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Are “Rockets and Feathers” Caused by Search or Informational Frictions?*

Ralph-C Bayer[†] & Changxia Ke[‡]

Abstract

Prices usually adjust much faster when costs increase than when costs decrease. The mechanism driving this “Rockets-and-Feathers” phenomenon is not well understood despite of ample empirical evidence for its existence. We use simple experimental markets with and without consumer search and either privately or publicly observed cost shocks to study this puzzle. In contrast to the theoretical predictions, we observe price dispersion and asymmetric price adjustment in all four settings. We attribute the pricing behavior to bounded rationality and its interaction with adaptive expectations. We conclude that neither search costs nor private information are indispensable for prices to adjust asymmetrically.

Keywords: Asymmetric Price Adjustment, Price Dispersion, Adaptive Search, Bounded Rationality

JEL codes: D82, D83, C91, L13

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1 Introduction

Consumers usually complain that the retail gasoline prices respond faster to increases in wholesale prices than to decreases. Karrenbrock (1991), Duffy-Deno (1996) and Borenstein et al. (1997) all study the US gasoline market and conclude that their data provide strong evidence that this phenomenon is real rather than just a misperception of the consumers. There is also evidence for Canada (Eckert 2002) and for some European countries (Bacon 1991; Galeotti et al. 2003), which shows that asymmetric price adjustment is not a US specific phenomenon. Moreover, Borenstein et al. (1997) find that this asymmetry does not only occur in the adjustment of retail prices to changes in wholesale prices, but also in the adjustment of spot oil prices to changes in crude oil prices.

The gasoline industry is not the only industry where asymmetric price adjustment to cost changes occurs. Hannan and Berger (1991) and Neumark and Sharpe (1992) find that banks adjust both mortgage rates and consumer deposit rates asymmetrically when the central bank changes its interest rate. The adjustment typically exhibits upward flexibility and downward rigidity on mortgage rates, whereas the opposite is true for deposit rates. Banks take advantage of both directions of interest movements by the central bank. In both the gasoline and the banking industry, input-price movements are observable to (alert) consumers, which explains why consumers recognize the asymmetric nature of the adjustment. However, for some other industries that impact even more on consumers' daily life (e.g., meat and vegetables), consumers sometimes have difficulty observing input price fluctuations. Ward (1982) and Goodwin and Harper (2000) confirm that also in these markets price adjustment is asymmetric.

Despite of the many empirical studies showing the existence of asymmetric price adjustment to cost shocks, plausible economic theory that can satisfactorily explain this phenomenon is only emerging. In traditional microeconomic theory, variations of input prices affect the output prices through marginal cost. The transmission from marginal cost to prices is governed by market power. Adjustment is instantaneous, and the direction of cost shocks has no role to play. The first potential reason that springs to mind for why prices adjust asymmetrically to cost shocks is (tacit) collusion. Based on Tirole (1988), Borenstein et al. (1997, p. 324) argue that "Prices are sticky downward because when input prices fall the old output price offers a natural focal point for oligopolistic sellers." In

a world with imperfect monitoring and multiple equilibria, firms can coordinate on a high-price equilibrium (after a cost reduction) using past prices as the focal point. If costs increase current prices might not be profitable anymore, which leads to the coordination on a new and higher price. Media and governments are quick at attributing asymmetric price adjustment to this kind of collusion. In the light of the comprehensive study by Peltzman (2000), such general judgement appears to be premature though. Peltzman observes “Rockets and Feathers” in more than two-thirds of 242 investigated markets. The markets included in the study cover 77 consumer and 165 intermediate goods across different industries with a large variety of market structures. Tacit collusion is unlikely to occur in the more competitive of these markets. Moreover, the study does not find any relation between measures for imperfect competition and asymmetric price adjustment.

Recent theoretical work by Yang and Ye (2008), Tappata (2009), Lewis (2011) and B. Cabral and Fishman (2011) points to search frictions as the underlying cause of the asymmetry. The mechanism that generates the “Rockets-and-Feathers” phenomenon usually requires a model with consumer search that causes equilibrium-price dispersion and different search behavior after positive and negative cost shocks. The latter is typically driven by some heterogeneity of consumers (in terms of their search cost) and asymmetric information. Our main aim in this paper is to determine conditions that are necessary for the “Rockets-and-Feathers” phenomenon to occur empirically. We use laboratory experiments for this purpose, as – in contrast to the field – the laboratory allows for the level of control necessary to identify causal effects of the environment on pricing behavior.¹

In the light of the recent, plausible explanations for the “Rockets-and-Feathers” phenomenon, this paper asks which of the ingredients of the theoretical search models are necessary to produce asymmetric price adjustment in the laboratory. We start with a simple search theoretic environment, where asymmetric price adjustment is not predicted by standard theory, while the two most common features appearing in the theory (i.e. search cost and private information) are still present. So the initial model features non-zero search cost and asymmetric information on production cost. Beyond these characteristics this environment lacks the assumptions on consumer or producer heterogeneity necessary to pro-

¹The usual caveat regarding the potential lack of external validity certainly applies.

duce price dispersion and asymmetric price adjustment in theoretical models. Finding asymmetric price adjustment in this environment would show that the heterogeneity assumptions are not necessary.

In two additional treatments we either remove the search cost or provide the consumers with complete information on the production cost. With these treatments we can investigate if both private information and search frictions are necessary conditions for asymmetric adjustment to occur. Finally, we run a treatment featuring neither of these factors, which leads to an environment equivalent to a homogeneous-good Bertrand oligopoly with complete information. This treatment helps to determine whether asymmetric price adjustment survives in the most competitive and transparent environment possible.

Our experimental results are very stark and counter-intuitive at times. We observe asymmetric price adjustment **in all** settings, including the Bertrand world with publicly announced cost shocks. Neither consumer or producer heterogeneity, nor search frictions or private information are necessary for “Rockets and Feathers” to be observed. We uncover the following mechanism causing asymmetric price adjustment. Like in other studies, we observe price dispersion, which is not predicted by standard theory. Such off-equilibrium play is likely to be caused by some degree of bounded rationality. Now that sellers experience off-equilibrium play before a shock they cannot be sure how others will adjust their prices after a cost shock.² Consequently, firms do not see a reason to lower their prices considerably after a cost decrease as long as they do not get a signal that other firms have decreased their prices. Being unsuccessful at selling is such a signal. Therefore only firms that are unsuccessful reduce their prices. As only half the sellers do not sell each period, adjustment downwards is slow. In contrast, when costs go up, sellers anticipate that everyone will increase prices, since it is in the sellers’ best interest if all do so, which leads to immediate adjustment upwards. Asymmetric price adjustment occurs.

Our second main result seems counter-intuitive. The factors that generally are believed to increase the degree of the asymmetry of price adjustment are not necessarily found to do so. While complete information, as expected, reduces the degree of asymmetric adjustment, the absence of search frictions does not.

²If pricing followed the theoretical prediction marginal cost pricing or monopoly pricing (depending on the treatment), then predicting the reaction to cost shocks would be easy for sellers.

Surprisingly, the adjustment is less asymmetric in markets with search frictions than in markets without. This initially surprising result can be easily explained once one takes into account that play before a cost shock does not follow standard equilibrium. In contrast to equilibrium play, prices in treatments with search frictions are not at monopoly levels and consumers are searching. Consumers' search decisions are based on the comparison between observed prices and the believed price distribution. Price expectations are found to contain an adaptive element, as search is influenced by past prices. In such a situation a firm has two separate incentives for reducing its price after a negative cost shock. A lower price reduces the likelihood that consumers search and increases the probability of having a lower price than the rival, which both increase the likelihood of a sale. In contrast, without search cost the only incentive for reducing the price stems from the undercutting motive, since the price level does not impact on the search intensity if consumers always search. Consequently, the price-reduction incentives are stronger if there are search frictions. This reduces the level of asymmetry.

The paper is organized as follows. The next sections provides some background and explains the theoretical mechanisms by which search frictions together with informational frictions can lead to asymmetric price adjustment. Section 3 lays out our underlying model, the experimental design and its implementation. Section 4 presents the results and Section 5 offers a brief conclusion and some policy implications.

2 Background and related literature

In a seminal paper Diamond (1971) shows that in a market, where consumers have to learn the prices charged by searching, all producers in equilibrium charge monopoly prices as long as search cost, however small, exist. This result seems counter-intuitive, as in the absence of search cost prices are predicted to be at marginal cost. This extreme impact of even a tiny search cost is typically referred to as the “Diamond Paradox”. To fill the gap between this and the other extreme of marginal cost pricing in Bertrand competition, in the past a large number of theoretical models (which generate equilibrium price dispersion) were developed (e.g., Reinganum 1979; Braverman 1980; Varian 1980; Burdett and Judd 1983; Carlson and McAfee 1983; Rob 1985; Stahl 1989, among

others). Equilibrium price dispersion arises in these models mainly due to the introduction of heterogeneity of either the sellers (in production cost) and/or the buyers (in search cost or search technology).

There also exists some experimental evidence on the Diamond Paradox. Grether et al. (1988) observe prices close to the monopoly price in three out of four sessions they conducted. More recent studies (David and Holt 1996; Abrams et al. 2000) find evidence that prices increase with search cost, without reaching the monopoly level. Interestingly, Cason and Friedman (2003) observe that prices are close to monopoly prices if the buyers are played by computer automata, while they are much lower if buyers are played by humans. These papers, which are designed to provide evidence on the “Diamond Paradox”, provide a nice starting point for our investigation into price adjustment to cost shocks.

In our study we use the simplest market set up where the Diamond result can occur. Two sellers (supplying one unit each) are faced by one buyer (with unit demand). First, both sellers (with identical production cost) set their prices. Then the buyer, who observes one price for free, has to decide whether to buy immediately or to search and to learn the other price before buying. In two of our treatments search costs are positive. In the other two treatments search costs are zero.

In order to study the occurrence of asymmetric price adjustment we introduce cost shocks. Initially, the production cost is commonly known to both sellers and the buyer. After a few periods a random production cost shock may occur. With equal probability the cost stays the same, increases or decreases by the same amount. Both sellers and buyers are informed of the stochastic process which governs the shock in all treatments. Treatments differ with respect to whether the realization of the shock is publicly announced to both buyers and sellers or only privately communicated to the sellers.

By varying whether search is free or not and whether shocks are publicly or privately observed we arrive at a 2×2 design. Recall that the cost shock can lead to three different realizations. So in each treatment three different conditions arise – up, constant or down – depending on which cost state is realized. Standard economic theory predicts either perfect competition when search is free or monopoly pricing when search is costly, irrespective of whether shocks are publicly or privately observed. Given that the production cost shock we im-

pose is symmetric, there should be no adjustment asymmetry in the treatments without search cost, as prices should fully reflect marginal cost changes. In the Diamond treatments no adjustment should happen at all, since the monopoly price in our setting does not depend on the marginal cost.

By allowing for search cost and private information our treatments share elements with recent theoretical models designed to explain the “Rockets-and-Feathers” phenomenon. However, in theory more assumptions are necessary in order to generate asymmetric price adjustment. Yang and Ye (2008) assume a continuum of firms (with homogeneous production cost and a capacity constraint) and a continuum of consumers (with high, medium or low search cost). Equilibrium price dispersion (on two prices) occurs in the static model. In contrast, Tappata (2009) proposes a model with a finite number of firms (with homogeneous production cost) and buyers (with heterogeneous search cost), which also generates price dispersion. Both papers assume Markov processes with some persistence governing the cost dynamics. Asymmetric price adjustment occurs naturally through the asymmetric updating process of heterogeneous consumers. Alternatively, instead of assuming full rationality of both sellers and buyers, Lewis (2011) developed a reference-price model with sequential search, where the buyers hold adaptive expectations of the market-price distributions. Assuming price dispersion, Lewis suggests that if the cost shock is positive, then sellers are forced to raise the prices immediately (as the profit margin is depressed) and consumers search more when prices are higher than expected. However, if the shock is negative, sellers only need to reduce the price slightly to prevent search. The search intensity stays at similar levels when prices are equal or slightly lower than expected. Hence, updating happens at a much slower pace when costs have fallen, which causes prices to adjust more slowly downwards than upwards.

Instead of facing industry-wide common shocks, sellers in B. Cabral and Fishman (2011, Section IV) have firm-specific but positively correlated random cost shocks. For any observed price change, consumers need to judge whether other firms are likely to have smaller or larger cost shocks when deciding if it is worth searching. Since shocks are positively correlated, one firm’s price increase (or decrease) signals that other firms are also likely to have positive (or negative) cost shocks. As a result, the expected benefits from search are smaller for a small price increase than for a small price decrease. Sellers prefer to leave

prices where they are after a shock that decreased costs, since they do not want to signal that costs have gone down. In the case of cost increases though, firms have an interest to signal that costs have gone up, which they do by increasing prices as much as possible without inducing consumers to search.

In summary, the predominant driver of asymmetric price adjustment in the recent literature are consumers with (typically heterogeneous) search cost, who do not (perfectly) observe firms' cost shocks and have to search for prices. The changes to the search intensity following price changes differ according to the direction of price changes. Firms respond to this asymmetric search behavior with asymmetric price adjustment.

Given that asymmetric search behavior is the key mechanism proposed in theoretical models, supporting empirical evidence to justify this type of behavior is needed. Lewis and Marvel (*in press*) provides empirical evidence for asymmetric search behavior using data from a gasoline-price reporting website. McGee (2011) run some pure search experiments and find that asymmetric search behavior also occurs in the laboratory. More importantly, the paper finds that the crucial assumptions required in the theoretical model, namely heterogeneous search cost and unknown cost shocks are not necessary to induce asymmetric search behavior. Consumers search more when prices increase and less when prices decrease even if the shifts in price distributions (potentially caused by shocks) are known to consumers, who face the same search cost. A model with reference dependent utility nicely explains this behavior. Based on this evidence, our starting point is an environment without the asymmetries theoretically necessary to lead to asymmetric search and consequently price adjustment. We still expect asymmetric price adjustment. We then one-by-one remove the other two factors that are seen as critical for asymmetric price adjustment. These factors are private information on cost shocks and non-zero search cost. Ultimately, we want to determine which conditions are necessary for prices to adjust asymmetrically. The answer our results suggest is as simple as surprising: none of them.

3 Experimental design and theoretical predictions

We adopt a simple two-phase dynamic market game. We will refer to the two phases as *pre-shock* and *after-shock* phase, which consist of 15 periods each. In

each period two sellers each offer one unit of a homogeneous good produced at a cost of mc to one buyer, who demands one unit of this product and values it at $v = 100$. The timing in a particular market period is as follows: first, the two sellers independently and simultaneously set prices. Then one of these prices is randomly drawn and displayed to the buyer. Having observed the free sample price the buyer can either *buy* at that price, *search*, or *exit* the market. The market ends immediately, if the buyer chooses to *buy* or to *exit*. However, if *search* is chosen, the buyer learns the other firm's price and incurs a search cost of c . In the different treatments the search cost are either 0 (in the *Bertrand* treatments) or 15 (in the *Diamond* treatments). Having observed both prices, the buyer can choose to buy at any one of the two prices, or exit the market. This setup implements a simple two-shop search model with recall.

The buyers' valuation (v), search cost (c) and production cost (mc) are common knowledge and remain constant in all *pre-shock* markets. Between the *pre-shock* and *after-shock* phase an industry-wide cost shock may occur. The shock may increase mc from 30 to 50 (leading to the *Up* condition), decrease mc from 30 to 10 (*Down* condition), or leave mc at 30 (*Constant* condition). The three events are equally likely to occur. The probabilities and mc values are made public. It is common knowledge that the shock is industry wide, i.e. it is known that all firms will have the same production cost after the shock. Depending on the treatment, the realization of the post-shock production cost is either privately observed by only the sellers (*Private* treatments) or public information to both sellers and buyers (*Public* treatments). Up to the changes in cost and the arising private information in the *Private* treatments, the *after-shock* markets are identical to the *pre-shock* markets.

A seller's payoff in a particular market is equal to the price less the production cost if a sale occurs and zero otherwise. The buyer's payoff (conditional on buying) in each market is equal to the valuation less the price paid and the search cost if search has taken place. In situations where the buyer exits the market, the payoff is either 0 or $-c$ depending on whether *exit* occurs without or after *search*. Recall that c takes on the values of 0 or 15 depending on the treatment.

Depending on whether search is free or costly and whether shocks are privately or publicly observed, we have four different treatments (*Bertrand-Public* and *Bertrand-Private*; *Diamond-Public* and *Diamond-Private*). In each treatment,

there are three conditions (*Up*, *Constant*, *Down*) indicating the direction of the cost shock. In the *Bertrand-Public* and *Bertrand-Private* treatments, standard economic theory predicts that prices are equal to marginal cost. So there price adjustment should be symmetric, with one-off jumps in the shock period. In the *Diamond-Public* and *Diamond-Private* treatments, the unique Bayesian Nash equilibrium predicts the monopoly price, i.e. $p = v = 100$. The basic intuition goes back to Diamond (1971). Introducing a small search cost into an otherwise perfectly competitive market lets firms become local monopolists. The optimal search strategy is that a rational buyer should only search if his expected gain from search is greater than the search cost. Keeping the buyer's strategy in mind, a seller always has an incentive to charge a higher price than the other firm as long as the deviation does not induce consumer search. For any price lower than the monopoly price set by a seller, the other seller has an incentive to raise the price as long as the price difference is smaller than c and the price is weakly smaller than the customer's valuation. This deviation process continues until the monopoly price is reached.³ In equilibrium a uniform monopoly price prevails, and consumers do not search in equilibrium. Consequently, in the *Diamond* treatment adjustment is not predicted to occur at all, since the monopoly price is independent of the marginal cost in our setting (as long as $v > mc$ is satisfied). Figure 1 visualizes the theoretical predictions in the four treatments.

The experiments were conducted at AdLab at the University of Adelaide. Subjects were recruited from university students in various disciplines and at various stages of their tertiary education. The experiments were programmed and conducted using Z-tree (Fischbacher 2007). In total, 756 subjects participated in 39 different sessions. In each session, one specific treatment and condition was randomly assigned. Subjects were given written instructions, which they had time to read before the experiments commenced. Subjects were randomly assigned their roles (seller or buyer) at the beginning of the experiment. Players' roles remained the same throughout the whole session but the three subjects playing together in one market were randomly re-determined before every period. This typed-stranger matching was chosen in order to minimize repeated game effects.

³More precisely, equilibrium requires that consumers have correct beliefs over the price distribution. Then for correct beliefs there exists a profitable deviation for at least one firm if not both prices are equal to the monopoly price.

Figure 1: Experimental design and theoretical predictions.

In each market, sellers had only one decision to make (i.e., set the price). After all sellers had set their prices, the buyers entered the market. The buyers each had one or two decisions to make depending on whether they decided to search or not. At the end of each market, profits were calculated and displayed to the subjects before a new market (after random re-matching) started. Sellers did not know the prices posted by other sellers in previous markets. Between the two phases (i.e., between period 15 and 16), subjects were reminded that a cost shock might have occurred. Subjects were informed of the potential states of the world (different marginal cost levels) and about the probability distribution over the states in all treatments. Depending on the treatment, the realized state of the new production cost after the shock was either displayed to all players or to the sellers only. Sessions took about 70 minutes during which subjects earned 20 Australian Dollars on average.

4 Results

While standard theory crisply predicts either Bertrand competition or unitary monopoly pricing, the experimental data paint a completely different picture. We observe price dispersion and asymmetric price adjustment in all four settings.⁴ Buyers seem to base their search behavior on adaptive expectations. Sellers appear to be boundedly rational and adjust their prices in reaction to past selling success instead of setting equilibrium prices. After a positive shock (i.e., costs increase), sellers adjust their prices upwards irrespective of whether they sold or not. In contrast, after a negative shock, only those who were unsuccessful and did not sell in the previous period reduce their prices. This leads to asymmetric price adjustment across the board. In this section we establish these stylized facts by analyzing the data first on an aggregate and subsequently on an individual level.

4.1 Price dynamics

In Figure 2 we plot the average posted-price time series over 30 periods by treatment and condition. In the *pre-shock* phase, the three cost-shock conditions (*Up*, *Constant* and *Down*) are identical within a treatment. The same is true for pre-shock behavior for the treatments with the same search cost but a different information structure. This not surprising, as those treatments are identical from the view of the participants until the cost shock introduces private information in half of the treatments. More remarkably, prices are nowhere near the theoretical predictions. Instead of being either at the monopoly or marginal cost level, average posted prices start out at about 60 in all treatments. Initially, posted prices are only marginally higher in the *Diamond* treatments. The main difference before the shock is that the prices in the *Bertrand* markets trend strongly downwards with time, while in the *Diamond* treatments the downward trend is very weak at best. These different trends lead to higher pre-shock average prices in the *Diamond* treatments (see Table 1). In the period before the shock prices in the *Diamond* treatments are significantly higher than in the corresponding *Bertrand* treatments (Mann-Whitney U-Tests two-sided, $p < 0.01$ for all pairwise

⁴The price dispersion we observe is in line with Baye and Morgan (2004), who showed that price dispersion in Bertrand oligopolies can be explained by bounded rationality captured by Quantal Response Equilibrium or ε -equilibrium.

comparisons and conditions, except *Public-Down*, where $p < 0.07$).

Figure 2: Average posted prices by treatment and period.

The order of price levels is preserved after the shock and after adjustment has occurred. Prices are higher in the *Diamond* treatments in the final period than in their respective *Bertrand* treatment in all cost-shock conditions (Mann-Whitney U-Tests, two-sided, $p < 0.01$ for all tests). The only clear difference private information makes is that in the *Diamond* treatments the prices after a negative shock are higher when only the firms know the direction of the cost shocks (Mann-Whitney U-Test, two-sided, $p < 0.01$). Prices are dispersed in all treatments. Before the shock the standard deviations of the price distribution are around ten in all treatments (see the values in brackets in Table 1). Recall that price dispersion is an important ingredient in theoretical models for generating asymmetric price adjustment. After the shock, price dispersion decreases if the shock is positive and increases if it is negative. This intuitively makes sense, since the range of prices that are between the competitive and the monopoly price narrows after a positive shock and widens after a negative shock.

Once a shock has occurred, prices adjust in the direction of the cost change. It is notable that (in all four settings) the initial magnitude and the speed of ad-

Bertrand-Public			Diamond-Public		
Pre-shock	After-shock		Pre-shock	After-shock	
	Up	61 (6)		Up	70 (7)
54 (9)	Constant	48 (6)	58 (10)	Constant	57 (9)
	Down	34 (10)		Down	40 (12)
Bertrand-Private			Diamond-Private		
Pre-shock	After-shock		Pre-shock	After-shock	
	Up	61 (7)		Up	68 (6)
52 (10)	Constant	49 (8)	59 (11)	Constant	58 (12)
	Down	36 (10)		Down	52 (12)

Table 1: Average posted prices by phase with standard deviation in brackets.

justment in the positive shock conditions considerably differ from those in the negative shock treatments. The adjustment is instantaneous following a positive shock, while the same magnitude of adjustment takes longer after a negative shock. The time it takes until the same level of adjustment has occurred differs by treatment. It is also interesting that the upward adjustment in all four treatments shows some overshooting. In all four treatments the highest of all average prices are observed in the period immediately after the shock in the *Up* condition. When the production cost remains unaltered, the prices in the *after-shock* phase follow similar patterns as in the *pre-shock* phase except for a small jump of prices in period 16 in the private information treatments. This small average price jump stems from a few sellers trying to signal that their cost have gone up even though they have not. These acts of pretense are not successful and soon prices follow the *pre-shock* trend again.

Regardless of the initial adjustment asymmetry, the size of the adjustment after positive and negative shocks tends to converge in size. This is more or less the case in all treatments. The size of the long-run adjustment ranges from about 40 percent of the cost change in the *Diamond-Private* treatment to about 75 percent in the other treatments.

In Figure 3 we plot the average price change from period to period (i.e., $p_t - p_{t-1}$) over time in different treatments. Looking at the first differences makes it easier to disentangle the adjustment to the shock from the general dynamics. Table 2 reports the average price changes including standard deviations for the period immediately after the shock. We see that (following a positive shock) average posted prices jump up immediately by around 20 units in the *Bertrand-*

Figure 3: Average price adjustment ($p_t - p_{t-1}$) by treatment and period.

Public and *Bertrand-Private* markets. The jump is still substantial with about 15 units in the *Diamond-Public* and *Diamond-Private* treatment. This implies that the existence of search cost has a negative impact on the the size of the initial jump upwards. This seems counter-intuitive at the first sight, as firms have more market power if consumers have to search. However, increasing the price in the markets with search cost has two negative effects on a firm's prospects. It increases the search intensity and at the same time reduces the probability of selling if a consumer searches and gets to know both prices. In the markets without search cost consumers always search and hence firms adjust the prices only according to their expectations about what other sellers will do. The only negative impact of a price increase is the increased likelihood of having a higher price than the competitor.

In stark contrast, following a negative shock, the initial drop in prices is only about one unit on average in both *Bertrand-Private* and *Diamond-Private* markets. The reductions are larger in the *Bertrand-Public* (six units) and the *Diamond-Public* (nine units) treatments. This initial adjustment is still smaller

Bertrand-Public			Diamond-Public		
Shock	Mean	Std.Dev.	Shock	Mean	Std.Dev.
Up	20	(8)	Up	15	(7)
Constant	2	(5)	Constant	2	(7)
Down	-6	(16)	Down	-9	(9)

Bertrand-Private			Diamond-Private		
Shock	Mean	Std.Dev.	Shock	Mean	Std.Dev.
Up	21	(12)	Up	15	(8)
Constant	8	(10)	Constant	4	(8)
Down	-1	(9)	Down	-1	(12)

Table 2: Average price adjustment in period 16.

than after positive shocks.⁵ After a negative shock the fact that matters most for the size of immediate price changes is if consumers observe the direction of the shock or not. If consumers observe the realization of the shock, then firms reduce their prices more aggressively then when consumers do not.

In summary, price adjustment is asymmetric in all treatments. The initial asymmetry is more pronounced in *Bertrand* markets than in *Diamond* markets with the same level of information given to the consumers. This observation is somewhat surprising but can be explained by the weaker incentives to increase prices after a positive shock and the stronger incentives to decrease the price after a negative shock when search is costly. Starting from an out-of-equilibrium situation the additional incentive in environments with search cost comes from the price's impact on the search intensity. We also find that the adjustment asymmetry is stronger when shocks are privately observed given the same level of search cost. This observation is more intuitive: sellers exploit their information advantage to the effect of withstanding the downward pressure after a negative shock for as long as possible. In what follows we conduct a detailed individual analysis in order to better understand the driving forces behind the results. We begin with the search behavior.

4.2 Search behavior

The standard theoretical prediction has buyers always searching in *Bertrand* markets if prices are above marginal cost, since search causes no cost. Behavior

⁵The statistical significance of these differences is established below (e.g. see Table 3).

matches this prediction closely. Consumers search in 98 percent of the *Bertrand* markets. This implies that we can rule out search behavior as the reason for the deviation from marginal-cost pricing in these treatments. In the *Diamond* environment consumers should never search in equilibrium, as without price dispersion there are no gains from search to be exploited. However, contrary to the prediction we observe price dispersion in all markets. Therefore, it becomes sensible for buyers to search in *Diamond* markets if the initial price is particularly high. A buyer who holds correct beliefs (i.e. she anticipates how prices are distributed) should search whenever the initial price is above a cut-off price. At prices above this cutoff price the expected savings from having another price to choose from outweigh the search cost. We do not observe such a cutoff price in the laboratory. Buyers' search behavior is heterogeneous.⁶ The fraction of subjects who search increases with the initially encountered price, which is sensible and shows that the consumers understand the situation. Over-all, in the *Diamond* treatments search takes place in about 25 percent of the markets.

Recall that *ceteris paribus* the search intensity determines how strong the competitive pressure for firms is. The more likely search is to occur (for a given price) the stronger the incentive for sellers to undercut competitors. The “Diamond Paradox” is based on firms having no competitive pressure at all when search costs are positive, since consumers do not search in equilibrium. In our experiments with positive search cost there is still some search, which drives prices away from the monopoly level. On the other hand, search is less frequent than in the *Bertrand* treatments, which explains why prices are higher in the *Diamond* treatments.

Search behavior does not only have a strong impact on price levels but also on the price adjustment after a cost shock. Comparing the price adjustment in the two *Bertrand* treatments we do not see much difference. There the search behavior does not change across treatments, as before and after the shock virtually every consumer searches, which is not surprising given that there is no search cost. In contrast, we observe starkly different price-adjustment dynamics in the *Diamond* treatments depending on whether the direction of the cost shock is common knowledge or not. In what follows we show that the differences in adjustment dynamics in the *Diamond* markets can be explained as direct reac-

⁶The heterogeneity could stem from either incorrect heterogeneous beliefs, bounded rationality or different risk preferences.

tions of the sellers to search behavior. For this purpose, we first identify the determinants of the buyers' search rules in the *Diamond* markets.

Figure 4: Predicted average search probability using a random-effects logistic model in *Diamond-Public* treatments.

We find that buyers are adaptive searchers who form expectations based on past observed prices when they do not know the realization of the cost shock. Knowing the direction of the cost shock though, leads to an immediate adjustment of the search rule. Given that prices are similar in the *pre-shock* phase, buyers (in *Diamond* markets) follow the same probabilistic search rule in different treatments and periods before the shock. Differences emerge after the shock. The search rules change in response to price changes and the information on the direction of the shock (*Public* treatment only). We use a random-effect logistic model to estimate buyers' search rules (allowing for individual heterogeneity). The dependent variable takes the values one and zero for search and no search, respectively. The covariates of particular interest are the initial price observed and interactions of price, treatments and period dummies after the shock. The regression allows us to identify changes in the search rule due to the cost shock and its interaction with the information condition. Figure 4 and 5 plot the pre-

dicted search probabilities averaged over all prices charged in the sample for different periods and conditions after the shock. Note that these average predicted probabilities are comparable across conditions, since we average over the same prices for all conditions. For this reason the different prices charged in the different conditions after the shock are controlled for.⁷ Differences in the average search probability represents differences in the search rule. The underlying regression can be found in the Appendix.

Figure 5: Predicted average search probability using a random-effects logistic model in *Diamond-Private* treatments.

The predicted search probability before the shock is at about 30 percent. After the shock in the *Diamond-Public* treatment consumers immediately revise their search rules. For given prices, the average search probabilities increase from around 30 percent to 60 percent after a negative shock, and decrease from around 30 percent to below 10 percent after a positive shock (see Figure 4). When production cost is kept constant, the search probability stabilizes at slightly above 20 percent. This change in search behavior is immediate and

⁷The results here are robust to changes in the specification of the underlying regression and also to using predictions at a particular price instead of an average over the whole sample.

stable. If consumers get the information how the underlying costs of production have changed they update their price expectations and adapt their search behavior accordingly. The shift in search behavior is quite large. In particular the jump of the search probability for given prices in the case of reduced production cost is substantive. This drastic adjustment causes strong incentives to lower prices after a negative cost shock.

In the *Diamond-Private* treatments, the upward price adjustment after a positive shock triggers a much increased search probability in period 16 (from 30 percent to more than 50 percent). Note that this is over and above the additional search induced by higher prices, since averaging controls for the price level. In the other two conditions there is no such jump. If anything, the search intensity goes down slightly. Recall that in *Diamond-Private* treatments prices jumped up dramatically after the shock in the up condition, while they hardly moved in the two other conditions. So consumers who are not observing the direction of the shock react with an increased search intensity after observing higher prices, while they conduct business as usual if the prices do not change (or decline slightly).

Increased prices and the lack of information seems to prompt consumer's suspicion of being exploited. In the subsequent rounds the search intensity for given prices drops below the initial search intensity in the cost-increase condition, as consumers become more and more sure that cost must have gone up. This learning is remarkably quick. By period 19 the difference of the search intensity to the baseline is already significant. In later rounds the predicted search intensity is close to that in the *Public* treatment. This quick learning makes it easy for firms to enforce the higher price level after a cost increase.

In contrast to the cost-increase condition, learning does not really happen when the cost decrease. Since consumers do not search more after the shock when prices stay the same or are slightly reduced, information transmission is slow. The predicted search probabilities are highly volatile and there is a large amount of heterogeneity across consumers. The search intensity is significantly greater than that in baseline in one single period only (5 percent confidence level). Therefore, the pressure to reduce the price after a negative cost shock is very weak. The incentive for price reductions comes from the competition with the other firm only. As we will see, only firms that do not sell reduce their prices subsequently. The consumer's search behavior does not put additional

downward pressure on prices.

In summary, the differences in pricing between the two *Diamond* treatments after a negative shock has to a large extent to do with search behavior. While the search rule adjusts in the case of public information immediately, adjustment occurs in the private information case if at all then only very slowly and erratically. The quick learning after a positive cost shock in the private information treatment allows for a similar sustained price rise as in the public information case, where the search rule adjusts immediately.

4.3 Boundedly rational sellers

An in-depth investigation into search behavior revealed how asymmetric information impacts on the pressure to adjust prices downwards, as long as search is costly. In this section we turn to the sellers' price-setting behavior. Here we analyze how sellers adjust their prices depending on selling history and shocks. This allows us to identify why the price adjustment is least asymmetric in the *Diamond-Public* treatment. First of all, it is obvious that firms' price setting behavior deviates from standard equilibrium in all four treatments. For Bertrand oligopolies, Baye and Morgan (2004) have shown that equilibrium concepts capturing noisy behavior (such as Quantal Response Equilibrium or ε -Equilibrium) can explain observed pricing. Quantal Response Equilibrium also explains the pricing behavior in the *Diamond* treatments before the shock reasonably well.⁸ However, stochastic equilibrium concepts cannot explain how subjects adjust their behavior in response to sales history and cost shocks.

In what follows we look at individual price changes between periods. We draw box plots of individual price adjustments (i.e., $p_t - p_{t-1}$) separately for those firms that sold their unit in the previous period and those who did not.⁹ Figure 6 shows the price adjustment in the *Up* conditions for all four treatments. Figure 7 plots the same data for the *Down* conditions.¹⁰

The two graphs reveal that in non-shock periods past sales success is a cru-

⁸We have shown this in an earlier working paper version of this article.

⁹Box plots summarize distributions by five values: the smallest observation, 25th percentile, median, 75th percentile, and largest observation, potentially with some values being considered as outliers. In our plot, we omit these outside values. The boxes contain the central 50 percent of the observations.

¹⁰For reasons of presentation we plot the 16 periods around the shock only. Behaviour in earlier and later periods is similar.

cial factor for pricing decisions. If firms sold in the period before, then slight price increases follow in all treatments, while unsuccessful sellers reduce their prices. Remarkably, the price reductions exist and have the same size in different treatments despite the fact that in *Diamond* treatments reduced prices might not be seen by the consumers who do not search, while in the *Bertrand* treatments all prices are (almost) always seen.

Figure 6: Box plots of price adjustment in *Up* treatments conditional on selling history.

4.3.1 Positive shocks: sales history does not matter

More interestingly, positive cost shocks lead to very similar reactions of sellers across the board. Regardless of the presence of search cost, the information condition and the selling history, the bulk of sellers increases prices by comparable amounts after a positive shock (see Figure 6). Median price jumps are very similar within a treatment across sales histories.¹¹ The immediate adjustment ranges from about 15 to 20 units. Note that the sellers' pricing decision

¹¹Mann-Whitney U-tests confirm that for the up condition in all treatments the price adjustments do not differ significantly for different sales histories.

Figure 7: Box plots of price adjustment for *Down* treatments conditional on selling history.

after a cost shock becomes a coordination problem if prices are dispersed due to noise and/or bounded rationality. Figure 6 reveals that successful coordination on a new higher price level is easily achieved after a positive cost shock. The price adjustment only takes two periods, the shock period and the following one. After the initial uniform jump of prices in the shock period, sellers who did not sell in that period, reduce their prices more strongly than unsuccessful sellers normally would. In other words, in the shock period prices jump and overshoot a little. In the subsequent period the overshooting is corrected by those who failed to sell in the shock period. Two periods after the shock, the price dynamics are already back to normal. Combining this insight with the results on search behavior explains why there are no large differences in price dynamics across treatments after positive shocks. Firms find it easy to coordinate on higher prices and consumers' search behavior does not prevent this coordination in any treatment.

In a next step we investigate the reasons why downward adjustment is slower. Previously, we have established that the competitive pressure from search is

stronger in the *Diamond-Public* than in the *Diamond-Private* treatment after a negative cost shock. This might explain why the adjustment is more asymmetric in the *Diamond-Private* treatment. There is further evidence that the search behavior plays an important role. The asymmetry is about the same size in the *Bertrand* treatments, where in both treatments search is close to one-hundred percent. Figure 7 plots the firms' price changes by sales history and treatment after a negative shock.

4.3.2 Negative shock: adjustment is history dependent

Generally, the sales history is very important in determining if a firm reacts with discounting after the cost have gone down. Firms that failed to sell reduce their prices more than otherwise in the cost shock period and/or the two to three periods thereafter. In the *Public* treatments the excess price reduction is instantaneous, while it takes one period until the price reduction by unsuccessful sellers begins in the *Private* treatments.¹² The dynamics only return to "normal" in the fifth period after the shock. The excess price reductions by unsuccessful sellers in the adjustment periods is substantial. In all treatments the median reduction is about ten units in the first period the reduction takes place.

The observation that the substantive price reduction of unsuccessful firms is delayed by a period in the private-information treatments provides some insight into subjects' beliefs. Sellers initially do not expect other sellers to reduce prices if the downward shock is private information. In the public information setting firms that did not sell expect prices of other firms to fall already in the shock period and therefore reduce their prices immediately when the shock hits. Failing to sell in the few periods after the shock is interpreted as a signal that other firms must have reduced the prices due to the shock, which prompts price reductions in excess of the normal reduction after unsuccessful sales.

In contrast to the behavior of unsuccessful firms, firms that sold their unit in the pre-shock period reduce their prices only marginally in all treatments except in *Diamond-Public*. The median price reduction is close to zero though. Instead of a small increase after a sale successful sellers react with a slight price decrease to a negative price shock. Having been able to sell serves as a signal that the

¹²Mann-Whitney U tests show that price adjustments significantly differ by sales history in period 16 only for the Public treatments, while in period 17 the adjustment is different in all treatments.

price has been right. Then a possible explanation for why prices are not reduced by successful sellers is that these sellers believe that the price distribution of the opponents will not change. In this case there is no reason for reducing the price if the shock does not change the search intensity. This explanation is consistent with the behavior of the buyers. Recall that we found that the search intensity does not change in these three conditions. In subsequent periods successful sellers return to business as usual (i.e. they slightly increase prices after selling).

The only treatment where successful sellers considerably reduce their prices in the shock period is the *Diamond-Public* treatment. There the median price reduction of a successful seller in the shock period is about ten units. This ten unit reduction is about the same size as the price reduction of unsuccessful sellers in the other treatments. This comparatively large reduction reduces the asymmetry of price adjustment considerably. Consequently, the “Rockets-and-Feathers” phenomenon is weakest in the *Diamond-Public* treatment. At first glance this is surprising. General intuition suggests that the adjustment in more competitive markets should be more symmetric. However, once one takes into account that subjects do not behave according to Nash equilibrium before the shock, then this initially unintuitive behavior becomes explainable.

Contrary to other treatments, successful sellers have an incentive to reduce the price in the *Diamond-Public* treatment after a negative shock even if they expect the prices of potential other firms to remain the same. Recall that buyers adjust their search behavior immediately in the *Diamond-Public* treatment. The increased search probability for given prices provides an extra incentive to drop prices. Ceteris paribus an increased search probability makes it more likely that the consumer sees both prices, which increases the incentive to reduce the price.

4.4 Regression analysis

Beyond the box-plot analysis we also conducted panel regressions for the different treatments, where the dependent variable is the price adjustment $p_t - p_{t-1}$.

The results of the linear regressions (with clustered standard errors on individuals) are given in Table 3. This regression formally establishes the result on the existence and relative size of asymmetric price adjustment and the role of sales history. The explanatory variables are a dummy variable indicating if a firm sold in the period before, and period dummies interacted with the condition

Dependent variable: $p_t - p_{t-1}$				
	Bertrand-Public	Bertrand-Private	Diamond-Public	Diamond-Private
Constant	-4.009*** (0.191)	-3.873*** (0.242)	-3.049*** (0.254)	-2.800*** (0.220)
Sold (in T_{t-1})	6.414*** (0.300)	5.861*** (0.312)	4.928*** (0.316)	4.866*** (0.299)
Constant-T16	2.326*** (0.846)	7.669*** (1.579)	2.960*** (1.065)	3.867*** (1.404)
Up-T16	20.976*** (1.237)	21.561*** (1.767)	15.086*** (1.008)	14.890*** (1.404)
Up-T24			1.199** (0.548)	
Up-T25				1.509*** (0.533)
Up-T30	1.801** (0.742)			
Other periods:	not significant at 5% significance level			
Down-T16	-5.199** (2.310)	-0.400 (1.604)	-8.749*** (1.092)	-0.967 (1.978)
Down-T17	-4.221*** (1.102)	-2.847** (1.245)	-1.931** (0.828)	-2.800* (1.648)
Down-T18				-2.244*** (0.773)
Down-T19			-1.281*** (0.472)	
Down-T20		-1.321** (0.643)		
Down-T27	-3.699** (1.723)			
Other periods:	not significant on 5% significance level			

Note: * p -value < 0.1; ** p -value < 0.05; *** p -value < 0.01. Robust Std.Err. in brackets.

Table 3: Liner regressions on sellers' price adjustment.

(*Up*, *Constant*, *Down*) for periods after the shock. For reasons of presentation we only report significant coefficients.

The regressions show a similar downward trend in all treatments. In all treatments firms increase their prices by about two units if they have sold the period before (i.e. the joint effect of the previous sales dummy and the constant). The price reduction of the other half of the firms, who did not sell is slightly larger in the *Bertrand* treatments than in the *Diamond* treatments (four

versus three units). The average adjustment in the period a positive cost shock occurs is larger in the *Bertrand* treatments (21 versus 15 units). In the case of downward shocks significant downward adjustments only happens in the *Public* treatments (five units in *Bertrand* and nine units in *Diamond*). In the treatments with private information on cost shock realizations, negative cost shocks only lead to significant average price reductions in the period after the shock period (by about three units in both search cost conditions). Subsequently in all four treatments in both the up and down conditions, there are periods with small significant average price adjustments.

In summary, although we observe asymmetric price adjustment in all four settings, information and cost condition both have some impact on the degree of the asymmetry. If we hold the search cost constant, comparing *Bertrand-Private* to *Bertrand-Public* markets and *Diamond-Private* to *Diamond-Public* markets, we find that private information on production cost increases the level of the adjustment asymmetry due to the same amount of upward price jumps combined with smaller downward adjustment when shocks are privately observed. However, if we hold the information condition constant, comparing *Diamond-Public* to *Bertrand-Public* and *Diamond-Private* to *Bertrand-Private*, the adjustment asymmetry is more pronounced in markets with no search cost due to a higher upward jump in the *Public* treatments.

5 Conclusion

Economists have long shown that asymmetric price adjustment to cost shocks is a widespread and robust phenomenon in many industries. The debate on what causes asymmetric price adjustment is still ongoing. Finding an answer to this question is important, since different causes might trigger different policy implications. Asymmetric price adjustment is often seen as being caused by tacit collusion. If the occurrence of different adjustment speeds after positive and negative cost shocks were a proven indication for collusion then anti-trust authorities should have a close eye on how prices adjust in certain industries.

Another, more recent, strand of literature attributes asymmetric price adjustment to search and informational frictions. If this explanation were true then the occurrence of asymmetric price adjustment would indicate that an industry is not very competitive due to the existence of search frictions. Then improv-

ing price transparency would be an immediate policy implication. Furthermore, providing information on cost shocks to consumers would also help to improve market outcomes.

In this study we investigated the validity of theoretical claims on the causes of the “Rockets-and-Feathers” phenomenon by using laboratory experiments. We implemented four treatments representing extreme points on the two dimensions of competitiveness and information. On the competition dimension we compared behavior in a (competitive) Bertrand duopoly setting with homogeneous goods to the behavior in a (monopolistic) Diamond search environment. On the information dimension we varied whether the direction of cost shocks was private information to firms or not. Asymmetric price adjustment is not predicted by standard theory in any of the treatments.

In contrast to standard theoretical predictions we find asymmetric price adjustment in all of our treatments. Therefore we conclude, that it is not possible to easily draw a clear and simple policy implication from the observation of asymmetric price adjustment in an industry. A more detailed analysis is necessary. We further find that private information on cost shocks amplifies the phenomenon, especially when there are also search frictions. Asymmetric price adjustment is strongest in the Diamond search environment with private information and weakest in the Diamond search environment with public information. Therefore, in markets with search frictions, providing timely information on cost shocks is effective in reducing the degree of the adjustment asymmetry. In Bertrand environments the level of asymmetric price adjustment is intermediate and private information has only a modest impact. We attribute the observed asymmetric price adjustment in our experiments to bounded rationality and its interaction with expectations and feedback. Traditional factors like collusion and search frictions might still have an impact on price adjustment. They are not necessary for the phenomenon to occur though.

Our result that the asymmetry of price adjustments in markets where cost shocks are readily observed (through, e.g., media coverage) is less pronounced if search frictions exist has an interesting immediate implication. Price transparency measures in some industries where cost shocks are common knowledge might have the unwanted side effects of stronger asymmetries of price adjustments. Price-watch websites like the recently suspended Gas Price Watch of the U.S. Department of Energy or Grocery Watch (previously proposed by the

federal government of Australia) could have such unintended effects. Removing search frictions in our experiment over all still has the positive effect of reducing prices. However, the price differences are not very large. If one also takes into account the common fear that transparency might promote collusion, then the over-all effectiveness of transparency measures becomes doubtful.

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A Experimental Instructions

(A sample for Diamond-Private-Constant treatment.)

Thank you for participating in this experiment. Please read the instructions carefully. This is important, as understanding the instructions is crucial for earning money. Please note that you are not allowed to communicate with other participants during the experiment. If you do not obey to this rule we may exclude you from the experiment. If you have any questions, please raise your hand. We will come to answer your questions individually.

The currency in this game is called E-Dollars. At the end of the game we will convert the E-Dollars you have earned into real money. The exchange rate is **100 E-Dollars = 2 Australian Dollars**. You will also be paid a base payment of **AUD 6.00** for your participation.

- **Your task**

You will play a market game in this experiment. There are two types of players in the game: sellers and the buyers. You will be randomly assigned your role (either as a seller or a buyer) at the beginning of the experiment. Your role will be announced to you and fixed for the whole duration of the experiment. In each round we will randomly pair two sellers with one buyer. Each of the two sellers wants to sell one unit of a good which will cost the seller **MC = 30 E-Dollars** to produce and sell. The buyer wants to buy one unit of the good, which he values at **V = 100 E-Dollars**. The profits for seller will be the selling price minus the cost MC if a sale takes place and zero otherwise. The profit of the buyer will be the valuation V minus the selling price. Your task in this market is to make as high a profit as possible (, the higher your profit the higher is your monetary payout after the experiment).

- **The trading environment**

The game is composed of two decision-making stages: the sellers' stage and the buyer's stage. In the sellers' stage, the two sellers in the same group simultaneously set the prices in E-Dollars at which they want to sell. After both sellers have entered their selling prices, the buyers enter the game. In the buyer's stage, the buyer will be randomly given one out of the two prices offered by the two sellers in the group. Then the buyer can decide if he a) wants to buy from this seller at this price, or b) invest 15 E-Dollars to see the price of the other seller or c) to exit the market. In the case that the buyer decided to invest **C = 15 E-Dollars** to see the second price he can then decide a) to buy from the first seller, b) to buy from the second seller, or c) to exit.

- **Your Profit**

The round profits will depend on the prices set by the sellers and the buying and search decision of the buyers. Depending on the type (seller or buyer) the profits will be given as follows:

a) Sellers:

$Price(P) - cost(MC=30, initially)$	<i>if the unit was traded</i>
<i>zero</i>	<i>if the unit was not traded</i>

Note that the production cost MC is only incurred if the unit is actually traded. Furthermore, the production cost is initially fixed at 30 but may change during the game (see below).

b) Buyers:

Valuation($V=100$)-Price(P)-searchcost if the unit was purchased

zero-searchcost if the unit was not purchased

Note that the search cost is $C = 15$ if the buyer invested in seeing the second price and zero if he did not.

• Repetition and cost shocks

You will play 30 rounds of this game in succession. You will always play the same role (buyer or seller); but you will play with changing partners in your group. The groups are newly and randomly formed after each round.

Recall, that the seller initially has production cost MC of 30. This cost stays the same for the first 15 rounds. In between rounds 15 and 16 there might be a cost shock (MC might take on a different value). Then the remaining rounds (16 to 30) will be played with the new cost. You will be given details about the cost shock on the screen once it occurs.

• Summary

In this market game you will be a buyer or a seller. If you are a seller you want to sell a unit of a good, if you are a buyer you want to buy a unit of the good. There are always two sellers setting prices simultaneously. They are paired with one buyer, who does only observe the price of one of the sellers initially. The seller of which a buyer sees the price is randomly determined. Then the buyer can decide to buy from this seller or to spend some search cost in order to learn the price of the second seller before making a purchasing choice.

Production costs are initially fixed at $MC=30$ and might change between rounds 15 and 16. This will be announced between rounds 15 and 16.

Again, please make sure that you understand the instructions clearly, as this is crucial for your earnings in this experiment. If you have any questions please raise your hand. We will come and answer your question. Once you are ready, we will play a trial period, which is of no consequence for your payout, after which you can raise your hand again and ask questions before we start with the 30 rounds, which will determine your earnings.

B Cost shock warnings

There might be a permanent cost shock in the next period. Due to some external factors, the production cost (now 30) may "go up by 20 (to 50)", "go down by 20 (to 10)", or "stay unchanged ". Each event ("going up by 20", "going down by 20", or "staying unchanged") is equally likely. The production cost will then stay at the same level for all the later periods. Both sellers and buyers will be informed the actual change at the beginning of next round.

Cost shock warnings for *Public* treatments.

There might be a permanent cost shock in the next period. Due to some external factors, the production cost (now 30) may "go up by 20 (to 50)", "go down by 20 (to 10)", or "stay unchanged ". Each event ("going up by 20", "going down by 20", or "staying unchanged") is equally likely. The production cost will then stay at the same level for all the later periods. If you are a seller, you will be informed of any cost changes in the next period. However, if you are a buyer the only information you know is that each event is equally likely to occur.

Cost shock warnings for *Private* treatments.

C Regressions on search probabilities

Variables:	Diamond-Public		Diamond-Private	
	Coefficient	Std.Err.	Coefficient	Std.Err.
Constant	-15.300***	1.197	-15.284***	1.255
P1	0.230***	0.019	0.229***	0.020
P1*aftershock	-0.008**	0.004	-0.007	0.005
P1*Up-T16	-0.031***	0.012	0.028**	0.013
P1*Up-T17	-0.026**	0.012	-0.012	0.010
P1*Up-T18	-0.030**	0.012	-0.012	0.011
P1*Up-T19	-0.038***	0.013	-0.028**	0.011
P1*Up-T20	-0.037***	0.013	-0.017*	0.010
P1*Up-T21	-0.032**	0.013	-0.020*	0.011
P1*Up-T22	-0.026**	0.013	-0.025**	0.011
P1*Up-T23	-0.045***	0.015	-0.036***	0.012
P1*Up-T24	-0.039***	0.013	-0.021*	0.011
P1*Up-T25	-0.035**	0.013	-0.034***	0.012
P1*Up-T26	-0.031**	0.013	-0.031***	0.012
P1*Up-T27	-0.045***	0.015	-0.047***	0.013
P1*Up-T28	-0.048***	0.015	-0.036***	0.012
P1*Up-T29	-0.040***	0.013	-0.034***	0.012
P1*Up-T30	-0.069***	0.018	-0.034***	0.012
P1*Down-T16	0.109***	0.019	-0.007	0.015
P1*Down-T17	0.065***	0.017	0.015	0.014
P1*Down-T18	0.055***	0.018	0.010	0.015
P1*Down-T19	0.038**	0.017	-0.019	0.017
P1*Down-T20	0.044**	0.021	0.026*	0.015
P1*Down-T21	0.059***	0.019	0.002	0.015
P1*Down-T22	0.081***	0.022	0.011	0.015
P1*Down-T23	0.056***	0.020	0.011	0.015
P1*Down-T24	0.076***	0.020	-0.017	0.022
P1*Down-T25	0.076***	0.020	-0.005	0.019
P1*Down-T26	0.089***	0.021	-0.016	0.019
P1*Down-T27	0.065***	0.020	0.010	0.017
P1*Down-T28	0.073***	0.020	-0.007	0.019
P1*Down-T29	0.056***	0.019	0.003	0.017
P1*Down-T30	0.064***	0.018	0.017	0.016
Log likelihood:	-482.683***		-392.561	
Wald χ^2 :	166.88***		160.19***	

Note: * p -value < 0.1; ** p -value < 0.05; *** p -value < 0.01

Table 4: Random-effect logistic estimations of the probability of search.