less sizable recovery after the shock as the other two capacity coordination treatments, NegNoPun and NegPun. The picture is different for the late negotiations periods (periods 32-end). While the performance of the two negotiations treatments without Chat either stabilized (as in NegPun) or even slightly deteriorated (as in NegNoPun), the NegChat markets demonstrated a significant decrease in capacities (p-value for the difference between early and late negotiation periods is 0.0136, sign rank test, two-sided), and a significant increase in prices and profits (p-values are 0.0274 for prices and 0.0098 for profits) in this time interval. Figure 2 demonstrates that towards the very end of the sessions, the median prices and profits in the NegChat treatment were above the medians in all other treatments. □

A closer look into capacity negotiations in NegChat markets allows us to explain why adding chat to structured negotiations had little effect until the very late periods. Table 5 present a summary of agreed-upon capacities, actual capacities, and chat contents by market.

TABLE 5 AROUND HERE

The table suggests that in only a few markets were the sellers able to quickly agree on low capacity levels. In some markets chat was barely used at all, whereas in others the sellers took a long time to settle on agreements to lower capacity levels (see the "Chat contents" column of the table). This may be attributed to participants' inexperience with the complex two-stage capacity-price setting institution. Still, most markets were able to reach working agreements in the late periods of the experiment. Further, even though the agreements in the NegChat markets were not enforced through an explicit punishment clause, the free-style communication option apparently worked as a substitute for agreement enforcement. From Table 8, the sellers in the NegChat treatments followed the capacity agreements most closely in the late periods; the average per market deviation of the actual per person capacity from the agreed capacity was only 0.36 units.

The above results suggest the following: First, capacity coordination had a strong and immediate effect on the industry performance, both in terms of firms' ability to reduce capacities and to increase prices and profits after the demand shock. Second, the effects of additional institutional provisions, such as an explicit enforcement clause and free-style communication, became the most pronounced in the late negotiations periods.

Some of the delays in the after-shock adjustments and in treatment effects may have been due to our experiment participants having little experience with the two-stage markets at the start or with capacity coordination institution introduced after the shock. To address the latter concern, we next consider additional treatments where firms are given a chance to learn to coordinate capacities before the demand changes. Historical cases of policies allowing for capacity coordination under regular market conditions are rare. Yet, considering experimental scenarios where capacity coordination starts before the demand shock may give us deeper insights into how capacity agreements are established and sustained.

### Early coordination and enforcement

Two additional treatments were designed to separate the effects of capacity coordination and punishment from the effects of the demand shock.

Treatment "Pre-Shock Negotiations, Punishment" (PreShockNegPun) is identical to the NegPun treatment, except that the capacity coordination mechanism is imposed in pre-shock period 8. Capacity coordination instructions were given in an unpaid trial in period 7. This treatment is designed to separate the effect of capacity coordination from the effect of adjustment to the demand shock with capacity coordination. We started capacity coordination early to allow enough time for the subjects to learn to coordinate their capacities before the shock. Subjects had fourteen paid periods of negotiations, periods 8-21, before the shock occurred in period 22.

Treatment "Pre-Shock Negotiations, No Punishment" (PreShockNegNoPun) is identical to the PreShockNegPun treatment described above except that there is no penalty for breaking the capacity agreement. This treatment is designed to isolate the effects of enforcement in the form of the revenue transfer clause in early capacity coordination.

A total of seven additional sessions were conducted, with 23 independent markets total. 11 markets were run under the PreShockNegPun treatment, and 12 markets were run under the PreShockNegNoPun treatment; see the bottom part of Table 1. The procedures were identical to those in the main treatments. Early capacity coordination considerably extended the period length in some markets, as many subjects took the full time allocated to negotiate the capacities. Due to the time constraint, three out of seven sessions ended before all 39 paid periods were completed, with the shortest session ending after period 24. Nevertheless the pre-shock periods 1-21 and the shock periods 22-24 were completed in all markets, and at least seven after-shock periods, starting from period 25, were complete in all but four markets. The average pay in these additional treatments was US $27.49 per subject.

The data from the additional treatments are displayed in Figure 3 and in the bottom sections of Tables 2-4. A gap in the trend in period 7 on the figure corresponds to the instruction period 7 when coordination was introduced.

FIGURE 3 AROUND HERE

The first question we address is whether capacity coordination in before-shock periods leads to a change in market outcomes even in the absence of a demand shift. Result 1 indicates that markets were often characterized by excess capacities. A drop in capacities following coordination would imply that coordination helps the firms to reduce these excess capacities. An additional increase in prices would indicate that coordination has a pro-collusive effect on firm behavior.

**Result 8** *Markets in early coordination treatments displayed a significant reduction in capacity immediately after the capacity negotiations started. This capacity reduction, along with a significant increase in prices and profits, persisted in markets with punishment, leading to Cournot outcomes. In the markets without punishment, capacity reduction did not persist and the prices did not rise above the pre-negotiations level, with seller profits rising only marginally.*

*Support:* Figure 3, Tables 2-4. From Table 2, in PreShockNegPun markets, capacities decreased, on average, from 266.12 in the very early periods to 204.21 in periods 8-14 when the negotiations started; the difference is statistically significant (p-value is 0.0049). Likewise, in PreShockNeg-NoPun markets, capacities decreased from 277.17 in the very early periods to 226.43 in periods 8-14 (p=0.0171). In comparison, none of the main treatments with no coordination before the shock displayed a significant change in capacity between these time intervals. Yet, in later period 15-21 before the shock, the capacities in PreShockNegNoPun increased back to the 254.02; the prices in this treatment stayed at above-Bertrand but below-Cournot levels in all time intervals before the shock, and the profits increased only marginally (p=0.0881) after the negotiations started. In contrast, in treatment PreShockNegPun with punishment, the capacity reduction continued in periods 15-21, reaching the level not significantly different from Cournot (p=0.3823). The prices in this treatment displayed a significant increase from 25.04 in the very early periods to 32.56 in periods 8-14 after the negotiations started (p=0.0093), and persisted at this Cournot level in periods 15-21. Seller profits increased significantly following the capacity coordination (p=0.0010). □

Next, we explore the effect of the demand shock on pre-existing capacity coordination. If firm behavior tracks the same equilibrium prediction – such as Cournot – before and after the shock, then we may expect the agreed capacities and prices to decline with a decline in demand. But if a change in demand suggests an opportunity for the firms to renegotiate and agree on a more collusive capacity level, then we may expect the prices not to drop and possibly increase, as was observed in markets with after-shock capacity coordination.

**Result 9** *The demand shock resulted in immediate decrease in capacities in both early-coordination treatments. In after-shock periods, capacities further decreased and prices increased to monopoly levels in markets with punishment. In markets without punishment, capacities stayed above and prices stayed below the Cournot levels.*

*Support:* Figure 3, Tables 2-3. In markets without punishment (PreShockNegNoPun), capacities dropped significantly from a before-shock level of 254.02 to 211.06 during the shock periods 22-24 (p=0.0017), and further declined to an average of 183.67 in the late after-shock periods. However, the capacities stayed marginally different (above) the Cournot level of 144 (p=0.0782). The prices did not change significantly during the shock periods compared to before the shock (p=0.6772), and did not reach the Cournot level even in the late after-shock periods (p=0.0547). In markets with punishment (PreShockNegPun), the immediate drop in capacities from pre-shock to shock periods was smaller in magnitude, from 187.26 to 162.58 (p=0.0615), and the price decrease was substantial, from 31.54 to 25.62 (p=0.0161). However, capacities continued to decrease from the shock to the early after-shock periods (p=0.0078), and prices quickly recovered, increasing to 33.41 by the early after-shock periods (p=0.0156 for the difference with the shock price level). In the late after-shock periods, capacities and prices reached levels not significantly different from the Monopoly prediction (p=0.6250 for both capacities and prices). □

The above two results suggest that both the switch from no coordination to coordination and the demand shift had an immediate and significant effect on firm performance. Whereas an increase in prices and firm profits following coordination under stable demand may be expected, a further increase in prices and a shift from Cournot to Monopoly outcomes after the demand shock in markets with punishment is notable. Apparently, the worsened demand conditions caused by the shock suggested to the firms a new opportunity to renegotiate capacity levels and improve joint profits, ultimately leading to fully collusive monopoly outcomes in many markets.

It is also apparent that while the initial effects of capacity coordination and the demand shock were qualitatively similar in the two early coordination treatments, the markets evolved very differently in treatments with and without punishment. We next consider the role of agreement enforcement in the form of punishment in the early coordination markets.

**Result 10** *In before-shock periods after capacity coordination started, the early coordination markets with punishment reached lower capacities and higher prices and profits than markets in any other treatment in this time interval. This difference in performance is attributable to firms' abilities to coordinate capacities along with the enforcement in the form of punishment.*

*Support:* Figures 1, 3, Tables 2-4. In pre-shock negotiation periods 15-21, the market capacities in PreShockNegPun markets dropped below those in PreShockNegNoPun markets (p=0.0031), and below the capacities in the main treatments with no coordination (p=0.0133). The prices and firm profits in PreShockNegPun markets increased above those in PreShockNegNoPun markets (p=0.0081 and p=0.0046 for prices and profit differences, respectively), and also above the prices and profits in the markets without capacity coordination before the shock (p=0.0204 and p=0.0216, respectively). These differences are attributable to treatment effects, rather than random factors, as capacities in the PreShockNegPun markets in the very early periods – before capacity coordination was imposed – were no different from the capacities in the PreShockNegNoPun markets (p=0.6225); the market capacities and prices were also no different from the corresponding characteristics in the four main treatments (p=0.4803 for capacities and p=0.6785 for prices). □

We conclude that the explicit threat of punishment, along with coordination itself, did make a difference in establishing and enforcing capacity agreements in early coordination markets. This seems at odds with our previous observation on markets in the main treatments. For those markets, punishment was found to play a relatively minor role in establishing capacity agreements, at least in the short-term (Result 6). These seemingly conflicting findings may be explained by the difference in our experimental subjects' experience with the markets at the time coordination started. In the main treatments, capacity coordination started when the sellers already went through 24 periods of uncoordinated markets and a demand shock. By that time, the sellers could have learned from experience the negative consequences of excess capacities and low prices, and could be looking for opportunities to coordinate with the other seller, just like many oligopolists in the real world do. In comparison, the sellers in the early coordination treatments were still very inexperienced with the institution when capacity coordination was introduced in period 7, and could be less aware of both advantages of coordination and consequences of breaking agreements. Explicit agreement enforcement in the form of punishment could then help the sellers to take the capacity negotiations seriously and to comply with agreements, leading to better outcomes for the sellers.

In a repeated setting, low capacity choices may be supported even without explicit punishment clause if sellers respond to other's high capacity with a future increase in own capacity. To investigate whether such tit-for-tat dynamics were present, we next compare individual seller capacity choices against a number of simple directional capacity-adjustment rules. Some rules we consider require the sellers to be responsive to each other's behavior, whereas other rules prescribe a movement toward a theoretical benchmark or an agreed capacity level irrespective of the other seller's actions. Formally, let $c_{it}$ denote seller $i$'s capacity choice in period $t$, and let $\Delta c_{it}$ denote the change in $i$'s capacity from the previous period, $\Delta c_{it} \equiv c_{it} - c_{it-1}$. Let index $j$ denote the other seller in the market, $j \neq i$. Let $c^T$ denote a given theoretical (Monopoly, Cournot or Bertrand) capacity prediction per seller, and let $c_{it}^{BR}(c_{jt})$ denote seller $i$'s Cournot best response to $j$'s capacity choice in period $t$. Finally, let $c_t^A$ denote capacity agreement in period $t$. The rules are defined as follows:

To Monopoly, To Cournot and To Bertrand rules prescribe to change the capacity in the direction of the corresponding theoretical prediction:

$$\Delta c_{it} > 0 \text{ if } c_{it-1} < c^T,\ \Delta c_{it} < 0 \text{ if } c_{it-1} > c^T, \text{ and } \Delta c_{it} = 0 \text{ otherwise.} \tag{1}$$

Cournot Best Response rule prescribes to change the capacity in the direction of the Cournot best response to the other seller's capacity:

$$\Delta c_{it} > 0 \text{ if } c_{it-1} < c_{it-1}^{BR}(c_{jt-1}),\ \Delta c_{it} < 0 \text{ if } c_{it-1} > c_{it-1}^{BR}(c_{jt-1}), \text{ and } \Delta c_{it} = 0 \text{ otherwise.} \tag{2}$$

Tit-for-tat Other's Capacity (TFT Cap) rule prescribes to increase (decrease) capacity only if the previous period choice is below (above) the other seller's capacity:

$$\Delta c_{it} > 0 \text{ if } c_{it-1} < c_{jt-1},\ \Delta c_{it} < 0 \text{ if } c_{it-1} > c_{jt-1}, \text{ and } \Delta c_{it} = 0 \text{ otherwise.} \tag{3}$$

Tit-for-tat Agreement (TFT Agree) rule prescribes to exceed the agreed capacity only if the other seller exceeded the agreement in the previous period, and not to exceed it otherwise:

$$c_{it} > c_t^A \text{ if } c_{jt-1} > c_{jt-1}^A, \text{ and } c_{it} \leq c_t^A \text{ otherwise.} \tag{4}$$

Agreement Compliance rule prescribes to never exceed the agreed capacity:

$$c_{it} \leq c_t^A. \tag{5}$$

To Monopoly, To Cournot and To Bertrand rules predict convergence to the corresponding theoretical benchmarks, but may be inconsistent with equilibrium behavior even in a repeated setting. (E.g., To Monopoly rule clearly creates incentives for the sellers to undercut each other.) Cournot Best Response rule is consistent with the Kreps and Scheinkman equilibrium, whereas both TFT Capacity and TFT Agree rules may support many capacity levels as equilibria in a repeated game setting. Agreement Compliance rule may be in line with an equilibrium, provided that agreements are supported by explicit punishment.

Table 6 summarizes the shares of individual capacity choices consistent with these adjustment rules, by treatment, before, during and after the shock. We only consider the seller behavior starting from period 8, when capacity cooridnation was introduced in early negotiations treatments. The bold numerical entries in the table represent the best predictions for the given treatment and time interval. We conclude:

TABLE 6 ABOUT HERE

**Result 11** *For markets without capacity coordination, Tit-For-Tat Capacity rule has, overall, the highest explanatory power among the rules considered, explaining half of the capacity choices. In* *markets with capacity coordination and punishment or Chat, Agreement Compliance rule explains the overwhelming majority of seller capacity decisions. In markets with coordination but without punishment, Tit-For-Tat Agreement rule explains the seller capacity choices best.*

*Support:* Tables 6. For the time intervals before the shock, TFT Capacity rule explains 48.42% of seller capacity choices in the four main treatments combined. It is also the best predictor in all time intervals in the NoNegNoPun treatment without coordination, explaining over 50% of seller choices. For markets with capacity coordination, agreement-based rules explain the capacity adjustments better than other rules. In after-shock periods, in the NegPun and NegChat treatments, agreement compliance explains over 85% of seller choices. In the early negotiations treatment with punishment PreShockNegPun, the subjects complied with agreements in over 90% of all cases, with this number rising to 96.2% in the after-shock periods. In negotiation treatments without punishment, agreement compliance was lower: only 62.0% in NegNoPun markets after the shock, and around 64-72% in different time intervals for PreShockNegNoPun treatment. For negotiations without punishment, Tit-For-Tat Agreement rule has the highest explanatory power, correctly explaining 63% of directional choices in the NegNoPun markets after the shock, and over 69% of choices in all time intervals in PreShockNegNoPun markets. □

We conclude that sellers were overwhelmingly responsive to each other's behavior, as capacity-adjustment rules that are not responsive to the other seller's choice (To Monopoly, To Cournot, To Bertrand) do not explain the behavior as well as the rules with a strategic component (Tit-For-Tat). Further, the explicit punishment clause played a clear disciplining role in capacity agreements, leading to higher agreement compliance. The difference between the early coordination markets with and without punishment is particularly apparent: whereas the PreShockNegPun markets with punishment showed over 90% compliance with agreements from the early pre-shock negotiations periods, the PreShockNegNoPun markets without punishment appear to have been caught in tit-for-tat agreement-compliance wars. Combined with the lack of subject experience in setting low capacity targets, these tit-for-tat dynamics did not lead to a lasting decrease in capacities and, to a large extent, undermined the benefits of capacity coordination. This suggests that even though tit-for-tat-type rules are widely used by inexperienced and experienced experimental subjects alike, the ability of these rules to generate beneficial outcomes depends on the sellers' abilities to set the correct targets. For sellers in the main treatments, who were quite experienced with the market by the time capacity coordination was introduced, ability to negotiate capacities did serve as a powerful coordination device, even though compliance with the agreements in the no punishment markets NegNoPun was relatively low (Result 6 above). Finally, we note that free-style communication was as effective in ensuring agreement compliance as the explicit punishment clause.

### Long-term effects and market convergence

To validate our findings for the long-run, we now evaluate the long-term effects of the institutional provisions. As behavior in most markets may not have stabilized either by the time of the shock in the pre-shock part of the session, or by the end of the session in the after-shock part, we estimate the long-term convergence levels for capacities and prices. Because we observed substantial variation across the 64 independent experimental markets, here we focus on market-level analysis, and evaluate each market against the alternative theoretical benchmarks of interest. This allows us to study within-treatment market heterogeneity and evaluate predictive power of the three alternative theoretical benchmarks: Bertrand, Cournot and Monopoly. It also allows us to better approximate the behavior of oligoplists with long-term experience with the industry, and evaluate the likely long-term differences between institutions of interest.

The following model, adopted from Noussair et al. (1995), is used to analyze the effect of time on the outcome variable (capacity or price) within each treatment and time interval (before or after the shock):

$$y_{it} = \sum_{i=1}^{N} (B_{0i}(1/t) + B_{1i}(t-1)/t)D_i + u_{it}, \tag{6}$$

where $i = 1, .., N$, is the market index, with $N$ being the number of independent markets in a given treatment, and $t = 1, .., T_i$ is the period index, with $T_i$ being the number of period observations in a given market. $D_i$ is the dummy variable for market $i$. Coefficients $B_{0i}$ estimate market-specific starting levels for the variable of interest, whereas $B_{1i}$ is the market-specific asymptote for the dependent variable. The error term $u_{it}$ is assumed to be distributed normally with mean zero. We allowed for different estimates for before-the-shock time interval (periods 1-21)[21] and after-the-shock interval (periods from 25, after capacity coordination had started in the corresponding treatments, until the end) to accommodate for possible changes in convergence processes, as all three theoretical models predict changes in convergence levels after the shock. We performed panel regressions using feasible generalized least squares estimation, allowing for panel-specific first-order autocorrelation within panels and heteroscedastisity across panels.

Based on the regression analysis, we classify whether capacities and prices in each market converge to Monopoly, Cournot or Bertrand equilibrium levels (pre-shock or post-shock, depending on the time interval), or in-between. The distributions of capacity and price asymptotes before and after the shock against the theoretical predictions, by treatments, are displayed in Figures 4-5.

FIGURES 4-5 AROUND HERE

More detailed results based on the panel regression analysis are presented in Table 9 (Capaci-

[21] Because of the shift in the market outcomes after the start of coordination in period 8 in the early coordination treatments, we only use the data from period 8 onwards for these treatments.

ties) and Table 10 (Prices) in Appendix C.[22] The convergence analysis results, as summarized in Figures 4-5 and Tables 9- 10, validate and strengthen our previous conclusions.

**Result 12** *There was considerable heterogeneity across markets both before and after the shock in all treatments. Before the shock, most of the markets without coordination were equilibrating towards levels between the Bertrand and Cornot predictions in both capacities and prices. In comparison, most of the early coordination markets with punishment were converging towards the Cournot or Monopoly levels.*

*Support:* Figures 4-5. Before the shock, in 29 markets out of 41 without coordination, capacity asymptotes exceeded the Cournot predictions, with 14 of them being no different than the Bertrand level. Likewise, in 27 out of 41 markets, the price asymptotes were below the Cournot level. However, 12 markets had capacity asymptotes at or below the Cournot level, and 14 markets had price asymptotes at or above the Cournot level. Two markets (market ID's 403 and 703) were able to achieve and sustain below-Cournot capacities and above-Cournot prices even without explicit coordination before the shock. In comparison, in the early coordination treatment with punishment (PreShockNegPun), seven out of 11 markets had capacity asymptotes at or below Cournot level, and six out of 11 markets had price asymptotes at or above the Cournot level before the shock. □

**Result 13** *Capacity asymptotes shifted down after the shock in most markets in all treatments. However, markets with capacity coordination were equilibrating towards Cournot or below-Cournot capacity levels more often than markets without capacity coordination.*

*Support:* Figures 4-5. In the baseline NoNegNoPun treatment, only 40% (4 out of 10) of the markets had after-shock capacity asymptotes at or below the Cournot level. Whereas in the three main capacity coordination treatments, 71.0% (or 22 out of 31) markets had asymptotes at or below the Cournot level. In the early coordination treatment with punishment (PreShockNegPun), 86% or markets (six out of seven) had capacities converging to the Cournot level or below. □

**Result 14** *Capacity coordination had a long-term pro-collusive effect on market prices: Without coordination, price asymptotes stayed the same or shifted down after the shock. Whereas with coordination, price asymptotes often shifted up after the shock, with prices in many markets converging to Monopoly level.*

*Support:* Figures 4-5. In the overwhelming majority of markets without coordination (9 out of of 10 markets), price asymptotes shifted down or stayed the same after the shock (Table 10);

[22]The tables display estimated asymptotes for each markets, along with $p$-values for the Wald test of their equivalence to the Monopoly, Cournot, and Bertrand predictions, for both before and after the shock time intervals. The tables also present the $p$-values for the equality of market asymptotes before and after the shock.

the price asymptote reached the monopoly level only in one market out of ten. However, in the main treatments with coordination after the shock, price asymptotes shifted up in 38.7% (12 out of 31) of markets; in 41.9% of these markets (13 markets out of 31), price asymptotes after the shock were no different from the Monopoly level. In early coordination treatments, the prices were converging to Monopoly level in 57% (four out of seven) of markets in PreShockNegPun treatment with punishment, and in 25% (three out of 12) of markets in PreShockNegNoPun treatment without punishment. □

**Result 15** *Among all treatments, the NegChat treatment that allowed free-style negotiations in addition to structured capacity coordination, and the early coordination treatment PreShockNegPun with punishment, resulted in the highest share of markets converging to monopoly outcomes.*

*Support:* Figures 4-5. In NegChat treatment, 80% (or 8 out of 10) of markets were converging to Cournot or above price levels, with 50% (or 5 out of 10) of markets converging to Monopoly pricing. In PreShockNegPun treatment, 71% (five out of 7) of the markets were converging to above-Cournot price levels, with 57% (four out of seven) converging to the Monopoly level. This compares to only 10% (1 out of 10) of markets converging to Monopoly prices in no negotiations NoNegNoPun markets. However, both NegNoPun and NegPun markets also had a significant proportion of markets (40% and 45%, respectively) converging to monopoly pricing. □

# 4 Discussion

This study provides us with a number of compelling results suggesting likely effects of capacity coordination on industry performance. Even though many subjects in our experiments tend to invest in excess capacity, the subjects quickly reduce capacity in response to a demand reduction in all treatments. This presents evidence that cost-cutting capacity reduction in industries in crisis can occur even if firms are unable to coordinate the reductions explicitly. However, we do observe that explicit capacity coordination results in a faster and larger reduction of market capacity following a demand shock, and a faster recovery of firm profits after the shock.

Further, our laboratory evidence clearly supports the conclusions of Blair et. al. (2007) and Kamita (2010) that the anti-trust exemptions have a pro-collusive effect, allowing prices to quickly return to pre-shock levels and then even rise above those levels despite a decrease in demand. The corresponding ability of capacity coordination to bring prices to monopoly levels in many markets suggests that anti-trust exemptions are likely to have a detrimental effects on consumer welfare.[23]

[23] In a study of cooperation spillovers and price competition in experimental markets, Cason and Gangadharan (2010) find that coordination on the cost-reduction investments has little anti-competitive effect on prices in the final market. Their finding seems at odds with our present finding. However, there are at least two differences between Cason and Gangadharan and our study. First, there may be a more obvious connection between capacities and prices

We find that the explicit punishment mechanism plays an especially critical role in establishing and enforcing capacity agreements for sellers who have little experience with the markets (as in our early coordination treatments). For the sellers who, just as real-world sellers, go through many periods of uncoordinated markets before given a chance to coordinate capacities (as in our main coordination treatments), the explicit punishment clause appears less critical, at least in the short-run. The ability to coordinate capacity, supplemented by the repeated nature of the markets, may be sufficient to establish collusive practices, rendering explicit punishment mechanisms superfluous. In addition, we find that free-style communication which supplements the structured negotiations may benefit the sellers even further; our experimental markets with free-style communication resulted in a higher share of monopoly outcomes than any other institution.

The finding that free-style communication does at least as well or better than explicit agreement enforcement may be somewhat surprising.[24] Yet, it is well in line with the existing experimental literature, which presents ample evidence that free-style non-binding communication often leads to increased cooperation (Holt, 1995). A likely reason, in view of the findings in behavioral economics, is that communication helps to "break the ice" and reduce social distance among competitors. Armstrong and Huck (2010) point out that an implication for competition policy is that communication may foster a sense of loyalty and trust among firms, making it socially costly to cheat on agreements. Armonstrong and Huck propose further that face-to-face communication seems to foster collusion in the laboratory more effectively than computer-mediated communication. Our experiments suggest that computer-mediated structured negotiations, supplemented by on-line chat, may be sufficient to resolve coordination problems and establish trust among firms.

It may also be surprising that not all sellers in our experiment were able to take full advantage of coordination opportunities, with, at most, half of all markets converging to monopoly outcomes. This result is, again, well in line with previous market experiments. Holt (1995) concludes that the effectiveness of non-binding communication in experimental markets is variable and sensitive to many factors, including the trading institution and the participants' incentives to defect. Andersson and Wengstroem (2007) report that when given a chance to costlessly communicate by computer in a repeated Bertrand duopoly, subjects exchanged messages frequently, but they had difficulties in maintaining collusive agreements. The two-stage Kreps and Sheinkman (1993) duopoly that we study is arguably more complicated than Bertrand price-setting duopoly; we therefore consider the observed 50% perfect collusion rate quite high.

It is notable that we obtain convincing evidence on the effects of capacity coordination on industry outcomes despite the rather complex nature of the institution and the lack of experience

in the Kreps and Scheinkman duopoly, whereas the connection between cost-reduction investments and pricing in the final market in the Cason and Gangadharan study may be less obvious to the subjects. Second, Cason and Gangadharan employ the double-auction institution, which is often considered collusion-proof.

[24]We are grateful to Rene Kamita for pointing this out.

of our experimental subjects. One would expect the effects of capacity coordination to be even more pronounced with experienced and highly motivated sellers. For this reason, we believe that these experimental results, along with already existing empirical evidence, may have strong implications for real-world industry practices.

Our findings suggest that capacity coordination may not be necessary to reduce capacities even in industries in crises. Such conclusions should be drawn with some cautions though, as they may be sensitive to the severity of the demand shock. In addition, cost structures in real-world industries with advanced capacity settings may be more complex than in our experiment and involve high fixed costs (other than capacity costs). Such high fixed costs may create extra difficulties for the firms in industries in crises; capacity coordination may then help such firms to sustain a certain level of profitability and avoid bankruptcies. Our experiments show, however, that persistent losses and firm bankruptcies are unlikely to be solely due to excess capacities, as firms are able to quickly reduce capacities even in the markets with no capacity coordination. Further, a common justification of antitrust immunity is that capacity coordination is imperfect and consumers are still better off than under monopoly. Our results demonstrate that some duopolists are able to reduce their capacities to monopoly levels and set monopoly prices given an opportunity to coordinate capacities. Thus capacity coordination by duopolists could potentially harm consumers as much as one firm going bankrupt, and the other firm becoming the monopolist. And beyond doubt, we find that allowing coordination harms consumers conditional on both firms surviving in the market.

**Appendix A: Instructions and Quiz**

**Appendix B: Subject decision screen: price-setting stage**

**Appendix C: Additional Tables**

TABLES 7-10 HERE

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## List of Tables



## List of Figures

TABLE 1. Summary of Experimental Sessions

| Treatment | Session ID | Session Date | Location | No. of Markets | No. Paid Periods** | Quiz? |
|---|---|---|---|---|---|---|
| *Main treatments: No Negotiations and After-shock Negotiations* | | | | | | |
| No Negotiation No Punishment (NoNegNoPun) | 1 | 5/4/2007 | UHM | 2 | 35 | N |
| | 4 | 5/22/2007 | UHM | 4 | 40 | Y |
| | 12 | 6/10/2010 | UAA | 4 | 39 | Y |
| Negotiation with Punishment (NegPun) | 2 | 5/10/2007 | UHM | 2 | 39 | N |
| | 3 | 5/18/2007 | UHM | 3 | 39 | N |
| | 5 | 5/23/2007 | UHM | 3 | 39 | Y |
| | 10 | 6/3/2010 | UAA | 3* | 39 | Y |
| Negotiation w/o Punishment (NegNoPun) | 6 | 5/24/2007 | UHM | 4 | 39 | Y |
| | 9 | 4/27/2010 | UAA | 2 | 39 | Y |
| | 11 | 6/9/2010 | UAA | 4 | 39 | Y |
| Negotiation w/o Punishment, with Chat (NegChat) | 7 | 9/28/2007 | UHM | 5 | 36 | Y |
| | 8 | 10/3/2007 | UHM | 2 | 39 | Y |
| | 13 | 6/17/2010 | UAA | 3 | 39 | Y |
| No. of markets, main treatments | | | | 41 | | |
| *Additional treatments: Pre-shock Negotiations* | | | | | | |
| Pre-shock Negotiations with Punishment (PreshockNegPun) | 15 | 4/21/2011 | UAA | 3 | 31 | Y |
| | 17 | 4/27/2011 | UAA | 4 | 39 | Y |
| | 18 | 4/28/2011am | UHM | 4 | 24 | Y |
| Pre-shock Negotiations w/o Punishment (PreshockNegNoPun) | 14 | 4/15/2011 | UAA | 3* | 39 | Y |
| | 16 | 4/26/2011 | UHM | 2 | 39 | Y |
| | 19 | 4/28/2011pm | UHM | 4 | 31 | Y |
| | 20 | 5/12/2011 | UAA | 4 | 39 | Y |
| No. of markets, additional treatments | | | | 23 | | |
| Total No. of markets | | | | 64 | | |

*Sessions 10 and 14 originally had four independent markets each, but one market in each session was excluded due to bankruptcies

**In treatments with negotiations, one unpaid instructional/trail period (period 25 in after-shock negotiations treatments and period 7 in pre-shock negotiations treatments) preceeded negotiations periods

TABLE 2. Average Total Market Capacity Before and After the Shock, physical units

| *Benchmark Predictions:* | | VERY EARLY: Per 1-7 | EARLY BEFORE: Per. 8-14 | BEFORE SHOCK: Per. 15-21 | SHOCK: Per. 22-24 | EARLY AFTER: Per. 25-31 | LATE AFTER: Per. 32-end |
|---|---|---|---|---|---|---|---|
| Monopoly | | 132 | 132 | 132 | 108 | 108 | 108 |
| Cournot | | 176 | 176 | 176 | 144 | 144 | 144 |
| Bertrand | | 264 | 264 | 264 | 216 | 216 | 216 |
| *Main treatments: No Negotiations and After-shock Negotiations* | | | | | | | |
| *NoNegNoPun (10 obs)* | *Mean* | 238.87 | 227.74 | 234.56 | 205.50 | 184.20 | 169.90 |
| | *Standard Deviation* | (56.29) | (52.31) | (49.63) | (58.50) | (42.24) | (34.70) |
| *NegPun (11 obs)* | *Mean* | 211.60 | 221.35 | 227.61 | 198.58 | 143.78 | 145.65 |
| | *Standard Deviation* | (50.28) | 53.78 | 81.99 | 52.15 | 33.59 | 33.92 |
| *NegNoPun (10 obs)* | *Mean* | 278.21 | 277.71 | 234.24 | 211.87 | 146.64 | 161.19 |
| | *Standard Deviation* | (119.56) | (74.27) | (52.83) | (54.04) | (38.86) | (68.35) |
| *NegChat (10 obs)* | *Mean* | 250.79 | 254.49 | 230.36 | 212.13 | 178.61 | 144.92 |
| | *Standard Deviation* | (76.52) | (77.48) | (51.52) | (42.82) | (65.64) | (54.40) |
| *Additional treatments: Pre-shock Negotiations* | | | | | | | |
| *PreShockNegPun (11 obs*)* | *Mean* | 266.12 | 204.21 | 187.26 | 162.58 | 128.39 | 127.03 |
| | *Standard Deviation* | (93.07) | (81.01) | (37.18) | (41.57) | (23.32) | (41.73) |
| *PreShockNegNoPun (12 obs**)* | *Mean* | 277.17 | 226.43 | 254.02 | 211.06 | 199.96 | 183.67 |
| | *Standard Deviation* | (61.24) | (65.62) | (51.92) | (51.63) | (69.98) | (59.12) |

*As some sessions in this treatment did not complete all periods because of time constraints, there are only 7 observations for Periods 25-31, and 4 observations for Periods 32-end

**As some sessions in this treatment did not complete all periods because of time constraints, there are only 8 observations for Periods 32-end

TABLE 3. Average Transaction Price Before and After the Shock, experimental dollars

| *Benchmark Predictions:* | | VERY EARLY: Per 1-7 | EARLY BEFORE: Per. 8-14 | BEFORE SHOCK: Per. 15-21 | SHOCK: Per. 22-24 | EARLY AFTER: Per. 25-31 | LATE AFTER: Per. 32-end |
|---|---|---|---|---|---|---|---|
| Monopoly | | 43 | 43 | 43 | 37 | 37 | 37 |
| Cournot | | 32 | 32 | 32 | 28 | 28 | 28 |
| Bertrand | | 10 | 10 | 10 | 10 | 10 | 10 |
| *Main treatments: No Negotiations and After-shock Negotiations* | | | | | | | |
| *NoNegNoPun (10 obs)* | *Mean* | 23.78 | 25.08 | 25.63 | 23.47 | 22.21 | 25.22 |
| | *Standard Deviation* | (6.28) | (8.60) | (7.70) | (9.72) | (7.46) | (6.21) |
| *NegPun (11 obs)* | *Mean* | 29.51 | 27.06 | 27.29 | 21.54 | 29.64 | 28.26 |
| | *Standard Deviation* | (6.08) | (6.16) | (9.01) | (5.73) | (6.88) | (7.77) |
| *NegNoPun (10 obs)* | *Mean* | 25.22 | 23.97 | 24.16 | 21.49 | 29.82 | 28.56 |
| | *Standard Deviation* | (7.67) | (5.59) | (9.15) | (7.15) | (6.61) | (8.84) |
| *NegChat (10 obs)* | *Mean* | 24.20 | 24.50 | 24.96 | 20.54 | 26.50 | 31.81 |
| | *Standard Deviation* | 9.12 | (9.84) | (8.17) | (5.75) | (9.38) | (9.34) |
| *Additional treatments: Pre-shock Negotiations* | | | | | | | |
| *PreShockNegPun (11 obs*)* | *Mean* | 25.04 | 32.56 | 31.54 | 25.62 | 33.41 | 33.26 |
| | *Standard Deviation* | (6.86) | (8.01) | (6.55) | (7.55) | (4.72) | (8.05) |
| *PreShockNegNoPun (12 obs**)* | *Mean* | 20.55 | 23.82 | 22.28 | 21.56 | 21.71 | 22.59 |
| | *Standard Deviation* | (7.89) | (8.77) | (7.60) | (8.02) | (9.20) | (6.91) |

*As some sessions in this treatment did not complete all periods because of time constraints, there are only 7 observations for Periods 25-31, and 4 observations for Periods 32-end

**As some sessions in this treatment did not complete all periods because of time constraints, there are only 8 observations for Periods 32-end

TABLE 4. Subject Per Period Profits Before and After the Shock, experimental dollars

| | | VERY EARLY: Per 1-7 | EARLY BEFORE: Per. 8-14 | BEFORE SHOCK: Per. 15-21 | SHOCK: Per. 22-24 | EARLY AFTER: Per. 25-31 | LATE AFTER: Per. 32-end |
|---|---|---|---|---|---|---|---|
| *Benchmark Predictions:* | | | | | | | |
| Monopoly | | 2178 | 2178 | 2178 | 1458 | 1458 | 1458 |
| Cournot | | 1936 | 1936 | 1936 | 1296 | 1296 | 1296 |
| Bertrand | | 0 | 0 | 0 | 0 | 0 | 0 |
| *Main treatments: No Negotiations and After-shock Negotiations* | | | | | | | |
| *NoNegNoPun (10 obs)* | *Mean* | 850.89 | 1133.87 | 1142.97 | 568.83 | 675.02 | 930.94 |
| | *Standard Deviation* | (543.52) | (603.50) | (628.93) | (516.68) | (512.69) | (426.23) |
| *NegPun (11 obs)* | *Mean* | 1188.26 | 1260.54 | 1261.85 | 648.06 | 1118.41 | 1122.80 |
| | *Standard Deviation* | (406.08) | (579.74) | (830.16) | (483.82) | (346.21) | (363.97) |
| *NegNoPun (10 obs)* | *Mean* | 686.98 | 781.16 | 1049.98 | 440.40 | 1021.18 | 855.34 |
| | *Standard Deviation* | (1093.82) | (701.91) | (555.12) | (525.43) | (311.82) | (509.69) |
| *NegChat (10 obs)* | *Mean* | 819.24 | 897.57 | 1091.24 | 502.57 | 716.70 | 1066.46 |
| | *Standard Deviation* | (822.48) | (844.78) | (580.23) | (342.83) | (631.38) | (439.37) |
| *Additional treatments: Pre-shock Negotiations* | | | | | | | |
| *PreShockNegPun (11 obs*)* | *Mean* | 783.65 | 1383.96 | 1601.04 | 818.88 | 1181.81 | 1263.39 |
| | *Standard Deviation* | (664.80) | (635.26) | (437.96) | (500.35) | (224.34) | (237.70) |
| *PreShockNegNoPun (12 obs**)* | *Mean* | 506.59 | 821.71 | 823.89 | 452.67 | 533.93 | 682.01 |
| | *Standard Deviation* | (657.71) | (531.58) | (581.89) | (477.27) | (585.11) | (474.41) |

*As some sessions in this treatment did not complete all periods because of time constraints, there are only 7 observations for Periods 25-31, and 4 observations for Periods 32-end

**As some sessions in this treatment did not complete all periods because of time constraints, there are only 8 observations for Periods 32-end

TABLE 5: Summary of Capacity Negotiations in Markets with Free-Style Chat

| Session location | Market ID | Range of Neg/chat periods | No. of Chat periods | No. of periods chat used | First period chat used | Last period chat used | Capacity discussed? | Agreed-upon capacity mean (stddv) | Actual p/p capacity mean (stddv) | Summary of Chat content |
|---|---|---|---|---|---|---|---|---|---|---|
| UHM | 701 | 25-38 | 12 | 12 | 25 | 38 | yes | 101.25 (22.48) | 85.21 (29.48) | Tried to implement a rotation shceme that only worked in the last 2 periods |
| UHM | 702 | 25-38 | 12 | 12 | 25 | 38 | yes | 112.27 (15.71) | 101.25 (21.33) | Chose too high a capacity of 120 per person, only lowered capacity in the last 2 periods |
| UHM | 703 | 25-38 | 12 | 5 | 26 | 35 | yes | 63.75 (11.51) | 60.04 (4.92) | First time chat was used (period 26), agreed on a low capacity of 60 |
| UHM | 704 | 25-38 | 12 | 0 | n/a | n/a | n/a | 158.00 (58.08) | 137.63 (24.90) | Chat was not used, capacity set too high |
| UHM | 705 | 25-38 | 12 | 12 | 25 | 38 | no | 50.60 (34.57) | 55.71 (45.22) | Did not discuss capacity or price, but still set low capacity |
| UHM | 801 | 25-39 | 15 | 6 | 26 | 37 | yes | 60.00 (0.00) | 57.27 (8.62) | Agreed on capacity of 60 in period 27; later used chat to confirm that this level worked well |
| UHM | 802 | 25-39 | 15 | 0 | n/a | n/a | n/a | 57.33 (15.45) | 69.97 (9.38) | No chat, noisy capacity negotiations with frequent deviations |
| UAA | 1301 | 25-39 | 15 | 2 | 26 | 34 | yes | 130.50 (68.72) | 114.27 (30.13) | Only used chat in 2 periods. Capacity set was highly variable and too high |
| UAA | 1302 | 25-39 | 15 | 2 | 25 | 30 | yes | 53.33 (10.47) | 52.10 (10.60) | Negotiated effectively without chat. Used chat to restate capacity proposals in two periods only. |
| UAA | 1303 | 25-39 | 15 | 4 | 25 | 34 | yes | 84.00 (55.27) | 81.13 (55.49) | Did not use chat much. Agreed on capacity of 50 only in period 34. |

*In market 701, specific capacity was not agreed upon in 4 negotiations periods

TABLE 6. Share of individual capacity choices consistent with behvaioral rules before, during and after the shock, by treatment*

| *Benchmark Predictions:* | | *No of obs* | To Mono-poly | To Cournot | To Bert-rand | Cournot Best Res-ponse | TFT other's capa-city | TFT agree-ment | Agree-ment compli-ance |
|---|---|---|---|---|---|---|---|---|---|
| *NoNegNoPun* | *Before* | 272 | 0.463 | 0.426 | 0.441 | 0.346 | **0.507** | n/a | n/a |
| | *Shock* | 60 | 0.433 | 0.383 | 0.350 | 0.350 | **0.500** | n/a | n/a |
| | *After* | 300 | 0.410 | 0.383 | 0.317 | 0.350 | **0.510** | n/a | n/a |
| *NegPun* | *Before* | 308 | 0.416 | 0.484 | 0.448 | 0.383 | **0.510** | n/a | n/a |
| | *Shock* | 66 | 0.470 | 0.485 | 0.379 | 0.455 | **0.500** | n/a | n/a |
| | *After* | 330 | 0.452 | 0.385 | 0.348 | 0.291 | 0.479 | 0.818 | **0.879** |
| *NegNoPun* | *Before* | 280 | 0.425 | 0.439 | **0.486** | 0.364 | 0.432 | n/a | n/a |
| | *Shock* | 60 | 0.517 | **0.533** | 0.467 | **0.533** | 0.450 | n/a | n/a |
| | *After* | 300 | 0.513 | 0.490 | 0.470 | 0.387 | 0.487 | **0.630** | 0.620 |
| *NegChat* | *Before* | 280 | 0.486 | 0.496 | **0.525** | 0.386 | 0.486 | n/a | n/a |
| | *Shock* | 60 | **0.450** | 0.383 | 0.283 | 0.417 | 0.333 | n/a | n/a |
| | *After* | 270 | 0.437 | 0.419 | 0.396 | 0.330 | 0.519 | 0.837 | **0.852** |
| *PreShockNegPun* | *Before* | 308 | 0.549 | 0.571 | 0.490 | 0.477 | 0.474 | 0.860 | **0.922** |
| | *Shock* | 66 | 0.576 | 0.500 | 0.318 | 0.515 | 0.364 | 0.924 | **0.955** |
| | *After* | 184 | 0.467 | 0.326 | 0.332 | 0.326 | 0.560 | 0.918 | **0.962** |
| *PreShockNegNoPun* | *Before* | 332 | 0.440 | 0.482 | 0.554 | 0.401 | 0.419 | **0.690** | 0.648 |
| | *Shock* | 72 | 0.639 | 0.597 | 0.472 | 0.556 | 0.556 | **0.736** | 0.639 |
| | *After* | 312 | 0.452 | 0.417 | 0.462 | 0.378 | 0.423 | **0.721** | 0.715 |

*From Period 8 onwards.

Figure 1: Median market characteristics by period: No Negotiations compared to Negotiation treatments pooled

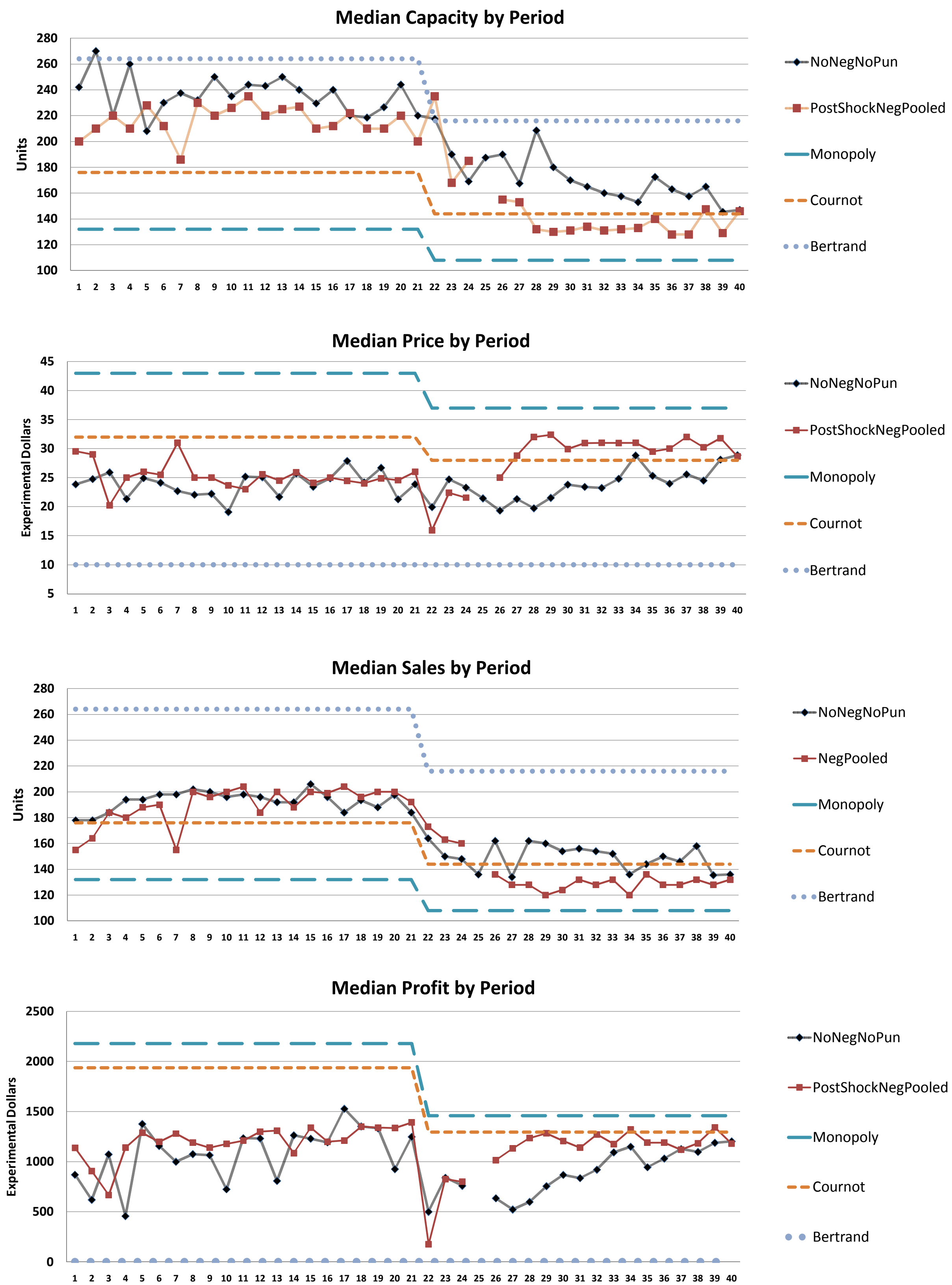


Figure 2: Median market characteristics by period, by treatment

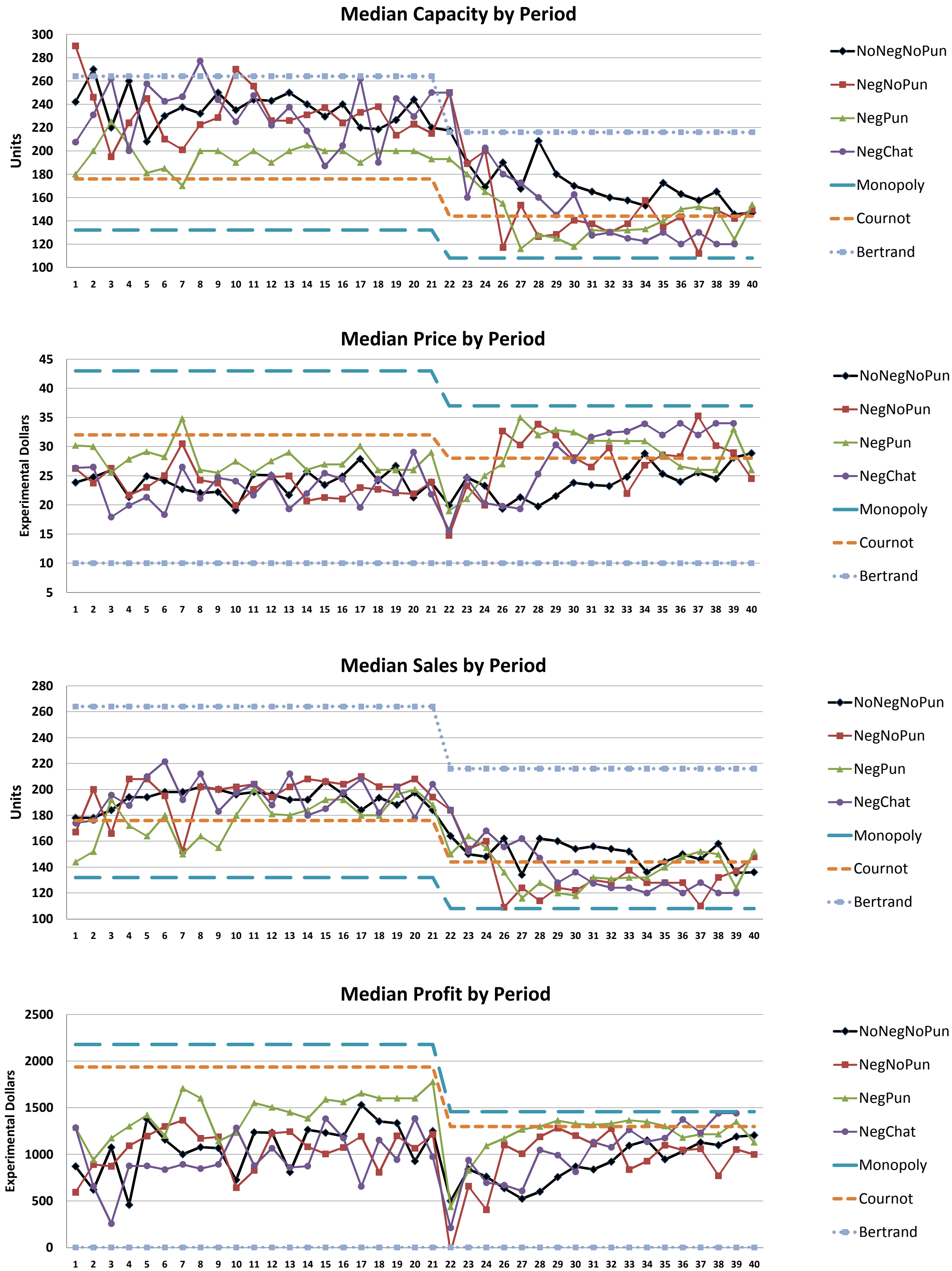


Figure 3: Median market characteristics in early negotiations treatments, by period

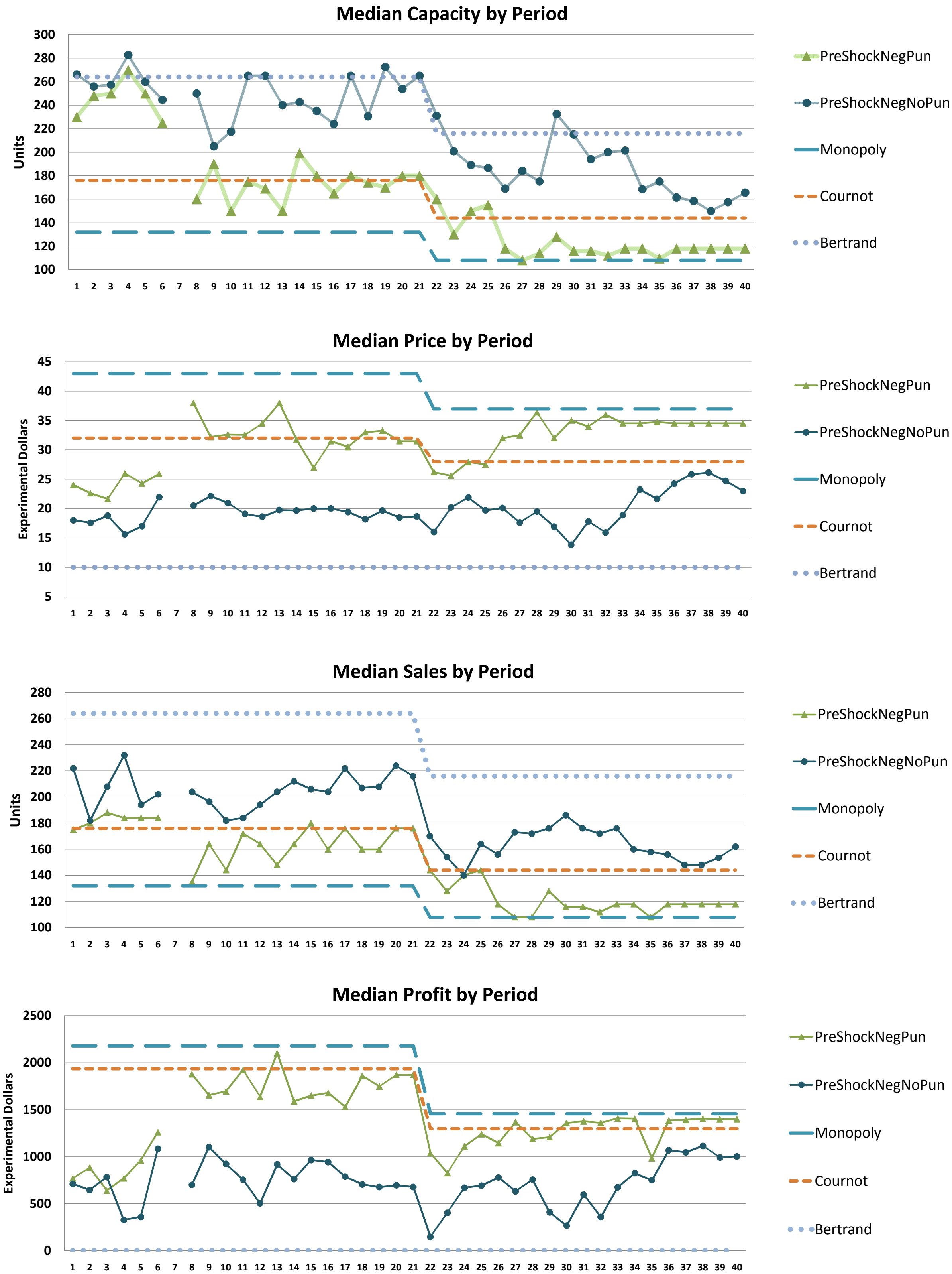


Figure 4: Capacity and Price Asymptotes Before and After Shock, Main Treatments

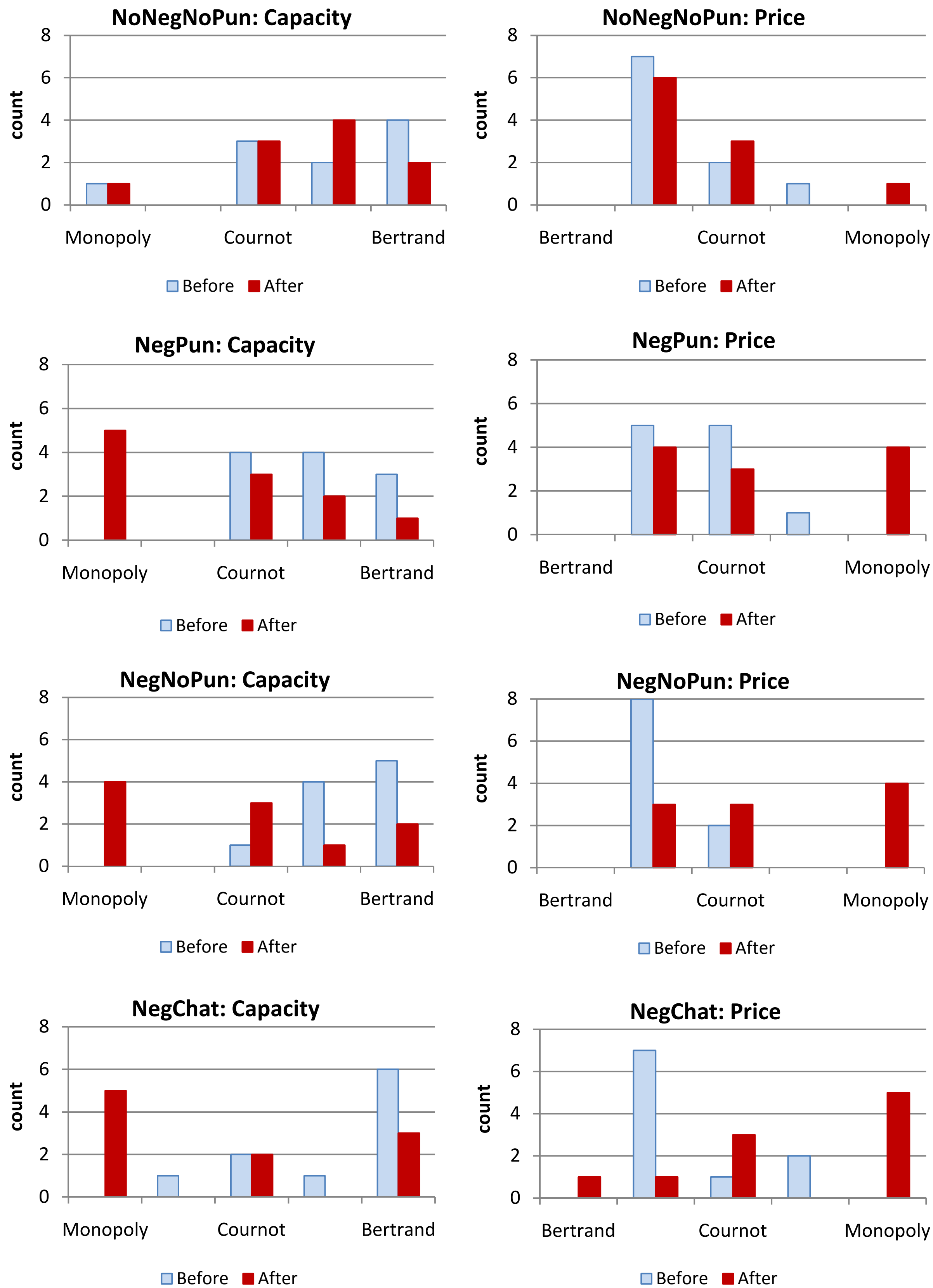
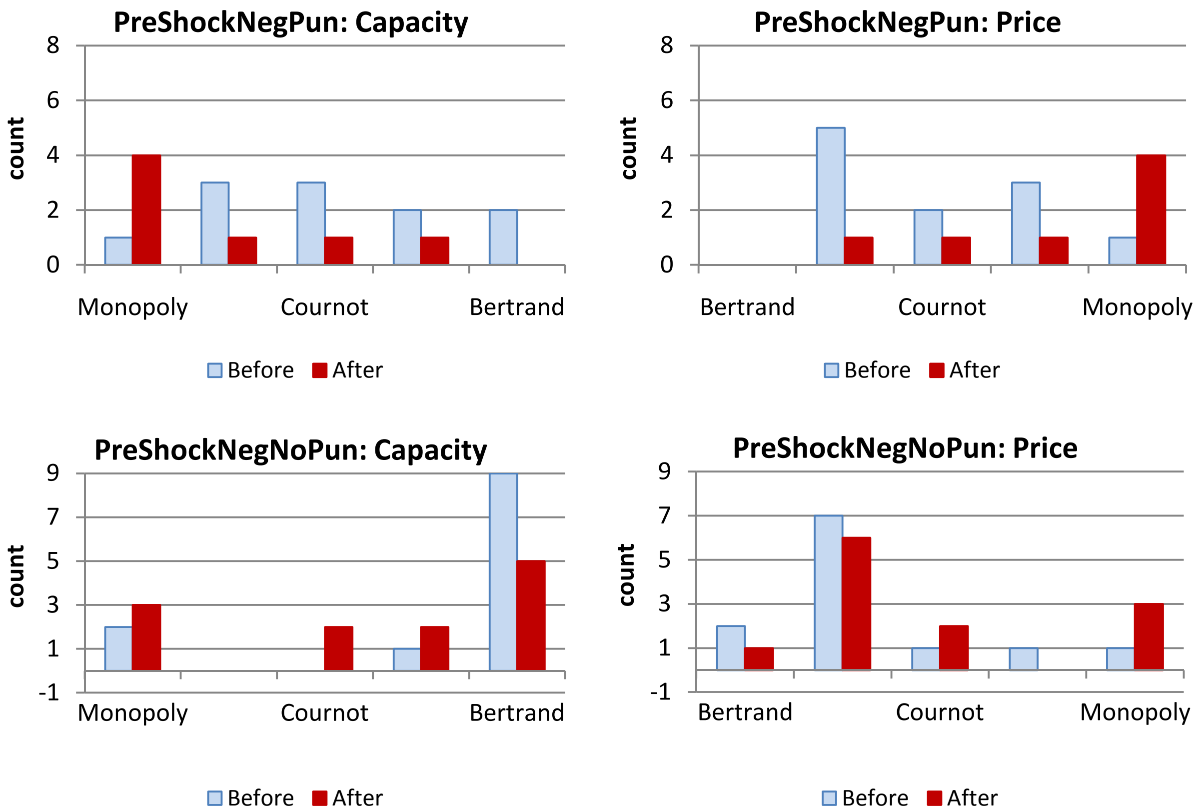


Figure 5: Capacity and Price Asymptotes Before and After Shock, Pre-Shock Negotiations Treatments



**Appendix A**

Experiment Instructions[1]

**Introduction**

You are about to participate in an experiment in the economics of market decision making in which you will earn money based on the decisions you make. All earnings you make are yours to keep and will be paid to you **IN CASH** at the end of the experiment.

During the experiment all units of account will be in experimental dollars. Upon concluding the experiment, you will paid **1** dollar in cash for every **1750** experimental dollars you earn in the experiment. Your cash earnings plus a show up payment of **5** dollars will be paid to you in private.

You will begin the experiment with 7500 experimental dollars. This is NOT part of your show-up payment.

Note your Current Earnings in the box at the top of the screen.

Do not communicate with the other participants except according to the specific rules of the experiment. If you have a question, feel free to raise your hand. An experimenter will come over to you and answer your question in private.

If you have any questions at this point, please raise your hand.

Click **Continue** when you are ready go on.

---

**Markets and Trading Periods**

In this experiment you are going to participate in a market in which you will be selling units of a fictitious good. At the beginning of the experiment, you will be assigned to a market with another participant. You will not be told which of the other participants is in your market. What happens in your market has no effect on the participants in other markets and vice versa.

You will remain in the same market with the same other seller until the end of the experimental session. This does not include trial periods. In trial periods, you may be matched with another individual.

In this experiment, you will be referred to by your seller ID number. Your seller number will be assigned to you by the computer and displayed to you in the upper left hand corner.

[1] Instructions were provided to the students in an interactive format via their computer terminals.

Production and trading in your market will occur in a sequence of independent market days or *periods*. The period number is also given in the upper left hand corner of the screen.

Unless you have questions, click **Continue** to go on.

---

**Decisions: Capacities and Prices**

Your earnings in each market period will depend on your and the other seller's *capacity* and *price* choices. This is how it works:

At the beginning of each period, you will be first asked to choose your capacity, which is the number of units you will produce. You will have the opportunity to change your capacity every period.

Both you and the other seller in your market will choose your capacities at the same time, without knowing the capacity chosen by the other.

As a seller, you will pay the cost of the units you produce (your capacity choice) <u>regardless of how many units you actually sell.</u> Your unit cost is **10 experimental dollars**, as given in the box at the top of the screen.

For example, if your produce 60 units, your total cost will be *60 * 10 = 600* experimental dollars.

Your *endowment* is a flat payment you receive each period regardless of your choices. The amount of the endowment is displayed under the unit cost.

**Example 1:** *(all numbers in the examples are hypothetical)*

As an example, enter 60 for your capacity. Click **OK** when you are done.

---

After all sellers make their capacity choices, the computer will display the sellers' capacity choices in your market, as well as the total market capacity. To illustrate, the computer shows that your capacity is 60, while other seller's capacity is 80, resulting in the total market capacity of *60 + 80 = 140* units.

After capacities are displayed, you (and other sellers in your market) will be asked to choose the price that you want to sell your goods for. You will choose your price without knowing the price chosen by the other seller.

**Computer Demand and Sales**

After the capacities and prices are chosen, the computer will buy goods from you and the other seller in your market. For each price, there is a maximum number of units that the computer will buy at this price, called *Computer Demand*. <u>The lower the price, the higher the number of goods demanded.</u>

The exact number of units the computer will demand (buy) at any price is given by the following expression:

*Units Bought = 304 - ( 4 * Price )*

You have a paper chart showing the computer demand at any price. This expression may change at any time. If it does, you will be informed.

The computer will always buy first from the seller offering the lowest price. It will buy as many units as it demands at this price, **or** until it exhausts the low price seller's capacity. If the computer can still buy more units after buying all the units produced by the first seller, it will then buy from the seller with the higher price until it satisfies all the demand at the higher price, **or** until it exhausts all the capacity of the high price seller.

To continue with our example, enter a price of 50 and click **OK** to continue.

---

Suppose the other seller charged a price of *55*. Because your price (50) is lower, the computer will buy your units first.

At a price of 50, the computer will buy all 60 units that you've produced. The total number the computer would be willing to buy at this price would be *304 - (4 * 50) = 104 units*. You can confirm this by looking at the demand chart provided to you. But since you've only produced 60, that is all that the computer purchases.

After buying all of your units, the computer would then consider how many more units to purchase at the higher price of 55 being offered by the other seller. At this price, the computer demands *304 - (4 * 55) = 84 units*. However, because the computer has already purchased 60 units from you, it will only purchase 84 - 60 = 24 units from the other seller.

Your earnings are equal to the difference between your revenue from sales and the cost of all the units you have produced, plus your endowment. That is:

***YOUR EARNINGS = YOUR REVENUE - TOTAL COST + ENDOWMENT***

Your revenue is equal to the price you charge times the number of units you sell at this price:

***YOUR REVENUE = YOUR PRICE * QUANTITY SOLD***

Your total cost is equal to per unit cost of production times the number of unit that you produce (your capacity):

***YOUR TOTAL COST = PER UNIT COST * YOUR CAPACITY***

In our example, if you produce 60 units at the unit cost of 10, and you sell all 60 units at the price of 50, then your revenue, cost and earnings are:

**YOUR REVENUE** = *(60 * 50) = 3000*
**YOUR TOTAL COST** = *60 * 10 = 600*
**YOUR EARNINGS** = *3000 - 600 + 50 = 2450*

When you understand these results, click **OK** to continue.

---

**Example 2:** *(all numbers in the examples are hypothetical)*

Alternatively, imagine the following situation:

Your Capacity: 200
Other's Capacity: 80

Your Price: 15
Other's Price: 15

If both sellers charge the same price, then the computer will buy an equal number of units from both buyers to the point where the computer's demand is satisfied. If the lower capacity seller sells every unit he or she produced and the computer still demands more, the computer will buy those units from the higher capacity seller until it has all the additional units it demands at the charged price **or** until they have purchased all of the additional units offered by the higher production seller.

In the above example, the computer demand at the price of 15 is *304 - (4 * 15) = 244 units*. Since both sellers are charging the same price, the computer will try to buy half of the demand, which is *244 / 2 = 122 units* from each seller. However, because the other seller's capacity is set to only 80 units, the computer will buy all 80 units from this seller, and the remaining *244 - 80 = 164 units* from you. Therefore, your earnings in this period will be:

***Earnings = (Price * Sales) + (Unit Cost * Capacity) + Endowment***

*= (15 * 164) - (10 * 200) + 50 = 2460 - 2000 + 50 = 510*

Click **OK** to continue.

---

**Example 3:** *(all numbers in the examples are hypothetical)*

Now suppose the capacity and price choices are as given below: \par \line \tab

Your Capacity: 80

Other's Capacity:  100

Your Price:  50
Other's Price:  20

In this example, the other seller is the low-price seller, so the computer will buy from that seller first. The computer demand at the low price of 20 is *304 - (4 * 20) = 224 units*, but since the other seller has only produced 100 units, the computer will buy all 100 units from this seller first.

To check whether the computer will buy any from you, note that at the price of 50 that you've charged, the computer demand is *304 - (4 * 50) = 104 units*. Since the computer has already bought 100 units from the other seller, it will buy *104 - 100 = 4 units* from you. Therefore, your earnings in this period will be:

***Earnings = (Price * Sales) - (Unit Cost * Capacity) + Endowment =***

***= (50 * 4) - (10 * 80) + 50 = 200 - 800 + 50 = -550***

Please click **OK** to continue.

---

**Calculator**

In order to help you determine the potential profits in light of the decisions of you and the other seller, you have access to the *Calculator* at all times.  This allows you to explore hypothetical situations before actually making your decisions.

You may want to try it out now.

**Example #4:**

Your Capacity:  80
Other's Capacity:  50
Your Price:  8
Other's Price:  30

**Example #5**

Your Capacity:  120
Other's Capacity:  50
Your Price:  46
Other's Price:  38

This process will continue for a number of periods. A history window at the bottom of your screen will allow you to keep track of capacity choices, price choices, and the resulting profits from all of the previous periods. You may scroll up and down the history window.

The next period will be a trial period. It will not count towards your earnings. After you feel satisfied you understand the experiment, click **Continue** to finish the instructions.

---

[The following instructions were presented to subjects in period 25 in the capacity negotiation treatments.]

**Capacity Coordination**

In this portion of the experiment, you and the other seller in your market will have the opportunity to coordinate your capacities prior to setting them. Each of you will have the ability to propose a **CAPACITY FOR EACH SELLER** in your market. For example, if you propose a capacity of 150, it means that the total proposed capacity in your market is 2 sellers * 150 units each = 300 units. You can change this proposal as many times as you like during this coordination stage.

When you propose a capacity setting, the other seller sees your proposal and vice versa. During this stage, you can change your proposal as many times as you like. When you change your proposal, the other seller sees that change in real time.

Try entering a number of capacity proposals now to see how it works.

At any point during this stage, you or the other seller can end the stage by clicking **Accept Proposal.** This accepts the most recent capacity proposal of the other seller and becomes a capacity agreement between the two of you. Be careful when you choose to accept a proposal. It can be changed at any time up until the moment you click the button.

If the time elapses in this stage without either seller clicking **Accept Proposal**, there is no capacity agreement for the period.

Feel free to coordinate a capacity agreement now. The next stage starts after you or the other seller in your market accepts a proposal, or time elapses.

Please note that your decisions in this period will not affect your earnings. This period is for instruction alone.

---

**Decisions**

After you agree on the capacity, the agreed capacity will be shown as in the box to the right.

The experiment will then proceed as before. You will be asked to enter your capacity choice, and then your price. Note that in your capacity choice **YOU ARE NOT CONSTRAINED TO ADHERE TO THE CAPACITY AGREEMENT**. You may enter whatever capacity you wish.

[The following text only appears in the instructions for the punishment treatments]

However, if you choose to exceed the agreed capacity, *you will be liable to pay a penalty of 7 experimental dollars per unit of capacity you produce over the agreed amount.* This penalty will be added to the earnings of the other seller in your market.

Likewise, if the other seller exceeds the agreed capacity, they will pay a penalty to you. If both of you exceed the agreed capacity, the penalties will offset with the actual transfer of money depending on the relative sizes of the excess capacities.

[end condition]

Enter your capacity choice now.

---

Then enter a price.

---

The results screen will then indicate your price, sales and costs, as well as whether you have exceeded the agreed upon capacity, and will calculate your resulting earnings.

[The following text only appears in the instructions for the punishment treatments]

Note that, in addition to your normal earnings, you may also receive and/or pay a penalty based on your capacity decisions relative to the agreed capacity.

If neither of you had exceeded the agreed capacity, neither of you would have to pay a penalty.

Also note that your calculator will **NOT** include penalties in its calculation of profit.

[end condition]

Please note that, in future rounds, you will be matched with the same other seller as you were in previous rounds. These future rounds count toward your earnings.

If you are ready to proceed, click **OK**.

---

Quiz

EXERCISES

**Use the calculator to answer the following questions.**
Suppose yours and the other seller's capacity and price choices are as suggested in Example 4:

Your capacity: 80
Other's Capacity: 50
Your price: 8
Other's price: 30

1.1 Will the computer buy from you or the other seller first? (Check one)
_____ you; _____ other seller

1.2 What are your sales? ____ Do you sell all your capacity? ______ yes; _____ no

1.3 What are your earnings? ____ Do you earn or lose money? _____earn; ____ lose

1.4 Suppose the capacity choices and the other seller's price stay unchanged. Suppose you could change the price, calculate how your earnings for each of the following price choices:

Price:__ $5experimental; Your Earnings: __________
Price:__ 10 experimental; Your Earnings: __________
Price:__ 20 experimental; Your Earnings: __________
Price:__ 30 experimental; Your Earnings: __________
Price:__ 40 experimental; Your Earnings: __________
Price:__ 50 experimental; Your Earnings: __________
Price:__ 100 experimental; Your Earnings: _________

1.5 From Question 1.4 above, what would be the lowest price that would allow you not to lose money? _____

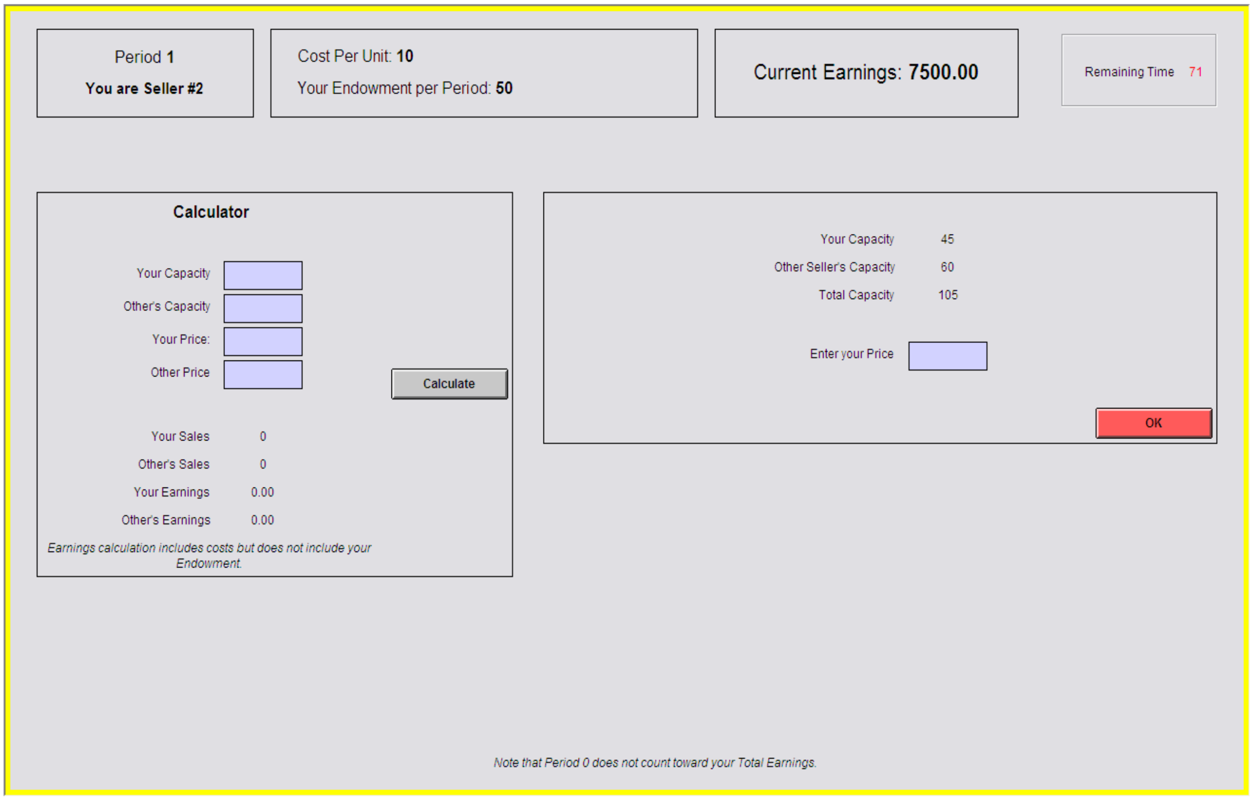
1.6 From Question 1.4 above, at which price will you earn the most money?

The price is: _______ Your earnings will be equal to ___________

1.7 Suppose now that you choose the price that allows you to earn most money, as in question 1.6 above. (Suppose, as before, that the capacity and price choices of the other sellers stay unchanged.) Given this price, how can you change your capacity to increase your earnings?
Price: _____ New capacity: _____ Your earnings: ___________

**Are there any questions?**

Appendix B: Subject decision screen: price-setting stage



## Appendix C: Additional Tables

**Table 7: Treatment effects: Cross-sectional time-series generalized least squares regressions**

| | Market Capacity | | | Average trading price | | | Average seller profit | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | P>z | Coef. | Std. Err. | P>z | Coef. | Std. Err. | P>z |
| Constant | 246.57 | *(7.45)* | 0.000 | 23.71 | *(0.88)* | 0.000 | 877.79 | *(72.84)* | 0.000 |
| NegNoPun | 6.36 | *(14.78)* | 0.667 | 3.00 | *(1.66)* | 0.071 | 59.61 | *(133.82)* | 0.656 |
| NegPun | -51.41 | *(10.24)* | 0.000 | 7.70 | *(1.42)* | 0.000 | 465.05 | *(105.35)* | 0.000 |
| NegChat | -8.43 | *(13.53)* | 0.533 | 2.11 | *(1.83)* | 0.248 | 35.55 | *(140.07)* | 0.800 |
| PreNegNoPun | 27.43 | *(13.60)* | 0.044 | -4.14 | *(1.72)* | 0.016 | -336.92 | *(127.25)* | 0.008 |
| PreNegPun | 5.75 | *(11.73)* | 0.624 | 2.68 | *(1.58)* | 0.090 | 7.73 | *(112.92)* | 0.945 |
| Periods8-21,NoNegNoPun | -9.56 | *(7.83)* | 0.222 | 1.42 | *(0.93)* | 0.126 | 235.56 | *(82.67)* | 0.004 |
| Periods8-21,NegNoPun | 2.33 | *(13.86)* | 0.866 | -3.31 | *(1.55)* | 0.033 | 42.81 | *(125.79)* | 0.734 |
| Periods8-21,NegPun | 1.69 | *(7.65)* | 0.825 | -2.31 | *(1.18)* | 0.050 | 171.28 | *(85.87)* | 0.046 |
| Periods8-21,NegChat | -1.89 | *(10.67)* | 0.860 | 0.61 | *(1.53)* | 0.693 | 138.62 | *(117.28)* | 0.237 |
| Periods8-21,PreNegNoPun | -38.32 | *(12.03)* | 0.001 | 2.59 | *(1.38)* | 0.060 | 190.02 | *(114.18)* | 0.096 |
| Periods8-21,PreNegPun | -57.39 | *(9.86)* | 0.000 | 6.96 | *(1.41)* | 0.000 | 693.52 | *(96.54)* | 0.000 |
| Shock | -32.57 | *(10.23)* | 0.001 | -2.03 | *(1.22)* | 0.096 | -285.25 | *(110.17)* | 0.010 |
| Shock, NegNoPun | 17.48 | *(20.91)* | 0.403 | -6.35 | *(2.38)* | 0.008 | -362.38 | *(200.06)* | 0.070 |
| Shock, NegPun | 23.78 | *(14.35)* | 0.098 | -4.57 | *(1.97)* | 0.020 | -225.32 | *(158.77)* | 0.156 |
| Shock, NegChat | 12.51 | *(17.35)* | 0.471 | -2.30 | *(2.35)* | 0.329 | -392.21 | *(189.10)* | 0.038 |
| Shock,PreNegNoPun | -26.33 | *(18.79)* | 0.161 | 0.57 | *(2.18)* | 0.794 | 49.67 | *(186.42)* | 0.790 |
| Shock,PreNegPun | -49.58 | *(16.63)* | 0.003 | 2.60 | *(2.23)* | 0.244 | 286.55 | *(169.59)* | 0.091 |
| After shock | -56.52 | *(10.02)* | 0.000 | -0.43 | *(1.18)* | 0.715 | -46.26 | *(99.94)* | 0.643 |
| After shock, NegNoPun | -36.91 | *(20.17)* | 0.067 | 2.02 | *(2.28)* | 0.375 | 46.97 | *(184.56)* | 0.799 |
| After shock, NegPun | 14.33 | *(13.87)* | 0.302 | -0.90 | *(1.92)* | 0.639 | -249.62 | *(145.19)* | 0.086 |
| After shock, NegChat | 24.86 | *(17.79)* | 0.162 | -1.21 | *(2.41)* | 0.617 | -424.98 | *(187.16)* | 0.023 |
| After shock,PreNegNoPun | -7.24 | *(18.48)* | 0.695 | -0.75 | *(2.25)* | 0.738 | -18.76 | *(174.53)* | 0.914 |
| After shock,PreNegPun | -49.06 | *(16.86)* | 0.004 | 5.06 | *(2.22)* | 0.022 | 345.73 | *(160.71)* | 0.031 |
| Late after shock, NoNeg | -14.54 | *(8.03)* | 0.070 | 1.42 | *(0.96)* | 0.138 | 164.19 | *(86.48)* | 0.058 |
| Late after shock,NegNoPun | 14.01 | *(14.44)* | 0.332 | -2.46 | *(1.63)* | 0.130 | -168.15 | *(132.46)* | 0.204 |
| Late after shock,NegPun | -2.98 | *(7.97)* | 0.708 | -0.32 | *(1.22)* | 0.794 | 87.08 | *(90.66)* | 0.337 |
| Late after shock,NegChat | -26.77 | *(10.98)* | 0.015 | 4.71 | *(1.58)* | 0.003 | 308.27 | *(121.20)* | 0.011 |
| Late after shock,PreNegNoPu | -19.92 | *(15.04)* | 0.185 | 1.39 | *(1.67)* | 0.405 | 228.75 | *(137.13)* | 0.095 |
| Late after shock,PreNegPun | -12.92 | *(12.99)* | 0.320 | 1.83 | *(1.78)* | 0.303 | 47.03 | *(129.69)* | 0.717 |
| *Number of obs* | *2357* | | | *2355** | | | *2357* | | |
| *Log likelihood* | *-12487* | | | *-7454* | | | *-17815* | | |

Heteroskedastic panels; panel-specific autocorrepaltion AR(1)

*Trading price observations are missing for cases of zero sales (two cases)

TABLE 8 Capacity agreements in main negotiations treatments, physical units per seller

| *Treatment* | | *Early Negotiations: Periods 25-31* | | | *Late Negotiations: Periods 32-end* | | | *p-value:** Early=Late* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agreed Capacity | Actual Capacity | Capacity Deviation | Agreed Capacity | Actual Capacity | Capacity Deviation | Agreed Capacity | Actual Capacity | Capacity Deviation |
| *NoNegNoPun (10 obs)* | *Mean* | | 92.31 | | | 84.08 | | | 0.0527 | |
| | *Standard Deviation* | | (20.72) | | | (16.86) | | | | |
| *NegPun (11 obs)* | *Mean* | 78.67 | 71.61 | -6.89 | 82.44 | 72.90 | -9.54 | 0.9658 | 0.9658 | 0.8310 |
| | *Standard Deviation* | (23.14) | (16.32) | (7.91) | (28.21) | (17.19) | (22.71) | | | |
| *NegNoPun (10 obs)* | *Mean* | 65.64 | 72.61 | 6.23 | 71.01 | 80.26 | 8.64 | 0.2322 | 0.4922 | 0.8458 |
| | *Standard Deviation* | (15.83) | (18.69) | (17.95) | (26.13) | (33.11) | (32.59) | | | |
| *NegChat (10 obs)* | *Mean* | 98.84 | 90.69 | -11.14 | 76.66 | 73.82 | 0.36 | 0.0098 | 0.0274 | 0.0040 |
| | *Standard Deviation* | (43.25) | (33.19) | (12.18) | (33.28) | (29.41) | (8.70) | | | |
| *p-value:** NegPun=NegNoPun | | 0.1053 | 0.9439 | 0.0112 | 0.2050 | 0.8880 | 0.0183 | | | |
| *p-value:** NegNoPun=NegChat | | 0.0288 | 0.2798 | 0.0052 | 0.6842 | 0.6842 | 0.0524 | | | |
| *p-value:** NegPun=NegChat | | 0.2908 | 0.2050 | 0.5261 | 0.3240 | 0.7782 | 0.3964 | | | |

* Wilcoxon Mann Whitney ranksum test

** Wilcoxon signed rank test

TABLE 9: Capacity Asymptotes Before and After the Shock

| | Before Shock | | | | | | After Shock | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| market ID | capa-city asym-tote | *Std. Err.* | p-value: Cap=132 (Monop) | p-value: Cap=176 (Cournot) | p-value: Cap=264 (Bert-rand) | Classifi-cation | capa-city asym-tote | *Std. Err.* | p-value: Cap=108 (Monop) | p-value: Cap=144 (Cournot) | p-value: Cap=216 (Bert-rand) | Classifi-cation | p-value: before= =after | Direc-tion of change |
| ***NoNegNoPun treatment*** | | | | | | | | | | | | | | |
| 101 | 240.58 | 10.93 | 0.0000 | 0.0000 | 0.0321 | Bert/Cour | 192.51 | 14.33 | 0.0000 | 0.0007 | 0.1011 | Bertrand | 0.0071 | down |
| 102 | 237.13 | 9.35 | 0.0000 | 0.0000 | 0.0040 | Bert/Cour | 235.16 | 12.08 | 0.0000 | 0.0000 | 0.1128 | Bertrand | 0.8976 | same |
| 401 | 194.18 | 15.46 | 0.0001 | 0.2398 | 0.0000 | Cournot | 149.14 | 18.30 | 0.0246 | 0.7789 | 0.0003 | Cournot | 0.0638 | same |
| 402 | 250.85 | 6.81 | 0.0000 | 0.0000 | 0.0534 | Bertrand | 170.42 | 8.18 | 0.0000 | 0.0012 | 0.0000 | Bert/Cour | 0.0000 | down |
| 403 | 138.97 | 3.85 | 0.0701 | 0.0000 | 0.0000 | Monop | 108.68 | 4.64 | 0.8831 | 0.0000 | 0.0000 | Monop | 0.0000 | down |
| 404 | 277.09 | 15.48 | 0.0000 | 0.0000 | 0.3978 | Bertrand | 179.68 | 17.94 | 0.0001 | 0.0467 | 0.0429 | Bert/Cour | 0.0001 | down |
| 1201 | 292.07 | 22.13 | 0.0000 | 0.0000 | 0.2046 | Bertrand | 142.83 | 27.35 | 0.2028 | 0.9660 | 0.0075 | Cournot | 0.0000 | down |
| 1202 | 311.37 | 9.24 | 0.0000 | 0.0000 | 0.0000 | above Bert | 178.39 | 11.57 | 0.0000 | 0.0030 | 0.0012 | Bert/Cour | 0.0000 | down |
| 1203 | 178.66 | 6.15 | 0.0000 | 0.6657 | 0.0000 | Cournot | 155.56 | 7.54 | 0.0000 | 0.1251 | 0.0000 | Cournot | 0.0196 | down |
| 1204 | 186.56 | 7.63 | 0.0000 | 0.1666 | 0.0000 | Cournot | 165.66 | 9.51 | 0.0000 | 0.0227 | 0.0000 | Bert/Cour | 0.0890 | same |
| ***NegNoPun treatment*** | | | | | | | | | | | | | | |
| 601 | 275.14 | 21.20 | 0.0000 | 0.0000 | 0.5995 | Bertrand | 116.69 | 25.65 | 0.7347 | 0.2871 | 0.0001 | Monop | 0.0000 | down |
| 602 | 212.05 | 10.45 | 0.0000 | 0.0006 | 0.0000 | Bert/Cour | 161.95 | 13.02 | | 0.1680 | | Cournot | 0.0029 | down |
| 603 | 195.51 | 7.93 | 0.0000 | 0.0139 | 0.0000 | Bert/Cour | 105.16 | 10.00 | 0.7766 | 0.0001 | 0.0000 | Monop | 0.0000 | down |
| 604 | 297.98 | 32.05 | 0.0000 | 0.0001 | 0.2890 | Bertrand | 309.24 | 40.03 | 0.0000 | 0.0000 | 0.0199 | above Bert | 0.8272 | same |
| 901 | 202.05 | 7.70 | 0.0000 | 0.0007 | 0.0000 | Bert/Cour | 107.00 | 9.68 | 0.9176 | 0.0001 | 0.0000 | Monop | 0.0000 | down |
| 902 | 244.14 | 16.81 | 0.0000 | 0.0001 | 0.2375 | Bertrand | 241.57 | 21.18 | 0.0000 | 0.0000 | 0.2273 | Bertrand | 0.9240 | same |
| 1101 | 330.54 | 27.24 | 0.0000 | 0.0000 | 0.0146 | above Bert | 166.87 | 33.61 | 0.0798 | 0.4962 | 0.1438 | Cournot | 0.0002 | down |
| 1102 | 261.13 | 21.78 | 0.0000 | 0.0001 | 0.8952 | Bertrand | 138.64 | 27.49 | 0.2650 | 0.8456 | 0.0049 | Cournot | 0.0004 | down |
| 1103 | 188.69 | 86.19 | 0.5107 | 0.8829 | 0.3822 | Cournot | 89.09 | 105.88 | 0.8582 | 0.6040 | 0.2307 | Monop | 0.4729 | same |
| 1104 | 224.28 | 4.05 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 181.22 | 5.09 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.0000 | down |

"Bert/Cour" ("Cour/Monop") indicates that the asymptote is between Bertrand and Cournot (Cournot and Monopoly) predictions.

TABLE 9 (continued): Capacity Asymptotes Before and After the Shock

| | Before Shock | | | | | | After Shock | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| market ID | capacity asym-tote | *Std. Err.* | p-value: Cap=132 (Monop) | p-value: Cap=176 (Cournot) | p-value: Cap=264 (Bert-rand) | Classifi-cation | capacity asym-tote | *Std. Err.* | p-value: Cap=108 (Monop) | p-value: Cap=144 (Cournot) | p-value: Cap=216 (Bert-rand) | Classifi-cation | p-value: before= =after | Direc-tion of change |
| ***NegPun treatment*** | | | | | | | | | | | | | | |
| 201 | 365.45 | 13.90 | 0.0000 | 0.0000 | 0.0000 | above Bert | 101.85 | 17.34 | 0.7227 | 0.0151 | 0.0000 | Monop | 0.0000 | down |
| 202 | 174.25 | 4.17 | 0.0000 | 0.6754 | 0.0000 | Cournot | 180.34 | 5.08 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.3635 | same |
| 301 | 284.63 | 11.34 | 0.0000 | 0.0000 | 0.0689 | Bertrand | 201.56 | 14.27 | 0.0000 | 0.0001 | 0.3115 | Bertrand | 0.0000 | down |
| 302 | 205.55 | 14.68 | 0.0000 | 0.0441 | 0.0001 | Bert/Cour | 156.51 | 18.41 | 0.0084 | 0.4967 | 0.0012 | Cournot | 0.0377 | down |
| 303 | 201.81 | 7.25 | 0.0000 | 0.0004 | 0.0000 | Bert/Cour | 196.08 | 9.15 | 0.0000 | 0.0000 | 0.0295 | Bert/Cour | 0.6215 | same |
| 501 | 343.80 | 16.40 | 0.0000 | 0.0000 | 0.0000 | above Bert | 106.05 | 20.06 | 0.9225 | 0.0585 | 0.0000 | Monop | 0.0000 | down |
| 502 | 178.91 | 9.39 | 0.0000 | 0.7564 | 0.0000 | Cournot | 149.09 | 11.82 | 0.0005 | 0.6670 | 0.0000 | Cournot | 0.0476 | down |
| 503 | 188.43 | 6.09 | 0.0000 | 0.0414 | 0.0000 | Bert/Cour | 114.44 | 7.57 | 0.3952 | 0.0001 | 0.0000 | Monop | 0.0000 | down |
| 1001 | 200.95 | 6.81 | 0.0000 | 0.0002 | 0.0000 | Bert/Cour | 159.09 | 8.58 | 0.0000 | 0.0788 | 0.0000 | Cournot | 0.0001 | down |
| 1002 | 169.50 | 8.30 | 0.0000 | 0.4336 | 0.0000 | Cournot | 112.86 | 10.45 | 0.6417 | 0.0029 | 0.0000 | Monop | 0.0000 | down |
| 1003 | 188.40 | 8.84 | 0.0000 | 0.1609 | 0.0000 | Cournot | 93.32 | 10.93 | 0.1792 | 0.0000 | 0.0000 | Monop | 0.0000 | down |
| ***NegChat treatment*** | | | | | | | | | | | | | | |
| 701 | 258.61 | 18.57 | 0.0000 | 0.0000 | 0.7717 | Bertrand | 157.57 | 26.81 | 0.0644 | 0.6126 | 0.0293 | Cournot | 0.0021 | down |
| 702 | 325.95 | 16.78 | 0.0000 | 0.0000 | 0.0002 | above Bert | 194.36 | 24.48 | 0.0004 | 0.0396 | 0.3768 | Bertrand | 0.0000 | down |
| 703 | 149.95 | 5.35 | 0.0008 | 0.0000 | 0.0000 | Cour,Monop | 114.03 | 7.23 | 0.4045 | 0.0000 | 0.0000 | Monop | 0.0001 | down |
| 704 | 301.41 | 18.67 | 0.0000 | 0.0000 | 0.0451 | above Bert | 257.12 | 26.85 | 0.0000 | 0.0000 | 0.1256 | Bertrand | 0.1804 | same |
| 705 | 308.09 | 25.93 | 0.0000 | 0.0000 | 0.089 | Bertrand | 84.91 | 36.94 | 0.5319 | 0.1097 | 0.0004 | Monop | 0.0000 | down |
| 801 | 217.28 | 8.21 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 116.35 | 10.32 | 0.4181 | 0.0074 | 0.0000 | Monop | 0.0000 | down |
| 802 | 171.15 | 6.66 | 0.0000 | 0.466 | 0.0000 | Cournot | 137.48 | 8.03 | 0.0002 | 0.4174 | 0.0000 | Cournot | 0.0016 | down |
| 1301 | 277.04 | 16.61 | 0.0000 | 0.0000 | 0.4325 | Bertrand | 221.24 | 20.99 | 0.0000 | 0.0002 | 0.8027 | Bertrand | 0.0356 | down |
| 1302 | 175.44 | 14.27 | 0.0023 | 0.9688 | 0.0000 | Cournot | 87.59 | 17.76 | 0.2505 | 0.0015 | 0.0000 | Monop | 0.0001 | down |
| 1303 | 301.56 | 39.54 | 0.0000 | 0.0015 | 0.3421 | Bertrand | 110.69 | 47.88 | 0.9552 | 0.4867 | 0.0279 | Monop | 0.0026 | down |

"Bert/Cour" ("Cour/Monop") indicates that the asymptote is between Bertrand and Cournot (Cournot and Monopoly) predictions.

TABLE 9 (continued): Capacity Asymptotes Before and After the Shock

| market ID | Before Shock: capacity asymptote | *Std. Err.* | p-value: Cap=132 (Monop) | p-value: Cap=176 (Cournot) | p-value: Cap=264 (Bertrand) | Classification | After Shock: capacity asymptote | *Std. Err.* | p-value: Cap=108 (Monop) | p-value: Cap=144 (Cournot) | p-value: Cap=216 (Bertrand) | Classification | p-value: before==after | Direction of change |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***PreShockNegPun treatment*** | | | | | | | | | | | | | | |
| 1501 | 156.17 | 11.33 | 0.0329 | 0.0800 | 0.0000 | Cour/Monop | 106.09 | 17.61 | 0.9138 | 0.0314 | 0.0000 | Monop | 0.0152 | down |
| 1502 | 150.35 | 13.45 | 0.1724 | 0.0566 | 0.0000 | Monop | 102.05 | 19.71 | 0.7629 | 0.0333 | 0.0000 | Monop | 0.0461 | down |
| 1503 | 155.96 | 8.34 | 0.0041 | 0.0162 | 0.0000 | Cour/Monop | 142.99 | 12.96 | 0.0070 | 0.9378 | 0.0000 | Cournot | 0.3928 | same |
| 1701 | 179.69 | 16.93 | 0.0048 | 0.8273 | 0.0000 | Cournot | 45.73 | 15.46 | 0.0001 | 0.0000 | 0.0000 | Monop | 0.0000 | down |
| 1702 | 142.36 | 2.05 | 0.0000 | 0.0000 | 0.0000 | Cour/Monop | 127.93 | 1.85 | 0.0000 | 0.0000 | 0.0000 | Cour/Monop | 0.0000 | down |
| 1703 | 315.55 | 52.56 | 0.0005 | 0.0079 | 0.9600 | Bertrand | 98.62 | 48.30 | 0.8459 | 0.3474 | 0.0151 | Monop | 0.0030 | down |
| 1704 | 184.74 | 6.25 | 0.0000 | 0.1618 | 0.0000 | Cournot | 186.92 | 5.68 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.7947 | same |
| 1801 | 236.87 | 37.55 | 0.0052 | 0.1051 | 0.4700 | Bertrand | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 1802 | 242.80 | 10.63 | 0.0000 | 0.0000 | 0.0461 | Bert/Cour | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 1803 | 225.76 | 11.25 | 0.0000 | 0.0000 | 0.0007 | Bert/Cour | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 1804 | 207.34 | 45.36 | 0.0967 | 0.4896 | 0.2117 | Cournot | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| ***PreShockNegNoPun treatment*** | | | | | | | | | | | | | | |
| 1402 | 379.01 | 37.58 | 0.0000 | 0.0000 | 0.0022 | above Bert | 356.49 | 25.69 | 0.0000 | 0.0000 | 0.0000 | above Bert | 0.6168 | same |
| 1403 | 269.44 | 34.63 | 0.0000 | 0.0070 | 0.8751 | Bertrand | 204.87 | 24.18 | 0.0001 | 0.0118 | 0.6453 | Bertrand | 0.1309 | same |
| 1601 | 281.31 | 24.56 | 0.0000 | 0.0000 | 0.4811 | Bertrand | 117.94 | 22.52 | 0.6589 | 0.2472 | 0.0000 | Monop | 0.0000 | down |
| 1602 | 248.11 | 16.47 | 0.0000 | 0.0000 | 0.3347 | Bertrand | 226.76 | 15.05 | 0.0000 | 0.0000 | 0.4746 | Bertrand | 0.3459 | same |
| 1901 | 118.39 | 14.93 | 0.3620 | 0.0001 | 0.0000 | Monop | 109.62 | 23.73 | 0.9457 | 0.1474 | 0.0000 | Monop | 0.7585 | same |
| 1902 | 236.69 | 6.84 | 0.0000 | 0.0000 | 0.0001 | Bert/Cour | 109.03 | 12.02 | 0.9316 | 0.0000 | 0.0000 | Monop | 0.0000 | down |
| 1903 | 301.71 | 22.94 | 0.0000 | 0.0000 | 0.1003 | Bertrand | 265.60 | 39.00 | 0.0001 | 0.0018 | 0.2034 | Bertrand | 0.4238 | same |
| 1904 | 267.94 | 7.18 | 0.0000 | 0.0000 | 0.5833 | Bertrand | 220.48 | 10.81 | 0.0000 | 0.0000 | 0.6786 | Bertrand | 0.0003 | down |
| 2001 | 255.51 | 24.96 | 0.0000 | 0.0014 | 0.7337 | Bertrand | 145.16 | 22.74 | 0.1023 | 0.9594 | 0.0018 | Cournot | 0.0011 | down |
| 2002 | 330.96 | 9.83 | 0.0000 | 0.0000 | 0.0000 | above Bert | 176.07 | 8.98 | 0.0000 | 0.0004 | 0.0000 | Bert/Cour | 0.0000 | down |
| 2003 | 243.81 | 26.73 | 0.0000 | 0.0112 | 0.4499 | Bertrand | 132.86 | 24.44 | 0.3092 | 0.6484 | 0.0000 | Cournot | 0.0026 | down |
| 2004 | 149.74 | 14.04 | 0.2065 | 0.0614 | 0.0000 | Monop | 176.01 | 12.84 | 0.0000 | 0.0127 | 0.0019 | Bert/Cour | 0.1752 | same |

"Bert/Cour" ("Cour/Monop") indicates that the asymptote is between Bertrand and Cournot (Cournot and Monopoly) predictions.

TABLE 10: Price Asymptotes Before and After the Shock

| | Before Shock | | | | | | After Shock | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| market ID | price asymp-tote | *Std. Err.* | p-value: price=43 (Monop) | p-value: price=32 (Cournot) | p-value: price=10 (Bertrand) | Classifi-cation | price asymp-tote | *Std. Err.* | p-value: price=37 (Monop) | p-value: price=28 (Cournot) | p-value: price=10 (Bertrand) | Classifi-cation | p-value: before= =after | Direc-tion of change |
| ***NoNegNoPun treatment*** | | | | | | | | | | | | | | |
| 101 | 25.83 | *1.81* | 0.0000 | 0.0007 | 0.0000 | Bert/Cour | 21.54 | *2.35* | 0.0000 | 0.0061 | 0.0000 | Bert/Cour | 0.1492 | same |
| 102 | 19.72 | *0.96* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 13.22 | *1.21* | 0.0000 | 0.0000 | 0.0078 | Bert/Cour | 0.0000 | down |
| 401 | 32.87 | *2.56* | 0.0001 | 0.7346 | 0.0000 | Cournot | 29.95 | *3.00* | 0.0186 | 0.5145 | 0.0000 | Cournot | 0.4679 | same |
| 402 | 23.36 | *0.89* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 24.47 | *1.07* | 0.0000 | 0.0010 | 0.0000 | Bert/Cour | 0.4238 | same |
| 403 | 38.79 | *1.08* | 0.0001 | 0.0000 | 0.0000 | Cour/Monop | 36.85 | *1.27* | 0.9075 | 0.0000 | 0.0000 | Monop | 0.2529 | same |
| 404 | 18.45 | *2.05* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 21.72 | *2.37* | 0.0000 | 0.0081 | 0.0000 | Bert/Cour | 0.3045 | same |
| 1201 | 21.36 | *4.22* | 0.0000 | 0.0116 | 0.0071 | Bert/Cour | 29.48 | *5.05* | 0.1364 | 0.7696 | 0.0001 | Cournot | 0.2235 | same |
| 1202 | 14.35 | *1.44* | 0.0000 | 0.0000 | 0.0024 | Bert/Cour | 22.59 | *1.75* | 0.0000 | 0.0020 | 0.0000 | Bert/Cour | 0.0004 | up |
| 1203 | 27.17 | *0.82* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 25.82 | *1.02* | 0.0000 | 0.0319 | 0.0000 | Bert/Cour | 0.3023 | same |
| 1204 | 30.52 | *1.90* | 0.0000 | 0.4344 | 0.0000 | Cournot | 23.59 | *2.31* | 0.0000 | 0.0567 | 0.0000 | Cournot | 0.0231 | down |
| ***NegNoPun treatment*** | | | | | | | | | | | | | | |
| 601 | 19.51 | *1.12* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 36.85 | *1.36* | 0.9135 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| 602 | 26.05 | *2.23* | 0.0000 | 0.0076 | 0.0000 | Bert/Cour | 25.49 | *2.77* | 0.0000 | 0.3637 | 0.0000 | Cournot | 0.8758 | same |
| 603 | 26.56 | *1.16* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 37.61 | *1.47* | 0.6753 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| 604 | 22.39 | *2.67* | 0.0000 | 0.0003 | 0.0000 | Bert/Cour | 20.51 | *3.25* | 0.0000 | 0.0211 | 0.0012 | Bert/Cour | 0.6615 | same |
| 901 | 30.09 | *1.72* | 0.0000 | 0.2679 | 0.0000 | Cournot | 36.94 | *2.15* | 0.9774 | 0.0000 | 0.0000 | Monop | 0.0136 | up |
| 902 | 22.30 | *2.13* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 19.71 | *2.61* | 0.0000 | 0.0015 | 0.0002 | Bert/Cour | 0.4486 | same |
| 1101 | 18.19 | *3.42* | 0.0000 | 0.0001 | 0.0165 | Bert/Cour | 22.52 | *4.42* | 0.0010 | 0.2146 | 0.0046 | Cournot | 0.4412 | same |
| 1102 | 20.18 | *1.86* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 28.01 | *2.32* | 0.0001 | 0.9977 | 0.0000 | Cournot | 0.0091 | up |
| 1103 | 30.37 | *8.58* | 0.1407 | 0.8488 | 0.0176 | Cournot | 40.81 | *10.63* | 0.7200 | 0.2281 | 0.0038 | Monop | 0.4506 | same |
| 1104 | 21.81 | *0.87* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 19.87 | *1.08* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.1636 | same |

"Bert/Cour" ("Cour/Monop") indicates that the asymptote is between Bertrand and Cournot (Cournot and Monopoly) predictions.

TABLE 10 (continued): Price Asymptotes Before and After the Shock

| | Before Shock | | | | | | After Shock | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| market ID | price asymp-tote | *Std. Err.* | p-value: price=43 (Monop) | p-value: price=32 (Cournot) | p-value: price=10 (Bertrand) | Classifi-cation | price asymp-tote | *Std. Err.* | p-value: price=37 (Monop) | p-value: price=28 (Cournot) | p-value: price=10 (Bertrand) | Classifi-cation | p-value: before= =after | Direc-tion of change |
| ***NegPun treatment*** | | | | | | | | | | | | | | |
| 201 | 17.08 | *1.14* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 38.15 | *1.41* | 0.4142 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| 202 | 35.19 | *0.86* | 0.0000 | 0.0002 | 0.0000 | Cour/Monop | 21.12 | *1.06* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.0000 | down |
| 301 | 15.61 | *1.01* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 14.61 | *1.28* | 0.0000 | 0.0000 | 0.0003 | Bert/Cour | 0.5371 | same |
| 302 | 31.13 | *2.42* | 0.0000 | 0.7176 | 0.0000 | Cournot | 25.17 | *3.02* | 0.0001 | 0.3481 | 0.0000 | Cournot | 0.1254 | same |
| 303 | 27.73 | *1.31* | 0.0000 | 0.0011 | 0.0000 | Bert/Cour | 19.43 | *1.64* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.0001 | down |
| 501 | 15.37 | *2.12* | 0.0000 | 0.0000 | 0.0113 | Bert/Cour | 38.32 | *2.50* | 0.5956 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| 502 | 33.40 | *1.96* | 0.0000 | 0.4765 | 0.0000 | Cournot | 27.49 | *2.45* | 0.0001 | 0.8334 | 0.0000 | Cournot | 0.0611 | same |
| 503 | 30.69 | *1.40* | 0.0000 | 0.3511 | 0.0000 | Cournot | 34.85 | *1.75* | 0.2199 | 0.0001 | 0.0000 | Monop | 0.0656 | same |
| 1001 | 23.59 | *0.75* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 26.07 | *0.93* | 0.0000 | 0.0370 | 0.0000 | Bert/Cour | 0.0406 | up |
| 1002 | 36.11 | *2.16* | 0.0014 | 0.0569 | 0.0000 | Cournot | 34.22 | *2.72* | 0.3078 | 0.0223 | 0.0000 | Cournot | 0.5852 | same |
| 1003 | 29.64 | *1.48* | 0.0000 | 0.1110 | 0.0000 | Cournot | 40.95 | *1.84* | 0.0314 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| ***NegChat treatment*** | | | | | | | | | | | | | | |
| 701 | 25.08 | *2.89* | 0.0000 | 0.0168 | 0.0000 | Bert/Cour | 31.12 | *4.20* | 0.1617 | 0.4570 | 0.0000 | Cournot | 0.2396 | same |
| 702 | 17.60 | *2.34* | 0.0000 | 0.0000 | 0.0011 | Bert/Cour | 30.60 | *3.23* | 0.0476 | 0.4207 | 0.0000 | Cournot | 0.0014 | up |
| 703 | 37.35 | *1.27* | 0.0000 | 0.0000 | 0.0000 | Cour/Monop | 34.60 | *1.59* | 0.1322 | 0.0000 | 0.0000 | Monop | 0.1470 | same |
| 704 | 14.90 | *1.17* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 11.71 | *1.68* | 0.0000 | 0.0000 | 0.3086 | Bertrand | 0.1239 | same |
| 705 | 17.95 | *2.91* | 0.0000 | 0.0000 | 0.0063 | Bert/Cour | 47.18 | *4.24* | 0.0162 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| 801 | 24.93 | *1.31* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 34.65 | *1.64* | 0.1525 | 0.0001 | 0.0000 | Monop | 0.0000 | up |
| 802 | 35.32 | *1.77* | 0.0000 | 0.0607 | 0.0000 | Cournot | 29.58 | *2.14* | 0.0005 | 0.4582 | 0.0000 | Cournot | 0.0425 | down |
| 1301 | 18.15 | *1.46* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 19.67 | *1.84* | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.5152 | same |
| 1302 | 37.74 | *2.29* | 0.0214 | 0.0121 | 0.0000 | Cour/Monop | 41.71 | *2.82* | 0.0947 | 0.0000 | 0.0000 | Monop | 0.2802 | same |
| 1303 | 15.48 | *2.60* | 0.0000 | 0.0000 | 0.0351 | Bert/Cour | 36.41 | *3.15* | 0.8519 | 0.0076 | 0.0000 | Monop | 0.0000 | up |

"Bert/Cour" ("Cour/Monop") indicates that the asymptote is between Bertrand and Cournot (Cournot and Monopoly) predictions.

TABLE 10 (continued): Price Asymptotes Before and After the Shock

| | Before Shock | | | | | | After Shock | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| market ID | price asymp-tote | *Std. Err.* | p-value: price=43 (Monop) | p-value: price=32 (Cournot) | p-value: price=10 (Bertrand) | Classifi-cation | price asymp-tote | *Std. Err.* | p-value: price=37 (Monop) | p-value: price=28 (Cournot) | p-value: price=10 (Bertrand) | Classifi-cation | p-value: before= =after | Direc-tion of change |
| ***PreShockNegPun treatment*** | | | | | | | | | | | | | | |
| 1501 | 38.00 | 1.76 | 0.0046 | 0.0007 | 0.0000 | Cour/Monop | 41.06 | 2.75 | 0.1401 | 0.0000 | 0.0000 | Monop | 0.3406 | same |
| 1502 | 41.53 | 3.27 | 0.6527 | 0.0036 | 0.0000 | Monop | 38.47 | 4.85 | 0.7617 | 0.0308 | 0.0000 | Monop | 0.6052 | same |
| 1503 | 37.41 | 1.49 | 0.0002 | 0.0003 | 0.0000 | Cour/Monop | 28.89 | 2.31 | 0.0004 | 0.7008 | 0.0000 | Cournot | 0.0017 | down |
| 1701 | 28.16 | 2.20 | 0.0000 | 0.0813 | 0.0000 | Bert/Cour | 45.78 | 2.01 | 0.0000 | 0.0000 | 0.0000 | Monop | 0.0000 | up |
| 1702 | 40.18 | 0.39 | 0.0000 | 0.0000 | 0.0000 | Cour/Monop | 32.01 | 0.35 | 0.0000 | 0.0000 | 0.0000 | Cour/Monop | 0.0000 | down |
| 1703 | 19.38 | 3.99 | 0.0000 | 0.0015 | 0.0186 | Bert/Cour | 38.11 | 3.66 | 0.7613 | 0.0057 | 0.0000 | Monop | 0.0007 | up |
| 1704 | 32.70 | 0.92 | 0.0000 | 0.4450 | 0.0000 | Cournot | 22.59 | 0.84 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.0000 | down |
| 1801 | 24.30 | 3.00 | 0.0000 | 0.0103 | 0.0000 | Bert/Cour | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 1802 | 20.81 | 1.79 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 1803 | 25.68 | 2.37 | 0.0000 | 0.0077 | 0.0000 | Bert/Cour | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 1804 | 30.46 | 3.99 | 0.0017 | 0.0700 | 0.0000 | Cournot | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| ***PreShockNegNoPun treatment*** | | | | | | | | | | | | | | |
| 1402 | 19.29 | 1.71 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 12.64 | 1.17 | 0.0000 | 0.0000 | 0.0247 | Bert/Cour | 0.0012 | down |
| 1403 | 16.03 | 3.74 | 0.0000 | 0.0000 | 0.1071 | Bertrand | 18.47 | 2.57 | 0.0000 | 0.0002 | 0.0010 | Bert/Cour | 0.5878 | same |
| 1601 | 13.37 | 5.31 | 0.0000 | 0.0005 | 0.5261 | Bertrand | 35.66 | 4.90 | 0.7842 | 0.1183 | 0.0000 | Monop | 0.0026 | up |
| 1602 | 17.48 | 0.84 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 13.67 | 0.77 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.0010 | down |
| 1901 | 45.81 | 3.34 | 0.3991 | 0.0000 | 0.0000 | Monop | 36.61 | 5.23 | 0.9408 | 0.0995 | 0.0000 | Monop | 0.1457 | same |
| 1902 | 27.12 | 3.22 | 0.0000 | 0.1296 | 0.0000 | Cournot | 36.49 | 4.66 | 0.9129 | 0.0686 | 0.0000 | Monop | 0.1013 | same |
| 1903 | 16.44 | 1.56 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 13.04 | 2.54 | 0.0000 | 0.0000 | 0.2313 | Bertrand | 0.2599 | same |
| 1904 | 16.16 | 1.54 | 0.0000 | 0.0000 | 0.0001 | Bert/Cour | 15.47 | 2.23 | 0.0000 | 0.0000 | 0.0144 | Bert/Cour | 0.8014 | same |
| 2001 | 19.55 | 4.68 | 0.0000 | 0.0079 | 0.0413 | Bert/Cour | 25.86 | 4.31 | 0.0098 | 0.6199 | 0.0002 | Cournot | 0.3335 | same |
| 2002 | 15.09 | 1.06 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 19.88 | 0.96 | 0.0000 | 0.0000 | 0.0000 | Bert/Cour | 0.0008 | up |
| 2003 | 24.73 | 3.87 | 0.0000 | 0.0604 | 0.0001 | Bert/Cour | 30.65 | 3.55 | 0.0739 | 0.4550 | 0.0000 | Cournot | 0.2709 | same |
| 2004 | 36.14 | 1.80 | 0.0001 | 0.0212 | 0.0000 | Cour/Monop | 21.55 | 1.64 | 0.0000 | 0.0001 | 0.0000 | Bert/Cour | 0.0000 | down |

"Bert/Cour" ("Cour/Monop") indicates that the asymptote is between Bertrand and Cournot (Cournot and Monopoly) predictions.