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The Informational Properties of Institutions: An Experimental Study of Persistence in Markets with Certification

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Institutions that form to reduce moral hazard often eliminate discretion and pool the actions of heterogeneous agents. An unintended consequence of this pooling is that agents' types cannot be determined by their actions. While in the short run such mechanisms may be optimal, in the long run inefficient institutions may persist because information about changes in the environment is lost. This paper studies a market with a moral hazard reducing certification technology. When certification is adopted, information embedded in market primitives is eliminated. This leads to the persistence of certification, an inefficient institution that makes *all* participants weakly worse off.

Keywords: Persistence of Institutions, Information, Externalities, Inefficient Market Structures, Experimental Economics.
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1 Introduction

Institutions that emerge to reduce moral hazard such as certification, monitoring, and process management often do so by taking discretion away from individual agents. A byproduct of eliminating discretion is that it can agglomerate the actions of heterogeneous agents so that observing a particular action or outcome may reveal less information about the type of agent performing it.

This paper explores how the agglomeration of actions in moral hazard reducing institutions may lead to inefficient institutional persistence. Intuitively, if an institution or market structure suppresses information about the underlying population, the institution is likely to persist because information necessary to evaluate relative efficiency and coordinate to a new equilibrium is missing.

The suppression of information provides a channel by which long-term inefficient institutions can arise even under conditions where market forces efficiently select short-run optimal market structures. Further, persistence is generated by properties of the institution *itself* and can occur even in an environment where *all* agents could be made better off by eliminating the institution.

Moral hazard reducing mechanisms represent one of the simplest yet most common types of economic institutions in existence. The persistence of these 'agglomerating' institutions can have negative long-run consequences in environments where the underlying population is stochastic and therefore the optimal institution varies over time. For example, in markets, the persistence of certification institutions may lead to needless verification costs and intermediation.[1] In government, the persistence of regulation can lead to regulatory burden and red tape.[2] In organizations, the persistence of monitoring can lead to a decrease in intrinsic motivation and experimentation.[3]

I develop a theoretical market with products of high and low quality where a costly

[1]The Agriculture Marketing Service, for instance, offers voluntary certification programs for a variety of US agriculture goods. Similar decentralized certification institutions exist for management standards, business school accreditation, health and safety management, and some environmental laws. See King, Lenox and Terlaak (2005) for more examples.

[2]The Sarbanes-Oxley Act, for instance, requires that all publicly traded companies implement standardized auditing and risk management as part of an effort to constrain publicly traded firms from taking undisclosed risks. These programs have high fixed costs, however, which potentially limits access to equity markets for small firms. See Section III of the SEC's *Final Report of the Advisory Committee on Smaller Public Companies* (2006).

[3]See Benner and Tushman (2003) for an empirical study of the effect of process management on firm innovation.

certification technology is required to guarantee quality. Heterogeneity in production costs divide sellers into three categories: good, bad, and conditional. Good sellers have incentives to always produce high-quality units while bad sellers have incentives to produce low-quality units. Conditional sellers are prone to moral hazard and produce either high-quality certified units or low-quality uncertified units.

For some initial distributions of seller types, two competitive equilibria may emerge— non-certifying and certifying— which vary in the adoption of the certification institution. These equilibria differ both in terms of efficiency and in the information they generate about the underlying environment. Characteristics of the equilibria are as follows:

- In the non-certifying equilibrium, no seller chooses to certify their product and the prevailing market price carries information about the proportion of good sellers. An exogenous decrease in the number of good sellers leads to an *observable* decrease in the price of uncertified goods. This decline in price can lead to an arbitrage opportunity for good and conditional sellers by adopting certification and provides a natural channel by which a market may endogenously adopt certification.

- In the certifying equilibrium, the certification technology is adopted by both good and conditional sellers so that their actions no longer reveal their types. Changes in the proportion of sellers between these two groups are not observable by the market and thus there is no information revealed when market conditions change. This information externality may lead to inefficient persistence of the certification institution since information about the underlying population is not transmitted through observable market signals.

I next use laboratory experiments to explore the informational properties of the certifying and non-certifying equilibrium by studying the response of the two equilibria to changes in the underlying population of sellers.[4] Subjects initially trade in one of two environments — Safe and Hazardous — which vary in the composition of sellers in the market. In the Safe environment, the proportion of good sellers in the market is large, thus favoring the formation of the non-certifying equilibrium. In the Hazardous environment, good sellers are replaced

[4]As argued by Ochs (1990), experiments are a natural environment to studying environments with multiple equilibria. In the current setting, experiments allow for the study of equilibrium selection in a replicable environment where there is exogenous control of supply, demand, information, and the number of equilibria. This allows for an empirical study of market dynamics with minimal assumptions about the strategies of agents. Experiments also allow for the elimination of other channels of persistence, such as the strategic actions of the intermediary, sunk investment, and reputation.

with conditional sellers, leading to significant amounts of moral hazard and the elimination of the non-certifying equilibrium. Subjects who begin in the Safe environment are switched to the Hazardous environment midway through the experiment. Likewise subjects who begin in the Hazardous environment are switched to the Safe environment.

Consistent with the theoretical predictions, individuals who begin in the Safe environment establish a non-certifying equilibrium and then adapt to the certifying equilibrium in response to a change in the underlying environment. Subjects who begin in the Hazardous environment form the certifying equilibrium and remain in this equilibrium when the environment is changed to Safe. The persistence of the certifying institution leads to a loss in efficiency relative to a market where the non-certifying equilibrium initially formed.

This paper contributes to a growing literature on the persistence of institutions. Whereas the political economy literature, developed by North (1990) and Acemoglu and Robinson (2008), has centered on the role agency plays in persistence, I develop an informational channel of persistence where the informational properties of institutions *themselves* endogenously affect long-run outcomes. While in political economy models persistence requires some agents to have a vested interest in the current institution, I show that persistence can occur even in an environment where all agents can be made better off. Given the prevalence of mechanisms that mitigate moral hazard such as regulation, certification, and monitoring, this form of informational externality may be of great importance to the function and efficiency of many markets and organizations.

The paper is organized as follows. Section 2 builds the theoretical model and characterizes its competitive equilibria in terms of efficiency and information. Section 3 relates the theoretical model to the broader literature. Section 4 develops the experimental design. Section 5 reports the main experimental results and is divided into three parts. Section 5.1 looks at initial convergence of the experimental market in the Safe and Hazardous environments. Section 5.2 demonstrates the difference in adaptation between the non-certifying and certifying equilibrium. Section 5.3 looks at the welfare consequences of persistence in the certifying equilibrium. Section 6 concludes.

2 The Model

In this section, I build a theoretical framework that illustrates the informational properties of institutions. I begin by developing a benchmark model of a market with unobservable quality, costly certification, and heterogeneity in seller types where the distribution of seller types is known. Using a simple Walrasian approach, I define and characterize the possible competitive equilibria. I show that two equilibria may exist, non-certifying and certifying, and that these equilibria vary in terms of both efficiency and information about the underlying environment.

The model developed here is intentionally stylized in order to concentrate on market-level information externalities. In order to ensure that there are two stable equilibria, a discrete certification technology is used. This eliminates many of the complications that out-of-equilibrium beliefs pose to equilibrium selection by ensuring that payoff relevant states are well defined.[5] While the goal of this research is to understand dynamic information effects, a static competitive equilibrium with a common value assumption is adopted for three reasons. First, from an experimental perspective, there is clear evidence that experimental markets converge toward the competitive equilibrium when the trading mechanism is a double auction.[6] From a theoretical perspective, simultaneous move double auctions also converge to the competitive equilibrium as the number of players grows large. As such, the use of a competitive equilibrium as a solution concept is meant to generate reasonable benchmark predictions for the experimental environment.

Second, the model environment is designed with market power on the sellers' side, so all rents from trade are likely to be appropriated by the sellers in any fully-specified bargaining process. For many reasonable game-theoretic auction models, the set of pure strategy equilibria is identical to the competitive equilibria with the key exception that the certifying equilibrium does not exist in an environment where a single seller, who chooses to sell an uncertified high-quality unit over a certified unit, can generate a new equilibrium.

Finally, any particular dynamic game will be sensitive to assumptions made about matching, memory, information, updating, bargaining, utility functions, and the formation of out-of-equilibrium beliefs. On the other hand, if agents are anonymous, trade is frictionless, and the number of players grow large, a few general restrictions should hold true: A buyer should be able to buy uncertified and certified goods at the cheapest price he can negotiate; sellers should be able to sell at the highest price they can negotiate; and all buyers and sellers should be able to enter and exit as many negotiations as they would like before the final resolution of the market. These restrictions bring us naturally to outcomes that are *ex post* stable, a property that directly leads to a set of prices identical to those in one of the

[5]For problems of existence in a competitive equilibrium with adverse selection, see Rothschild and Stiglitz (1976). For a more general model of equilibrium selection in a market with adverse selection and a continuous contract space see Gale (1992).

[6]See Walker and Williams (1988) for a discussion of convergence across varying institutions.

competitive equilibria.

2.1 Benchmark Model

Consider a world with high (H) and low (L) quality units. There are N buyers indexed by $i \in \{1, \ldots, N\}$ divided into a finite number of types $b \in \mathcal{B}$. There are $M < N$ sellers indexed by $j \in \{1, \ldots, M\}$ divided into three types $s \in \{G, C, B\}$ (Good, Conditional, and Bad). The number of buyers who are of type b is N_b. Likewise the number of sellers who are of type s is M_s. Each buyer can consume a single high- or low-quality unit. Likewise, each seller can produce a single high- or low-quality unit.

Consider the case where there is only one type of buyer denoted by b_0. Buyers of type b_0 have gross utilities for consuming the high and low quality good of U^H and U^L relative to a separable numéraire good, are risk and loss neutral, and receive zero utility if they do not trade.

The quality of units being traded is initially unknown to buyers. However, sellers have available a costly technology that certifies quality. Certification costs $T \in (0, U^H - U^L)$ and eliminates all uncertainty over the quality of the unit to the buyer. This certification cost is common knowledge and is paid by the seller when a trade occurs. Since $U^H > U^L$, certifying the low-quality unit can not increase its value and thus a certified low-quality unit will never be offered by a profit maximizing firm. Analysis is thus restricted to cases where all certified units are of high quality.

Given the choice over certification, buyers and sellers may exchange in three markets $m \in \mathcal{M} = \{\mathcal{C}, \mathcal{NC}, \varnothing\}$. $\mathcal{C}$ is a market for high-quality certified units, $\mathcal{NC}$ is a market of uncertified units, and $\varnothing$ is a "market" without trades. In the certified market, all three types of sellers produce the high-quality unit. In the uncertified market, a seller is free to exchange a unit of either quality.

If a seller exchanges a low-quality unit, she pays a cost of C^L which is constant across all sellers. If a seller exchanges a high-quality unit, she pays a cost C_s^H which differs by seller type. Types are defined such that

$$C_B^H > C_C^H > C^L > C_G^H \tag{1}$$

and

$$C_B^H > C^L + U^H - U^L - T > C_C^H. \tag{2}$$

Condition 1 distinguishes sellers of type G from the other types by giving them incentives to produce high-quality units if they trade in the uncertified market. Condition 2 distinguishes type-C sellers from type-B sellers by giving type-C sellers incentives to adopt the certification institution and produce high-quality units if the market price for uncertified units is sufficiently low.

To focus on the most interesting case of the model, two additional assumptions are made on the relative value and cost of units. Let $C^L < U^L$ so that trade is always welfare improving and assume $C_B^H - C^L < U^H - U^L$ so that the social optimal occurs when all three seller types produce high-quality units. Given that type-B sellers always produce low-quality units, all equilibria are inefficient relative to the first best.

As will be shown later, the adoption of certification by sellers of type C alters their production decision so that it coincides with the social optimum. In a proscriptive sense, the formation of a certifying equilibrium resolves the problem of hidden action for sellers of type C. Define the "degree of moral hazard" in the environment as the proportion of sellers who are of type C. Let the proportion of sellers who are type G, C, and B be given by $\mathfrak{g}$, $\mathfrak{c}$, and $\mathfrak{b}$ respectively where $\mathfrak{g} = \frac{M_G}{M}$.

Definition 1 ***Degree of moral hazard:*** *The proportion of type-C sellers $\mathfrak{c}$.*

A buyer of type $b \in \mathcal{B}$ who matches with a seller of type $s \in \{G, C, B\}$ in market $m \in \{\mathcal{C}, \mathcal{NC}, \varnothing\}$ at price P^m receives utility $u(m, P^m, b, s)$. The market affects this utility by restricting the set of actions that a seller can take. For instance, if a buyer matches with a type-C seller in market $\mathcal{NC}$, the conditional seller is free to exchange a unit of either high or low quality and optimally supplies a low-quality unit. If the buyer had matched with the same seller in market $\mathcal{C}$, the conditional seller is constrained and would supply a high-quality unit. In the baseline case:

$$u(m, P^m, b_0, s) = \begin{cases} U^H - P^{\mathcal{C}} & \text{if } m \in \mathcal{C}, s \in \{G, C, B\} \\ U^H - P^{\mathcal{NC}} & \text{if } m \in \mathcal{NC}, s \in \{G\} \\ U^L - P^{\mathcal{NC}} & \text{if } m \in \mathcal{NC}, s \in \{C, B\}. \end{cases} \tag{3}$$

In extensions of the model, buyer types, b, will be used to generate heterogeneity in risk and loss preferences. As the baseline model assumes risk and loss neutrality, this parameter is omitted from the right hand side of equation 3.

Similarly, a seller of type s who matches with a buyer of type b in market m at price P^m

receives utility $v(m, P^m, b, s)$. A seller maximizes expected value and thus, given optimal action in both markets, has a utility function of:

$$v(m, P^m, b, s) = \begin{cases} P^{\mathcal{C}} - C_s^H - T & \text{if } m \in \mathcal{C}, s \in \{G, C, B\}, \\ P^{\mathcal{NC}} - C_s^H & \text{if } m \in \mathcal{NC}, s \in \{G\}, \\ P^{\mathcal{NC}} - C^L & \text{if } m \in \mathcal{NC}, s \in \{C, B\}. \end{cases} \tag{4}$$

Note that the sellers value is independent of the buyer type in which she is matched. We leave the parameter b in the left hand side of equation 4 to be clear that both buyer and seller utility are defined over matches.

The description of the competitive equilibrium[7] is comprised of three parts: an attainable allocation (D, S), a belief system μ, and a price system P.

Attainable Allocations: The number of buyers of type b who demand from market m is denoted by $D(m, b)$. An allocation of buyers is a function $D : \mathcal{M} \times B \to \mathbb{I}_+$ such that $\Sigma_{m \in \mathcal{M}} D(m, b) = N_b$. Likewise, the number of sellers of type $s \in \{G, C, B\}$ who supply in market m is denoted by $S(m, s)$. An allocation of sellers is a function $S : M \times \{G, C, B\} \to \mathbb{I}_+$ such that $\Sigma_{m \in \mathcal{M}} S(m, s) = M_s$. An allocation (D, S) is *attainable* iff $\Sigma_{s \in \{G,C,B\}} S(m, s) = \Sigma_{b \in B} D(m, b)$ for $m \in \{\mathcal{C}, \mathcal{NC}\}$. Note that this market clearing condition is not binding in the $\varnothing$ market.

Belief System: Buyers and sellers form beliefs about the types of agents exchanging within a market. Let $\mu_b(m, s)$ denote the subjective probability that a unit purchased in market m by a buyer is in fact supplied by a seller of type s. Let $\mu_s(m, b)$ denote the subjective probability that a unit sold in market m by a seller is in fact bought by a buyer of type b. A belief system is a pair of beliefs $\mu = (\mu_b, \mu_s)$ such that $\mu_b(m, s) : \mathcal{M} \times \{G, C, B\} \to \mathbb{R}_+$ satisfies $\Sigma_s \mu_b(m, s) = 1$ for every m and $\mu_s(m, b) : \mathcal{M} \times B \to \mathbb{R}_+$ satisfies $\Sigma_b \mu_s(m, b) = 1$ for every m.

Price System: A price system is a function $P : \mathcal{M} \to \mathbb{R}_+$. I define $P^{\mathcal{C}}, P^{\mathcal{NC}}, P^{\varnothing}$ as the prices in each market.

Suppose that a buyer of type b purchases a unit in market m at price P^m. If the buyer's

[7] This formulation is also defined as a price equilibrium or rational expectations equilibrium depending on author. As it is a natural extension of a competitive equilibrium to uncertainty, the simplest term is used here.

beliefs are given by $\mu_b(m, s)$, his expected utility is given by

$$\Sigma_s u(m, P^m, b, s)\mu_b(m, s), \tag{5}$$

where $u(m, P^m, b, s)$ is the utility received when a seller sells her market constrained optimal unit to the buyer. A buyer will choose a market that maximizes (5). Consequently, an equilibrium allocation must assign all buyers of type b to markets that are in the arg max of (5):

$$D(m^*, b) \neq 0 \Leftrightarrow m^* \in \arg\max_m \Sigma_s u(m, P^m, b, s)\mu_b(m, s) \quad \forall b. \tag{6}$$

Likewise, suppose that a seller sells a unit in market m at price P^m. If the seller's beliefs are given by $\mu_s(m, b)$ her expected utility is given by

$$\Sigma_b v(m, P^m, b, s)\mu_s(m, b), \tag{7}$$

where $v(m, P^m, b, s)$ is the value the seller receives from selling her optimal unit to a buyer of type b subject to the constrains of the market she has entered. Like the buyer, any competitive equilibrium requires:

$$S(m^*, s) \neq 0 \Leftrightarrow m^* \in \arg\max_m \Sigma_b v(m, P^m, b, s)\mu_s(m, b) \quad \forall s. \tag{8}$$

Finally, the competitive equilibrium requires that beliefs are rational. For any market in which there are a positive number of sellers, the buyers belief that a unit is supplied by a seller of type s must be equal to the actual proportion of type-s sellers in the market. Likewise, the sellers belief that a unit in a market is bought by a buyer of type b is proportion to the actual proportion of type-b buyers in the market. If a market has no trades in equilibrium, then these proportions are not well-defined and beliefs may be arbitrary. In the entire analysis, I look at the case where there is at least one type-B seller who always trades in the uncertified market. Thus buyers' beliefs about the uncertified market are always well defined. Since the utility of other trades do not depend on beliefs, there is never a case where an equilibrium is supported by out-of-equilibrium beliefs.

Definition 2 ***Competitive Equilibrium:*** *A Competitive Equilibrium is a triple $\langle (D \times S), \mu, P\rangle$ consisting of an attainable allocation $(D \times S)$, beliefs μ, and a price system P that satisfy:*

$E.1: \qquad S(m^*, s) \neq 0 \Leftrightarrow m^* \in \arg\max_m \Sigma_b v(m, P^m, b, s)\mu_s(m, b) \qquad \forall s,$

$E.2: \quad D(m^*, b) \neq 0 \Leftrightarrow m^* \in \arg\max_m \Sigma_s u(m, P^m, b, s)\mu_b(m, s) \quad \forall b,$

$E.3a: \quad \mu_b(m, s) = \frac{S(m,s)}{\Sigma_s S(m,s)} \quad \textit{if } \Sigma_s S(m, s) > 0,$

$E.3b: \quad \mu_s(m, b) = \frac{D(m,b)}{\Sigma_b D(m,b)} \quad \textit{if } \Sigma_b D(m, b) > 0.$

Analysis of the competitive equilibrium is simplified by two characteristics of the benchmark environment. First, the sellers valuation $v(m, P^m, b, s)$ is independent of the buyer that she is matched with and thus $\mu_s(m, b)$ does not affect the seller's decision. It follows that condition (E.1) can be reduced to

$E.1b: \quad S(m^*, s) \neq 0 \Leftrightarrow m^* \in \arg\max_m \Sigma_b v(m, P^m, b, s) \quad \forall s,$

which is the requirement that all sellers enter the market where the difference between price and the cost of their constrained optimal production choice is largest. Second, since all buyers share the same utility function given in equation (3), only beliefs about $\mu_b(\mathcal{NC}, G)$, the probability of matching with a type-G seller in the uncertified market, affect utility. Since seller's actions only depend on prices, I define a function $\pi^H(\Delta P)$ where $\pi^H : P \rightarrow [0, 1]$ is a buyer's belief about the proportion of high-quality units in the uncertified market for a difference in prices of ΔP. Note that $\pi^H(\Delta P) = \mu_b(\mathcal{NC}, G)$ for $\Delta P = P^{\mathcal{C}} - P^{\mathcal{NC}}$.

Solving for the equilibrium is done in two steps. First, the set of $S(m, s)$ that satisfy (E.1b) is determined for each potential price system P. Second, the set of $D(m, b)$ for which (E.2) is satisfied for each potential price system P and (correct) belief system $\mu_b(m, s)$. Attention is restricted to the case where $M_B \geq 1$ so that $\mu_b(\mathcal{NC}, s)$ is well defined.

2.1.1 Supply Decisions by Sellers

For a price system P, a seller produces in the certified market if

$$v(\mathcal{C}, P^{\mathcal{C}}, b, s) > v(\mathcal{NC}, P^{\mathcal{NC}}, b, s). \tag{9}$$

For all sellers, this reduces to the condition

$$P^{\mathcal{C}} - C_s^H - T \geq P^{\mathcal{NC}} - min(C_s^H, C_L). \tag{10}$$

Define $\overline{P}^{\mathcal{C}}$ as the maximum willingness to pay for a certified unit across all buyers. Similarly, define $\underline{P}^{\mathcal{NC}}$ as the minimum willingness to pay across all buyers for an uncertified unit.

In the baseline model $\overline{P}^{\mathcal{C}} = U^H$ and $\underline{P}^{\mathcal{NC}} = U^L$. In equilibrium it will be the case that $\underline{P}^{\mathcal{NC}} \leq P^{\mathcal{NC}} \leq P^{\mathcal{C}} \leq \overline{P}^{\mathcal{C}}$ so that i) ΔP is always either zero or positive and ii) both buyers and sellers have incentive to trade in either the certified or uncertified market for prices within these bounds. Given the definition of Good, Conditional, and Bad seller types:

Lemma 1 *For a price system P with $\underline{P}^{\mathcal{NC}} \leq P^{\mathcal{NC}} \leq P^{\mathcal{C}} \leq \overline{P}^{\mathcal{C}}$:*

- *A seller of type G has $C_G^H \leq C^L$ and will always produce high-quality units. A type-G seller will trade in the uncertified market if $\Delta P \leq T$.*
- *A seller of type C has $C_C^H \in (C^L, C^L + \overline{P}^{\mathcal{C}} - \underline{P}^{\mathcal{NC}} - T)$ and will produce either low-quality units to the uncertified market or high-quality units to the certified market. A type-C seller will trade to the uncertified market if $\Delta P \leq T + (C_C^H - C^L)$.*
- *A seller of type B has $C_B^H \geq C_L + \overline{P}^{\mathcal{C}} - \underline{P}^{\mathcal{NC}} - T$. Given the bounds on possible prices, type-B sellers never sell high-quality units and will always produce low-quality units in the uncertified market.*

Proof. All proofs given in the appendix. ■

2.1.2 Demand Decisions by Buyers

Suppose that a buyer has a choice of buying a certified unit at price $P^{\mathcal{C}}$ or a non-certified unit at price $P^{\mathcal{NC}}$. Let $\pi^H(\Delta P)$ be a buyer's belief about the proportion of high-quality units in the uncertified market given the difference in price between certified and uncertified units. A buyer is indifferent between purchasing in the certified and uncertified market if

$$\pi^H(\Delta P)U^H + (1 - \pi^H(\Delta P))U^L - P^{\mathcal{NC}} = U^H - P^{\mathcal{C}}. \tag{11}$$

Lemma 2 *In Equilibrium:*

- *If $\Delta P > T$ the buyer believes that all type-G sellers will certify their goods and thus that $\pi^H(\Delta P) = 0$. In this case, a risk neutral buyer prefers to purchase the certified unit as long as $\Delta P < U^H - U^L \equiv \overline{P}^{\mathcal{C}} - \underline{P}^{\mathcal{NC}}$ and is indifferent between buying a non-certified unit and not purchasing if $P^{\mathcal{NC}} = U^L$.*
- *If $\Delta P \leq T$ the buyer believes that all sellers trade in the uncertified market. In this case $\pi^H(\Delta P) = \mathfrak{g}$ and a risk neutral buyer prefers to purchase the uncertified unit as long as $\Delta P \geq (1 - \mathfrak{g})(U^H - U^L)$.*

2.2 Market Equilibria

Since there are more buyers than sellers and all buyers have identical utility functions, buyers must be indifferent between purchasing and not purchasing a unit of the good. Setting payoffs in equation (11) equal to zero yields the following two equilibria:[8]

- **Certifying Equilibrium:** $P^{\mathcal{C}} = U^H, P^{\mathcal{NC}} = U^L$. Type-$G$ and type-C sellers produce and sell certified high-quality units. Type-B sellers produce uncertified low-quality units. $M_G + M_C$ buyers buy in the certified market and M_B other buyers buy in the uncertified market.

- **Non-certifying Equilibrium:**[9] $P^{\mathcal{NC}} = U^H - (1 - \mathfrak{g})(U^H - U^L), P^{\mathcal{C}} = U^H$. Type-$G$ sellers produce uncertified high-quality units. Type-C and type-B sellers produce uncertified low-quality units. M buyers buy from the uncertified market.

Theorem 1 ***Existence:*** *The certifying equilibrium always exists. The non-certifying equilibrium exists if and only if* $(1 - \mathfrak{g})(U^H - U^L) \leq T$.

Multiplicity occurs in this market due to the cost associated with certification which diminishes the incentive of type-G sellers to identify the quality of their product. The existence of the non-certifying equilibrium requires the cost of certification to be larger than the premium that buyers place on guaranteeing a high-quality unit. This will be the case if, for instance, the proportion of type-G sellers is high.

When the price difference between the certified and uncertified market is large, type-G sellers will respond by selling in the certified market. Since the probability of receiving a high-quality unit in the uncertified market is zero, a buyers' willingness to pay for uncertified units falls to U^L and the difference in price between the uncertified and certified markets becomes $\Delta P = U^H - U^L = \overline{P}^{\mathcal{C}} - \underline{P}^{\mathcal{NC}}$. Type-$C$ sellers, defined as having $C_C^H - C_L < \overline{P}^{\mathcal{C}} - \underline{P}^{\mathcal{NC}} - T$, also choose to certify since the profit gained from switching markets is greater than the increase in production and transaction costs.

[8]In general, a partial-certifying equilibrium will also exist where $\Delta P = T$ and type-G sellers are indifferent to trading in the certified and uncertified market. In the baseline model, since all buyers have the same utility function and seller types are discrete, the partial-certifying equilibrium is degenerate. See section 2.2.3 for an extension of the model where partial-certifying equilibria are more likely to exist.

[9]Note that in the Non-Certifying Equilibrium, $\Sigma_s S(\mathcal{C}, s) = 0$ and thus beliefs about the distribution of seller types in the certified market is arbitrary. While each set of beliefs could technically be considered a different competitive equilibrium, for exposition purposes they are classified as a single equilibrium since their price and quantity characteristics are the same.

2.2.1 Welfare

The relative welfare of the non-certifying and certifying equilibrium depend critically on the degree of moral hazard in the market and the cost of certification. For type-C sellers, the adoption of certification increases the quality of their goods. Not factoring in the certification cost, this leads to a efficiency gain of:

$$M_C[U^H - U^L - (C_C^H - C^L)]. \tag{12}$$

However, in the certifying equilibrium, both type-G and type-C sellers certify their product leading to a total certification cost of:

$$(M_G + M_C)T. \tag{13}$$

Combining the two terms and normalizing by M yields:

Theorem 2 *the certifying equilibrium is constrained Pareto efficient if*

$$\mathfrak{c}[U^H - U^L - (C_C^H - C^L)] > (\mathfrak{g} + \mathfrak{c})T. \tag{14}$$

Otherwise, the non-certifying equilibrium is constrained Pareto efficient.

The certifying equilibrium is likely to be efficient when the degree of moral hazard in the environment is high and the proportion of type-G sellers in the environment is low. It is also more likely to be efficient if the cost of certification T is low or the additional surplus for altering the production decision of a conditional type from low-quality units to high-quality units is large.

Note that, in this environment, sellers have market power and thus extract all rents from the buyers. As such,

2.2.2 Market Information

Suppose that a sequence of markets generate either the certifying or non-certifying equilibrium above. If a new buyer of type b_0 enters the market and can observe price and the volume of trades in each market, what can he deduce about the proportion of sellers who are good, conditional, and bad?

In the certifying equilibrium, the prices $P^{\mathcal{C}} = U^H$ and $P^{\mathcal{NC}} = U^L$ only provide information about the demand function of buyers. Since only bad sellers trade in the non-certified market, the share of goods traded in the uncertified market provides information on the proportion of sellers who are of type-B but provides no additional information about the relative proportion of type-G and type-C sellers.

By contrast, in the non-certifying equilibrium, the non-certifying price $P^{NC} = U^H - (1-\mathfrak{g})(U^H - U^L)$ carries information about the proportion of good sellers. Given only the non-certifying price, any agent in the market can determine the proportion of the sellers who are of type G. Since no sellers certify their units, sellers of type C and type B are indistinguishable.

Theorem 3 *In a non-certifying equilibrium, price is a sufficient statistic for the proportion of type-G sellers in the environment. In the certifying equilibrium, no market signal generates information that can distinguish between type-G and type-C sellers.*

The difference in information that is generated in a market with or without the adoption of the certification institution is stark. In the non-certifying equilibrium, the proportion of type-G sellers in the market can be inferred directly from the market price, a primitive that is inherently observable in the market. In the certifying equilibrium, no information is generated when the proportion of type-G and type-C sellers changes. This may lead to persistence of the certification institution since the true state of the world is not transmitted through individual and group decisions.

2.2.3 Loss Aversion, Partial Certification, and Public Information

One interesting corollary from the previous section is that if a market has converged to a certifying or non-certifying equilibrium, *ex post* revelation of uncertified trades does not generate new information about the distribution of seller types. In the case of the non-certifying equilibrium, this result arises because the pooling price is a sufficient statistic for the proportion of type-G sellers in the market. In the case of the certifying equilibrium, this result occurs due to only low-quality units being traded in the uncertified market.

In an experimental setting, agents typically exhibit some aversion toward accepting actuarially fair gambles. This section briefly comments on how differences in the willingness to accept gambles can lead to a partial-certifying equilibrium where *ex post* disclosure of trade quality can generate new information. Due to its tractable nature and players' responses to survey questions at the end of the experiment, I model the aversion toward gambles using loss aversion. All the results of this section carry over to alternative models using risk or ambiguity aversion.

Suppose that some buyers are loss averse and put a greater weight on aggregate losses than gains. Let $\mathcal{B} = \{\lambda_1, \lambda_2, \ldots, \lambda_N\}$ where λ_i is the idiosyncratic loss aversion parameter for buyer i with $\lambda_i \geq 1$ for $i \in \{1, 2, ..., N\}$. Without loss of generality, I order buyers according to their risk aversion parameter such that $\lambda_1 \leq \lambda_2 \leq ... \leq \lambda_N$ and again normalize the utility obtained from not trading to zero.

For a price system P with $\underline{P}^{\mathcal{NC}} \leq P^{\mathcal{NC}} \leq P^{\mathcal{C}} \leq \overline{P}^{\mathcal{C}}$, a buyer of type λ_i buying from market m at price P^m from a seller of type s gets utility

$$u(m, P^m, \lambda_i, s) = \begin{cases} U^H - P^{\mathcal{C}} & \text{if } m \in \mathcal{C}, s \in \{G, C, B\} \\ U^H - P^{\mathcal{NC}} & \text{if } m \in \mathcal{NC}, s \in \{G\} \\ -\lambda_i(P^{\mathcal{NC}} - U^L) & \text{if } m \in \mathcal{NC}, s \in \{C, B\} \end{cases}. \tag{15}$$

In the non-certifying equilibrium, the market price $P^{\mathcal{NC}} > U^L$ and there is a potential for losses in the market. Since buyers are heterogeneous in loss aversion, the aggregate demand curve for uncertified units becomes downward sloping and the uncertified price is pinned down by the loss aversion of the M^{th} buyer. If the M^{th} buyer is sufficiently loss averse, he may be unwilling to trade for uncertified units at a price where $\Delta P \geq T$. In this case, partial certifying equilibria may form. Let $S^{\mathcal{C}}$ be the number of certified units in an equilibrium. Then for each $S^{\mathcal{C}} < M_G$, a partial certifying equilibrium may exist with the following properties:

- **Partial-Certifying Equilibrium:** $P^{\mathcal{NC}} = U^H - T$, $P^{\mathcal{C}} = U^H$. Type-C and type-B sellers produce uncertified low-quality units. $S^{\mathcal{C}}$ type-G sellers produce certified high quality goods. $M_G - S^{\mathcal{C}}$ type-G sellers produce uncertified high quality goods. Buyers $i \in \{1, \ldots, M - S^{\mathcal{C}}\}$ buy uncertified units. $S^{\mathcal{C}}$ other buyers buy certified units.

In the benchmark model, the partial-certifying equilibrium was degenerate because both type-G sellers and all buyers needed to be indifferent between trading in the certified and uncertified market. With heterogeneity in buyer preferences, however, partial-certifying equilibrium may be stable since the willingness to pay for uncertified units is decreasing in loss aversion leading to a downward sloping aggregate demand function.

In the partial certifying equilibrium, since $P^{\mathcal{NC}} = U^H - T$ and $P^{\mathcal{C}} = U^H$, price alone does not convey information about the proportion of type-G sellers. While a lower bound on the number of type-G sellers can be constructed using the number of sellers in the certified market (where all sellers are of type-G) and on the decision of the M^{th} buyer to trade in the uncertified market, public information about the proportion of high-quality units in the uncertified market can generate new information unavailable from market signals. Information about the proportion of high-quality units traded in the uncertified market in conjunction with the size of the certified market once again allows an outside observer to determine the proportion of type-G sellers in the environment.

3 Related Theoretical Approaches

The model developed here is one of many channels by which agglomerating institutions may become persistent. Intermediaries may, for instance, be strategic and resist changes to market structure through quality differentiation (List, Kato and Jin (Forethcoming)) or political lobbying (Acemoglu and Robinson (2006) and Acemoglu and Robinson (2008)). The approach taken in this paper is to suppress this agency channel of persistence in order to concentrate directly on the role information. It should be noted, however, that the approach studied in this paper is complementary to the political economy literature. Agency models require bargaining frictions which prevent elites from being paid to change institutions. While the standard approach is to assume incomplete contracts or problems with commitment, information externalities may be a compelling alternative.[10]

The model presented here is most similar in spirit to models of history dependence, herding, and conventions. History dependent models establish links between actions today and global actions in the future. Multiple equilibria exist due to non-convexity in investment costs (e.g. Arthur (1994)), coordination (Argenziano and Gilboa (2006), Cooper and John (1988), Murphy, Shleifer and Vishny (1989)), expectations (Krugman (1991)), or imperfect reputation (Tirole (1996)). In Tirole (1996), for instance, the reputations of members within

[10]Indeed, an inspiration for this paper is a passage in *The Prince*:

> It ought to be remembered that there is nothing more difficult ... than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have long experienced them. -*Machiavelli*

a group are observed imperfectly. A member's current incentives are affected by his past behavior and, because of imperfect observation, by actions of other agents in his group. The destruction of reputation in one generation may lead to reduced incentives for reputation for all future generations and eliminate the ability of the market to restore good faith. By contrast, the model presented in this paper generates history dependence due to informational differences between institutional structures. This model is most suitable in situations in which global coordination can be mutually beneficial to all parties but where deviation from the current institution requires information that is obscured by the institution itself.

In the herding literature, pioneered by Banerjee (1992), Bikhchandani, Hirshleifer and Welch (1992), and Welch (1992), the ability to observe the actions of past actors may lead individual agents to follow past play rather than their own signal.[11] This can lead to an information cascade where individuals discard their private signals and all agents continue to make the wrong, inefficient choice. Whereas the herding literature concentrates on individual-level actions, I concentrate on how naturally occurring institutions are likely to affect the informativeness of observable market primitives, an information externality *inherent* to institutions themselves.

In the convention literature, a game with multiple equilibria is augmented with small amounts of persistent randomness to study how random mutations in strategies might affect the persistence of equilibria. Developed by Foster and Young (1990), Kandori (1992), and Young (1993), the conventions literature has the appealing characteristic that it often selects a unique equilibrium in games with multiple equilibria.[12] This paper differs from the conventions literature in that it studies a specific channel by which history and information together might dynamically influence final outcomes. The informative properties of signals depend critically on the institution that have formed and thus the probability that individual explore other strategies is based directly on the institutions that have formed from past play.

The current paper is also intimately related to the literature on asymmetric information in equilibrium markets, especially the areas related to refinements and equilibrium selection. Closest in modeling spirit is Gale (1992) which uses a similar rational expectations equilibria to study equilibrium selection in a general equilibrium framework with adverse selection.

[11]For more general theoretical treatments of herding, see Chamley (1999) and Smith and Sorensen (2000). Information cascades have also been studied in the lab by Anderson and Holt (1997) and more recently by Goeree, Palfrey, Rogers and McKelvey (2007). In both studies, reversals of cascades are observed in the long run suggesting that individual agents may overweight their own information and mitigate inefficient herding.

[12]For an overview of conventions see Ellison (1993). The convention literature has been experimentally explored in Van Huyck, Battalio and Rankin (1997) and Van Huyck, Battalio and Samuelson (2001).

Whereas Gale and similar papers such as Rothschild and Stiglitz (1976), Riley (1979), and Hellwig (1987) attempt to develop selection criterion for a single equilibrium, this paper is interested in an environment where multiple stable equilibria exist.[13] Foreshadowing our experimental results, we find that both the non-certifying equilibrium and the certifying equilibrium are selected under different configurations of the underlying environment. However, only the non-certifying equilibrium adapts in relation to changes in good and conditional sellers, a result consistent with information externalities.

Reassuringly, this paper shares empirical characteristics to the broader experimental literature. As with Brandts and Holt (1992), we find that learning from a sequence of historical interactions has a large effect on equilibrium selection. History matters — a theme echoed in the coordination literature (e.g., Cooper, DeJong, Forsythe and Ross (1990), Cachon and Camerer (1996)). As in Cooper and Kagel (2008), adaptation from the non-certifying equilibrium to the certifying equilibrium is fast, far quicker than expected by purely myopic learning. This suggests that individuals are updating in a sophisticated way and using information both from their own quality outcomes and the market price. It is all the more compelling, therefore, that there is no adaptation away from the certifying equilibrium, an outcome that requires only a paired deviation of one buyer and seller for significant gains to be generated from both sides of the market.

4 The Experiment

Subjects in this experiment were drawn from a centralized database comprised of undergraduate students from The University of Zurich and UTH-Zurich. 12 sessions were run divided evenly between treatments with a total of 121 subjects. Trades were conducted in points and converted to Swiss Francs at the end of the experiment at a conversion rate of 30 points to 1 Swiss franc. A session lasted on average 140 minutes and paid an average of 45 Swiss Francs ($38 at the time of the experiment). The first 40 minutes of each session was devoted to an extensive set of written, oral, and computerized instructions which included a control quiz. All programs for this experiment were written in Z-Tree.[14]

[13]See also Noldeke and Samuelson (1997) for a dynamic model in which both pooling and separating equilibria might be stable.

[14]See Fischbacher (2007) for a description of Z-Tree.

4.1 Valuations and Costs

Each experimental session consisted of 5 buyers and 6 sellers who participated in a total of 24 market periods. Each market period consisted of two simultaneous exchanges — one with certification and one without — in which buyers and sellers could exchange high-quality "red" units and low-quality "blue" units.

In a given period, each of the six sellers could sell a total of two units across both markets in any combination of high and low quality. As shown in Table 1, sellers could be assigned one of three possible cost functions for producing high- and low-quality units which, following the notation of section 2, I designate as G, C, and B (Good, Conditional, and Bad). Type-G sellers had a lower cost for producing a high quality unit, type-C sellers had a slightly higher cost for producing high-quality units than low-quality units, and type-B sellers had a very high cost for producing high-quality units.

Table 1: Seller Production Costs

	Uncertified Low Units	Uncertified High Units	Certified High Units
Good	50	30	90
Conditional	50	80	140
Bad	50	130	190

The certification cost, known to both buyers and sellers, was 60 points. If the difference in price between the certified and uncertified market grew larger than the certification cost, type-G sellers had an incentive to sell a high-quality unit in the certified market rather than a high-quality unit in the uncertified market. Likewise if the difference in price between the certified and uncertified market grew larger than 90, type-C sellers had an incentive to sell a high-quality unit in the certified market rather than a low-quality unit in the uncertified market.

Each of the five buyers could purchase a total of three units across both markets creating an aggregate demand of 15 units. Since sellers could produce a total of 12 units, each experimental period had excess demand. This excess demand was implemented to allow sellers to capture any residual surplus that existed in either of the two markets and to capture rents generated through certification.

Buyers and sellers were allowed to trade multiple units in order to increase the thickness of the market and to avoid using passive buyers who might cause noise in the experiment by trying to participate. The supply and demand curves were constructed so that no seller or buyer could change the equilibrium price by more than 10 points by withholding their entire supply or demand from the market. This was small relative to the market prices which ranged from 100 to 200 points. Since no buyer or seller had market power, the certifying and non-certifying equilibrium for the experimental environment are the same as the simplified model of section 2.1.[15]

As shown in Table 2, each buyer's demand schedule was downward sloping. This downward slope was implemented to generate some surplus for the buyers, which is shown by Holt, Langan and Villamil (1986) to improve the speed of convergence in markets. Conditional on buying a unit, the valuation of both the high- and low-quality units declined for each unit purchased. Thus, if buyer 1 had purchased a low-quality unit and then purchased a high-quality unit, his valuation for the two units would have been 140 and 220 respectively. The demand functions of buyers four and five were staggered slightly to smooth the aggregate demand function.

Table 2: Buyer Valuations

Buyers 1-3				Buyers 4-5			
	Unit 1	Unit 2	Unit 3		Unit 1	Unit 2	Unit 3
High Quality	240	220	200	High Quality	230	210	190
Low Quality	140	120	100	Low Quality	130	110	90

Earnings from one period did not carry over into the following periods. After each trade, the type of unit purchased was revealed and a buyer's earnings or losses from the transaction were added to or subtracted from his current cash. To avoid bankruptcy, buyers were given 100 points as an initial cash endowment. If at any point during a period a buyer had negative earnings, his trading privileges for the period were revoked. This form of bankruptcy was infrequent, occurring only 8 times out of the 1728 unique buyer-period observations.

4.2 The Trading Mechanism

Trade was conducted through two computerized exchanges where both buyers and sellers were anonymous. The only distinguishable feature between the various seller offers and buyer bids were the public price and quality characteristics visible in the exchange.

Each exchange was conducted as a double auction.[16] Departing slightly from the design

[15] The set of potential partial certifying equilibrium is slightly smaller in the experimental environment since the loss aversion coefficient for multiple units is from the same individual buyer. However, the price and informational properties of these partial-certifying equilibrium remain the same.

[16] A double auction mechanism is one in which 1) both buyers and sellers can submit bids and asks to a

developed by Smith (1964), subjects in this experiment were free to enter the bid and ask queues at any price. Subjects were also free to accept any offer from the opposite side of the market and were not bound to accept the lowest possible price. These changes allowed sellers some flexibility in their pricing strategies and allowed buyers a way to avoid offers that they believed to be of low quality.

In the uncertified market, a seller who posted an offer publicly submitted an asking price and secretly selected the quality of the offered unit. A buyer who bid in the uncertified market publicly submitted a bid price and a quality request. Quality requests in the uncertified market were not binding and a seller who filled a request had the option of supplying either quality good. Information about the actual quality of units traded in the uncertified market were private and revealed only to the buyer who purchased the unit.

In the certified market, the quality of the seller's offered unit was observable and quality requests by buyers were binding.[17] If a seller transacted in the certified market, either by having an offer accepted or fulfilling a buyer's trade request, she was charged the certification fee of 60 points.

Each seller could have one certified offer and one uncertified offer open at one time. Likewise, each buyer could have one certified bid and one uncertified bid open at any given time. If a seller sold her last unit or a buyer exhausted his demand, all their remaining open contracts were automatically withdrawn from the market. Bids and offers could be changed or withdrawn at any time with no restriction on pricing.

In the first three periods of the experiment, each trading period lasted four minutes to allow for subjects to become accustomed to the interface. In the remaining periods, the trading period lasted two minutes.

4.3 Information

Information about seller costs and buyer valuations was private information. At the beginning of the experiment, sellers were shown the three possible cost functions that they might be assigned in the instructions and told that their cost schedule might change across periods. Sellers were not given information on the assignment of other sellers or on the demand schedule of the buyers. Buyers were given only their own demand schedule and were informed via

centralized exchange, 2) trade occurs continuously over a fixed time interval, and 3) trade occurs any time a buyer's bid is above a seller's ask or a seller's ask is below a buyers bid.

[17]Buyers were free to request certified low-quality units. In practice, this never occurred.

the discussion of a bonus game that some of the sellers might have a lower cost for producing high-quality units than low-quality units.

In each period, a history of trades from the current period was available in graph form for all subjects in the market. Certified trades showed up in this graph in the color of the actual unit traded while uncertified trades showed up as black lines. If a buyer purchased an uncertified unit in a period, he was privately informed about the quality of the unit at the time of sale.

After each trading period, both buyers and sellers participated in a bonus phase. The bonus phase asked all participants for the number of sellers that they believed had lower costs for producing high quality goods over low quality goods. Subjects were paid a bonus of 20 points in each round they were correct. This bonus was intentionally small relative to the total earnings in a period to minimize the possibility that buyers were purchasing from the uncertified market solely for the purpose of increasing their success in the bonus game.

Following the bonus game, subjects were given a summary sheet which varied by the information treatment. In the "Private Information" treatments, individuals were only informed about the total number of units traded with and without certification. In the "Public Information" treatment, individuals were informed in the information screen about the actual number of high- and low-quality units traded in the uncertified market. Information was given *ex post* rather than during the trading period to keep the trading environment as similar as possible across treatments.

4.4 Treatments

Experimental sessions were divided into four treatments which varied in the amount of public information available about past trades and in the degree of moral hazard (the number of type-C sellers). Half the treatments were conducted using the Public Information treatment discussed in the last section. This *ex-post* information was expected to be informative only in cases where the partial certifying-equilibrium formed.

Treatments were next stratified into two environments — Safe ($\mathcal{S}$) and Hazardous ($\mathcal{H}$) — which varied in the number of sellers who were assigned to the three seller types. In the Safe environment, five of the sellers were of type G and one seller was of type B. In the Hazardous environment, one seller was of type G, four sellers were of type C, and one seller was of type B. The single type-B seller was included in both treatments in order to have both certified and uncertified prices available when the certifying equilibrium formed.

Table 3: Moral Hazard Environments

	Good	Conditional	Bad
Safe ($\mathcal{S}$)	5	0	1
Hazardous ($\mathcal{H}$)	1	4	1

In the sessions that began in a Safe environment, the environment was switched to the Hazardous environment at period 13 by assigning new cost charts to four of the sellers who were originally of type G. This process was reversed in the sessions beginning in the Hazardous environment. To distinguish between periods before and after the switch, I use Pre and $Post$ superscript appended to the environment identifier.

Table 4: Treatments

Treatment	Periods 1-12	Periods 13-24	Information	Identifiers
1	Safe	Hazardous	Private	$\mathcal{S}^{Pre}$,$\mathcal{H}^{Post}$
2	Safe	Hazardous	Public	$\mathcal{S}^{Pre}$,$\mathcal{H}^{Post}$
3	Hazardous	Safe	Private	$\mathcal{H}^{Pre}$,$\mathcal{S}^{Post}$
4	Hazardous	Safe	Public	$\mathcal{H}^{Pre}$,$\mathcal{S}^{Post}$

The Hazardous environment was designed so that only the certifying equilibrium existed.[18] The Safe environment was designed so that under full information about the distribution of types, the certifying equilibrium was extremely unlikely to form or persist.[19] If all buyers were loss neutral, the non-certifying and certifying equilibrium under the Safe environment were as follows:

- **Non-Certifying Equilibria for Safe Environment :** $P^{NC} = 183$. Type-G sellers produce uncertified high-quality units for a surplus of 153 points per unit. Type-B sellers produce uncertified low-quality units for a surplus of 133 per unit. All trades occur in the uncertified market.

[18]For intermediate distributions of good and conditional sellers, the existence of the non-certifying equilibrium depended critically on the distribution of loss aversion in the buyer population. Given that these preferences could not be controlled while maintaining a random sample, the polar cases were used where the number of equilibria in existence were clear.

[19]Under full information, if a single type-G sellers switched to the uncertified market, a loss neutral buyer who knew the proportion of agents in each market would be willing to pay $.5U^H + .5U^L$ for an uncertified good and U^H for an uncertified good. Since $U^H - U^L$ was 100 points across all units, the difference in willingness to pay for a certified and an uncertified unit was $.5(U^H - U^L) = 50$. This difference was less than the certification cost of 60 points. Thus under full information, a paired deviation from the certifying equilibrium by a seller and risk neutral buyer could eliminate the certifying equilibrium.

- **Certifying Equilibrium for Safe Environment :** $P^C = 200, P^{NC} = 100$. Type-G sellers sell certified high-quality units for a surplus of 133 per unit. Type-B sellers produce uncertified low-quality units for a surplus of 50 per unit.

Prices in these equilibria were determined by the valuation for the twelfth unit traded. Under loss and risk neutral preferences, this corresponded to the marginal valuation of Unit 3 for a buyer with the higher set of valuations.

Comparing the two equilibria, type-G sellers received a surplus of 153 points in the non-certifying equilibrium versus 133 points in the certifying equilibrium. The type-B seller received a surplus of 133 points in the non-certifying equilibrium versus 50 points in the certifying equilibrium. Thus, all sellers were better off in the non-certifying equilibrium and had group incentives to coordinate to this equilibrium.[20]

Equilibria were efficiency ranked in the Safe environment with the non-certifying equilibrium being most efficient and the certifying equilibrium being the least efficient. As noted in Table 5, all possible equilibria were inefficient relative to the first best due to inefficient production by the type-B seller.

Table 5: Efficiency

	Perfect Information	Non-Certifying	Certifying
Safe	2100*	2060	1460
Hazardous	1700*	1100*	1060

*not supportable as an equilibrium

4.5 Lottery Treatment

After all 24 periods of the main experiment, aversion to accepting gambles was measured via a series of lottery choices similar to those used in Holt and Laury (2002). Subjects made a series of decisions between a guaranteed return of 90 points and a 50-50 gamble between earning 0 and x, where x varied between 60 and 360 in increments of 30. Individuals were considered averse to gambles if they rejected the 50/50 gamble with high payment of 210. Interpreted as risk aversion with initial wealth of zero, this corresponds to a $\sigma = .19$ in a CRRA utility function of the form $u(x) = \frac{x^{1-\sigma}}{1-\sigma}$. Interpreted as loss aversion with the

[20]While no conditional sellers existed in the safe environment, this type of seller also would have preferred the non-certifying equilibrium.

earnings from the safe gamble used as the reference point, this corresponds to a loss aversion $\lambda = 1.333$.[21]

5 Experimental Results

The theoretical model predicts that when a market reaches the certifying equilibrium, no new information is generated when the number of good and conditional sellers changes in the underlying population. Empirical testing of this theoretical prediction is taken in two steps. I first establish that absent a preexisting market structure, the efficient non-certifying or partial-certifying equilibria forms in the Safe environment, while the certifying equilibrium forms under the Hazardous environment. I then study how the non-certifying and certifying equilibria adapt to exogenous changes in the number of type-G and type-C sellers in the environment.

For convenience, average price information for the last six periods of the pre and post treatments are included in table 6. The $\mathcal{S}$ and $\mathcal{H}$ letters correspond to the Safe and Hazardous environments while the *Pre* and *Post* superscript correspond to the first and second half of the experiment. The average number of loss averse buyers in a session was 2.33. Individual session level data is located in the appendix.

Table 6: Summary Statistics Across Treatments

	$\mathcal{S}^{Pre}$	$\mathcal{H}^{Post}$	$\mathcal{H}^{Pre}$	$\mathcal{S}^{Post}$
Average Uncertified Price	151.6	116.2	113.2	116.2
Quantity (Observations)	217	158	156	110
Average Certified Price	198.2	203.3	201.4	197.1
Quantity (Observations)	205	254	255	319

[21] Counting the total number of safe gamble and setting a threshold for the number of safe choices yields a measure similar to the one used. Since some individuals had inconsistent choice patterns, this approach had a higher degree of subjectivity. Previous versions of this paper also used a loss aversion measure from the exit survey. This measure had greater variation across sessions and generated parameter estimates closer to theoretical predictions. Due to it being an *expost* measure, the more conservative results are shown here.

5.1 Do markets converge to the efficient equilibrium?

5.1.1 Hypothesis and Empirical Strategy

The experimental design was constructed so that absent an initial market equilibrium, the certifying equilibrium was expected in the Hazardous environment and the non-certifying or partial-certifying equilibrium was expected in the Safe environment. I test these predictions by comparing the prices of uncertified trades in the $\mathcal{S}^{Pre}$ environment where the degree of moral hazard is low with those in the $\mathcal{H}^{Pre}$ environment where the degree of moral hazard is high. To allow time for the market to converge, I restrict attention to periods 7-12.[22] Using session fixed effects, I estimate:

$$P_{i,s} = \alpha_0 + \Sigma\alpha_s + \beta_{Cert}I_{Cert} + \beta_{\mathcal{S}^{Pre}}I_{\mathcal{S}^{Pre}} + \epsilon_{i,s} \tag{16}$$

where $P_{i,s}$ is the price of an individual trade i in session s, α_s are individual session fixed effects, I_{Cert} is an indicator for a certified trade, and $I_{\mathcal{S}^{Pre}}$ is an indicator variable for uncertified trades in the Safe environment. Note that since the estimation includes both certified and uncertified trades, session level fixed affects do not eliminate the variation in uncertified trades across treatments.

In markets where the certifying equilibrium forms, the predicted equilibrium prices for certified and uncertified units are 200 and 100. In markets where the partial-certifying or non-certifying equilibrium forms, the predicted equilibrium price for uncertified units is between 140 and 183. The predicted price for certified units remains 200. Expecting the the certifying equilibrium to form in the $\mathcal{H}^{Pre}$ environment and the non-certifying or partial-certifying equilibrium to form in the $\mathcal{S}^{Pre}$ environment, the empirical predictions are as follows:

Hypothesis 1 $\alpha_0 = 100$, $\alpha_0 + \beta_{Cert} = 200$, $\alpha_0 + \beta_{\mathcal{S}^{Pre}} \in [140, 183]$.

The likelihood that the partial-certifying equilibrium should form over the non-certifying equilibrium is directly tied to the proportion of the buyer population that are unwilling to

[22]The number of omitted periods was decided prior to running the experiment and based on two initial pilots. As can be seen in the individual experiment in section 5.2, the price of the uncertified market converges to the non-certifying or partial-certifying equilibrium from below. Thus, increasing the number of periods in the analysis decreases the estimated uncertified price for treatments that converge to the non-certifying equilibrium. All results remain statistically significant in the full sample with attenuated magnitudes on the uncertified price coefficient.

accept actuarially fair lotteries. As a simple control for aversion toward lotteries, the total number of buyers categorized as lottery averse in the lottery treatment is used. Interacting this number with the safe treatment I estimate

$$P_{i,s} = \alpha_0 + \Sigma\alpha_s + \beta_{LA}(LA * I_{\mathcal{S}^{Pre}}) + \beta_{Cert}I_{Cert} + \beta_{\mathcal{S}^{Pre}}I_{\mathcal{S}^{Pre}} + \epsilon_{i,s}, \tag{17}$$

where LA is the total number of buyers in a session who were averse to the lottery. Since the partial-certifying equilibrium is most likely to occur in sessions with the largest proportion of aversion to lotteries, β_{LA} is expected to be negative with $\alpha_0 + \beta_{\mathcal{S}^{Pre}} + \beta_{LA}(LA * I_{\mathcal{S}^{Pre}}) \approx 140$ for observations with the highest number of individuals who are averse to lotteries.

5.1.2 Results

The predicted convergence of the Hazardous treatment to the certifying equilibrium and the Safe treatment to the partial-certifying or non-certifying equilibrium is largely supported in the empirical data. Table 7 presents regression results from equations 16 and 17 with varying degrees of control from the lottery treatment. As can be seen in column (1), when the lottery is not taken into account, the empirical uncertified price ($\alpha_0 + \beta_{\mathcal{S}^{Pre}} = 147$) is lower than the predicted non-certifying equilibrium price of 183 but above the minimum price that could sustain a partial-certifying equilibrium. When an aggregate measure for the lottery is used, as in column (2), within sample uncertified prices range from 190.8 for the case of one lottery averse buyer to 141.0 for the case of three lottery averse buyers, relatively close to the theoretical predictions. The parameter for the number of lottery averse buyers, β_{LA}, is larger than predicted from theory. This reflects the fact that one of the six markets that started in the Safe environment converged to the certifying equilibrium. Estimated prices for uncertified and certified units in the $\mathcal{H}^{Pre}$ environment are 106.6 and 198.0, both close to their predicted values of 100 and 200.

5.2 Do market structures adapt to changes in the environment?

5.2.1 Hypothesis and Empirical Strategy

I next look at how the equilibrium that formed in the initial 12 periods adapts to changes in the underlying environment. In the theoretical model, I showed that when the certifying equilibrium is reached, there is no aggregate information observable when type-C sellers are replaced with type-G sellers. Thus the certifying equilibrium is predicted to persist even

Table 7: Hypothesis 1: Convergence of *Pre* Treatments to the Non-Certifying or Certifying Equilibrium

	(1)	(2)
Certification	91.414***	91.414***
	(2.968)	(2.970)
Treatment $I_{\mathcal{S}^{Pre}}$	39.100***	101.96***
	(8.105)	(25.77)
Number of Lottery Averse Buyers in $I_{\mathcal{S}^{Pre}}$		–24.887*
		(10.940)[a]
Constant	108.496***	113.72***
	(3.500)	(5.035)
Fixed Effects[b]	Yes	Yes
Adj. R^2	0.841	0.852
Observations (Trades in Period 7-12)	834	834

[a]Since aversion to lotteries is an aggregate measure in specification (2) and there is serial correlation in prices, the standard error from the trade-level regression may be biased. As a better measure, I use randomization inference to construct a confidence interval. I begin by estimating the session-level regression $AvgP_s = \alpha_0 + \beta_{LA}(LA_s)$. I then take every permutation of possible assignments to construct placebo estimates of the lottery aversion parameter. This generates a distribution of possible parameters centered at zero. The true estimated value of β_{LA} lies outside the 90% confidence of this placebo distribution. See Bertrand, Duflo and Mullainathan (2004)

[b]Fixed effects are at the session level. Robust standard errors in parenthesis clustered at the session level. Significance levels: *** $p < .01$, ** $p < .05$, * $p < .1$.

when it is no longer efficient. By contrast, when the non-certifying equilibrium is reached, a replacement of type-G sellers with type-C sellers leads to a reduction in the uncertified price and an eventual change to the certifying equilibrium. This leads to:

Hypothesis 2 *Any market equilibrium that reaches the certifying equilibrium will remain certifying for any changes in the number of type-C and type-G sellers.*

I test this hypothesis by comparing the price of uncertified trades that occur in the last six trading periods of each treatment. If there is no aggregate information observable when the environment changes from Hazardous to Safe, equilibrium prices in periods under the $\mathcal{S}^{Post}$ treatment should be the same as those from $\mathcal{H}^{Pre}$ and significantly differ from those in $\mathcal{S}^{Pre}$. I thus estimate:

$$\begin{aligned} P_{i,s} &= \alpha_0 + \Sigma\alpha_s + \beta_{LA}(LA * I_{\mathcal{S}^{Pre}}) + \beta_{Cert}I_{Cert} \\ &\quad + \beta_{\mathcal{S}^{Pre}}I_{\mathcal{S}^{Pre}} + \beta_{\mathcal{S}^{Post}}I_{\mathcal{S}^{Post}} + \beta_{\mathcal{H}^{Post}}I_{\mathcal{H}^{Post}} + \epsilon_{i,s}, \end{aligned} \tag{18}$$

where $P_{i,s}$ is the price of an individual trade i in session s, α_s are individual session fixed effects, I_{Cert} is an indicator for a certified trade, and $I_{\mathcal{S}^{Pre}}$, $I_{\mathcal{S}^{Post}}$, and $I_{\mathcal{H}^{Post}}$ are indicator variables for uncertified trades in their respective environment. I predict that $\alpha_0 + \beta_{\mathcal{S}^{Pre}} \in [140, 183]$, and $\beta_{\mathcal{S}^{Post}} = \beta_{\mathcal{H}^{Post}} = 0$.

5.2.2 Results

The persistence of the certifying equilibrium is most easily seen by comparing an individual session that began in the Safe environment to one that began in the Hazardous environment. Figure 1 makes this comparison, showing the complete trade history of session 6 and session 12. The horizontal dashed lines show the predicted price of the certified and uncertified market in the case of the non-certifying equilibrium for the $\mathcal{S}^{Pre}$ environment and the certifying equilibrium in the case of the other three environments. The vertical dashed lines split trades into six-period increments with the aggregate number of certified and uncertified trades reported at the bottom of each block.

As can be seen in the top half of Figure 1, a session that begins in the Safe environment converges to the partial-certifying equilibrium in the first 12 periods and then adapts to the certifying equilibrium when the environment changes. Note that in the Safe environment, there is always a single type-B seller. Thus the predicted composition of units without loss aversion is 60 uncertified, high-quality units and 12 uncertified, low-quality units. Typical of all sessions that began in the Safe environment, convergence of the uncertified price to a partial-certifying equilibrium is from below with a subset of certified trades conducted in each period at a premium 60 points above the prevailing uncertified market price. When the environment changes, sellers who switched from type G to type C sell low-quality units leading to a decrease in price and the eventual establishment of a certifying equilibrium.

In the session that began in the Hazardous environment, the certifying equilibrium is established in the first 12 periods. When the environment switches to Safe at period 13, there is no noticeable change in the uncertified price nor in the composition of certified and uncertified trades. This is the case in the bottom half of Figure 1 where convergence to the certifying equilibrium is rapid and the convergence of the uncertified price is from above.

The patterns of adaption and persistence evident in this example are typical across all sessions. Figure 2 shows average uncertified prices for the last six periods of each environment. Notice that the uncertified price in the $\mathcal{S}^{Post}$ environments is nearly identical to both the $\mathcal{H}^{Pre}$ and $\mathcal{H}^{Post}$ treatments and markedly different from the $\mathcal{S}^{Pre}$ treatment.

Figure 1: Hypothesis 2 — Persistence of the Certifying Equilibrium

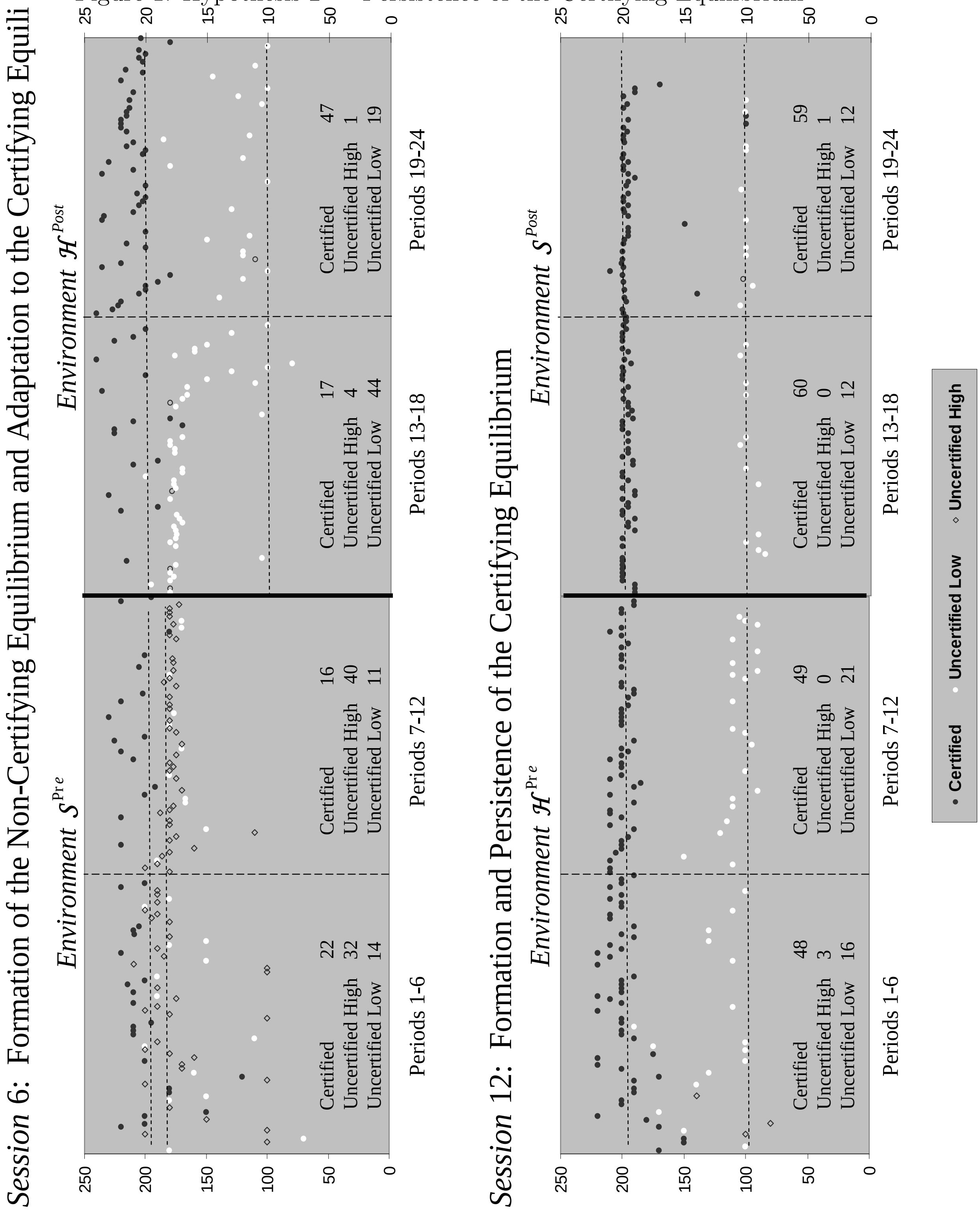
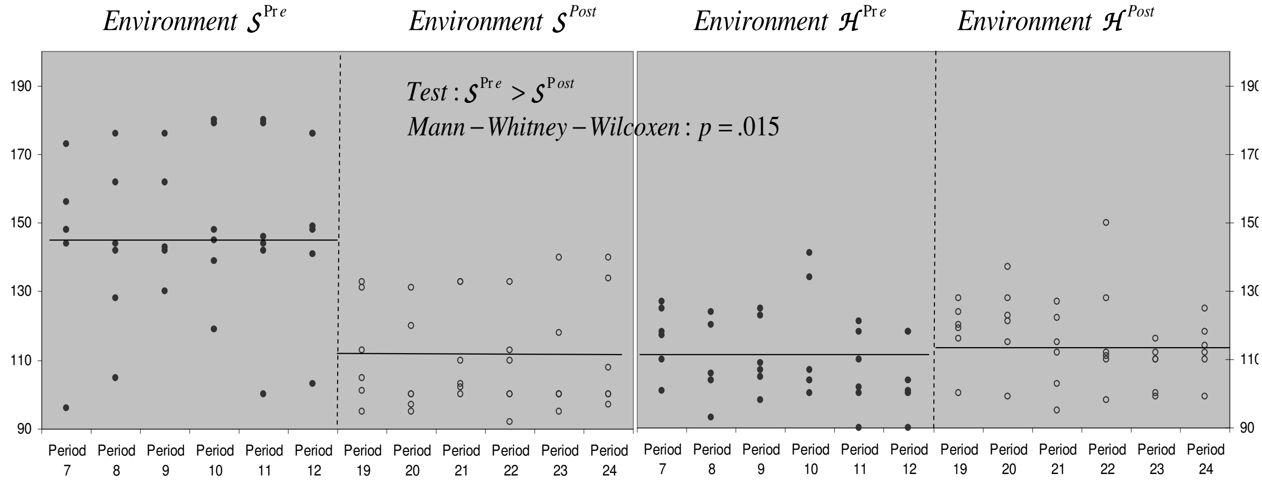


Figure 2: Average Uncertified Prices by Environment



Mann-Whitney-Wilcoxen test conducted on the uncertified price in $\mathcal{S}^{Pre}$ and $\mathcal{S}^{Post}$ averaged at the session level.
Clustered versions of the Rank-Sum Test yield similar results.

Turning to the price regression developed in equation 18, Table 8 extends the original regressions to include periods 18-24 of each session. In support of Hypothesis 2, there is no significant difference between the uncertified prices in the $\mathcal{S}^{Post}$ and $\mathcal{H}^{Post}$ environments relative to the baseline environment of $\mathcal{H}^{Pre}$.

The informational theory of persistence predicts that markets in a certifying equilibrium should show no observable change when a type-C seller is replaced by a type-G seller. To analyze this claim, I next look at the composition of trades over time in each of the two environment orderings. In the treatments that began in the Safe environment, the switch to the Hazardous environment should lead to an initial shift of units from uncertified, high-quality units to uncertified, low-quality units followed by a gradual transition to certified trades as the uncertified market price falls. In sessions that began in the Hazardous environment, theory would predict no change in the composition of goods when moral hazard is decreased.

Figures 3 and 4 show the average number of certified and uncertified trades in treatments that start in the Safe environment and the Hazardous environment. Apparent in Figure 3, the change in environment from Safe to Hazardous results in an immediate shift from uncertified high-quality units to uncertified low-quality units. Over time, uncertified low-quality units are replaced with certified high-quality units leading to the certifying equilibrium in all sessions.[23]

[23]There is also a small but consistent shift of transactions from certified high-quality units to uncertified low-quality units in the two periods following the change in treatment. Recall that in the partial-certifying

Table 8: Hypothesis 2: Persistence of the Certifying Equilibrium

	(1)	(2)
Certification	89.003***	89.003***
	(2.645)	(2.647)
Treatment $\mathcal{S}^{Pre}$	36.610***	88.190***
	(7.597)	(26.680)
Treatment $\mathcal{S}^{Post}$	2.776	2.776
	(3.184)	(3.195)
Treatment $\mathcal{H}^{Post}$	3.620	3.448
	(4.019)	(3.942)
Number of Lottery Averse Buyers in $I_{\mathcal{S}^{Pre}}$		–21.293***
		(10.746)
Constant	112.190***	114.942***
	(3.306)	(3.521)
Fixed Effects[a]	Yes	Yes
Adj. R^2	0.863	0.869
Observations	1675	1675

[a]Fixed effects are at the session level. Robust standard errors in parenthesis clustered at the session level. Significance levels: *** $p < .01$, ** $p < .05$, * $p < .1$.

As shown in Figure 4, the only observable change in the composition of trades for sessions that began in the Hazardous environment is an increase in the number of certified units. This is most likely a result of weaker incentives for type-G sellers to trade uncertified units relative to sellers of type-C.[24]

5.3 Can the persistence of the certifying equilibrium lead to a decrease in efficiency?

Recall that in the Safe environment, the possible equilibria are efficiency ranked with the non-certifying equilibrium being the most efficient market structure and the certifying equilibrium

equilibrium, it may be the case that the type-G sellers are indifferent between trading in the certified and uncertified markets while type-C sellers strictly prefer to sell uncertified units. Given a replacement of type-G sellers with type-C sellers, there is an increase in incentives to sell uncertified units. This effect may increase the speed of adaptation by increasing the number of uncertified low-quality units observed in the market.

[24]Unlike treatments that began in the Safe environment where the shift in environment lead to more conditional with incentive to trade uncertified goods, here the change in environment reduces reduces experimentation and increases the likelihood that the non-certifying equilibrium persists.

Figure 3: Composition of Trades: Treatments Beginning in the Safe Environment

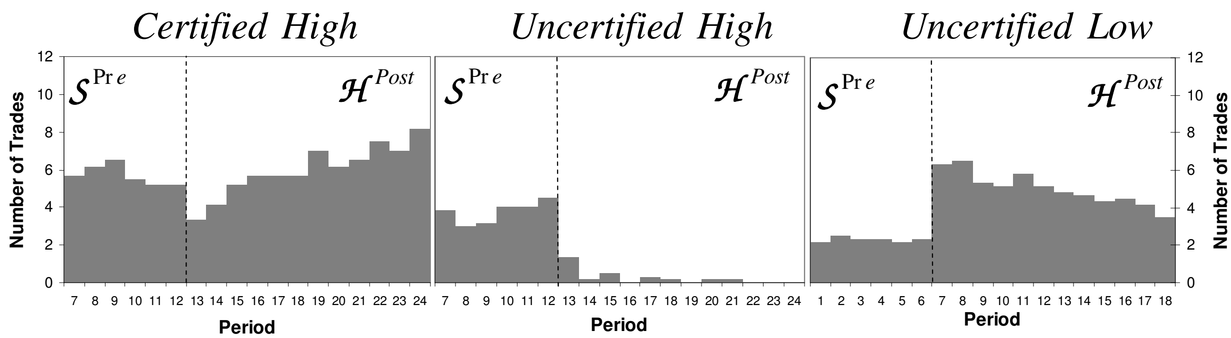
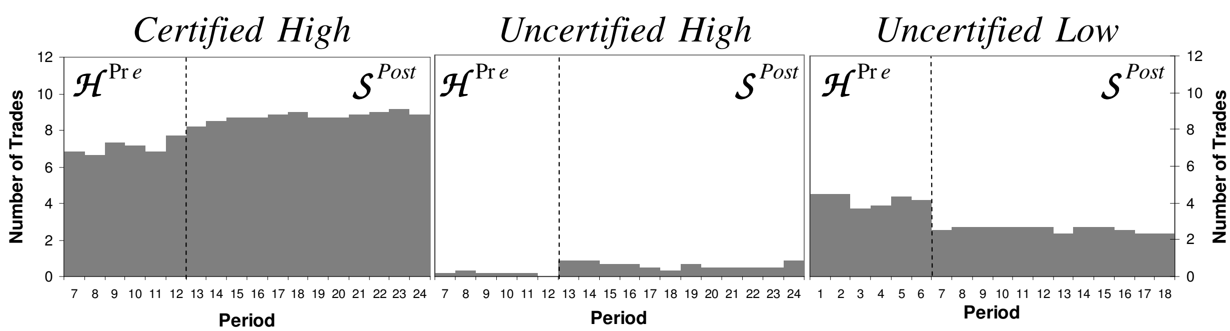


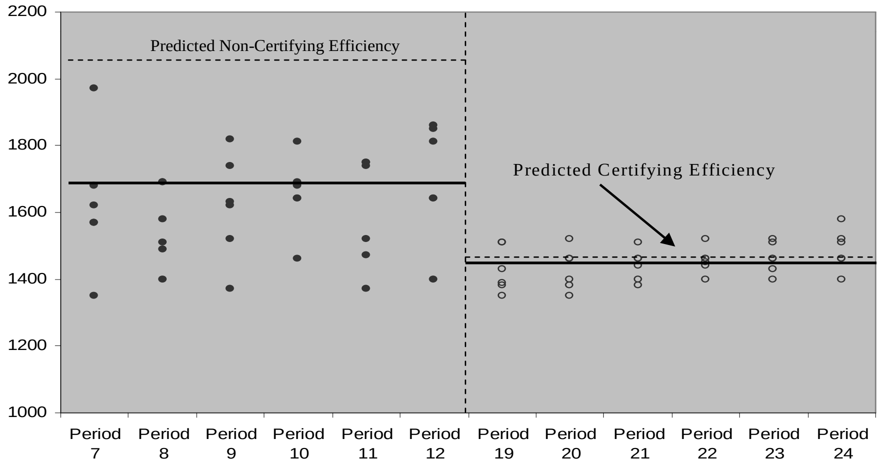
Figure 4: Composition of Trades: Treatments Beginning in the Hazardous Environment



the least efficient market structure. The efficiency of the partial-certifying equilibria falls between these benchmarks, with efficiency declining as more type-G sellers trade certified units over uncertified ones. Based on these design features and the observed persistence of the certifying equilibrium, it is therefore expected that there is an efficiency loss in the $\mathcal{S}^{Post}$ environment relative to the $\mathcal{S}^{Pre}$ Environment — a direct result of the certification institution's persistence.

In Figure 5, I compare period-by-period efficiency of the Safe environment across treatments, where efficiency is defined as the total number of points earned in a given period. The dashed horizontal line in the graph shows the predicted efficiency of a pure non-certifying equilibrium for $\mathcal{S}^{Pre}$ and the certifying equilibrium for $\mathcal{S}^{Post}$. On the left hand side of the figure, it can be seen that overall efficiency in $\mathcal{S}^{Pre}$ is above that of the $\mathcal{S}^{Post}$ environment but lower than the predicted efficiency of the non-certifying equilibrium. This decline in efficiency is a reflection of partial certification as well as a small number of missed trades that occurred in these sessions.[25] On the right hand side of the figure, it can be seen that all six treatments in the $\mathcal{S}^{Post}$ have efficiency levels consistent with the predictions of the certifying equilibrium.

Figure 5: Efficiency Loss Due to the Persistence of Certification



As a more precise test of efficiency, I look at the overall efficiency of the last six periods of the $\mathcal{S}^{Pre}$ environment and compare it to the efficiency of the last six periods in the $\mathcal{S}^{Post}$ environment. I estimate

$$\text{Efficiency}_{t,s} = \alpha_0 + \beta_{\mathcal{S}^{Pre}} I_{\mathcal{S}^{Pre}} + \beta_{LA}(LA * I_{\mathcal{S}^{Pre}}) + \epsilon_{t,s} \tag{19}$$

where $I_{\mathcal{S}^{Pre}}$ is an indicator variable for the $\mathcal{S}^{Pre}$ environment and LA is the total number of lottery averse individuals in the session.

Unsurprising given the visible difference in efficiency, the price regression in Table 9 shows a significant increase in efficiency in the $\mathcal{S}^{Pre}$ environment relative to $\mathcal{S}^{Post}$. Aversion to gambles in the $\mathcal{S}^{Pre}$ leads to a decrease in efficiency, a result consistent with the efficiency rankings of the partial-certifying equilibria.

6 Conclusion

This paper represents a first step in understanding how the informational properties of institutions may lead to inefficient persistence. I showed formally that, in a market with

[25]Quantity efficiency was 95.7% in the $\mathcal{S}^{Pre}$ versus 99.8% in the $\mathcal{S}^{Post}$ treatment.

Table 9: Efficiency Loss Due to the Persistence of Certification

Treatment $\mathcal{S}^{Pre}$	522.5**
	(174.2)[a]
# Lottery Averse Buyers in $\mathcal{S}^{Pre}$	–138.9
	(79.6)
Constant	1450.8***
	(15.3)
Adj. R^2	0.488
Observations	72

[a]Robust standard errors clustered at the session level. Significance levels: *** $p < .01$, ** $p < .05$, * $p < .1$.

endogenously formed certification institutions, observable information about changes in the underlying environment could be lost. This lost information could lead to the persistence of an equilibrium where all participants in the environment are weakly worse off relative to a world without the certification institution. The experimental evidence of inefficient persistence of the certifying equilibrium was striking. No session that initially adopted the certification institution showed observable changes in price or the distribution of trades in response to a change in the underlying distribution of seller types. This led to a loss of efficiency relative to a market with the same underlying environment but where the certifying equilibrium had not initially formed.

The experiments described in this paper constitute a stable baseline on which to guide future theoretical and experimental work. I showed that in a double auction environment with anonymity, the benchmark model performed extremely well in predicting both initial convergence and adaptation. I further demonstrated that for some initial distribution of seller types, both the non-certifying and certifying equilibrium were stable. Building on the consistency of these initial experiments, future research will focus on the types of information necessary to adapt away from the certifying equilibrium and on the dynamic learning processes that generate persistence.

The information externality highlighted in this paper represents a general phenomenon that extends beyond the simple certification market considered here. Common mechanisms designed to mitigate moral hazard such as regulation, certification, monitoring, process management, and credit scoring all share the common characteristic that they group heterogenous agents into the same action. Given the ubiquity of these institutions in everyday markets and organizations, developing an understanding of how information externalities dynamically alter the institutional landscape is of great importance.

7 Appendix

7.1 Proofs

Proof. Lemma 1: By the definition of $s \in \{G, C, B\}$, $C_B^H \geq C_L + U^H - U^L - T \geq C_C^H \geq C_L \geq C_G^H$. Thus, in the uncertified market, only type-G sellers will produce high-quality goods. Writing out the utility of the seller:

$$v(m, P^m, b, s) = \begin{cases} P^C - C_s^H - T & \text{if } m \in \mathcal{C}, s \in \{G, C, B\}, \\ P^{NC} - C_s^H & \text{if } m \in \mathcal{NC}, s \in \{G\}, \\ P^{NC} - C^L & m\text{if } \in \mathcal{NC}, s \in \{C, B\}. \end{cases}$$

By Definition 2,

$$S(m^*, s) \neq 0 \Leftrightarrow m^* \in \arg\max_m \Sigma_b v(m, P^m, b, s) \quad \forall s.$$

Finding the points where each seller type is indifferent between the certified and uncertified markets lead directly to Lemma 1. ■

Proof. Lemma 2: In the baseline model, there is only one type of buyer which I denote as b_0 whose utility is as follows:

$$u(m, P^m, b_0, s) = \begin{cases} U^H - P^C & \text{if } m \in \mathcal{C}, s \in \{G, C, B\} \\ U^H - P^{NC} & \text{if } m \in \mathcal{NC} s \in \{G\} \\ U^L - P^{NC} & \text{if } m \in \mathcal{NC} s \in \{C, B\} \end{cases}$$

It follows:

1. When $\Delta P > T$, $v(\mathcal{C}, P^{\mathcal{C}}, b, G) > v(\mathcal{NC}, P^{\mathcal{NC}}, b, G)$ and thus $S(\mathcal{NC}, G) = 0$. By the definition of the competitive equilibrium, $\mu_b(\mathcal{NC}, G) = \frac{S(\mathcal{NC}, G)}{\Sigma_s S(\mathcal{NC}, s)} = 0$ and thus

$$\Sigma_s u(\mathcal{NC}, P^{\mathcal{NC}}, b_0, s)\mu_b(\mathcal{NC}, s) = U^L - P^{\mathcal{NC}}.$$

Since $\forall s$, $u(\mathcal{C}, P^C, b_0, s) = U^H - P^{\mathcal{C}}$ and $u(\varnothing, P^{\varnothing}, b_0, s) = 0$, it follows that an agent is indifferent between all three markets when $P^{\mathcal{NC}} = U^L, P^{\mathcal{C}} = U^H$

2. When $\Delta P \leq T$, $\forall s$, $v(\mathcal{C}, P^{\mathcal{C}}, b, s) < v(\mathcal{NC}, P^{\mathcal{NC}}, b, s)$ and thus $S(\mathcal{NC}, G) = M_G$. By the definition of the competitive equilibrium, $\mu_b(\mathcal{NC}, G) = \frac{S(\mathcal{NC},G)}{\Sigma_s S(\mathcal{NC},s)} = \frac{M_G}{M} = \mathfrak{g}$. It follows that

$$\Sigma_s u(\mathcal{NC}, P^{\mathcal{NC}}, b_0, s)\mu_b(\mathcal{NC}, G) = \mathfrak{g}U^H + (1-\mathfrak{g})U^L - P^{\mathcal{NC}}.$$

A buyer is indifferent across all three markets if $P^{\mathcal{NC}} = U^H - (1-\mathfrak{g})(U^H - U^L)$ and $P^{\mathcal{C}} = U^H$.

■

Proof. Theorem 1:

1. When $\Delta P = U^H - U^L$:

   (a) By Lemma 1, $S(\mathcal{NC}, B) = M_B$, $S(\mathcal{C}, G) = M_G$, and $S(\mathcal{C}, C) = M_C$.

   (b) By Lemma 2, if $P^{\mathcal{NC}} = U^H, P^{\mathcal{C}} = U^L$, $D(\mathcal{C}, b_0) = [0, N_{b_0}] \in \mathbb{I}_+$, $D(\mathcal{NC}, b_0) = [0, N_{b_0}] \in \mathbb{I}_+$, $D(\varnothing, b_0) = [0, N_{b_0}] \in \mathbb{I}_+$ with $\Sigma_m D(m, b_0) = N_{b_0}$.

   Thus the attainable allocation where $P^{\mathcal{NC}} = U^H, P^{\mathcal{C}} = U^L$, $D(\mathcal{C}, b_0) = M_G + M_C$, $D(\mathcal{NC}, b_0) = M_B$, and $D(\varnothing, b_0) = N_{b_0} - M$ always exists.

2. When $\Delta P > T$:

   (a) By Lemma 1, $S(\mathcal{NC}, B) = M_B$, $S(\mathcal{NC}, G) = M_G$, and $S(\mathcal{NC}, C) = M_B$.

   (b) By Lemma 2, a buyer is indifferent between all three markets if $P^{\mathcal{NC}} = U^H - (1 - g)(U^H - U^L)$ and $P^{\mathcal{C}} = U^H$.

   If $P^{\mathcal{C}} - P^{\mathcal{NC}} = (1-g)(U^H - U^L) > T$, then $D(\mathcal{NC}, b_0) = M, D(\varnothing, b_0) = N_{b_0} - M$ is an equilibrium. Otherwise, there does not exist a set of prices such that $\Delta P > T$ and a buyer is indifferent between the certified and uncertified markets.

■

Proof. Theorem 2: By Lemma 1, $S(\mathcal{C}, C) > 0 \rightarrow S(\mathcal{C}, G) = M_G$. It follows that for any competitive equilibrium where type-C sellers certify their good, all type-G sellers certify their good. Define the total welfare function W as

$$W = \Sigma_m u(m, P^m, b_0, s)\mu_b(m, s)D(m, b_0) + \Sigma_{s,m} v(m, P^m, b_0, s)S(m, s).$$

Since $u(\mathcal{C}, P^{\mathcal{C}}, b_0, G) + v(\mathcal{C}, P^{\mathcal{C}}, b_0, G) - T \leq u(\mathcal{NC}, P^{\mathcal{NC}}, b_0, G) + v(\mathcal{NC}, P^{\mathcal{NC}}, b_0, G)$, W is decreasing in $S(\mathcal{C}, G)$. Likewise, since $u(\mathcal{C}, P^{\mathcal{C}}, b_0, C)+v(\mathcal{C}, P^{\mathcal{C}}, b_0, C)-T \geq u(\mathcal{NC}, P^{\mathcal{NC}}, b_0, C)+ v(\mathcal{NC}, P^{\mathcal{NC}}, b_0, C)$, W is increasing in $S(\mathcal{C}, C)$. Thus, the constrained Pareto Efficient equilibrium must either be the certifying equilibrium where all the type-C sellers trade in the certified market or the non-certifying equilibrium where no type-G sellers certify their goods. In cases where the non-certifying equilibrium does not exist but where partial-certifying equilibria do exist, it is either the certifying equilibrium or the partial-certifying equilibrium with the least amount of certification that is constrained Pareto efficient. ∎

Proof. Theorem 3: Let $\bar{\mathfrak{g}}$, $\bar{\mathfrak{c}}$, $\bar{\mathfrak{b}}$ be the prior beliefs about the proportion of good, conditional and bad agents in the market. When a non-certifying equilibrium exists, $P^{\mathcal{NC}} = U^H - (1 - \mathfrak{g})(U^H - U^L)$. When a certifying equilibrium exists, only type-B sellers are in the uncertified market.

Define $S^{\mathcal{NC}}$ as the number of sellers trading in the uncertified market. Then, if the number of buyers in each market are known, prices are observable, and the marginal valuations for the pivotal buyer are known, the posteriors $\hat{\mathfrak{g}}$, $\hat{\mathfrak{c}}$, $\hat{\mathfrak{b}}$ under the non-certifying and certifying equilibrium are as follows:

Type	Non-Certifying Equilibrium	Certifying Equilibrium
$\hat{\mathfrak{g}}$	$\frac{P^{NC}-U^L}{U^H-U^L}$	$\frac{\bar{\mathfrak{g}}}{\bar{\mathfrak{g}}+\bar{\mathfrak{c}}}(1-\hat{\mathfrak{b}})$
$\hat{\mathfrak{c}}$	$\frac{\bar{\mathfrak{c}}}{\bar{\mathfrak{c}}+\bar{\mathfrak{b}}}(1-\hat{\mathfrak{g}})$	$\frac{\bar{\mathfrak{c}}}{\bar{\mathfrak{g}}+\bar{\mathfrak{c}}}(1-\hat{\mathfrak{b}})$
$\hat{\mathfrak{b}}$	$\frac{\bar{\mathfrak{b}}}{\bar{\mathfrak{c}}+\bar{\mathfrak{b}}}(1-\hat{\mathfrak{g}})$	$S^{\mathcal{NC}}/M$

When U^H and U^L are known and the market is in a non-certifying equilibrium, $\hat{\mathfrak{g}} = \mathfrak{g}$ and thus price is a sufficient statistic for the proportion of type-G sellers in the environment. ∎

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7.1 Summary Statistics

Table 10: Summary Statistics for $\mathcal{S}^{Pre}$ Environment (Periods 7-12)

Session[a]	Uncertified[b] Price	Certified Price	Uncertified[c] High Quality	Uncertified Low Quality	Certified High Quality	Number Lottery Averse
1	141	194	22	12	28	3
2	170	203	19	13	40	2
3	103	193	1	17	53	3
4	145	202	19	12	39	3
5	143	197	34	18	19	2
6	176	209	40	11	16	2

[a]Sessions 4-6 are public information treatments.
[b]Average Price of both high-quality and low-quality units traded in the uncertified market.
[c]Total number of trades across the six periods.

Table 11: Summary Statistics for $\mathcal{H}^{Post}$ Environment (Periods 19-24)

Session	Uncertified Price	Certified Price	Uncertified High Quality	Uncertified Low Quality	Certified High Quality	Number Lottery Averse
1	114	200	0	44	25	3
2	126	203	1	31	34	2
3	98	199	0	19	51	3
4	119	204	0	23	47	3
5	114	211	0	20	50	2
6	124	201	1	19	47	2

Table 12: Summary Statistics for $\mathcal{H}^{Pre}$ Environment (Periods 7-12)

Session	Uncertified Price	Certified Price	Uncertified High Quality	Uncertified Low Quality	Certified High Quality	Number Lottery Averse
7	125	202	0	39	28	3
8	97	193	1	14	51	2
9	106	201	0	22	46	2
10	109	202	0	25	45	3
11	118	212	2	29	36	2
12	106	200	0	21	49	1

Table 13: Summary Statistics for $\mathcal{S}^{Post}$ Environment (Periods 19-24)

Session	Uncertified Price	Certified Price	Uncertified High Quality	Uncertified Low Quality	Certified High Quality	Number Lottery Averse
7	134	201	12	24	36	3
8	102	192	0	11	60	2
9	99	198	0	18	54	2
10	111	198	2	12	56	3
11	121	205	6	12	54	2
12	101	191	1	12	59	1

Sellers Instructions

Before the experiment, subjects were randomly split into two groups: buyers and sellers. These are a translated version of the instructions given to the sellers. Instructions for the buyers as well as the computerized instructions are available upon request.

Today you will take part in a market experiment. Please read through the following instructions carefully. All the information you need to successfully participate in this experiment is written here. If you have questions regarding the experiment or the instructions, please raise your hand. An instructor will come to your desk and will answer your question.

By participating in this experiment, you automatically receive a show-up fee of **10 Francs**. In the course of the experiment you can earn additional money by earning points through trading. The amount of points you will earn depends on your decisions and the decisions of other participants during the experiment.

The experiment is split up into **24 separate periods**. In each period you will interact with other participants in the experiment using the computer in front of you. The points that you earn during this experiments are converted into francs at the end of the experiment. The conversion rate is:

30 Points = 1 Swiss Franc

At the end of the experiment, six periods are randomly chosen and you will receive the amount of money you earned in these periods plus the 10 francs show-up fee in cash.

Please be aware that communication is strictly forbidden during the time you are in the laboratory. Also note that the use of the computer is restricted to the experimental program only. Communication or manipulating of the computer will result in exclusion from the experiment. If you have any questions please raise your hand and an instructor will answer them.

Overview of the course of the experiment

In this study you are a **seller** in a market with RED and BLUE products. The market consists of 5 buyers and 6 sellers. As a seller, you may sell **up to two** products. You will earn a number of points on a transaction equal to the price that you sell a unit minus the cost for producing the unit and any certification costs that you incur.

Your Earnings = Price – Production Cost – Certification Fee

In the market, you may sell two types of products: RED and BLUE. These products are of different quality and may have different valuations to the buyers in the market. **A buyer earns money if he pays less than his valuation for a product.** A buyer's valuation for a product depends on the quality of the product that he receives and the total number of units that he has already bought in the period.

Initially, the buyers and other sellers can not observe the quality of the unit that you are selling. You may choose to offer certified units instead of normal units which guarantee a specific color to the buyer. If you sell a certified unit, you will be charged 60 points in certification fees at the time of transaction.

In total the experiment consists of 24 Periods. The course of each period is as follows:

1. **The Trading Phase:** In the trading phase, you will trade with buyers in the market. The trading phase in the first 3 periods will be 4 minutes. The trading phase for the remaining periods will be 2 minutes. During the trading phase, you may complete trades either by posting offers that a buyer accepts or by accepting bids from the buyers.

<u>Your offer to sell:</u>

- Your offer to sell consists of the following specifications:
    1) the price that buyers have to pay for a unit of the product
    2) the quality of the product
    3) whether there is a certificate for the product
- The other participants can only see the actual quality of a product if the product is certified. If the product is not certified, the product quality will be labeled "UNKNOWN".

<u>The offers from buyers:</u>

- A buyer's bid to buy consists of the following specifications:
    1) the price he is willing to pay for a unit of the product
    2) the desired quality of the product
    3) whether the buyer requires a certificate or not
- If a buyer requests a certificate you **must** sell the buyer his desired quality. If the buyer doesn't request a certificate you can sell either quality.

2. **The Bonus Phase:** The next phase is the bonus phase. In this phase you have to guess how many of the sellers had lower cost producing the RED quality than producing the BLUE quality during the respective period. If your guess is correct you will earn 20 points.

3. **The Earnings Screen:** At the end of each period you will see the earnings screen. Each participant is informed how much he has earned during the last trading period.

6 out of the 24 Periods are randomly chosen and the earnings of these periods and the show-up fee will be paid out in cash at the end of the experiment.

Detailed course of the experiment

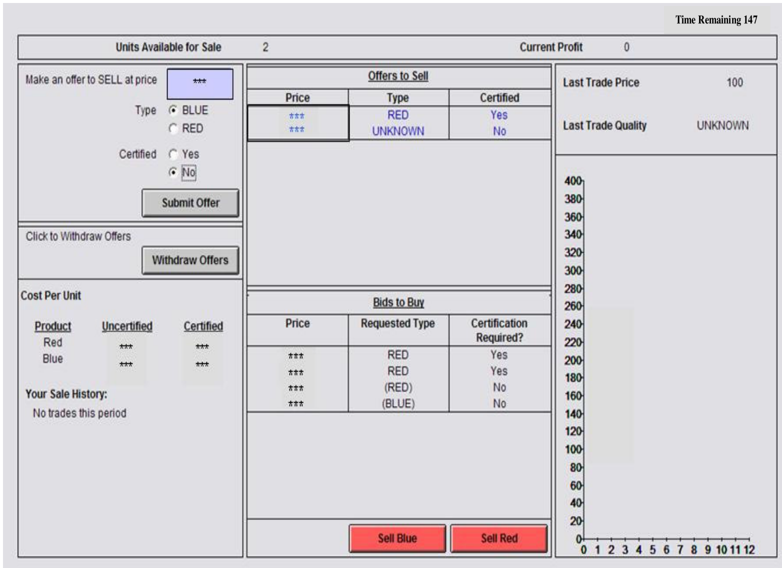
During the experiment you will enter your decisions using the computer. In the following instructions, all the functions will be explained in detail.

<u>1. The Trading Phase</u>

At the beginning of the trading phase, you will be informed of the production costs for the following period. When all players have reviewed their cost and value information, the trading phase will begin.

During the first three periods the trading phase will last for **4 minutes.** In the remaining periods, the trading phase will last **2 minutes**. The clock in the upper right hand corner of the screen will show the remaining time in a period in seconds. When this clock reaches zero the game will immediately end and you will not be able to make any more trades.

During each trading phase you will see the following screen:



Product Quality

There are two possible product qualities: RED and BLUE. Your production costs as well as the valuations of the buyers differ with the quality. In each period either the RED or the BLUE quality can be cheaper for you to produce.

Sellers Production Costs

The production costs of a product depend on two things. First the quality (RED or BLUE) of the product influence the costs and second certification increases the production costs. In every period you will see your costs on the lower left side of the trading screen.

Your costs can change from period to period, so please pay close attention to your production costs.

The following cost structures can occur during the experiment. In each period one of the three following cost structures will be applicable. Please note that different sellers may have different costs during each period.

Case 1, RED Quality is cheaper to produce:

Quality	Costs without certification	Costs with certification
RED	30	30+60 = 90
BLUE	50	50 + 60 = 110

Case 2a, BLUE Quality is cheaper to produce:

Quality	Costs without certification	Costs with certification
RED	80	80 + 60 = 140
BLUE	50	50 + 60 = 110

Case 2b, BLUE Quality is cheaper to produce

Quality	Costs without certification	Costs with certification
RED	130	130 + 60 = 190
BLUE	50	50 + 60 = 110

Certification

The other participants, buyers and sellers, can only see the quality of a product if the product is certified. A buyer can see the quality of products without a certificate only after the purchase. In this case the quality of the product will be labeled “UNKNOWN”.

To reveal the quality of a product to the buyers, you can elect to certify your product. **As you can see in the table above, certification increases the production cost by 60 Points.** The certification costs only occur when a product is sold. So you don’t have to pay certification costs for an unsold unit.

Your offers to buyers

You and all the other sellers can post offers to buyers during the whole period. If you want to post an offer you have to specify the following:

- You have to specify a price, which the buyer has to pay for the product. The price has to lie between 0 and 400:

0 ≤ Price ≤ 400

- You have to specify the quality:

Quality = RED or BLUE

- You have to decide whether you will issue a certificate:

Certificate = Yes or No
Costs of certification = 60

As soon as you have made all the required specifications you can validate your offer by clicking on the “post offer”-button.

This information will appear on the screen in the field offers to sell and all the other participants, buyers and sellers can see it. Your own offers will appear in blue, the offers of all the other sellers appear in black. **The offers to sell appear in descending order of the price on the screen.**

As soon as a buyer accepts an offer, the respective offer disappears from the screen. If you want to post the same offer again, you have to reenter all the specifications.

As long as you can sell at least one unit you can have two standing offers, one that is certified and one that is not certified. After your second sale all of your standing offers will be deleted.
If you have a standing offer, and you enter a new offer, the new offer replaces the old one, if both offers have the same certification status.

Example:
You have the following standing offers:

Quality	Price	Certified
RED	400	Yes
BLUE	50	No

Now you enter an offer for a RED quality product at the price of 350 and you offer a certificate. Your standing offers will change to:

Quality	Price	Certified
RED	**350**	Yes
BLUE	50	No

Now you enter an offer for a RED quality product at the price of 250 and you do not offer a certificate. Your standing offers will change to:

Quality	Price	Certified
RED	350	Yes
RED	**250**	No

To withdraw offer you can click the "withdraw offers"-button and **all your offers are withdrawn.**

Accepting offers from buyers

The offers to buy are sorted in descending order of the price.

To accept an offer from a buyer, you select the line of the respective offer and click the "sell RED"-button, if you want to sell the RED Quality or click the "sell BLUE"-button if you want to sell the blue quality.

- If the buyer doesn't request certification, you can sell either quality.
- If the buyer request certification, you have to sell the desired quality AND you have to pay the certification cost.

History

On the bottom left side of the screen, you will see your personal history. There you will see detailed information about the products you have sold so far during the respective period. For every product purchased you will see:

- the quality
- whether the product was certified
- the price you got
- the resulting earnings

On the right side of the screen you will see the market history. On the top you will find the information of the last traded good. Below you find a chart with all the trades of the period.
On the axis to the right you will find the amount of products traded. On the other axis you will find the price that has been paid for the product. Depending on the quality and certification of the product, the entry is of a different color:

- RED certified products appear in **red**
- BLUE certified products appear in **blue**
- Uncertified products appear in **black**

2. The bonus phase

Following the trading phase is the bonus phase. In this phase you have to guess how many of the sellers had lower cost producing the RED Quality than producing the BLUE quality during the respective period. If your guess is correct you will get 20 points.

3. The earning screen

At the end of each period you will see the earnings screen. There you will find your market earnings of the period.

Six out of the 24 Periods are randomly chosen and the earnings of these periods and the showupfee will be paid out in cash at the end of the experiment.

Omitted: Examples of How Earnings Is Calculated, Example of Randomized Payment

Exercises

The experiment starts only after all participants are fully accustomed with the experiment. To ensure this, we ask you to solve the exercises on this page.

Please also write down intermediary steps.

After these exercises you will have the possibility to get to know the trading screen before the first period starts. The options you have will be presented again in detail and you can do some trial trades.

For these exercises please use the following cost structure:

	Cost without certification	Cost with certification
ROT	80	140
BLAU	60	120

Exercise 1: A buyer bids 180 for a product and doesn't request a certificate, how much do you earn with this sale?

Earnings if you sell a BLUE quality product =
Earnings if you sell a RED quality product =

Exercise 2: You sell a RED Quality good for which a buyer paid 150. How high are your earnings if the buyer requests a certificate and what do you earn if he doesn't request a certificate?

Earnings with certificate =
Earnings without certificate =

Exercise 3: There are the following two standing offers of buyers:

Offer number	Price	Quality	Certificate requested
1	220	BLUE	Yes
2	180	RED	No

Through which sale can you make the higher earnings?

Possible earnings through offer number 1 =
Possible earnings through offer number 2 =