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Environmental Labeling and Incomplete Consumer Information in Laboratory Markets[1]

Timothy N. Cason[2]

Department of Economics, Krannert School of Management, Purdue University, West Lafayette, Indiana 47907-1310
E-mail: cason@mgmt.purdue.edu

and

Lata Gangadharan

Department of Economics, University of Melbourne, Parkville, Victoria 3052, Australia
E-mail: gangadha@cupid.ecom.unimelb.edu.au

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Survey evidence suggests that consumers care about the environment and are willing to pay a higher price for a product that generates less environmental harm. We induce buyer preferences over quality in a laboratory posted offer market to study sellers' incentives to offer products of differing quality. Buyers are unaware of the product quality before purchase, as is often the case for goods with differing environmental quality. We first document the market failure that arises from incomplete information when no signaling or reputations are possible. We then study various treatments that could remedy this failure. Seller reputations and unverified "cheap talk" signals sometimes increase the number of higher-valued "green" goods. The only reliable way to improve product quality in the experiment, however, is to use a third party that charges a fee to certify product quality claims.

Key Words: moral hazard; experiments; environmental goods; Green labeling; certification.

1. INTRODUCTION

Over the last decade firms have increasingly included environmental product claims in their advertising and packaging. These "green" claims have emerged as a marketing strategy in part due to growing evidence that consumers care about the environment and are willing to pay a higher price for a product or process that

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[2] To whom correspondence should be addressed.

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generates less environmental harm.[3] Examples include sustainable forestry, electricity generated from renewable resources, and organically grown agricultural products. Green claims have been regulated to varying degrees in different countries and states. For example, the U.S. Federal Trade Commission (FTC) has issued guidelines for environmental marketing claims (the most recent guidelines are in FTC [7]), rather than more formal regulations with standardized terminology as proposed in the Environmental Marketing Claims Act, which was not acted upon by Congress (U.S. Senate [21]). Environmental claims are regulated slightly more stringently in Australia by the Trade Practices Commission (Kangun and Polonsky [11]), which seeks to protect both consumers and competitive conditions between firms, using one set of guidelines.

One form of regulation is third-party certification of environmental quality. These "eco-label" programs are typically voluntary and range from government-sponsored schemes (e.g., Germany's Blue Angel) to private systems (e.g., the Green Seal in the U.S.). These labeling programs can reduce transactions costs of regulation enforcement relative to broad restrictions on the use of environmental terms, as is done in the FTC guidelines (see Grodsky [8]). Although the labels can simplify decisions for consumers when products have multi-dimensional environmental attributes, for this same reason labeling schemes have been criticized as being too simplistic (Church [4]). Moreover, recent theoretical research has questioned the ability of labeling to improve market outcomes (Dosi and Moretto [6]). Nevertheless, labels could play a useful role because consumers often view claims by producers suspiciously (Boulding and Kirmani [1]).

To provide some empirical evidence on the role of certification in improving the provision of environmental quality, in this paper we use laboratory posted offer markets to examine the incentives firms have to offer products of differing environmental quality to consumers. The experiment explicitly addresses the problem that consumers often find it difficult to identify the environmental quality of a good prior to purchase. This is because environmental attributes are often experience or credence qualities (as opposed to search qualities) of the product (Church [4]; Karl and Orwat [12]). We consider the case in which consumers have higher valuation for environmentally clean products than for environmentally dirty products. The clean products are also more expensive to produce, and the sellers choose which quality to deliver. Quality is unobservable prior to purchase, so this is a classic seller moral hazard problem. We examine whether reputations alone, "cheap talk" signaling, or certification of product quality can help the market reach the efficient market equilibrium.

The literature on markets with asymmetric information has emphasized the role of reputations to improve efficiency. Firm's quality claims can in some cases be relied upon in markets where sellers and buyers are involved in ongoing relationships. In this case, sellers may invest in a reputation for high quality that they

[3] For example, according to a poll by Market and Opinion Research International, between 1988 and 1989 the proportion of respondents who bought a product because of its environmental friendliness increased from 19 to 42%; and a survey by a UK based product development consultancy in 1989 revealed that 75% of the respondents were willing to buy a product that was biodegradable and had recyclable packaging and roughly as many were willing to pay more for such products (Cairncross [3]). In a 1990 poll by the J. Walter Thompson advertising agency, 82% of the respondents said that they would pay at least 5% more for a product that was environmentally friendly (Levin [14]). The "green market" has consequently emerged as an important consumer segment and is the focus of considerable marketing research (e.g., Shrum *et al*. [20]).

would hesitate to risk for short-term gains from selling low quality products. Consequently, reputations alone may be sufficient to overcome the asymmetric information problem in environmental quality provision. We include treatments both with and without opportunities for seller reputation formation to evaluate the effectiveness of reputations alone in increasing the delivery rate of clean goods.

In an alternative cheap-talk signaling treatment, sellers can label their products with non-binding quality claims. In the early 1990s, Iyer and Banerjee [10] found that nearly one-third of all green advertising claims were nothing more than vague statements (e.g., "Brand X is environmentally friendly") or were obvious attempts to hitch the company to the growing green movement (e.g., "in response to the growing demand for an environmentally friendly product, we are proud to offer Brand X"). The increasing use of these vague claims is one reason that the FTC green marketing guidelines have required substantiation of environmental claims to ensure that they contain qualifications to not mislead consumers.[4] FTC enforcement is somewhat limited, however, so it is quite possible that firms can still manage to convey unsubstantiated marketing claims.[5]

In a final certification treatment, sellers can pay an explicit certification cost to assure buyers that the offered product is environmentally clean. This form of certification appears to be growing in the marketplace, and it is favored by proponents of life cycle analysis to inform consumers of the overall ("cradle-to-grave") environmental impact of consumption (Grodsky [8]). Certification is particularly important for credence goods such as forestry products, where consumers may otherwise find it difficult to identify suppliers who employ sustainable production processes (Van Orsdol and Kiekens [22]).

We find that reputations alone are insufficient to generate efficient outcomes reliably. Likewise, simple cheap talk (analogous to unregulated environmental claims) often fails to generate the efficient delivery of clean products. By contrast, when verifiable ("certified") quality claims are possible, sellers typically choose to pay for certification and deliver clean products. This suggests that public or private third party certification can help solve the information problem facing consumers.

The paper is organized as follows. Section 2 provides a brief summary of the experimental literature on quality provision in markets characterized by asymmetric information. Section 3 presents the experimental environment, the treatment variables, and the models to be tested. Section 4 reports the results and Section 5 concludes.

2. EXISTING EXPERIMENTAL LITERATURE

The experimental literature addressing this issue of endogenous quality determination in markets is rather limited. Miller and Plott [17] conducted an experiment to study the effect of signaling on market equilibrium. Sellers were endowed with

[4] For example, the claim "recyclable" must be qualified to indicate which portions of the product or packaging are recyclable, and "claims of recyclability should be qualified to the extent necessary to avoid consumer deception about any limited availability of recycling programs and collection sites" (FTC [7, p. 24249]).

[5] For example, in 1994—two years after the initial FTC guidelines were issued—the FTC litigated only 8 specific environmental cases (Scammon and Mayer [19]). Moreover, firms continue to make broad claims regarding their environmental responsibility; e.g., "At Apple Computer, Inc., we recognize our responsibility to minimize the environmental impacts of our operations and products" (http://www.apple.com/about/environment).

products that were exogenously designated as Regulars or Supers. They could then add costly quality to their products, and this quality was observable to buyers. They found that signals have the greatest impact when the signal cost is substantially different for the Regular and Super grades.

In Lynch *et al*. [15] sellers chose endogenously between two grades (Regular or Super). They found that if buyers cannot observe the quality prior to purchase, then sellers have a strong incentive to offer Regulars, which cost less per unit to produce. Our laboratory environment draws heavily on the Lynch *et al*. environment, with the primary differences between our experiment and theirs being the trading institutions and the choice of "regulation" treatments. Lynch *et al*. use an oral double auction, whereas we employ a posted offer market to approximate retail sales of goods that may differ in environmental quality. Lynch *et al*. examined a number of different treatment variables, including warranties, warranty enforcement, identification of the sellers of units and the timing and public and private nature of grade revelation. They were able to identify conditions under which inefficient market outcomes are consistently observed. Lynch *et al*. do not consider the possibility of costly grade certification, which is a key treatment in the present study.

Both of the experiments discussed above were conducted using the double auction trading institution, which is known to have strong competitive tendencies. Retail markets in the field with inefficient low quality outcomes, however, are often organized using the posted offer trading institution. In this institution, sellers make take-it-or-leave-it price offers each period, and buyers simply accept or reject the various price offers. Holt and Sherman [9] examine a posted offer market with endogenous quality and find that lack of buyer information about quality handicaps market performance, whether or not price advertising is permitted. Also using data from posted offer markets, Brozovsky and Richardson [2] show that when buyers of auditing services have incomplete information about the quality of the audit, participating auditors fail to achieve quality assuring prices and receive lower profits. DeJong *et al*. [5] study this problem of seller moral hazard in a series of four sealed offer auctions. They demonstrate that the presence of moral hazard leads to shirking by agents and the provision of low quality services. Reputations alone are not sufficient to eliminate this problem.

3. EXPERIMENTAL ENVIRONMENT, TREATMENTS, AND MODELS

3.1. *Environment*

Experimental subjects were undergraduate students from Purdue University and the University of Melbourne. Eleven subjects participated in each session, randomly assigned as 5 sellers and 6 buyers. Subjects were seated in a large classroom facing a whiteboard. The instructions (shown in Appendix A) were read aloud.[6] A

[6] The instructions used neutral wording, without any reference to environmental characteristics of the goods being traded. Neutral wording is common practice in research on experimental markets because the experimenter wishes to control the valuations of the goods through induced monetary resale values and production costs. Since some subjects may be affected by environmental terminology and others may not be—and because these influences are unobservable—using environmental terminology would have resulted in potentially less experimental control.

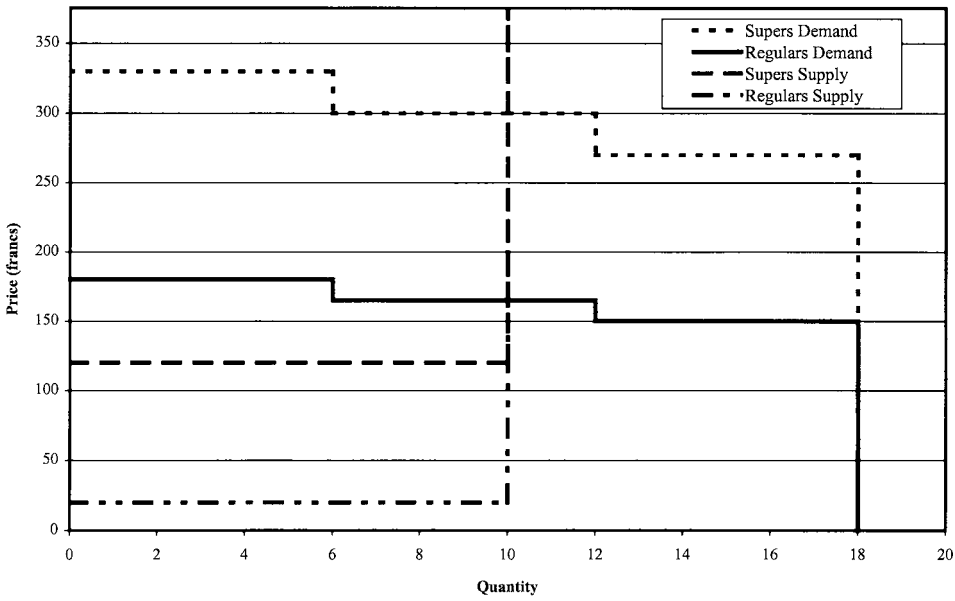

FIG. 1. Market supply and demand.

practice period was conducted in order to verify subjects' understanding of the trading rules and the accounting procedures.

We report 21 sessions. All sessions except the first have 20 trading periods, and the total number of trading periods was highlighted on the whiteboard and read in the instructions. Each session lasted between 90 and 120 minutes. Subjects traded using experimental francs, which were converted to local currency at the end of the experiment using a known but private dollar conversion rate. All sellers had the same conversion rate (one franc = 0.005 Australian dollars or 0.004 U.S. dollars) and all buyers had the same conversion rate (one franc = 0.012 Australian dollars or 0.01 U.S. dollars). Earnings typically ranged between U.S.$15 and U.S.$35 per subject.

During each market period sellers can sell a maximum of two units of grade Regular or two units of grade Super. It is public information that Supers are more expensive to produce than Regulars, but only sellers know the exact cost. Each Super cost the seller 120 francs and each Regular cost the seller 20 francs. Buyers' resale values for Supers are more than for Regulars and this is also public information, but only buyers know the exact values. The marginal value of the Supers is always greater than for Regulars as in Lynch *et al.* [15]. The value of the first unit of Super is 330 francs, the second unit is 300 francs, and the third is 270 francs. For Regulars the values are 180, 165, and 150 respectively. Buyers therefore prefer to buy Supers unless they are priced 120-150 francs more than Regulars.

All buyers and sellers have identical value and cost schedules, resulting in the market demand and supply schedules shown in Fig. 1. In the efficient equilibrium with Supers delivered, the equilibrium price is 300 francs with 10 units exchanged, resulting in a total (maximum) exchange surplus of 1980 francs. In the inefficient equilibrium with all Regulars delivered, the equilibrium price is 165 francs with 10

TABLE I
Experimental Design

Treatment	Features	Number of sessions
Baseline	Seller identification not revealed, no product claims allowed	3 inexperienced (UM1[a], UM3, PU1)
Reputations only	Seller identification revealed, but no product claims allowed	4 inexperienced (PU2, PU3, UM4, UM10) 1 experienced (PU4x)
Cheap talk signaling	Seller identification revealed, unregulated product claims allowed	4 inexperienced (UM7, UM8, PU7, PU8) 1 experienced (UM9x)
Certification	Seller identification revealed, binding ("certified") product claims and unregulated product claims allowed	4 inexperienced (PU5, PU6, UM5, PU9) 1 experienced (UM6x)
Reputations only with outside option	Seller identification revealed, but no product claims allowed; buyers received ten francs for "no-purchase" option	2 inexperienced (PU10, PU11) 1 experienced (PU12)

Note. A PU in the session name denotes Purdue University, and a UM in the session name denotes University of Melbourne. An x in the session name denotes experienced subjects.
[a] Session UM1 lasted 16 periods. All other sessions lasted 20 periods.

units exchanged, resulting in a total exchange surplus of 1540 francs. Trading efficiency in the inefficient Regulars equilibrium is therefore $1540/1980 = 0.778$. In addition to the profits earned from the units bought, buyers receive a bonus of 50 francs each period and a starting balance of 200 francs at the beginning of the experiment. This was stated explicitly in the experiment instructions. The reason for these bonus payments is that in this market design buyers could incur significant losses in the early part of the session if they naively buy Regulars at high (Super) prices. The bonus plus the starting balance helped them absorb early losses and therefore maintained control over monetary incentives. Lynch *et al*. also employed identical bonus payments and starting balances.

3.2. *Treatments*

Table I summarizes the experimental design. We conducted three *Baseline* sessions to measure the market performance in the presence of informational asymmetry when seller identification is not revealed. In these sessions the sellers are asked at the beginning of each period to indicate privately the number of units they want to sell, the offer price per unit and the grade of the units. Note that here (and in all treatments) sellers have to precommit to a grade at the beginning of the period. The price offers by the sellers are then posted on the board in a random order to hide the seller identity so that no reputations are possible. Buyers are then randomly selected to take turns accepting the offers. After all the buyers have an opportunity to purchase or all the units are sold, the grades of the units are written on the board next to each price offer. Note that in this and in every other treatment, grade information of all sellers is revealed publicly at the end of each period.

We conducted four sessions with inexperienced subjects and one session with experienced subjects in the three main research treatments. In the *Reputations Only* treatment the trading procedure is exactly as described above, except that in this treatment the first seller's price offer is always written in the first row on the board, the second seller's offer in the second row, etc. This allows the buyers to track the sales record of each seller and identify if a particular seller has a history of selling Regulars or Supers. Prices are also written on the board in the specific order of the seller identification numbers for the other two treatments described below.

The *Cheap Talk Signaling* treatment studies whether unregulated claims could by themselves help in increasing the number of efficient, Super units sold. In this treatment the sellers have the following two options: (1) indicate no grade information to buyers, in which case only the price and the number of units offered for sale is indicated on the board; or, (2) indicate a grade to be shown on the board, although this need not correspond to the actual grade offered. This second option corresponds to the case of unregulated environmental quality claims—so-called cheap talk. It represents, for example, claims (especially vague claims) made by producers that have not (or cannot) be verified by third parties. Recall that in all cases sellers still must commit to a specific quality level privately to the experimenter at the start of the period.

The *Certification* treatment examines whether sellers would choose the option of certifying (or green labeling) their products at an extra fixed cost of 30 francs. In this treatment, sellers are given options (1) and (2) described in the Cheap Talk Signaling treatment, as well as a third option: (3) Sellers can pay 30 francs to certify that the product they are offering is a Super. In this case the buyers are sure that they are buying a high quality product. This certification is indicated on the board by a "star" next to the price offer, and it corresponds to third-party verified environmental labeling schemes. We chose to make this certification costly because in practice real resources are needed to test products, and in many cases the certification fees are used for financial support of the certifying firm or organization.

Note that a feature of this market design is that buyers who choose not to buy in a particular period do not make any profits. An anonymous referee correctly points out that some of the puzzling results discussed in the next section could be due to the fact that buyers cannot profitably exit from this market and therefore are locked in. Following his or her suggestion we conducted three sessions (two inexperienced and one experienced) in the Reputations Only treatment, in which buyers could choose not to purchase from any seller and still earn ten francs.[7] This outside option is described as alternative "no-purchase" earnings in the experiment.

Sellers' profit per unit in equilibrium is $165 - 20 = 145$ when selling a Regular and $300 - 120 = 180$ when selling a Super. When selling two units, the profits are 290 and 360, respectively. The difference $(360 - 290 = 70)$ is greater than the certification cost (30), so this regulated green labeling can lead to the efficient

[7] Buyers earn 15 francs per period in the market equilibrium with Regulars and 30 francs with Supers. In order to retain these as market equilibria the outside option has to be less than 15 francs.

equilibrium.[8] Note that if all five sellers certify their product and all 10 units are sold, efficiency is less than 100% because of the certification cost. With five certifying sellers these costs are $5 \times 30 = 150$ in total, so in this case efficiency would be $(1980 - 150)/1980 = 0.924$.

3.3. *Models Tested*

Lemons Model. When sellers face buyers who cannot distinguish between Regulars and Supers, they will only offer Regulars. Buyers observe only Regulars delivered and so they will behave as if they expect only Regulars. Hence in equilibrium, only Regulars will be delivered and the price prevailing in the market will be P_R (the equilibrium price for Regulars—165 francs). This equilibrium is particularly likely when sellers cannot establish reputations, as in the Baseline treatment.

Reputation Model. In the presence of some imperfect information, even in finite period games sellers may establish reputations for delivering Supers in sequential equilibrium (e.g., Kreps and Wilson [13]). According to this model, for some early range of periods some sellers will deliver Supers at a price of P_S (the equilibrium price for Supers—300 francs). A buyer who observes a seller delivering a Regular will update her beliefs and expect that seller to always deliver Regulars in the future. Therefore, in later periods more Regulars will be delivered at P_R.

Signaling Models with Unverifiable Signals. Standard signaling models applied to this environment would allow a meaningful role for the signal if the cost of adding the signal were significantly lower for Supers than for Regulars (Miller and Plott [17]). When it is not possible to verify product claims by sellers, then no cost differential exists between adding the "Super" signal to Supers and to Regulars. In a "babbling" cheap talk equilibrium, no seller adheres to her signals, and buyers do not believe that the signals convey any information; consequently, market outcomes would be unchanged by the introduction of signaling (e.g., see Matthews *et al*. [16] for a discussion). Signaling could, however, assist sellers in establishing the reputations discussed in the previous paragraph.

Signaling Models with Verifiable Signals. When the signaled product claims are verifiable, as discussed above sellers would find it profitable to deliver certified Supers since the certification cost is less than the marginal profit from delivering Supers rather than Regulars at their respective equilibrium prices. Buyers know that if the product is certified, they are guaranteed to receive a Super and are thus willing to pay the higher equilibrium Super price P_S. Hence when certification is available, outcomes correspond to the full information equilibrium.

[8] The sellers' equilibrium gain from certification $(70 - 30 = 40)$ is less than the 50 franc per period bonus paid to buyers. There is no way for traders to make any kind of interpersonal earnings comparison, however, so this difference should be unimportant. The comparison is impossible because buyers' bonus and resale values and sellers' production and certification costs are all private information.

4. RESULTS

4.1. *Quality and Efficiency Comparison*

A primary goal of this experiment is to determine whether market performance improves when sellers can make unverifiable (Cheap Talk) or verifiable (Certified) quality claims. We focus on two measures of market performance: The frequency of high quality (Super) products delivered to consumers, and overall market efficiency.

Result 1. Allowing seller reputations increases the rate at which Supers are traded, but Cheap Talk does not affect the rate at which Supers are traded compared to the treatment with Reputations Only. Certification is sufficient to increase the rate that Supers are traded.

Evidence. Table II presents the treatment average of Super and Regular units traded over all periods, as well as over the final 5 and the final 10 periods. Over all periods, about 12% of the units sold in the Baseline (no reputations) treatment are Supers, whereas over 40% of the units sold in the Reputations Only treatment are Supers. A very conservative test using one (overall proportion) observation from each independent session rejects the null hypothesis that the Super delivery rate is equal in these two treatments (one-tailed nonparametric Wilcoxon test p-value < 0.02).

In the Cheap Talk treatment (Table II), about one-third of the units sold are Supers. This rate is not significantly different from the Reputations Only treatment. By contrast, in the Certification treatment more than two-thirds of the units sold are Supers. This rate is significantly higher than the Reputations Only rate even based on the conservative test employing one (overall proportion) observation per session (one-tailed nonparametric Wilcoxon test p-value < 0.02).

Table III presents some additional evidence for Result 1 based on a random effects probit model of the Super delivery outcome. The dependent variable in this model is equal to one if a seller sells Super units, and is zero otherwise. The maximum likelihood estimates are based on a seller specific random effects error structure. The model contains dummy variables for the various experimental treatments, each interacted with two variables that capture the dynamic tendencies in the data. Following Noussair *et al*. [18], the variables $1/t$ and $(t-1)/t$ allow the estimates to reflect both the early period Super delivery rate as well as where the rate is approaching as t increases in the long run. In the initial period ($t = 1$), the $(t-1)/t$ interactions are excluded since $(t-1)/t = 0$, and the $1/t$ interactions are at their maximum ($1/t = 1$). Therefore, the $1/t$ interaction terms capture the estimated Super delivery rate in the initial period. As t grows, the $1/t$ term approaches zero while $(t-1)/t$ approaches one, hence the $(t-1)/t$ interactions capture the long-run tendencies of the outcomes. The top two terms in the table ($1/t$ and $(t-1)/t$) capture initial and long-run Super delivery for the omitted Reputations Only treatment. The other interaction terms indicate whether the delivery rate is different in the other treatments from the rate in this omitted treatment.[9]

[9] In alternative specifications (not reported) we found that factors such as experiment location and experience are always insignificant. To improve the estimation efficiency, we do not include these insignificant factors.

TABLE II

Treatment Average of Number of Super and Regular Units Sold and Efficiency

	Number of super and regular units sold								Efficiency including surplus loss from certification			
	Baseline		Reputations only		Cheap talk signaling		Certification		Baseline	Reputations only	Cheap talk signaling	Certification
	Reg	Sup	Reg	Sup	Reg	Sup	Reg	Sup	Efficiency	Efficiency	Efficiency	Efficiency
Treatment average (all periods)	6.5	0.9	4.8	3.4	5.7	3.4	2.6	6.2	0.646	0.787	0.813	0.813
Treatment average (final 5 periods)	7.1	0.5	5.2	3.2	6.3	3.2	1.8	7.4	0.643	0.812	0.826	0.866
Treatment average (final 10 periods)	6.9	0.7	4.9	3.6	5.9	3.5	2.4	6.9	0.658	0.806	0.834	0.870

TABLE III
MLE of Random Effects Probit Model for Super Delivery

Dependent variable: Supers delivered = 1 if seller sells Super units and 0 otherwise
Number of observations: 1780
Log likelihood function: −842.23
Restricted log likelihood: −1033.55
Chi-squared (1): 382.65
Significance level: 0.00000

Variable	Coefficient	Standard error
Time variable for initial outcomes $(1/t)$	−1.541*	0.227
Time variable for long-run outcomes $((t-1)/t)$	−0.595*	0.138
(Certification treatment) × $(1/t)$	−0.324	0.390
(Certification treatment) × $((t-1)/t)$	1.249*	0.218
(Baseline treatment) × $(1/t)$	0.271	0.598
(Baseline treatment) × $((t-1)/t)$	−1.096*	0.269
(Cheap talk treatment) × $(1/t)$	1.058*	0.298
(Cheap talk treatment) × $((t-1)/t)$	−0.303	0.191
$E\pi$(supers)/$E\pi$(regulars)[a]	0.003	0.002
Standard Hausman test statistic for the presence of random effects	0.517*	0.044

* Indicates significant at the 95% significance level.
[a] These expected profits are calculated based on fictitious play expectations; see the text for details.

To link the Super delivery decision to past payoffs from delivering Supers we also include the ratio of expected earnings from offering Supers to the expected earnings from offering Regulars. These expectations are calculated based on the seller's own experience, using fictitious play beliefs for updating. According to this belief model, subjects have a long memory and each observation updates the expectation with a declining weight. In other words, subjects accumulate evidence from offering Supers and Regulars, and their beliefs are simply the running average of payoffs for each choice.[10]

The results are consistent with the simple nonparametric tests based on the number of Supers and Regulars summarized in Table II, but this dynamic specification allows for a more detailed analysis of how the treatments differ in the early periods and in the long run. The $1/t$ and $(t-1)/t$ estimates for the omitted treatment of Reputations Only indicate that the Super delivery rate in this treatment rises over time (because -0.595 exceeds -1.541). The long-run interaction (no reputations) Baseline × $(t-1)/t$ indicates that the Super delivery rate is significantly less in the no reputations than the Reputations treatment in later periods. The initial period rate is not significantly different in these two treatments. The estimates indicate a higher Super delivery rate in the early periods in the

[10] For example, if a seller has offered Regulars in N previous periods and offers Regulars in this period, she updates the expected profit of offering Regulars as [(N* previous period expected profit of offering Regulars) + current profits from offering Regulars]/(N + 1). The ratio included in the regression is the expected profit of offering Supers/the expected profit of offering Regulars. We also estimated an alternative model using Cournot expectations—a very short (myopic) belief process where, e.g., the expected profit of offering Supers = profit the last time a subject offered Supers. These myopic expectations performed very poorly, with insignificant estimates on the myopic ratio that are very close to zero.

Cheap Talk treatment relative to the Reputations Only treatment, but this difference does not persist in the long-run. The Certification treatment results in a significantly higher Super delivery rate in the long-run but not in the initial periods. Finally, the ratio of expected earnings from offering Supers to the expected earnings from offering Regulars is positive as expected, but it is not quite significant.[11]

Before turning to the next result concerning efficiency, we should note that although the last result indicates that Supers tend to be delivered more often late in the session, in the (known) final period most units offered are Regulars except in the Certification treatment. That is, there is clear evidence of an endgame effect, which is an implication of most models of reputation formation. In the final period, 3 of the 15 sellers offer Supers in the Baseline (no reputations) treatment, only 2 of the 25 sellers offer Supers in the Reputations Only treatment, and 7 of the 25 sellers offer Supers in the Cheap Talk treatment. By contrast, 19 of the 25 sellers in the Certification treatment offer Supers in the final period.[12]

Result 2. Allowing seller reputations marginally increases efficiency, but neither Cheap Talk nor Certification significantly improve efficiency compared to the treatment with Reputations Only.

Evidence. Define efficiency in the usual way—the fraction of the maximum gains from trade actually realized by subjects. Table II also presents the average efficiency for each treatment for all periods as well as separately for the final 5 and the final 10 periods. These efficiency figures include the surplus lost when sellers pay to certify their product in the Certification treatment. These averages indicate that efficiency rises from about 65% to near 80% when sellers can establish reputations. A conservative test based on a single overall efficiency observation per session rejects the hypothesis that efficiency is equal in the no reputation Baseline and Reputation Only treatments, but only at a marginal significance level (one-tailed nonparametric Wilcoxon test p-value = 0.07). Although efficiency rises above 80% in the Cheap Talk and Certification treatments, according to this same conservative test efficiency in these two treatments is not significantly different from the Reputation Only treatment.[13] Note that although average efficiency tends to rise over time, except in the Certification treatment it does not rise substantially above the 78% efficiency of the Regulars equilibrium.

Table IV presents an alternative parametric comparison of the efficiency in the various treatments using a random effects tobit model. The session is the random effect, and the tobit specification accounts for the restriction that efficiency is bound above by one. A session contributes one observation per period to this model. As in the Super delivery model shown in Table III, we include $1/t$ and $(t-1)/t$ interaction terms with each of the treatment dummy variables to differ-

[11] Conclusions are qualitatively similar using alternative measures of the seller quality choice, such as the rate that Supers are offered (rather than delivered) to buyers, or the proportion of Super units that all sellers deliver in a period.

[12] We reestimated the model shown in Table III after dropping the final period to determine if the estimates are influenced strongly by this end period effect. The alternative estimates lead to the same qualitative conclusions; the only notable difference is that the long-run Baseline (no reputations) reduction in the Super delivery rate is even stronger after dropping the final period.

[13] In the final 5 periods, however, efficiency is significantly greater in the Certification treatment than in the Cheap Talk Signaling treatment (one-tailed Wilcoxon test p-value < 0.05).

TABLE IV
MLE of Random Effects Tobit Model for Efficiency

Dependent variable: Efficiency levels
Number of observations: 338
Log likelihood function: 228.50
Restricted log likelihood: 222.89
Chi-squared (1): 11.21
Significance level: 0.00081

Variable	Coefficient	Standard error
Time variable for initial outcomes $(1/t)$	−0.421*	0.122
Time variable for long-run outcomes $((t-1)/t)$	−0.335*	0.072
(Certification treatment) × $(1/t)$	−0.019	0.132
(Certification treatment) × $((t-1)/t)$	0.384	0.067
(Baseline treatment) × $(1/t)$	0.312	0.177
(Baseline treatment) × $((t-1)/t)$	−0.159*	0.043
(Cheap talk treatment) × $(1/t)$	0.066	0.134
(Cheap talk treatment) × $((t-1)/t)$	0.007	0.047
Lagged efficiency	0.180*	0.075
Constant[a]	1.000	

* Indicates significant at the 95% significance level.

[a] The constant term of 1.0 is included because the estimated model has 1—efficiency as the dependent variable. This transformation was required because the statistical package used (LIMDEP) only allows a lower threshold for the random effects tobit model estimation and the upper bound of 1.0 is binding for efficiency. The estimates shown in this table therefore add one to the right-hand side and multiply all coefficients by −1.

entiate between early period and long-run differences in efficiency. We also include lagged efficiency as an explanatory variable to further capture any dynamic tendencies in efficiency.[14]

The estimates for the omitted case of the Reputations only treatment indicate that estimated efficiency is lower in the opening period than in the long run, as is observed commonly in market experiments. None of the $1/t$ treatment dummy interaction terms are significant, indicating that initial period efficiency levels are not different across treatments. The only significant treatment dummy variable is the Baseline (no reputation) dummy interacted with $(t-1)/t$, indicating lower efficiency compared to the omitted case of Reputations Only in the long run.[15]

[14] As we include lagged efficiency, we must drop period $t = 1$ from the model estimation. The first period in the estimation is $t = 2$, so to aid in the interpretation of the results on the time interaction terms we have adjusted the terms to be $1/(t-1)$ and $(t-2)/(t-1)$ to make their interpretation easier. Also, although we have lagged efficiency as an explanatory variable, there is little evidence of error autocorrelation (for example, the Durbin–Watson Statistic is only 2.096).

[15] Like the Super delivery model of Table III, we estimated alternative specifications including dummy variables for the session site and experience. The results indicated that neither factor significantly affects efficiency, so we report in Table IV specifications without those terms. We also calculated alternative estimates after dropping the final period to check for sensitivity to an end period effect. The estimates are virtually unchanged when we exclude the final period.

4.2. *Signaling and Certification*

Result 3. Non-certified Super signals are frequently false.

Evidence. We find that of the 222 Super signals in the Cheap Talk treatment, 49 (22%) are false; that is, sellers actually offered Regulars even though they claimed to be offering Supers. Non-certified Super signals are more rare in the Certification treatment, but they are also frequently false; in particular, of the 135 non-certified Super signals in the Certification treatment, 45 (33%) are false. Regular signals are much less common in both treatments, and they are almost always truthful.[16]

Result 4. Given the opportunity in the Certification treatment, sellers frequently certify their units as Super.

Evidence. In some sessions such as the experienced session UM6x, nearly all offered units are certified. The average number of sellers certifying in this session is 4.75 for all periods (out of a total of 5 sellers) and this number increases to 5 in both the last 10 and the last 5 periods. In the other sessions the certification rate usually ranges between 2 and 4 sellers, and it tends to increase later in the sessions.

In the early periods many sellers try to use certification to establish reputations and then use their reputation (without certification and sometimes with cheap talk) to obtain higher prices. Buyers, however, often choose to buy only from sellers who certify and in later periods they refuse to buy at high (Super) prices unless they see a certification. This pattern is most pronounced in sessions UM5 and UM6, where in later periods all sellers certify. In session PU9, by contrast, many sellers successfully establish reputations through early period certification. In this session they are able to sell (cheap talk) signaled Supers at high prices in later periods, thus saving on certification costs.

4.3. *Reputation Formation*

Because so many of the non-certified signals are false (Result 3), are sellers able to obtain a reputation for delivering Supers? Our next result indicates that sellers do seem to be able to establish reputations and they also sell at higher prices when signaling Super products.

Result 5. (a) Reputations modestly impact transactions prices in certain conditions; (b) signals have an impact on transaction prices in the Cheap Talk treatment; and (c) certification is necessary for sellers to sell at substantially higher prices in the Certification treatment.

Evidence. Table V presents random effects regression models of the transaction price on several predetermined explanatory variables. The seller is the random effect, and we include the lagged transaction price to capture dynamic properties of the price time series. The estimates are corrected for first order autocorrelation. Following a specification from Lynch *et al*. [15] (which did not include lagged price or correct for autocorrelation), we proxy the "market reputation" with the total number of Supers sold in the market during the previous period. In the double

[16] More details on the number of non-certified signals in each session and in each period are available from the authors on request.

TABLE V
Estimates of the Random Effects Model of Transaction Price

Variables	Description	Treatment			
		Baseline	Reputations only	Cheap talk signaling	Certification
Own reputation	Lag of # of Supers sold by individual sellers		0.176 (2.193)	−1.070 (1.521)	3.674* (1.546)
Mkt reputation	Lag of # of Supers sold in the market	6.773* (2.094)	1.070 (0.821)	0.119 (0.588)	0.342 (0.554)
Ssignal	= 1 if signal is Super			46.498* (2.340)	−2.780 (3.45)
Rsignal	= 1 if signal is Regular			−10.517* (3.163)	−75.098* (4.325)
Lagprice	Lag of transaction price	−0.103* (0.034)	−0.132* (0.029)	−0.232* (0.030)	−0.129* (0.023)
Certif	= 1 if certified				63.084* (2.741)
Constant		190.012* (8.796)	236.494* (11.463)	231.337* (10.634)	257.769* (7.216)
Rho	Autocorrelation coefficient	0.494* (0.045)	0.772* (0.023)	0.811* (0.020)	0.672* (0.026)

* Indicates significant at the 95% significance levels.
Note. Numbers in parentheses are standard errors.

auction markets of Lynch *et al*. this term was positive and significant in 5 out of 12 sessions, leading the authors to conclude that demand sometimes depends on the overall market reputation. By contrast, for our data Table V indicates that the market reputation is positive and significant for only the Baseline (no reputations) treatment.

We also include an "own reputation" term—the number of Supers sold by that specific seller during the previous market period. This term obviously is inappropriate for the Baseline treatment because seller identities are not observed. This own reputation term is only significant for the Certification treatment, indicating that in this treatment sellers can establish reputations and sell for a higher price when they delivered Supers in the previous period. The magnitude of the coefficient, however is not economically significant: a seller who delivered two Supers in the previous period could only obtain prices that are $2 \times 3.67 \approx 7$ francs higher on average.

The signaling dummy variables for the Cheap Talk and Certification treatments provide evidence for our conclusions regarding the value of the signals. Surprisingly, even though Super signals were false 22% of the time when not certified, the dummy variable for the signal indicates that sellers nevertheless obtained significantly higher prices on average when signaling Super in the Cheap Talk treatment. This at first seems puzzling. Because 78% of the Super signals are truthful, however, the expected resale value of a unit with a Super signal is much closer to the Super than Regular resale value. The average estimated price premium of 46 francs is reasonable because the difference in resale value between Regular and Super units ranges between 120 and 150 francs. In the certification treatment the

Super signal does not significantly affect prices. But sellers who certify are able to obtain significantly higher prices—on average 63 francs higher—which is an amount substantially greater than the per-unit certification cost of 15 francs.

RESULT 6. Sellers who reveal themselves as "cheaters" by delivering Regular units at "Super prices" can frequently regain a positive reputation quickly—often in the next period. This seems to be due in part to the lack of an explicit outside option for buyers in most of our sessions.

Evidence. This result replicates the puzzling finding from the double auction market of Lynch *et al*. Buyers necessarily lose money when they purchase a Regular at a price above 180. Recall that quality grades are revealed publicly at the end of each period. It would not be unreasonable for buyers to avoid purchasing from a seller who very recently "cheated" a buyer. When a seller is able to sell an uncertified unit at a price above 180 one period after they sold a Regular at a price above 180, this provides an example of an "immediate reputation recovery." Over all 15 of our sessions in which seller identities are revealed, in 163 periods a seller sold a Regular at a price above 180 (out of a total of 5 sellers*20 periods*15 sessions = 1500 seller-periods). In 90 of these 163 periods (55 percent) the seller is able to immediately recover her reputation and sell at least one unit in the next period at a price above 180. Similar calculations from the Lynch *et al*. double auction data reveal a slightly higher immediate reputation recovery rate: 25 out of 41 periods, or 61%.

As discussed in Subsection 3.2, a referee suggested that this puzzling high rate of reputation recovery could be due to the fact that buyers' only source of profit is from making purchases in the market. In order to test this conjecture, we conducted three additional sessions where buyers could choose not to purchase from any seller and still earn ten francs.[17] Resource constraints did not permit us to conduct sessions with this outside option in all of our treatment conditions, so we focused on the Reputations Only treatment because in this treatment the reputation recovery rate was particularly high (71 out of 102 periods—70%). In the Cheap Talk and Certification treatments the reputation recovery rate is only 36 and 21%, respectively.

The buyers opt for the no purchase option in exactly one-quarter of the periods (90 out of 360 buyer-periods) in these three sessions. This indicates that the modest ten-franc outside option represented a viable opportunity for buyers. Nevertheless, in these three outside option sessions, the overall performance is similar to the five sessions with Reputations Only and no outside option. For example, in the final 10 periods the number of Supers delivered averages 3.7 per period, compared to 3.6 per period with no outside option (Table II). The number of Regulars delivered in the outside option sessions is somewhat lower than the previous Reputations Only sessions—averaging 4.2 per period compared to 4.9 per period over the final 10 periods of the sessions. Market efficiency is also lower in the new outside option sessions, averaging 71% over the three sessions, compared to 79% in the Reputa-

[17]An alternative way to address this conjecture would be to examine the order in which buyers make purchases to determine if trades with "bad" sellers occur mostly near the end of the trading period after other "good" sellers have sold out their units. Although we suspect that this is the case, unfortunately in the initial 18 sessions we did not record the order in which buyers purchased. We of course recorded this information in the 3 follow-up sessions, which allows us to determine when buyers exercised their "no purchase" option—refusing to purchase when units were available.

tions Only treatment (Table II). This lower rate of Regular delivery and efficiency is due to the fact that buyers exercise this new outside option frequently, resulting in losses in trading surplus. Importantly, the reputation recovery rate declines substantially in these new sessions with an outside option, to 10 out of 30 periods (33%). The puzzling high reputation recovery rate we observe in our sessions without the outside option (70% in the Reputations Only treatment) could hence be explained in part by the inability of the buyers to exit the market profitably.

5. SUMMARY

Permitting seller reputations (only) increases the number of high-quality goods delivered relative to the no-reputation baseline. Outcomes in this treatment remain inefficient, however, particularly in the experienced session. Cheap talk signaling does not increase efficiency or the number of high-quality units delivered, except when subjects are experienced. Thus, unverified claims are not sufficient to improve market outcomes. Although certification is costly, sellers usually opt to certify; consequently, the number of high-quality units increases, even though efficiency does not significantly increase due to the certification costs. Certification therefore appears sufficient to overcome the moral hazard problem studied here. Moreover, at least compared to the other regulatory schemes we have studied in our various treatments, certification also appears to be a necessary condition.

A distinct advantage of the posted offer trading institution relative to earlier experimental studies in this environment using double auction rules is that the discrete strategy choices of the traders (e.g., what single offer price to select each period) permit straightforward empirical models of behavior based on the history of play. This is useful when we study reputation formation using data from our various treatments. We find that seller reputations modestly influence prices in some conditions, and that signals and certification have a significant impact on transaction prices. Buyers in turn are willing to forgive sellers quickly who previously deliver Regulars at Supers prices. This is contrary to theoretical predictions, but it is explained at least in part by the fact that in most of our sessions buyers could not profitably exit the market.

One of the goals of environmental regulation is to create incentives for firms to provide environmentally clean goods or use clean production processes. When it is difficult to determine the environmental quality of goods in a market, consumers may hesitate to pay higher prices for products that might be environmentally superior. In this scenario of asymmetric information, our laboratory results suggest that government regulators or non-governmental organizations can improve environmental performance by providing the option of certified green labeling. Firms wishing to deliver an environmentally superior product could incur explicit costs to obtain a certified label, which can potentially increase the proportion of clean goods produced. Such broad conclusions should be considered preliminary, however, because the experiment examines only one of many possible parameter configurations and does not evaluate all aspects of environmental quality. For example, subject preferences in our experiments are based on only a single dimension of the product, and product quality claims are perfectly verifiable if certified. We leave for future research extensions that address the multidimensional quality of products, the possible bundling of attributes, and more complex

information treatments with imperfect product quality signals. Nevertheless, the experiment does implement a realistic (posted offer) trading institution and is an actual market with profit-motivated participants. The results suggest that even voluntary certification could help achieve the goal of improving the provision of clean goods.

APPENDIX — INSTRUCTIONS IN CERTIFICATION TREATMENT

General

This is an experiment in the economics of decision making. The instructions are simple and if you follow them carefully and make good decisions you will earn money that will be paid to you in cash at the end of the experiment.

We are going to conduct markets in which you will be a participant in a sequence of trading periods. Attached to these instructions you will find a sheet labeled Information and Record Sheet, which will help you calculate your earnings based on the decisions you might make. You are not to reveal this information to anyone. It is your own private information.

During each market period you will be free to buy or sell units as you choose. Your Record Sheet indicates whether you are a buyer or a seller in today's experiment, and you will remain in this role throughout the experiment. Some important information such as the number of sellers, the number of buyers, and the number of trading periods is written on the blackboard.

The type of currency in this market is francs. All trading and earnings will be in terms of francs. Each franc is worth _____ dollars to you. Do not reveal this number to anyone. At the end of the experiment your francs will be converted to dollars at this rate, and you will be paid in dollars. Notice that the more francs you earn, the more dollars you earn.

Buyers

During each market period buyers are free to purchase from any seller or sellers as many units as they may want. The resale value of a unit depends on its grade. There are two grades (Regular and Super) and the resale value of a Super is much greater than the value of a Regular. At the time buyers buy a unit they may not know the grade but at the end of a trading period they will be told the grade of each unit they bought.

Buyers also have the option of not buying units from any seller in a period and instead receiving alternative "no purchase" earnings for that period, as described later.[18]

Resale implies that you can sell the unit to the experimenter at a set price. If you are a buyer, your Personal Record Sheet includes two Resale Value schedules. The schedule on the left column identifies the resale values of Regulars and the schedule on the right column contains the resale values for the Supers. The resale value of the first Regular you purchase is in the row marked First Units and the

[18] The sentences in italics are the lines added to the instructions for the Sessions where buyers have an outside "no-purchase" option.

column marked Regular. The resale value of the first Super you purchase is found on the same row, under the column marked Supers. The resale value of the second unit is found in the second row, etc. If you buy a unit during the trading period you will receive this Resale Value at the end of the trading period. The profits from each purchase (which are yours to keep) are computed by taking the difference between the resale value and the price paid for the unit. That is,

$$[\text{your earnings} = (\text{resale value}) - (\text{purchase price})].$$

In addition to these earnings you will receive an extra payment of _____ francs each period, and a starting balance of _____ francs at the beginning of the experiment. These figures are also shown on your Record Sheet.

Suppose, for example, that the resale value for your first Regular unit is 1000 and the resale value of your first Super unit is 4000. If you buy two units at 1200 and one is a Regular and one is a Super your profits are

$$\begin{aligned} 1000 - 1200 &= -200 \\ 4000 - 1200 &= \underline{2800} \\ \text{TOTAL:} \quad & 2600 \end{aligned}$$

Buyers should now turn to the second page of their information and record sheet. The purchase price of the first unit they purchase should be listed in row two for the first unit purchased. The purchase price of the second unit should be listed in row six, etc. When the grades of units become known buyers should enter the resale values in rows one, five, etc. for each unit purchased. If, for example, your first unit purchased is a Super and if your second purchase is a Regular, you record the resale value for the first Regular in row five. This is because even though the Regular unit is the second purchase it is only your first Regular purchase. Profits at the end of the period should be recorded at the bottom of the page. An experimenter will help you fill out your record sheet for the practice period.

Buyers can also choose not to buy any units from any seller. In this case they would earn _____ francs for this "no purchase" choice, in addition to the usual extra payment of _____ francs explained above. This "no purchase" amount is entered on row 14 *of the information and record sheet, and the total profit entered on row* 16 *in this case would be _____ (row* 14*) + _____(row* 15*) = _____. These are the earnings for a buyer who wishes to purchase zero units in a particular period.*

Sellers

During each market period sellers may sell to any buyer or buyers as many as _____ units. There are two types of units, Supers and Regulars. Each Super will cost sellers _____ and each Regular will cost sellers _____. Notice that the cost of Supers is more than the cost of Regulars. If you do not sell any unit in a particular period you do not incur the cost for that unit; therefore, the profit on any unit not sold is simply zero. The profits or losses on each sale (which are yours to keep) are computed by taking the difference between the price at which you sold the unit and its cost. That is,

$$[\text{your earnings} = (\text{sale price of unit}) - (\text{cost of unit})].$$

Suppose, for example, that your cost per unit of a Super is 1000, and that you sell two Super units. If you sell both units at a price of 1600, your earnings are

$$\begin{aligned} 1600 - 1000 &= 600 \\ 1600 - 1000 &= \underline{600} \\ \text{TOTAL:} \quad & 1200 \end{aligned}$$

Sellers' total profits for a market period are computed by adding the profits or losses on each sale during the period. Their record sheet is used to keep track of profits or losses. Sellers enter the price of the first unit they sell in the appropriate column (Super or Regular) in row one at the time of sale. They then record the profit or loss in row three. The sale price of the second unit sold should be entered on row 4, and profits on this unit should be similarly calculated on row 6, etc. Total profits for the period are recorded at the bottom of the row.

Trading Procedure

Sellers fill in their offer sheets at the beginning of the period. Sellers have 3 options for indicating the grade to the buyers on the blackboard:

(1) They can indicate no grade information, by circling the appropriate phrase on their offer sheet. In this case, only the offer price and quantity is written on the blackboard.

(2) They can indicate a grade (either super or regular) to be shown on the blackboard with their offer, but this grade does not need to correspond to the actual grade of the product they sell. Buyers will learn the actual grade at the end of the trading period.

(3) They can pay 30 francs to certify the product they offer is a super. The experimenter indicates this "Certified Super" information with a "star" next to the super grade information on the blackboard. Buyers will know for certain that this offer is for super grade products. Sellers must deliver the super grade in this case, and the 30-franc fee for the "certified super" listing is paid by the seller regardless of how many units of the product she sells. Sellers should enter "-30" on row 7 of their record sheet for the appropriate period as soon as they fill in their offer sheets.

The experimenter will come around and collect the offer sheets. Then the experimenter will write the price offers on the blackboard, with the first seller's offer always shown in the first row, the second seller's offer shown in the second row, etc. If any sellers indicated the grade or the certified grade on their offer sheets, this will also be shown on the blackboard.

Once the prices are posted on the board, buyers are randomly selected to take turns accepting the offers they want. The buyer who is selected gets to make her purchases in the following manner: "I will buy 2 units from the second offer on the blackboard and I will buy 1 unit from the fourth offer on the blackboard. That is all for me." Then the next selected buyer gets his turn. After all buyers have had an opportunity to purchase (or all units are sold), the experimenter will write on the board next to each price offer, the *actual* type of unit (Regular or Super) that was offered so that buyers can learn the type that they have bought. Now everyone can

calculate your profits. The market will be re-opened for a new trading period by having sellers submit prices and grades again and the whole procedure will be repeated.

Summary

• Buyer earnings (for each unit) = resale value of unit − purchase price of unit.

• Seller earnings (for each unit) = sale price of unit − cost of unit.

• Sellers make a single price offer in each period, by preparing their offer price and quantity and indicating the unit type (Super or Regular) on their offer sheet.

• Buyers choose whether to buy at the offer price.

• *Buyers can choose not to buy any units and receive "no purchase" earnings for any period.*

• The grade information written on the blackboard before buyers make purchases does not have to be accurate, unless the seller pays a 30-franc cost to offer "Certified Super" products.

Are there any questions now before we begin the experiment?

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