An Experiment on Retail Payments Systems*

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Abstract

We study the behavioral underpinnings of adopting cash versus electronic payments in retail transactions. A novel theoretical and experimental framework is developed to primarily assess the impact of sellers' service fees and buyers' rewards from using electronic payments. Buyers and sellers face a coordination problem, independently choosing a payment method before trading. In the experiment, sellers readily adopt electronic payments but buyers do not. Eliminating service fees or introducing rewards significantly boosts the adoption of electronic payments. Hence, buyers' incentives play a pivotal role in the diffusion of electronic payments but monetary incentives cannot fully explain their adoption choices. Findings from this experiment complement empirical findings based on surveys and field data.

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JEL codes: E1, E4, E5

1 Introduction

In the last decades, electronic payments have gained a significant share of retail transactions, eroding the usage share of cash and checks. For example, debit cards

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have become the most used means of payment in one third of countries across the world (World Bank, 2011). Convenience, reliability are among the suggested reasons for the growing popularity of electronic payments in retail transactions. Yet, significant differences in payment method adoption persist between developed and developing regions and several surveys show that cash enjoys a wide use also in developed economies.[1]

The open issue—and the objective of this study—is to understand the empirical determinants of the adoption of one payment method over another by consumers and retailers. Developing such an understanding is especially important for policymakers—central banks and government regulators—in assessing social costs and benefits associated with the diffusion of specific payment methods.[2] Unfortunately the available data have two significant limitations. A main shortcoming is that estimates of cash usage are notoriously unreliable and it is difficult to characterize the relationship between relative payment costs and the adoption of a payment method (Humphrey, 2010). An additional limitation is that the available data mostly come from survey answers that are not incentivized and therefore are subject to a number of biases and confounds. This study takes a step towards resolving such problems by constructing in the laboratory a prototypical retail market in which buyers and sellers must coordinate on using a payment method. We build on a literature that has successfully adopted experimental methodologies to empirically analyze the operation of market mechanisms (Smith, 1962), financial markets' (in)efficiency (Noussair and Tucker, 2103), and coordination problems (Devetag and Ortmann, 2007; Arifovic et al., 2014; Arifovic and Jiang, 2014).

The primary goal of this study is to identify features of the experimental

[1] See for instance World Bank (2011). For the US, Klee (2008) reports that cash captures 54 percent of all transactions collected from scanner data at 99 grocery stores. Survey data from Austria and Canada shows that more than 50 percent of all consumption purchases are paid for with cash (Huyn et al., 2013).

[2] For example, Humphrey (2010) ranks the overall unit cost of various payment methods based on US data and report that debit cards have the lowest cost while cash has the highest ($.90 versus $1.49). There can be also non-monetary considerations such as safety, convenience for record-keeping, privacy, tax evasion and counterfeiting, etc. For a theoretical discussion of some of these issues see Camera (2001) and Kahn et al. (2005).

markets that facilitate coordination on electronic payments as opposed to cash payments. We focus on the impact of service fees and rewards associated with electronic payments because these monetary components are at the forefront of the current debate (Board of Governors, 2011). In the experiment we manipulate the cost that *sellers* sustain from executing an electronic transaction. This cost represents the "merchant service fee" customarily paid by sellers to the service provider—the seller's financial institution.[3] We also manipulate the monetary benefit for *buyers* who use electronic payments, treating subjects with a monetary "reward" from electronic purchases, which commonly takes the form of dollars, miles, or other types of bonuses.

We construct in the lab a retail market for a homogeneous good. Before trading, buyers and sellers independently select cash or electronic payment methods, then meet in pairs to trade. In the pair the seller acts as a monopolist, posting a price, and then the buyer chooses a quantity. The payment methods adopted affect the ability to trade and, as a result of decentralized decision-making, payment methods' selections might be incompatible in some trading pairs. A transaction may fail to occur because the seller does not accept the buyer's payment method. The experimental design captures features that are central to the debate about the adoption of electronic payments as opposed to cash payments. Specifically, the design assumes that cash is legal tender and that sellers cannot price discriminate based on the buyer's payment method.

Analysis of the data suggests the existence of strong behavioral components in payment methods' adoption patterns. First, we find that sellers' service fees

[3] Sellers pay a service fee (or discount fee) to the service provider of the electronic payment, which generally takes the form of a percentage of amount transacted. The "interchange transaction fee," which is paid to the debit card issuer, makes up for the largest share of the service fee (U.S. Government Accountability Office, 2009). The Federal Reserve System has recently limited interchange fees for debit cards transactions to 21 cents plus 5 basis points times the transaction value, but only if the issuer of the debit card has more than $10 billion in assets; the average service fee is $0.43 for exempt institutions and dropped to $0.23 for non-exempt (Board of Governors, 2011). Credit card transactions are still exempted. Other components of the service fee are the cost of transaction processing, terminal rental and customer service, and the service provider's margin. There are other fees, such as the authorization fee, paid per authorization, communication fees, etc., but the service fee is the main one *directly* faced by the merchant.

have a sizable impact on the diffusion of electronic payments for a reason that is, perhaps, surprising. Service fees are paid by sellers who accept electronic payments. However, the presence of service fees altered the buyers' selection of payment method significantly more than the sellers'. Sellers passed on to buyers the anticipated service fees, as theory predicts. Some buyers therefore selected manual payments in the hope to induce sellers to post lower prices. But this did not lead to coordination on either payment method—consequently trade frictions emerged and inefficiencies arose. Second, the experimental data reveal that buyers' rewards from electronic purchases had a significant impact on buyers' desire to pay electronically and was very effective at enhancing the diffusion of electronic payments in the market. The data also allows us to assess the efficiency loss generated by mismatch in adoption of payment systems, and we find that such inefficiency is greater when there is a greater frequency of use of cash payments.

The rest of the paper is organized as follows. Section 2 reviews the literature on retail payments. Section 3 presents the experimental design and Section 4 illustrates the theoretical predictions. Section 5 shows the empirical results on payment methods' adoption and aggregate efficiency, Section 6 concludes.

2 Literature review

There is a vast literature on payment systems. Here, we focus on empirical studies that document how consumers' characteristics and payment methods attributes affect the diffusion and use of electronic payments relative to cash.

There is evidence that cash is still predominantly used in low-value transactions. The literature reports a significant correlation between consumers socio-demographic characteristics and the payment method adopted; for example, see Arango et al. (2012) for recent Canadian survey data. Field evidence also suggests that acceptability at the point of sale and monetary incentives are relevant variables. For instance, the study of Austrian and Canadian consumers in Huyn et al. (2013) has documented that acceptability is central to payment method frequency of use. Arango et al. (2011), Ching and Hayashi (2010), and Simon et al. (2010)

report that monetary incentives such as buyer rewards and loyalty programs are significantly associated with payment choices. Another important consideration that emerges from field studies is the importance of the relative cost of use of payment methods for their adoption. Borzekowski et al. (2006) document this aspect for consumers, by looking at survey data. In addition, Humphrey et al. (2001) document the existence of a significant sensitivity to relative costs by looking at aggregate-level field data from Norway. There is also evidence that price discrimination plays a role: Bolt et al. (2010) consider survey data from the Netherlands where retailers can price discriminate depending on the payment method used and found that surcharges favor cash over card payments.

3 Experimental design

This Section presents the set-up of the model and the experimental procedures. The illustration of the theoretical predictions is in Section 4.[4] The experiment has three treatments: Baseline, No-Fee, and Reward (Table 1). Each treatment reproduces in the laboratory a prototypical retail market with an even number of homogeneous buyers and sellers, in which frequency of use and acceptability of different payment methods are endogenous.

In each session, sixteen subjects are randomly divided into two groups: eight buyers and eight sellers. Subjects interact anonymously and play 40 trading periods always in the same role. In each period, sellers are monopolists who can produce a non-storable good for buyers who are endowed with m transaction balances, called tokens. Sellers and buyers can remain idle or trade goods for tokens. Tokens have a fixed redemption value, while the value of a good to a buyer (or, seller) depends on the quantity consumed (or, produced).

A trading period includes six stages:

(1) Payment method choice: everyone independently selects a manual or electronic

[4]A variety of models has been proposed to study payment methods. For instance, Camera (2001) studies competition between cash and electronic payments in a random matching model, Freeman (1996) studies payment systems in an overlapping generations model, and Kahn et al. (2005) study the problem of transactions' privacy in a model with spatial separation. The design we adopt is simple enough to be suitable for a laboratory investigation.

	Treatment		
	Baseline	No-Fee	Reward
Parameters			
Service fee for electronic payments, $1-\varepsilon$	0.1	0	0.1
Rebate rate for electronic payments, r	0	0	0.05
Predictions and results			
Prices			
Theory $p^*_M, \max p^*_E$	120, 133	120, 120	120, 133
Data p_M, p_E	180, 193	203, 190	192, 203
Quantities			
Theory $q^*_M, \min q^*_E, \min \hat{q}^*_E$	2, 1.62, 1.62	2, 2, 2	2, 1.62, 1.79
Data q_M, q_ME, q_E	1.24, .97, .85	1.24, .93, 1.06	1.19, .95, .92
Adoption of manual payments			
Sellers (% of choices)	14.4	2.5	6.2
Buyers (% of choices)	55.3	13.0	28.2
Manual settlements (% of all possible)	48.1	11.3	25.1
Sessions (dd/mm/yy)			
	26/01/12	24/01/12	31/01/12
	26/01/12	24/01/12	0 2/02/12
	12/03/13	11/03/13	13/03/12
	12/03/13	11/03/13	13/03/12
N. participants	64	64	64

Table 1: Overview of the experiment

Notes: The notation is as follows: M = manual, E = electronic. Prices: p^*_M = equilibrium price posted by sellers who only accept manual payments; p^*_E = upper bound of equilibrium price posted by sellers who accept both payments; p_M = average observed price posted by sellers who refused electronic payment; p_E = average price posted by sellers who accepted both payments. Quantities: q^*_M = equilibrium demand for manual transactions at price p^*_M; $\min q^*_E$ = equilibrium demand for manual transactions at price p^*_E; $\min \hat{q}^*_E$ = equilibrium demand for electronic transactions at price p^*_E; q_M = average observed demand for buyers who paid manually at sellers who refused electronic payments; q_{ME} = average observed demand for buyers who paid manually when seller accepted electronic payments; q_E = average observed demand for buyers who paid electronically. The quantities' data refer to completed trades and prices are rounded to the nearest integer. 2012 sessions were conducted at Purdue University and 2013 sessions at Chapman University.

means to settle the current trade, i.e., how to transfer tokens from buyer to seller;
(2) Pricing: each seller chooses a unit price $p \in [0, 400]$ for the good;
(3) Matching: buyer-seller pairs are randomly formed, according to a strangers matching protocol;
(4) Demand: each buyer observes the posted price p and demands $q \in [0, 4]$ goods;
(5) Payment: buyers complete the trade by transferring no less than pq tokens to the seller;
(6) Outcome: payoffs are realized.

The Baseline treatment captures two key empirical characteristics of retail payments. Sellers cannot refuse cash payments. Electronic payments are more convenient and reliable than cash payments, but are also more costly for sellers.

In the experiment all sellers must accept manual payments and their choice is whether to also accept electronic payments. Buyers must select either manual or electronic payment for the period—a design feature that decreases complexity, as buyers do not have to make an additional portfolio choice. The choice of payment method is costless and remains private information until the outcome stage.

When everyone has selected a payment method, each seller chooses a price p. Then, buyer-seller matches are randomly formed with uniform probability among all possible matches. At this point, each buyer sees the seller's price and is given the opportunity to demand a quantity q. Choosing $q = 0$ amounts to choosing not to trade. Finally, buyers must pay, after which earnings are realized at the end of the period. The interaction is local: subjects observe only the outcome in their pair and have no information about the economy as a whole. Furthermore, the interaction is anonymous: subjects cannot see the identity of the other person in their pair (experimental ID), hence there is no scope for reputation formation.

Payoffs. Subjects' instructions (in Appendix C) described the payoff functions in tokens, by means of tables and charts reporting tokens' earnings for given amounts $q \geq 0$ traded.

If there is no trade ($q = 0$), then the buyer's payoff corresponds to his transaction balance endowment for the period, m, which is a random integer uniformly distributed between 250 and 350 tokens. The seller's payoff corresponds to a fixed endowment $A = 350$, a parameter introduced to minimize differences in cash payments for subjects with different roles.

If there is trade, then the buyer's payoff is

$$m + u(q) - pq,$$

where $u(q) = 2\theta\sqrt{q}$ is the consumption utility, pq is the expenditure and $\theta = 169.5$. The seller's payoff is

$$A + q(\varepsilon p - g) - F, \qquad \text{with} \qquad \varepsilon = 0.9.$$

Net earnings include the gross revenue pq minus production costs and service fees. Production costs have a fixed component $F = 15$ and a variable component gq, with $g = 60$. If payments are electronic, then the seller pays the *merchant service fee* $(1 - \varepsilon)pq$, where $1 - \varepsilon = 0.1$ is called the *service fee*.[5]

Settling a trade. A trade of quantity q and price p can take place only if the seller accepts the buyer's method of payment, and if the buyer has transaction balances $m \geq pq$. A buyer starts the period with m transaction balances in a manual or an electronic account (depending on the payment method chosen). Manual payments have an explicit manual component. A buyer's manual account displays the transaction balances as a set of tokens of different sizes (1, 5, 10, or 50-unit tokens) ordered from large to small. Large-size tokens can be broken down into smaller ones by clicking a button. To pay the amount pq, the buyer must manually select a suitable combination of tokens with a series of mouse clicks, and then must execute the payment by clicking a button (see Instructions in Appendix C). Electronic payments, instead, are executed with a mouse click, which immediately transfers pq tokens to the seller. Hence, electronic payments

[5]In field economies, sellers who accept credit or debit cards pay a Merchant Discount Rate or Merchant Service Fee to the acquirer bank. Service fees range from a few basis points up to 3% or more, and account for costs for electronic payment processing, settling fees, interchange fees paid to the issuer, etc. In addition to explicit service fees, there may be implicit costs associated with tax-avoidance, which is more easily accomplished if payments are made in cash. Given these considerations, the 10% fee of the design—selected to better differentiate equilibrium prices across treatments— is therefore not so much unrealistic.

eliminate execution errors and minimize the effort and time to completion.

To induce differences in reliability and convenience of the two payment methods, subjects face a trading-time constraint. The entire trade sequence, from Pricing to Payment (stages 2-5), must be completed within 60 seconds.[6] A trading clock starts after everyone has selected their payment method and trade fails if payments are not completed in time.

Outcomes. A transaction (or trade) *succeeds* if the seller accepts the buyer's payment method, the trade is executed on time, and with a sufficient transfer of tokens. Otherwise the trade *fails*. At the end of each period, in the Outcome stage, buyer and seller are informed whether trade succeeded or failed. In the first case, they see the quantity traded, the earnings, and the payment method selected by their counterpart. Otherwise, they are informed about the reason for the failure. At each point in time, subjects can see their own trading history in the session. These rules and parameters are common knowledge.

Other treatments. Compared to the Baseline treatment, in the No-Fee treatment the sellers' service fee is set to zero, so $\varepsilon = 1$ in the seller's payoff function. In the Reward treatment, instead, half of the seller's service fee is rebated to the buyer, so the buyer's payoff is

$$m + u(q) - pq(1-r), \qquad \text{where} \qquad r = \frac{1-\varepsilon}{2}.$$

We recruited 192 subjects through announcements in undergraduate classes, half at Purdue University and half at Chapman University (Table 1). The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007). Instructions (see Appendix C) were read aloud at the start of the experiment and left on the subjects' desks. No eye contact was possible among subjects. Average earnings were $22 per subject.[7] On average, a session lasted about 2

[6]To familiarize subjects with the experiment, in periods 1-6 the time constraint was 120 seconds and the payment method was exogenously imposed (electronic in periods 1-3, and manual in periods 4-6).

[7]The show up fee was $5 for all treatments at Purdue (at Chapman, $7 for No-Fee and $14 for Baseline and Reward) and the conversion rate was 7 cents for every 100 tokens at Purdue (at Chapman, $0.12 for No-Fee and $0.07 for the other treatments). Following local lab standards,

hours, including instruction reading and a quiz.

4 Theoretical predictions

This section studies the symmetric Nash equilibria of the game described in the previous section. To do so, we move backwards, starting with the derivation of the optimal demand schedule in a trade match, given a price p and rebate rate r. Then, we study the optimal price posted by sellers given a service fee $1-\epsilon$. Finally, given optimal pricing and demand schedules, the optimal payment method adoption strategy is studied.

Let $\mu_i \in [0,1]$ denote the probability that player $i = b, s$ (b =buyer, s =seller) selects manual payments. Hence, μ_s is the probability that a seller only accepts manual payments, $1-\mu_s$ is the probability that a seller also accepts electronic payments, while $1-\mu_b$ and μ_b are, respectively, the probabilities that a buyer pays electronically and manually. The following definitions will be helpful in what follows:

- *Acceptability of electronic payments* is the probability that a seller accepts an electronic payment, $1-\mu_s$. Manual payments are always accepted.

- The *reliability* of a payment method is the probability of a successful trade conditional on the given payment method being accepted by the seller. In the experiment, reliability is endogenous. The (absolute) reliability of electronic payments is denoted R_e and the (absolute) reliability of manual payments is denoted R_m. Let $\sigma := R_m/R_e$ be the relative reliability of manual payments.

- *Trade risk* for a buyer is the probability of failing to trade with a given payment method because of acceptability or reliability problems. The trade risk of electronic payments is $\mu_s + (1-R_e)(1-\mu_s)$. The trade risk of manual payments is $1-R_m$.

- *Trade frictions* in the economy are the expected share of failed trades out of all possible trades, i.e., the expected failure rate of electronic transac-

Chapman students were paid more.

tions (due to mismatch and reliability problems) and of manual transactions (due to reliability problems). Normalizing trade frictions by the reliability of electronic transactions when R_e is close to one, trade frictions are approximately[8]

$$\tau := (1 - \mu_b)\mu_s + (1 - \sigma)\mu_b.$$

In the experimental data R_e is close to one, but R_m is not. Hence, theoretical predictions can be derived considering electronic transactions as being approximately always reliable, implying that σ approximates the reliability of manual payments, while $1 - \sigma$ and μ_s approximate the trade risk of manual and electronic payments.

4.1 Prices and quantities

Optimal demand is characterized in the following lemma.

Lemma 1 (**Optimal demand).** *Given a price p and a rebate parameter r, the optimal demand of an unconstrained buyer satisfies*

$$q(p; r) := \left(\frac{\theta}{p}\right)^2 \times \frac{1}{(1 - r)^2},$$

while a constrained buyer demands m/p.

Proof. See Appendix A. □

If the buyer's transaction balances are insufficient to satisfy her demand, $m < p \times q(p; r)$, then the optimal quantity demanded is simply m/p. Otherwise, if the buyer is unconstrained, she optimally demands $q(p; r)$ goods. This quantity decreases with the price p and increases with the rebate rate r.

The model is parameterized so that in equilibrium demand is always interior (Appendix A). The quantity demanded is unaffected by the seller's payment

[8]The expected share of failed trades out of all possible trades is

$$\tau^* := (1 - \mu_b)\mu_s + (1 - R_e)(1 - \mu_b)(1 - \mu_s) + (1 - R_m)\mu_b,$$

i.e., the expected failure rate of electronic transactions (first two terms, capturing mismatch and reliability problems) plus that of manual transactions (third term). Normalized trade frictions are $\tau = \frac{\tau^*}{R_e}$. For $R_e \approx 1$—as in the experimental data (see later)—we have $\tau \approx (1 - \mu_b)\mu_s + \mu_b(1 - \sigma)$, where $\sigma = \frac{R_m}{R_e}$.

method because sellers cannot price-discriminate. It depends on the buyer's payment method if there are rewards from electronic payments. The quantity *traded*, instead, depends on the payments methods of both parties.

To derive the optimal pricing schedule, recall that sellers are monopolists with linear preferences over tokens. They choose a price p to maximize expected profits. A trade succeeds only if the seller accepts the buyer's payment method and, conditional on that, if the trade can be executed on time.

Lemma 2 (**Optimal posted price**). *Consider the treatment parameters* (ε, r) *and the endogenous probabilities* (μ_b, σ). *The profit-maximizing prices for a seller who, respectively, refuses and accepts electronic payments are*

$$p_M := 2g \qquad \text{and} \qquad p_E := p_M \times \frac{\mu_b \sigma (1-r)^2 + (1-\mu_b)}{\mu_b \sigma (1-r)^2 + (1-\mu_b)\varepsilon}.$$

Proof. See Appendix A. □

A seller who does not anticipate receiving electronic payments posts a price p_M, which is below the price p_E posted if some electronic payments are expected, where

$$p_M \leq p_E \leq \frac{p_M}{\varepsilon},$$

Sellers who expect some electronic payments charge premium prices to recoup the expected service fees. The premium depends on the anticipated incidence of electronic transactions, and therefore is bounded above (approximately) by the service fee $1-\varepsilon$; it falls in μ_b and converges to zero as $\mu_b \to 1$.[9]

To summarize, the design ensures that if sellers pay a service fee to receive electronic payments (Baseline), then they charge premium prices, where the premium is roughly equal to the service fee $1-\varepsilon$. If buyers earn rewards from electronic purchases (Reward), then they increase their demand by a percentage roughly equal to the service fee. If electronic payments have neither costs nor benefits (No-Fee), then prices and quantities are independent of the payment method adopted.

[9]Due to the fixed cost F, sellers trade only if their expected profit is non-negative. The design parameters ensure that equilibrium profits are positive, i.e., F is below net earnings $q(p;r)(\varepsilon p - g)$ and $q(p)(p-g)$. See Appendix A.

4.2 Payment methods' adoption

Given optimal prices and quantities, we determine the choice of payment methods in symmetric Nash equilibrium. In doing so, we differentiate *use* from *adoption* of a payment method. Use refers to the payment method utilized in a successful trade. Adoption refers to the individual choice of payment method.

Using Lemma 1, let $q(p) := q(p; 0)$ when $r = 0$, hence let $q_E := q(p_E)$ and $q_M = q(p_M)$ denote the (optimal) quantity demanded by a buyer who pays manually and faces, respectively, prices p_E and p_M. In contrast, let

$$\hat{q}_E := \frac{q(p_E)}{(1-r)^2}$$

denote the quantity demanded by a buyer who pays electronically; clearly, the buyer cannot trade with sellers posting p_M, because they only accept manual payments. Using a linear approximation around $\varepsilon = 1$, observe that $\hat{q}_E/q_E \approx 1-\varepsilon$ when ε is small. To summarize, all else equal, buyers demand an identical quantity unless rewards are given for electronic payments; in that case, buyers who have selected electronic payments demand more than other buyers.

Let μ_i denote the probability that any player i selects manual payments in symmetric Nash equilibrium. The equilibrium payoff $\mathcal{V}_j^b$ to a buyer who pays using method $j = E, M$ and has m transaction balances is

$$\begin{aligned} \mathcal{V}_E^b &= m + (1-\mu_s)[u(\hat{q}_E) - p_E(1-r)\hat{q}_E], \\ \mathcal{V}_M^b &= m + \sigma\left\{(1-\mu_s)\left[u(q_E) - p_E q_E\right)] + \mu_s\left[u(q_M) - p_M q_M\right]\right\}. \end{aligned} \tag{1}$$

Sellers who, respectively, accept and refuse electronic payments have payoffs

$$\begin{aligned} \mathcal{V}_E^s = &\quad A + \mu_b\sigma[q_E(p_E - g) - F] + (1-\mu_b)[\hat{q}_E(\varepsilon p_E - g) - F], \\ \mathcal{V}_M^s = &\quad A + \mu_b\sigma[q_M(p_M - g) - F]. \end{aligned}$$

The payoff-maximizing choice of payments method μ_j' for player $j = b, s$ satisfies

$$\mu_j' = \begin{cases} 1 & \text{if } \mathcal{V}_M^j - \mathcal{V}_E^j > 0 \\ [0,1] & \text{if } \mathcal{V}_M^j - \mathcal{V}_E^j = 0 \\ 0 & \text{if } \mathcal{V}_M^j - \mathcal{V}_E^j < 0. \end{cases}$$

Traders evaluate the expected relative benefits of paying manually and electronically. Everyone benefits from the greater reliability of electronic payments. However, buyers and sellers face different incentives. For buyers, electronic payments generate rewards but may also carry the risk of being declined. The opposite is true for sellers; accepting electronic payments resolves coordination problems in payment methods, but using them may generate costs. This generates coordination problems.

Proposition 1 (Equilibria). *Let prices and quantities satisfy Lemmas 1-2. Every treatment supports two symmetric pure-strategy Nash equilibria characterized by homogeneous adoption of a single payment method.*

Proof. See Appendix A. □

The design ensures that in all treatments two Nash equilibria coexist, which are characterized by the uniform adoption of one payment method. The two pure strategy equilibria $\mu_j = 0, 1$ for $j = b, s$ coexist in each treatment (Table 1).[10] These equilibria always coexist because payment method choices are strategic complements. If sellers refuse electronic payments, then a buyer's dominant action is to pay manually, hence $\mu_b = \mu_s = 0$. If every seller accepts both payment methods, then buyers prefer electronic payments when these generate rewards or are more reliable; otherwise, buyers are indifferent. Hence, $\mu_b = \mu_s = 1$ is always a symmetric equilibrium. It follows that, in each treatment, subjects face a coordination problem, which by design cannot be solved through communication.

Note that payment methods' adoption choices have implications for the level of trade frictions τ in the economy. Although manual payments are less reliable than electronic, buyers' adoption of manual payments is not necessarily a source of trade frictions. In fact, an increase in buyers' frequency of adoption of electronic payments reduces trade frictions τ only when electronic payments have a lower relative trading risk, $\mu_s < 1 - \sigma$. Therefore, this design ensures an endogenous association between relative diffusion of electronic payments and trade frictions.

[10] Appendix A reports the complete set of symmetric equilibria. In particular, there exists a symmetric equilibrium in which sellers mix, while buyers adopt manual payments. This equilibrium is not robust to trembles as it introduces mismatch risk; hence, sellers have an incentive to accept both payments since there is no cost from doing so.

This, and the pricing associated with different adoption modes, has implications for efficiency, as we explain next.

4.3 Efficiency

The economy may exhibit inefficiencies because of pricing distortions, which lead to inefficient quantities, and because of frictions due to failed transactions.

Consider the first inefficiency, which is along the intensive margin. Let q^* satisfy $u'(q^*) = g$, where $q^* := \left(\frac{\theta}{g}\right)^2$. From Lemmas 1-2, the quantities traded in each of the two pure strategy equilibria are

$$q = \begin{cases} q_M = q^*/4 & \text{if } \mu_b = \mu_s = 1, \\ \hat{q}_E = (q^*/4) \times \left(\frac{\varepsilon}{1-r}\right)^2 < q_M & \text{if } \mu_b = \mu_s = 0. \end{cases}$$

Traded quantities are inefficiently low when all transactions involve costly electronic payments because service fees amount to a distortionary tax. Minimum equilibrium consumption occurs when buyers earn no rewards, $r = 0$. It follows that trade surplus is the lowest when costly electronic payments are adopted, because

$$\begin{aligned} u(\hat{q}_E) - g\hat{q}_E \quad &= \frac{3\theta^2}{4g} \times \frac{\varepsilon}{1-r}\left[1 - \frac{\varepsilon}{4(1-r)}\right] - F \\ &< \frac{3\theta^2}{4g} - F = u(q_M) - gq_M. \end{aligned} \tag{2}$$

Now consider the extensive margin inefficiency. We measure aggregate efficiency by ex-ante social welfare $\mathcal{W}$, defined as the sum of payoffs to buyer and seller, net of fixed payments, plus un-rebated service fees, i.e.,

$$\mathcal{W} := \sum_{i=b,s} [\mu_i \mathcal{V}_M^i + (1-\mu_i)\mathcal{V}_E^i] + (1-\mu_b)(1-\mu_s)p_E q(p_E; r)(1-\varepsilon-r) - (A+m),$$

Here, service fees are not a deadweight loss because they either compensate buyers (rewards) or some unmodeled service providers. In the expression $\mathcal{W}$ service fees are net of rewards, $p_E q(p_E; r)(1-\varepsilon-r)$, and are multiplied by $(1-\mu_b)(1-\mu_s)$, which is the expected frequency of electronic purchases. Substituting for $\mathcal{V}_E^i, \mathcal{V}_M^i$

we obtain

$$\begin{aligned}\mathcal{W} = &(1-\mu_b)(1-\mu_s)[u(\hat{q}_E) - g\hat{q}_E - F] + \mu_b(1-\mu_s)\sigma[u(q_E) - gq_E - F] \\ &+ \mu_b\mu_s\sigma[u(q_M) - gq_M - F].\end{aligned} \tag{3}$$

The expression above indicates that a planner would impose the uniform adoption of the highest-return payment method to avoid mismatch in payment preferences, and note that

$$\mathcal{W} = \begin{cases} \mathcal{W}_M := \sigma[u(q_M) - gq_M - F] & \text{if } \mu_b = \mu_s = 1, \\ \mathcal{W}_E := u(\hat{q}_E) - g\hat{q}_E - F & \text{if } \mu_b = \mu_s = 0. \end{cases}$$

What payment system would the planner adopt, then?

Proposition 2 (**Efficiency**). *Let prices and quantities satisfy Lemmas 1-2. If the relative reliability of manual payments is*

$$\sigma \leq \sigma^* := \frac{u(\hat{q}_E) - g\hat{q}_E - F}{u(q_M) - gq_M - F},$$

then social welfare $\mathcal{W}$ is maximized by common adoption of electronic payments.

To prove it, note that manual trades are associated with the greatest trading efficiency, $\hat{q}_E \leq q_M$, but are unreliable—trade succeeds only with probability σ. The planner selects electronic payments if $\mathcal{W}_M \leq \mathcal{W}_E$, i.e., when manual payments are sufficiently unreliable. This occurs if $\sigma \leq \sigma^*$ where $\sigma^* < 1$ whenever $\varepsilon < 1$; see (2). Given the design parameters we have $\sigma^* = .93$ in Baseline and $\sigma^* = .96$ in Reward. It is immediate that $\sigma^* = 1$ in No-Fee since quantities are independent of payment method used; coordinating on the use of electronic payments is always optimal in this treatment since there are no price distortions. For the other treatments, it depends on the realized value of σ.

5 Results

This section focuses on two questions: did our experimental markets succeed in coordinating on using a common payment method? And how did service fees and rewards associated with electronic payments alter trade patterns and efficiency? We report four main results. Results 1-3 concern the diffusion of the payment methods. Result 4 reports the relationship between payment methods and trade frictions and efficiency.

All analyses exclude the initial six periods, where, in order to familiarize participants with the task, only one payment method was made available. Recall that *use* refers to the payment method observed in a transaction successfully completed and *adoption* refers to the individual choice of payment method.

Result 1 (**Use of payment methods**). *There was mixed use of payment methods in the Baseline treatment. The use of electronic payments prevailed in the No-Fee and Reward treatments.*

Tables 1 and 2 provide support for Result 1. Among all trades that are successfully completed, 51.4 percent were settled with an electronic payment in Baseline, 74.9 in Reward and 88.7 in No-Fee (Table 1). A Wilcoxon rank-sum test reveals that both the difference between Baseline and No-Fee and between Baseline and Reward are significant ($p = 0.021$ and $p = 0.083$ respectively, two-sided, $N_1 = N_2 = 4$). Further support is provided by a probit regression, where the dependent variable is the use of payment methods and takes value 1 for electronic trades and 0 for manual trades (Table 2, Model 1). The econometric analysis shows that introducing rewards for buyers or eliminating sellers' service fees significantly raised overall use of electronic payments.

Recall that in all treatments the equilibrium where everybody trades manually coexists with the one where all trades are electronic. A possible interpretation of Result 1 is that the cost associated with electronic payments serves as a coordination device for payment methods' selection.

To shed further light on Result 1, we separately study the adoption choices of sellers and buyers.

Result 2 (**Adoption choices**). *In all treatments, sellers were more likely to adopt electronic payments than buyers.*

Figure 1 shows adoption rates by type of trader. Pooling all treatments, sellers chose electronic payments in 92 percent of cases, while buyers adopted electronic payments in 68 percent of instances; such difference is significant according to a

Dependent variable: *Payment method selected* *(1=electronic, 0=manual)*	Buyers who traded (use) Model 1		All buyers & sellers (adoption) Model 2		Model 3	
No-Fee treatment	2.831	***			1.677	***
	(0.473)				(0.261)	
Reward treatment	1.507	***			0.721	***
	(0.469)				(0.246)	
Buyer role			-1.367	***	-1.346	***
			(0.229)		(0.208)	
Period	0.025	***	0.029	***	0.029	***
	(0.004)		(0.003)		(0.003)	
Purdue location	-0.599		-0.571	**	-0.553	***
	(0.375)		(0.228)		(0.207)	
Constant	-0.650	*	1.858	***	1.024	***
	(0.393)		(0.210)		(0.240)	
N.obs.	2986		6528		6528	
N.subjects	96		192		192	
Log likelihood	-904.833		-1717.309		-1698.241	

Table 2: Use and adoption of electronic payments

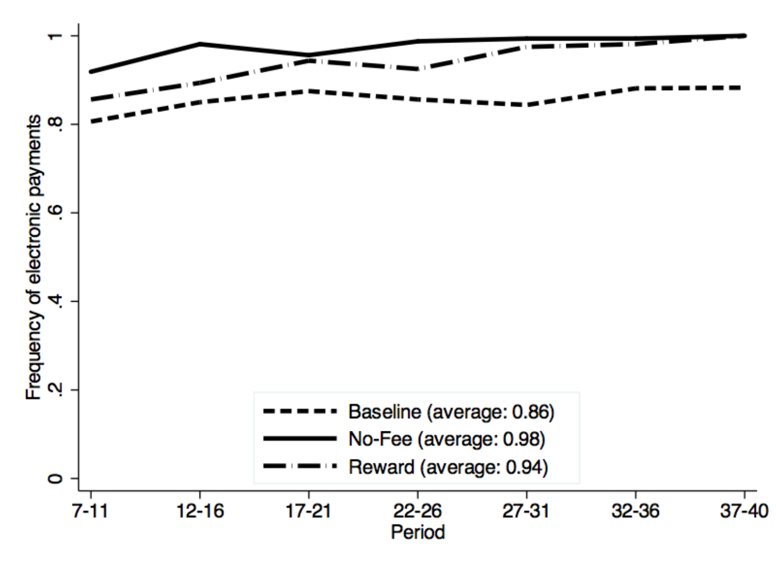
Notes: Probit regression with individual random effects. The dependent variable takes value 1 if electronic payments are choosen and 0 otherwise. Model 1 considers only buyers who successfully traded. In Models 2 and 3, we pool adoption choices of both sellers and buyers. The default treatment is Baseline. The explanatory variable *Buyer role* equals 1 for a buyer and 0 for a seller, while the dummy *Purdue* assumes value 1 for sessions carried out at Purdue University and 0 for sessions at Chapman University. Periods 7-40 only. Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

Wilcoxon rank-sum test ($p < 0.001$, two-sided, $N_B = N_S = 12$). This significance is confirmed by a probit regression, where the dependent variable is the payment method adopted by a trader (Table 2, Model 2). The disparities in adoption rates between buyers and sellers remain significant even after controlling for treatment effects (Table 2, Model 3); Buyers were significantly more reluctant to adopt electronic payments than sellers (p= 0.043, p=0.020, p=0.021 in Baseline, No-Fee, and Reward, respectively; two-sided Wilcoxon rank-sum, $N_B = N_S = 4$).

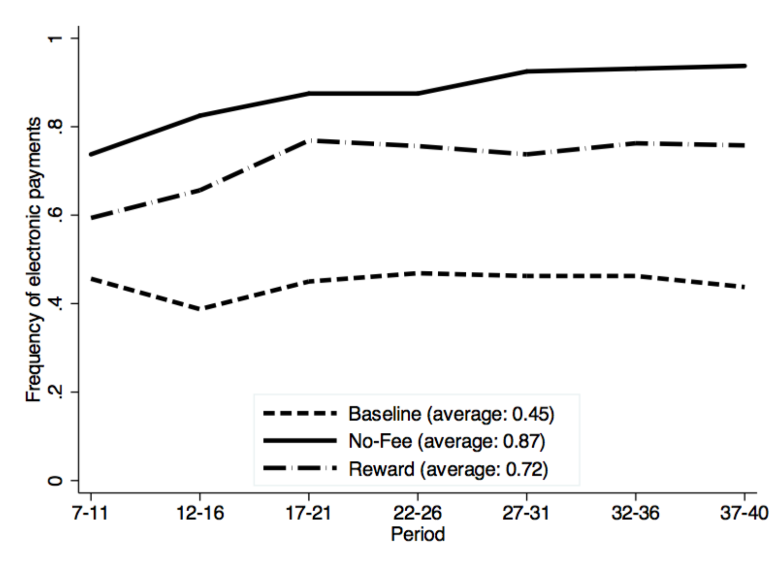
Introducing buyers' rewards from electronic purchases or eliminating sellers' service fees boosts the diffusion of electronic payments primarily because it alters buyers' behavior. On average, 45 percent of buyers chose electronic payments in Baseline, a rate that increased to 72 percent if rewards were added and to 87 percent if fees were removed. The increases relative to Baseline are significant (p=0.021 and p=0.083 for No-Fee vs. Baseline and Reward vs. Baseline, respectively; two-sided Wilcoxon rank-sum, $N_1 = N_2 = 4$). In contrast, sellers' adoption choices did not significantly change across treatments. Average adoption rates of electronic payments for sellers were 86, 94 and 98 percent in Baseline, Reward, and No-Fee. The only significant difference is between No-Fee and Reward (p=0.042, two-sided Wilcoxon rank-sum, $N_{NF} = N_R = 4$). This is interesting because it implies that monetary costs and benefits from using electronic payments cannot entirely explain adoption choices in the experiment.

Result 3 (**Buyers' adoption choices**). *A group of buyers consistently adopted manual payments when service fees were present. This behavior was no longer observed when service fees were removed or rewards added; a group of consistent users of electronic payments emerged, instead.*

Table 3 provides support for Result 3. Buyers who always adopted manual payments were 22 percent in Baseline and none in the other treatments. There also exists a group of buyers who regularly adopted electronic payments; this group grew from 6 to 44 percent when the service fee was removed. Most buyers were occasional users who switched payment systems. The switching probability significantly declined with experience and increased whenever a buyer experienced a trade failure. It made no difference whether the failed trade involved an electronic



(a) Sellers



(b) Buyers

Figure 1: Adoption of payment methods

	Treatment		
Fraction of buyers	Baseline	No-Fee	Reward
Regular users			
Manual payment	0.22	0.00	0.00
Electronic payment	0.06	0.44	0.22
Occasional users			
1 or 2 switches	0.13	0.25	0.16
3 or more switches	0.59	0.31	0.63

Table 3: Buyers' adoption of payment methods

or manual attempt to pay.[11] Such disparities in adoption choices contributed to generate endogenous trade frictions and inefficiencies, as discussed below.

Result 4 (Trade frictions and efficiency). *There is a positive association between trade frictions, efficiency losses and buyers' adoption of manual payments.*

Tables 4-5 provide support for Result 4. Trade frictions are measured as the frequency of failed transaction in the economy (see Section 4). Frictions endogenously emerged in every treatment and were positively associated with the diffusion of manual payments in the experimental retail markets. The highest incidence of trade frictions is found in Baseline, followed by Reward, and No-Fee (Jonckheere-Terpstra test; p-value= 0.012, N=12, two-sided). Tobit regressions show a positive, significant association between trade frictions and buyers' adoption of manual payments also after controlling for treatments effects (Table 4).

Buyers were pivotal in determining the diffusion of payment methods in our experimental retail markets, and trade frictions largely depended on their adoption choices. The data allow us to separately measure trade frictions that are due to reliability problems and to acceptability problems (Table 5). Buyers who adopted manual payments were exposed to trade risk that was entirely due to reliability issues because by design manual payments were always accepted. On the other hand, buyers who adopted electronic payments, were primarily exposed to trade risk due to acceptability issues because electronic payments were very reliable.

[11] Evidence comes from a probit regression on individual changes in payment methods (Table B-1 in Appendix B), where we controlled for buyers' types according to their prevalent adoption of payment methods, electronic or manual.

Dependent variable: *Fraction of buyers who adopted manual payments*	Model 1		Model 2	
Trade frictions	0.257	***	0.253	***
	(0.064)		(0.063)	
No-Fee treatment			-0.436	***
			(0.089)	
Reward treatment			-0.273	***
			(0.089)	
Purdue location			0.135	*
			(0.073)	
Constant	0.288	***	0.457	***
	(0.067)		(0.073)	
N.obs.	408		408	
Log. Likelihood	151.347		158.555	

Table 4: Buyers' adoption of manual payments

Notes: Tobit regressions with session random effects, censored at 0. The dependent variable is the fraction of buyers who chose manual payments in each period of each treatment. The unit of observation is the period average within a session. Trade frictions are per-period session averages. Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

In the experiment, reliability and acceptability of payment methods were endogenous. Manual payments had about 85 percent reliability, which means that a buyer who intended to pay manually faced a 15 percent probability of being unable to complete the trade. In contrast, electronic payments were very reliable (97-98 percent) but their acceptability varied between 86 and 98 percent, depending on the treatment.[12] As a result , buyers who adopted electronic payments faced a trade risk that was between 3.9 and 10.5 percent.

Overall, the two payment methods exhibited similar trade risk in Baseline, while electronic payments minimized trade risk when service fees were removed or buyers' rewards added. This suggests that relative trade risk considerations could well be the driving force behind buyers' adoption of payment methods.

Trade frictions, together with price and quantity distortions gave rise to substantial inefficiencies. Table 6 reports theoretical and realized efficiency measures.

[12]The data reveal that manual trades failed primarily due to time constraints and not underpayment, while the reverse is true for electronic trades, which primarily failed due to underpayment and not time constraints (see also Table B-2 in Appendix B).

	Treatment		
	Baseline	No-Fee	Reward
Trade frictions τ	.114	.051	.091
Buyers' choice of manual payments			
Fraction of choices μ_b	.553	.130	.282
Trade risk	.103	.154	.127
Reliability R_m	.869	.846	.873
Acceptability	1	1	1
Buyers' choice of electronic payments			
Fraction of choices $1 - \mu_b$	.447	.870	.718
Trade risk	.105	.039	.083
Reliability R_e	.973	.985	.977
Acceptability	.859	.976	.935
Performance of manual relative to electronic payments			
Relative reliability σ	.893	.859	.893
Relative acceptability	1.2	1.0	1.1

Table 5: Endogenous trade frictions: acceptability, reliability, and trade risk

Notes: Average incidence of trade failures unconditional and conditional on the buyer's payment. *Trade frictions* are the incidence of failed trades as a percentage of all possible trades. *Trade risk* for a buyer using payment method $i = E, M$ is the incidence of trade failures either due to reliability or acceptability by the seller. *Reliability* is the percentage of successful trades, conditional on the payment method being accepted. *Acceptability* is the percentage of times the buyer's payment method is accepted by the seller. Reliability and acceptability measures are an average of session averages. All numbers are rounded up to the closest decimal point.

The highest theoretical efficiency level is $\mathcal{W} = 344.13$ (Equation 3) but it cannot be achieved in every treatment. It can be achieved either when everyone adopts manual payments that are fully reliable ($\mu_b = \mu_s = 1$ and $\sigma = 1$), or when everyone adopts electronic payments that carry no costs for sellers ($\mu_b = \mu_s = 0$ and $\epsilon = 1$). We use this upper bound to normalize all values in Table 5 so that our efficiency measure are reported as a fraction of the highest theoretical value.

Table 6 reports the *theoretical* efficiency for a treatment as the highest (normalized) value $\mathcal{W}$ that is feasible in that treatment.[13] According to Proposition 2, the highest feasible value implies uniform adoption of electronic payments, because in the experiment they were sufficiently more reliable than manual payments, $\sigma < \sigma^*$ (Table 5). Differences in theoretical efficiency across treatments were due to price and quantity distortions from service-fees and rewards (Lemma 1 and 2).

Realized efficiency is the (normalized) value $\mathcal{W}$ observed in the experiment.

	Treatment		
Normalized efficiency $\mathcal{W}$	Baseline	No-Fee	Reward
Theoretical	0.93	1.00	0.96
Realized	0.59	0.69	0.62
Breakdown of efficiency losses			
a. Sub-optimal adoption	19.7%	11.5%	19.8%
b. Sub-optimal prices	37.2%	68.5%	46.8%
c. Sub-optimal consumption	43.1%	20.0%	29.7%

Table 6: Measures of aggregate efficiency

The ordering of treatments in terms of their theoretical efficiency corresponds to their ordering in terms of realized efficiency. In all treatments there are efficiency losses, which range from .31 to .34 of the highest possible efficiency. These losses originate from three sources: (a) sub-optimal adoption of payment methods; (b) price departures from theoretical predictions; (c) quantities traded that differ from theoretical predictions.

The greatest source of inefficiency is associated with quantities and prices that departed from equilibrium. Average prices movements across treatments are con-

[13]For instance, in the Baseline treatment the theoretical highest value is $\mathcal{W} = 320.04$, which is based on $p_e^* = 133$ and $q_e^* = 1.62$. This value is then normalized, dividing it by 344.13.

sistent with the theoretical comparative statics. In particular, the mean price posted by sellers who did not accept electronic payments was similar across treatments; in the Baseline treatment this price was significantly below the mean price of sellers who accepted electronic payments. However, in the remaining treatments, prices were not significantly affected by the seller's payment method choice.[14] Average price levels, instead, were higher than theoretical equilibrium predictions (Table 1) and such pricing distortion was responsible for a significant efficiency loss because average quantities traded were below the theoretical equilibrium quantities.

All treatments had some inefficiency resulting from mis-coordination in payment method adoption. Yet, the inefficient adoption of payment methods accounted for twice as much efficiency loss in the Baseline and Reward treatments compared to the No-Fee treatment, where there was the highest adoption of electronic payments.

6 Discussion and conclusions

This study provides a novel experimental framework to advance research and to inform policies about payment methods adoption. Experiments have the potential to address a vast array of issues in retail payments for several reasons. In the lab, one can construct model economies where agents have perfect information about the institutions under study. Unlike in the field, one can also manipulate exogenously the variables of interest, hence establishing the relationship between payment systems' attributes—such as service fees or reward programs—and their diffusion in the economy. Finally, the possibility to combine data on usage and costs of payment systems, as well as the ability to precisely test theoretical predictions, makes experiments a useful tool to advance the literature on retail payments.

In this study we have first developed a simple and flexible laboratory testbed that captures some basic features of retail electronic payments. Then, using well-established tools from experimental economics, we have investigated the in-

[14]Statistical evidence is reported in Appendix B, see Table B-3.

dividual payment method's adoption decisions of consumers and retailers who are motivated by actual incentives. In this manner, this paper complements existing survey-based studies about consumers and retailers' adoption decisions.

Our aim is to shed light on the association between features of the economy and individual payment method's adoption choices on one hand, and endogenous trading frictions and social efficiency on the other hand. To achieve this goal we study economies where there always exist an equilibrium in which every trade is executed using manual payments, and another in which electronic payments are always used. Coordinating on using electronic payments guarantees the greatest social welfare. The design captures empirically-relevant features of retail markets and, in particular, that buyers and sellers face different incentives. For buyers, electronic payments generate benefits but may carry the risk of being declined. The opposite is true for sellers; accepting electronic payments reduces the risk of trade failures but using electronic payments generates costs.

The experiment comprises three treatments: Baseline, No-Fee, and Reward. In the Baseline treatment, sellers suffer a cost from executing an electronic transaction, which is proportional to the revenue. Service fee are removed in No-Fee, while buyers' rewards are introduced in Reward. There are two main lessons.

First, analysis of the data suggests that buyers are pivotal in the diffusion of electronic payments. Sellers readily adopted electronic payments in all treatments, and did so significantly more than buyers. This is particularly interesting given that in our set-up only sellers suffered electronic payments' usage costs, and could not price-discriminate based on the buyer's choice of payment method. When sellers had to pay a service fee, a sizeable group of buyers regularly adopted manual payments. This behavior was no longer observed when service fees were removed or rewards added; under these conditions, a new group of buyers emerged, which regularly adopted electronic payments.

Second, the data suggest that regulatory policies aimed at fostering competition among providers or at increasing reward programs could boost the diffusion of electronic payments among consumers in retail markets. The experimental data collected allows us to measure the endogenous extent of trade frictions, to pin down their source, and to assess their impact in terms of efficiency loss for the entire market. We find that trade frictions, together with price and quantity distortions, gave rise to substantial inefficiencies. Interestingly, inefficient diffusion of payment methods accounted for twice as much efficiency loss in Baseline and Reward, compared to the No-Fee treatment, where there was the highest adoption of electronic payments.

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Appendix A: Theory

Proof of Lemma 1

Consider an economy with a population composed of equal numbers of anonymous, homogeneous sellers and buyers. We use M to denote manual as opposed to electronic payments, denoted E.

At the beginning of the period the buyer receives a random amount of tokens $m \in [m_L, m_H]$, with uniform pdf. These transaction balances can either be spent to purchase goods or simply consumed. Buyers have quasilinear preferences defined over transaction balances and goods. If we normalize the price of tokens to one (the numeraire), then the utility (in tokens) of a buyer who has m transaction balances and purchases $q > 0$ goods at price $p > 0$ is

$$m + u(q) - pq(1 - r).$$

Here $u(q)$ is the utility from consuming q gods, with $u' > 0$, $u'' < 0$, and $u(0) = 0$. The expenditure is pq and r denotes a possible reward rate to the buyer, which can be positive or zero. The reward is earned *after* the purchase has been executed—it takes the form of a rebate—and so it is simply "consumed;" the reward cannot be used to relax the expenditure constraint, i.e., we have $pq \leq m$.

The buyer chooses $q \geq 0$ to solve the problem

$$\max[m + u(q) - pq(1 - r) + \lambda(m - pq)]$$

where λ is the Kühn-Tucker multiplier on the expenditure constraint. The first order condition is

$$u'(q) - p(1 - r) - \lambda p \leq 0.$$

We can thus define the buyer's inverse demand function by

$$\begin{cases} 0 & \text{if } u'(0) \leq p(1-r), \\ q(p(1-r)) := (u')^{-1}(p(1-r)) & \text{if } u'(0) > p(1-r) \text{ and } pq \leq m, \\ \dfrac{m}{p} & \text{otherwise .} \end{cases} \tag{4}$$

Demand depends on the price p posted by the seller, the transaction balances m, and the rebate rate r, which may be zero or positive, depending on the treatment. The demand does not directly depend on the payment method because the seller cannot price-discriminate based on the payment method selected, and neither payment method generates a cost to the buyer. If demand is positive, then $u(q) - pq(1 - r) > 0$.

We parameterize the model such that the decomposition $q(p(1-r)) = k(r)q(p) \geq q(p)$ holds, where $k(0) = 1$, $k'(r) > 0$, and $q'(p) < 0 < q''(p)$. When $r = 0$ we have

$q(p(1-r)) = q(p)$. In the experiment we assume $u(q) = 2\theta\sqrt{q}$, which implies

$$\begin{aligned} q(p) &= \left(\frac{\theta}{p}\right)^2, \\ q(p(1-r)) &= k(r)q(p) = \frac{q(p)}{(1-r)^2}, \\ \frac{\partial q(p(1-r))}{\partial p} &= q'(p)k(r) = -\frac{2q(p)}{p}k(r) < 0. \end{aligned}$$

That is, for a buyer who encounters a seller posting a price p, $q(p)$ is quantity purchased if the buyer pays manually, and $q(p(1-r))$ is quantity purchased if the buyer pays electronically and there is a proportional rebate r on electronic purchases. □

Proof of Lemma 2

Each seller is a monopolist who has linear preferences over tokens and chooses the price p to maximize expected profits, given expected demand. If $q = q(p(1-r))$ for all $m \in [m_L, m_H]$, then expected demand is simply $q(p(1-r))$. We will work under this conjecture because, under the parametrization selected, this is true in equilibrium (see Supplementary Materials).

A seller who accepts electronic payments must accept also manual payments, and cannot price discriminate. Given that the buyer demands q goods when the price is p and the rebate rate is r, the transaction can be completed only if the seller accepts the buyer's chosen payment method, and if the buyer transfers at least pq tokens to the seller. We presume that manual transactions are settled with probability σ. If a transaction cannot be settled, then the seller produces nothing.

The expected profit $\mathcal{V}_E^s(p)$ of a seller who accepts electronic payments and posts price p is thus

$$\mathcal{V}_E^s(p) := A + \mu_b\sigma[q(p)(p-g) - F] + (1-\mu_b)[k(r)q(p)(\varepsilon p - g) - F],$$

where μ_b denotes the (endogenous) probability that the buyer encountered uses manual payments and we have used the fact that $q(p(1-r)) = k(r)q(p)$.

The seller always receives the fixed payment A, and may have earnings from trading with the buyer. With probability $1-\mu_b$ the seller meets a buyer who uses electronic payments; here, demand is $k(r)q(p)$, so the seller's profits are $k(r)q(p)(\varepsilon p - g) - F$. With probability μ_b the seller meets a buyer who uses manual payments, in which case demand is $q(p)$, and expected profits are $\sigma q(p)(p-g) - F$.

The FOC for an interior solution is

$$\mu_b\sigma[q'(p)(p-g) + q(p)] + (1-\mu_b)k(r)[q'(p)(\varepsilon p - g) + \varepsilon q(p)] = 0.$$

Define

$$\eta_0 := \mu_b\sigma + (1-\mu_b)k(r)\varepsilon \qquad \text{and} \qquad \eta_1 := \mu_b\sigma + (1-\mu_b)k(r). \tag{5}$$

Let p_E be the profit-maximizing price for a seller who accepts electronic payments; $p_E > 0$ uniquely solves

$$q'(p)\left(p\eta_0 - g\eta_1\right) + q(p)\eta_0 = 0,$$

so we have the identity

$$p_E = \frac{g\eta_1}{\eta_0} - \frac{q(p_E)}{q'(p_E)}$$

where $p_E > g$ since $\eta_0 < \eta_1$ and $q' < 0$.

A seller who does not accept electronic payments trades with probability $\mu_b\sigma$, i.e., when she meets a buyer who has adopted a manual payment method. The expected profit is

$$\mathcal{V}^s_M(p) := A + \mu_b\sigma[q(p)(p-g) - F].$$

The profit-maximizing price p_M uniquely satisfies $Q'(p)(p-g) + Q(p) = 0$, so we have the identity

$$p_M = g - \frac{q(p_M)}{q'(p_M)}.$$

Hence, p_M is independent of μ_b, $p_M \leq p_E$, and $p_E = p_M$ only if $\mu_b = 1$ or $\varepsilon = 1$ (which is when $\eta_1 = \eta_0$)

Given the functional forms for optimal demand in (4) we have

$$p_M := 2g \qquad \text{and} \qquad p_E := p_M\frac{\eta_1}{\eta_0}. \tag{6}$$

It should be clear that $p_M \leq p_E \leq \dfrac{p_M}{\varepsilon}$ because $\dfrac{\eta_1}{\eta_0}$ falls in μ_b, equalling 1 when $\mu_b = 1$ and $\dfrac{1}{\varepsilon}$ when $\mu_b = 0$. Note that p_M is invariant to μ_b while $\dfrac{\partial p_E}{\partial \mu_b} \propto \sigma k(r)(1-\varepsilon) < 0$.

Due to the fixed cost F, sellers trade only if their expected profit is non-negative for any choice of payment selected by the buyer. We choose parameters so that sellers are never inactive, i.e., F is below then net earnings $q(p)(\varepsilon p - g)$ and $q(p)(p-g)$. To do so, we need to ensure that

$$F < q(p_E)(\varepsilon p_E - g)$$

in which case $F < q(p_M)(p_M - g)$. To see this, note that $p = p_M$ is the unique maximizer of $q(p)(p-g)$; it follows that $q(p_M)(p_M-g) > q(p_E)(p_E-g)$ for all $p_M < p_E$.We have $q(p_E)(p_E-g) > q(p_E)(\varepsilon p_E - g)$. So, if $q(p_E)(\varepsilon p_E - g) - F > 0$, then $q(p_M)(p_M-g)-F > 0$; notice also that this implies $k(r)q(p_E)(\varepsilon p_E - g) - F > 0$ since $k(r) > 0$. For the parameters used in the experiment $F < q(p_E)(\varepsilon p_E - g)$ holds in all symmetric equilibria (see Supplementary Materials). □

		No-Fee			Baseline			Reward		
$\mu_s =$		0	x	1	0	x	1	0	x	1
	0	$\checkmark$			$\checkmark$			$\checkmark$		
$\mu_b =$	y	$\checkmark^{-}$			$\checkmark^{-}$					
	1	$\checkmark^{-}$	$\checkmark^{--}$	$\checkmark$		$\checkmark^{--}$	$\checkmark$		$\checkmark^{--}$	$\checkmark$

Table A-1: Multiplicity of equilibria

Notes: The Table reports all the possible symmetric equilibria. $^{-}$ indicates that the equilibrium exists only if $\sigma = 1$ (manual and electronic payments are equally reliable). $^{--}$ indicates that the equilibrium is not robust to trembles in buyers' choice. We let $y = (0, 1)$, i.e., any number in the open unit interval, and $x = (1 - \sigma(1 - r), 1)$.

Proof of Proposition 1

Proposition 1 is a special case of proposition A-1 which we next present and prove.

Proposition A-1. *Let prices and quantities satisfy Lemmas 1-2. Each treatment supports multiple symmetric Nash equilibria:*

$$(\mu_b, \mu_s) = \begin{cases} (0,0), (y,0)^\star, (1,0)^\star, (1,x), (1,1) & \textit{if } (\varepsilon, r) = (1,0); \\ (0,0), (y,0)^\star, (1,x), (1,1) & \textit{if } (\varepsilon, r) = (.9,0); \\ (0,0), (1,x), (1,1) & \textit{if } (\varepsilon, r) = (.9,.05), \end{cases}$$

for $y = (0, 1)$, and $x = (1 - \sigma(1 - r), 1)$. The notation * indicates the equilibrium exists only if $\sigma = 1$.

Table A-1 summarizes the possible equilibria, by treatment.

Consider a symmetric stationary outcome. Let $\mu_i \in [0, 1]$ denote the probability that a player of type $i = b, s$ (b =buyer, s =seller) has adopted the manual payment method. Hence, $1 - \mu_s$ is the probability that a seller accepts both electronic and manual payments, while $1 - \mu_b$ is the probability that a buyer uses the electronic payment method.

A buyer who adopts electronic payments can only make a purchase if the seller accepts electronic payments. A buyer who adopts manual payments can buy from any seller.

Conjecturing that the buyer is unconstrained in his purchases. Let

$$\hat{q}_E = q(p_E(1 - r))$$

denote the equilibrium quantity demanded when the price is p_E and the rebate rate is r. There is never a reward for a buyer who trades using manual payments, so we let $q_E = q(p_E)$ and $q_M = q(p_M)$ denote the equilibrium quantity demanded, when the price is p_E and p_M, respectively, and the buyer pays manually.

The payoff $\mathcal{B}_j$ to a buyer who has adopted payment method $j = M, E$ and has m transaction balances is thus

$$\begin{aligned} \mathcal{V}^b_M &= m + \sigma \left\{ (1 - \mu_s) \left[u(q_E) - p_E q_E \right] + \mu_s \left[u(q_M) - p_M q_M \right] \right\}, \\ \mathcal{V}^b_E &= m + (1 - \mu_s)[u(\hat{q}_E) - p_E(1 - r)\hat{q}_E]. \end{aligned}$$

Here q_j satisfies (4), p_j satisfy (6) and $\sigma \in (0,1]$ denotes the probability that a manual payments is completed in the time allocated to transact. It follows that

$$\mathcal{V}^b_M - \mathcal{V}^b_E = \mu_s\sigma[u(q_M) - p_M q_M] - (1-\mu_s)[u(q_E) - p_E q_E]\Big(\frac{1}{1-r} - \sigma\Big).$$

The second term in the equality above follows from $\hat{q}_E = k(r)q(p_E) = \frac{q(p_E)}{(1-r)^2}$ so we have $u(\hat{q}_E) = u(q_E)\frac{1}{1-r}$ since $u(q) = \sqrt{q}$.

The choice of payment method μ'_b of the generic buyer must satisfy:

$$\mu'_b = \begin{cases} 1 & \text{if } \mathcal{V}^b_M - \mathcal{V}^b_E > 0, \\ [0,1] & \text{if } \mathcal{V}^b_M - \mathcal{V}^b_E = 0, \\ 0 & \text{if } \mathcal{V}^b_M - \mathcal{V}^b_E = 0. \end{cases} \tag{7}$$

The buyer evaluates the difference between the expected surplus earned when sellers accept only manual payments $\mu_s\sigma[u(q_M) - p_M q_M]$ and the opportunity cost of using manual payments, which is simply the expected surplus from trading manually with a seller who accepts electronic payments, $(1-\mu_s)[u(q_E) - p_E q_E]$; this terms is adjusted for the loss of the rebate rate r and the possibility that the manual transaction is not completed, σ.

Let $\mathcal{S}_j$ denote the payoff to a seller who adopts payment method $j = M, E$. Conjecturing an outcome in which buyers are never constrained in their purchases, we have

$$\begin{aligned} \mathcal{V}^s_M = &\quad A + \mu_b\sigma[q_M(p_M - g) - F], \\ \mathcal{V}^s_E = &\quad A + \mu_b\sigma[q_E(p_E - g) - F] + (1-\mu_b)[\hat{q}_E(\varepsilon p_E - g) - F], \end{aligned} \tag{8}$$

Seller j does not observe the buyers' method of payment before choosing the price p_j.

Clearly, $\hat{q}_E = q_E k(r) = \dfrac{q_E}{(1-r)^2}$, hence

$$\begin{aligned} \mathcal{V}^s_M - \mathcal{V}^s_E = &\quad \mu_b\sigma\{q_M(p_M - g) - [q_E(p_E - g)]\} \\ &\quad -(1-\mu_b)\left\{\frac{q_E}{(1-r)^2}(\varepsilon p_E - g) - F\right\}. \end{aligned}$$

The choice of payment method μ'_s of the generic seller must satisfy

$$\mu'_s = \begin{cases} 1 & \text{if } \mathcal{V}^s_M - \mathcal{V}^s_E > 0 \\ [0,1] & \text{if } \mathcal{V}^s_M - \mathcal{V}^s_E = 0 \\ 0 & \text{if } \mathcal{V}^s_M - \mathcal{V}^s_E < 0. \end{cases} \tag{9}$$

Two remarks are in order. First, we choose parameters so that $q_E(\varepsilon p_E - g) > F$. This not only implies $\dfrac{q_E}{(1-r)^2}(\varepsilon p_E - g) > F$ for all $r \geq 1$ but also $q_E(p_E - g) > F$; that is a seller who accepts electronic payments makes positive profits when he engages either in an electronic or in a manual transaction (see Supplementary Materials). Second, when p_j satisfy (6), we have:

- If $\mu_b = 0$, then $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$;
- If $\mu_b = 1$, then $\mathcal{V}^s_M - \mathcal{V}^s_E = 0$ (because $p_M = p_E = g$), and
- If $\mu_b \in (0,1)$, then $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$ for $\varepsilon < 1$ sufficiently large.

To prove the last bullet point recall that $q_M(p_M - g) > q_E(p_E - g)$ for all $p_M < p_E$. The price p_E monotonically falls to p_M as μ_b grows to 1, while p_M is invariant to μ_b. Hence, $q_M(p_M - g) > q_E(p_E - g)$ when $\varepsilon < 1$ or $r > 0$ and the first term of the expression $\mathcal{V}^s_M - \mathcal{V}^s_E$ is positive for all $\mu_b \in (0,1)$. If $\mu_b = 0$, then $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$; if $\mu_b = 1$, then $\mathcal{V}^s_M - \mathcal{V}^s_E = 0$. In principle we could have $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$ for $0 < \mu_b \leq \bar{\mu}_b < 1$, and $\mathcal{V}^s_M - \mathcal{V}^s_E > 0$ otherwise. However, $\bar{\mu}_b < 1$ only if ε is sufficiently small; otherwise, there is no $\mu_b \in (0,1)$ that satisfies $\mathcal{V}^s_M - \mathcal{V}^s_E = 0$. To see this note that for $\varepsilon = 1$ we have $p_E = p_M$, in which case $\mathcal{V}^s_M - \mathcal{V}^s_E$ is negative and increasing in μ_b. By continuity, this holds also for some $\varepsilon < 1$ sufficiently close to 1. In the experiments we set parameters such that this was always the case. It follows that $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$ for all $\mu_b < 1$.

It is now a matter of algebra to verify that the existence of equilibria in Proposition A-1. The procedure is constructive. First, we conjecture that a given value of μ_b is an equilibrium. Given this, we find the optimal value for μ'_s using (9). Imposing symmetry, $\mu'_s = \mu_s$, we confirm whether the conjecture is correct for some parameters by considering (7). If no parameters support the conjectured value μ_b The details can be found in the Supplementary Materials. □

Deriving the symmetric equilibrium μ_b and μ_s

In the following, we derive the symmetric equilibrium μ_b and μ_s for each treatment using a constructive method. We let x, y denote arbitrary numbers in the open unit interval.

No-Fee Here $r = 0$, $\varepsilon = 1$, hence $\eta_0 = \eta_1$. Consequently $p_M = p_E$ and $q_M = q_E$. We have:

$$\mathcal{V}^b_M - \mathcal{V}^b_E = [u(q_M) - p_M q_M](\mu_s + \sigma - 1).$$

$$\mathcal{V}^s_M - \mathcal{V}^s_E = -(1 - \mu_b)[q_M(p_M - g) - F]$$

- $(\mu_b, \mu_s) = (0,0)$ is always an equilibrium.
  Conjecture $\mu_b = 0$. In this case $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$; Hence, $\mu'_s = 0$ from (9). Given $\mu'_s = \mu_s = 0$ (symmetry), we have $\mathcal{V}^b_M - \mathcal{V}^b_E \leq 0$. If $\sigma < 1$, then $\mathcal{V}^b_M - \mathcal{V}^b_E < 0$; here (7) implies $\mu'_b = 0$. If $\sigma = 1$, then $\mathcal{V}^b_M - \mathcal{V}^b_E = 0$—in which case (7) implies $\mu'_b = [0,1]$. Hence $\mu'_b = 0$ is always a best response when $\mu_s = 0$, and $(\mu_b, \mu_s) = (0,0)$ is always an equilibrium.

- $(\mu_b, \mu_s) = (0, x), (0, 1)$ are never equilibria.
  Conjecture $\mu_b = 0$. In this case $\mathcal{V}^s_M - \mathcal{V}^s_E < 0$; Hence, $\mu'_s = 0$ from (9). This contradicts $\mu'_s = \mu_s \in (0,1]$ is a symmetric equilibrium.

- $(\mu_b, \mu_s) = (y, 0)$, is an equilibrium if $\sigma = 1$ but not if $\sigma < 1$.
  Conjecture $\mu_b = y \in (0, 1)$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$ (for the parameters selected, see discussion in the paper); Hence, $\mu_s' = 0$ from (9). When $\mu_s' = \mu_s = 0$ (symmetry), we have $\mathcal{V}_M^b - \mathcal{V}_E^b \leq 0$. If $\sigma = 1$, then $\mathcal{V}_M^b - \mathcal{V}_E^b = 0$ (< 0 if $\sigma < 1$), in which case (7) implies $\mu_b' = [0, 1]$. Hence any $\mu_b' = y \in (0, 1)$ is a best response when $\mu_s = 0$. Consequently, $(\mu_b, \mu_s) = (y, 0)$ is an equilibrium only if $\sigma = 1$.

- $(\mu_b, \mu_s) = (y, x), (y, 1)$ are never equilibria.
  Conjecture $\mu_b = y \in (0, 1)$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$ from (9). This contradicts $\mu_s' = \mu_s \in (0, 1]$ is a symmetric equilibrium.

- $(\mu_b, \mu_s) = (1, 0)$, is an equilibrium if $\sigma = 1$ but not if $\sigma < 1$.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$; Hence, $\mu_s' = [0, 1]$ from (9). Given $\mu_s' = \mu_s = 0$ (symmetry), it is clear that $\mathcal{V}_M^b - \mathcal{V}_E^b = 0$ only if $\sigma = 1$ (otherwise, it is < 0). In this case (7) implies $\mu_b' = [0, 1]$. Hence any $\mu_b' = 1$ is a best response to $\mu_s = 0$; and $(\mu_b, \mu_s) = (1, 0)$ is an equilibrium only if $\sigma = 1$.

- $(\mu_b, \mu_s) = (1, x), (1, 1)$ are equilibria with $x \in (1 - \sigma, 1)$.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$; Hence, $\mu_s' = [0, 1]$ from (9). If $\mu_s' = \mu_s > 1 - \sigma$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b > 0$. In this case, (7) implies $\mu_b' = 1$. Consequently, $(\mu_b, \mu_s) = (1, x)$ is an equilibrium if $\sigma < 1$ for any $x \in (1 - \sigma, 1)$. It should be clear that this equilibrium is not robust to small trembles in the choice of buyers. In that case $\mu_b < 1$, hence $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$. So $\mu_s' = 0$. Finally, it is clear that $(\mu_b, \mu_s) = (1, 1)$ is always an equilibrium.

Baseline Here $r = 0$, $\varepsilon < 1$, hence $\eta_0 < \eta_1$. Consequently $p_M < p_E$ and $q_M > q_E$ for all $\mu_b < 1$, while $p_M = p_E$ and $q_M = q_E$ for $\mu_b = 1$. We have:

$$\mathcal{V}_M^b - \mathcal{V}_E^b = \mu_s \sigma [u(q_M) - p_M q_M] - (1 - \mu_s)[u(q_E) - p_E q_E](1 - \sigma).$$

$$\begin{aligned} \mathcal{V}_M^s - \mathcal{V}_E^s = \quad & \mu_b \sigma \{q_M(p_M - g) - [q_E(p_E - g)]\} \\ & -(1 - \mu_b)[q_E(\varepsilon p_E - g) - F]. \end{aligned}$$

- $(\mu_b, \mu_s) = (0, 0)$ is always an equilibrium.
  Conjecture $\mu_b = 0$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$ from (9). Given $\mu_s' = \mu_s = 0$ (symmetry), we claim that $\mathcal{V}_M^b - \mathcal{V}_E^b \leq 0$. If $\sigma < 1$, then $\mathcal{V}_M^b - \mathcal{V}_E^b < 0$; here (7) implies $\mu_b' = 0$. If $\sigma = 1$, then $\mathcal{V}_M^b - \mathcal{V}_E^b = 0$—in which case (7) implies $\mu_b' = [0, 1]$. Hence $\mu_b' = 0$ is a best response when $\mu_s = 0$, and $(\mu_b, \mu_s) = (0, 0)$ is always an equilibrium.

- $(\mu_b, \mu_s) = (0, x), (0, 1)$ are never equilibria.
  Conjecture $\mu_b = 0$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$. This contradicts $\mu_s' = \mu_s \in (0, 1]$ is a symmetric equilibrium.

- $(\mu_b, \mu_s) = (y, 0)$, is an equilibrium if $\sigma = 1$ but not if $\sigma < 1$.
  Conjecture $\mu_b = y \in (0, 1)$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$

from (9). Given $\mu_s' = \mu_s = 0$ (symmetry), $\mathcal{V}_M^b - \mathcal{V}_E^b \leq 0$. If $\sigma = 1$, then $\mathcal{V}_M^b - \mathcal{V}_E^b = 0$ (< 0 if $\sigma < 1$), in which case (7) implies $\mu_b' = [0, 1]$. Hence $\mu_b' = y$ is a best response when $\mu_s = 0$. Consequently, $(\mu_b, \mu_s) = (y, 0)$ is an equilibrium only if $\sigma = 1$.

- $(\mu_b, \mu_s) = (y, x), (y, 1)$ are never equilibria.
  Conjecture $\mu_b = y \in (0, 1)$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$ from (9). This contradicts $\mu_s' = \mu_s \in (0, 1]$ is a symmetric equilibrium.

- $(\mu_b, \mu_s) = (1, 0)$ is not an equilibrium if $\sigma < 1$, and it is an equilibrium otherwise.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$ because $p_E = p_M$, hence $q_M(p_M - g) = q_E(p_E - g)$. It follows that $\mu_s' = [0, 1]$ from (9). If $\mu_s' = \mu_s = 0$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b < 0$, as long as $\sigma < 1$, hence $\mu_b' = 0$, from (7), which is a contradiction. Otherwise, if $sigma = 1$ then $\mathcal{V}_M^b - \mathcal{V}_E^b = 0$; hence $\mu_b' = [0, 1]$, from (7), and $(\mu_b, \mu_s) = (1, 0)$ is an equilibrium.

- $(\mu_b, \mu_s) = (1, x)$ is an equilibrium if $\sigma < 1$ and $x > 1 - \sigma$.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$ because $p_E = p_M$, hence $q_M(p_M - g) = q_E(p_E - g)$. It follows that $\mu_s' = [0, 1]$ from (9). If $\mu_s' = \mu_s = x \in (0, 1)$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b = [u(q_M) - p_M q_M](\mu_s + \sigma - 1)$. If $\mu_s > 1 - \sigma$ we have $\mathcal{V}_M^b - \mathcal{V}_E^b > 0$. Hence, $\mu_b' = 1$ (from (7)). Consequently, $(\mu_b, \mu_s) = (1, x)$ is an equilibrium if $\sigma < 1$ for any $x \in (1 - \sigma, 1)$. This equilibrium is not robust to small trembles in the choice of buyers. In that case $\mu_b < 1$, hence $p_E > p_M$ and $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$. So $\mu_s' = 0$.

- $(\mu_b, \mu_s) = (1, 1)$ is always an equilibrium.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$ because $p_E = p_M$, hence $q_M(p_M - g) = q_E(p_E - g)$. It follows that $\mu_s' = [0, 1]$ from (9). If $\mu_s' = \mu_s = 1$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b > 0$. Hence, $\mu_b' = 1$, from (7) and $(\mu_b, \mu_s) = (1, 1)$ is an equilibrium.

Reward Here $r = 0.05$, $\varepsilon < 1$, hence $\eta_0 < \eta_1$. We have $p_M < p_E$ and $q_M > q_E$ for all $\mu_b < 1$, while $p_M = p_E$ and $q_M = q_E$ for $\mu_b = 1$, with

$$\mathcal{V}_M^b - \mathcal{V}_E^b = \mu_s \sigma [u(q_M) - p_M q_M] - (1 - \mu_s)[u(q_E) - p_E q_E]\left(\frac{1}{1 - r} - \sigma\right).$$

$$\begin{aligned} \mathcal{V}_M^s - \mathcal{V}_E^s = \quad & \mu_b \sigma \{q_M(p_M - g) - [q_E(p_E - g)]\} \\ & -(1 - \mu_b)\left\{\frac{q_E}{(1 - r)^2}(\varepsilon p_E - g) - F\right\}. \end{aligned}$$

- $(\mu_b, \mu_s) = (0, 0)$ is always an equilibrium.
  Conjecture $\mu_b = 0$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$ from (9). Given $\mu_s' = \mu_s = 0$ (symmetry), $\mathcal{V}_M^b - \mathcal{V}_E^b < 0$ for any $\sigma \leq 1$; here (7) implies $\mu_b' = 0$. Hence $(\mu_b, \mu_s) = (0, 0)$ is always an equilibrium.

- $(\mu_b, \mu_s) = (0, x), (0, 1)$ are never equilibria.
  Conjecture $\mu_b = 0$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$. This contradicts $\mu_s' = \mu_s \in (0, 1]$ is a symmetric equilibrium.

- $(\mu_b, \mu_s) = (y, 0)$, is never an equilibrium.
  Conjecture $\mu_b = y \in (0,1)$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$ from (9). Given $\mu_s' = \mu_s = 0$ (symmetry), $\mathcal{V}_M^b - \mathcal{V}_E^b < 0$ for all $\sigma \leq 1$. Hence, (7) implies $\mu_b' = 0$, which contradicts the conjecture $\mu_b = y \in (0,1)$.

- $(\mu_b, \mu_s) = (y, x), (y, 1)$ are never equilibria.
  Conjecture $\mu_b = y \in (0,1)$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$; Hence, $\mu_s' = 0$ from (9). This contradicts $\mu_s' = \mu_s \in (0,1]$ is a symmetric equilibrium.

- $(\mu_b, \mu_s) = (1, 0)$ is never an equilibrium.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$ because $p_E = p_M$, hence $q_M(p_M - g) = q_E(p_E - g)$. It follows that $\mu_s' = [0,1]$ from (9). If $\mu_s' = \mu_s = 0$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b = [u(q_M) - p_M q_M](\frac{\mu_s - 1}{1-r} + \sigma) < 0$ always, hence $\mu_b' = 0$, from (7), which is a contradiction.

- $(\mu_b, \mu_s) = (1, x)$ is an equilibrium for $x \in (1 - \sigma(1-r), 1)$.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$ because $p_E = p_M$, hence $q_M(p_M - g) = q_E(p_E - g)$. It follows that $\mu_s' = [0,1]$ from (9). If $\mu_s' = \mu_s = x > 1 - \sigma(1-r)$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b = [u(q_M) - p_M q_M](\frac{\mu_s - 1}{1-r} + \sigma) > 0$. Hence, $\mu_b' = 1$ (from (7)). Consequently, $(\mu_b, \mu_s) = (1, x)$ is an equilibrium for all σ for any $x \in (1 - \sigma(1-r), 1)$. This equilibrium is not robust to small trembles in the choice of buyers. In that case $\mu_b < 1$, hence $p_E > p_M$ and $\mathcal{V}_M^s - \mathcal{V}_E^s < 0$. So $\mu_s' = 0$.

- $(\mu_b, \mu_s) = (1, 1)$ is always an equilibrium.
  Conjecture $\mu_b = 1$. In this case $\mathcal{V}_M^s - \mathcal{V}_E^s = 0$ because $p_E = p_M$, hence $q_M(p_M - g) = q_E(p_E - g)$. It follows that $\mu_s' = [0,1]$ from (9). If $\mu_s' = \mu_s = 1$ (symmetry), then $\mathcal{V}_M^b - \mathcal{V}_E^b > 0$. Hence, $\mu_b' = 1$, from (7) and $(\mu_b, \mu_s) = (1, 1)$ is an equilibrium.

The interiority of equilibrium

The experimental parameters are given by

$$F = 15, g = 60, \theta = 169.5, \sigma = 1, \varepsilon = 0.9, r = 0.05, m \in [250, 350].$$

Buyers' payment constraint never binds in equilibrium, so q is interior for any value of μ_b that is consistent with equilibrium. To verify this note that

$$p_M q(p_M) = \frac{\theta^2}{2g}, \qquad p_E q(p_E(1-r)) = p_E k(r) q(p_E) = \frac{\theta^2}{2g} \times \frac{\eta_0}{\eta_1(1-r)^2}.$$

Given the parameters, we have $\frac{\theta^2}{2g} = 239.5 < m$; this implies that the equilibrium is always interior in the No-Fee treatment, whether or not sellers accept manual payments. We also have $\frac{\eta_0}{\eta_1} < 1$ when $r = 0$, which implies that if in the Baseline treatment sellers accept electronic payments, then buyers are never constrained in equilibrium. This is also true in the Baseline & Reward treatment since if sellers accept electronic payments, then $\mu_b = 0$; hence, $\frac{\eta_0}{\eta_1} = 0.9$, which implies $\frac{\eta_0}{\eta_1(1-r)^2} = 0.99$ because $\frac{1}{(1-r)^2} = 1.1$.

It is also immediate that given the parameters, sellers who accept electronic payments make a positive profit also when a buyer pays manually, i.e., $F < q(p_E)(\varepsilon p_E - g)$ holds.

Appendix B: Additional Tables

Dep. var.: Payment's method in comparison to the previous period 1=switch; 0= no switch	Model 1		Model 2	
Failure t-1	0.808	***		
	(0.098)			
Electronic (median)	0.049		0.049	
	(0.244)		(0.244)	
Period	-0.025	***	-0.025	***
	(0.004)		(0.004)	
No-Fee treatment	-0.654	**	-0.654	**
	(0.271)		(0.271)	
Reward treatment	0.089		0.089	
	(0.248)		(0.248)	
Failure manual t-1			0.809	***
			(0.133)	
Failure electronic t-1			0.807	***
			(0.130)	
Constant	-0.905	***	-0.905	***
	(0.232)		(0.232)	
N.obs.	3168		3168	

Table B-1: Dynamics in adoption of payment methods by buyers

Notes: probit regression with individual random effects. Data for period 7-40. Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

	Failed transactions (%)						
	Manual			Electronic			
	Time	Underpay	Total	Time	Underpay	Declined	Total
Baseline	52.1	47.9	100	3.9	13.7	82.4	100
No-Fee	55.6	44.4	100	8.1	29.7	62.2	100
Reward	64.7	35.3	100	15.4	9.2	75.4	100

Table B-2: Why transactions failed

Notes: Time= the transaction was not completed within the time limit. Underpay= the transaction was not completed because the buyer did not transfer a sufficient number of tokens to the seller. Declined= the seller did not accept electronic payments. Data for periods 7-40.

Dependent variable: *Posted prices*	Baseline Model 1		No-Fee Model 2		Reward Model 3		Electronic Declined Model 4	
Accept electronic	18.260	**	-15.096		7.815			
	(7.600)		(10.533)		(7.686)			
No- Fee treatment							27.938	
							(22.451)	
Reward treatment							12.134	
							(18.019)	
Period	-0.295		-0.787	***	-0.556	***	0.305	
	(0.180)		(0.161)		(0.184)		(0.487)	
Purdue location	24.602	**	-20.561		-12.072		-11.745	
	(11.516)		(18.108)		(12.466)		(16.495)	
Constant	170.075	***	233.780	***	214.349	***	183.832	***
	(11.481)		(16.528)		(11.736)		(19.320)	
N.obs.	1088		1088		1088		252	
R squared	0.040		0.033		0.016		0.015	

Table B-3: Treatment effect on prices

Notes: OLS regression with individual random effect. Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

Appendix C: Experimental Instructions (Reward treatment)

Stefania: include figures and tables.

This is an experiment in decision-making. The National Science Foundation and Purdue University have provided funds for this research. You can earn money based on the decisions you and the other participants make in the experiment. Please turn off your cell-phones, do not talk to others and do not look at their screens. These instructions are a detailed description of the procedures we will follow. You will benefit from understanding them well.

How do you earn money?

In the experiment you will either be a seller or a buyer of a good. The experimental currency for trading is called tokens and will be converted into dollars. For every 100 tokens you earn, you will receive 7 cents (.07).$Youwillalsobepaida5$ show up fee. All earnings will be paid to you in cash at the end of the experiment. In each period, you make some choices:

- You must choose a method of payment, i.e., how to settle trades.
- You must make trading decisions:
- If you are a seller, then you choose a price for the good you sell. You earn tokens depending on the price at which you sell and on the quantity sold. The seller's table (see later) reports earnings for different combinations of quantities and prices.
- If you are a buyer, you receive an endowment of tokens and then you choose a quantity to buy. You can earn tokens if you buy at a price lower than your utility value. The buyer's table (see later) reports utility values in tokens for different quantities bought.

How long will the experiment last?

This session will last **40 periods.**

In the room there are 8 sellers and 8 buyers. The computer assigns you a role through a coin flip and you keep the same role for whole duration of the experiment.

At the beginning of each period, every seller meets a buyer who is selected at random. Therefore, most likely you will interact with different participants in different periods because there is only one chance out of eight to have the same trading partner in two consecutive periods. No matter what participants choose to do, every seller is always equally likely to meet any buyer. Moreover, you will not be able to tell whether you have met before your trading partner, because you will not see her identity.

What exactly do you need to do in each period?

Each period has the following timeline:

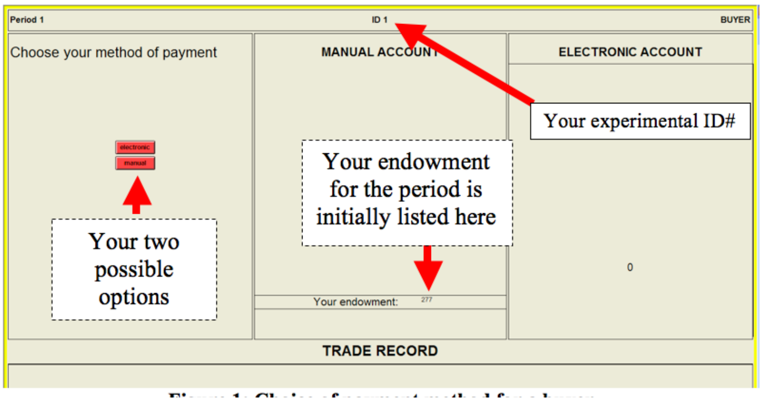

Figure C-1: Choice of payment method for a buyer

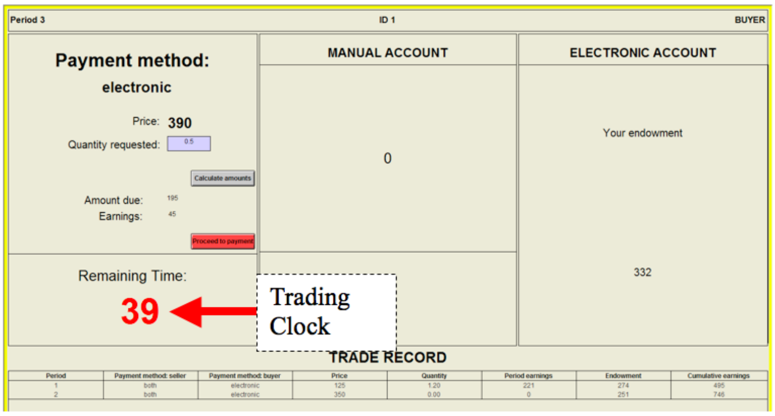

Figure C-2: Choice of payment method for a buyer

1. Buyers receive an endowment of tokens
2. Everyone chooses a payment method for trading in the period THEN A TRADING CLOCK STARTS
3. Each seller meets a buyer and chooses the price for the good
4. Each buyer decides how much to buy at the given price
5. Buyers carry out payments THEN THE TRADING CLOCK STOPS
6. Everyone sees their outcome

We now discuss each of the above items in detail:

1. At the beginning of each period, each buyer receives a random amount between 250 and 350 tokens. This endowment can be used to buy goods or can be simply kept.
2. At this point, buyers and sellers independently choose a payment method for their trades, which is either a **manual** or an **electronic** transfer of tokens. How these methods work will be explained in a moment. Sellers always

accept manual payments and can choose to accept electronic payments, **also.** Buyers must choose to make either a manual or an electronic payment, **but not both** (Figure C-1). You will be asked to choose a payment method each period.

There is a fee charged for electronic transfers and no fee for manual transfers. The fee is always paid by the seller and never by the buyer. The seller pays a proportional fee for each electronic payment received: the fee is 10 tokens for every 100 tokens received.

Buyers receive a proportional rebate for each electronic payment made. A buyer receives 5 tokens for every 100 tokens paid using an electronic transfer.

As soon as methods of payments are chosen, a trading clock starts. The clock displays the remaining seconds to complete a trade in a large red font on your screen (Figure C-2). Initially the available time is 120 seconds; from period 7 it will be reduced to 60 seconds.

3. When the trading clock starts, each seller must choose the unit price for the goods. The price must be an integer number between 0 and 400. Then, sellers must click the button **Confirm.**

   Seller's earnings vary according to the price and quantity sold, as illustrated in the Seller's table. Each row of the table lists earnings for a given price of 0, 10, 20, ..., 400. Sellers can use the table to guide their choice of price. Let's see an example.

   Example: Find the row with a price of 390. As you can see, the seller?s earnings change depending on the quantity sold. The seller picks the price but it is the buyer who picks the quantity. If nothing is sold, then the seller's earnings are fixed at 350 tokens. If a quantity = 1 is sold, then earnings are 665 tokens. If a quantity = 2 is sold, then earnings are 995 tokens. And so on. For quantities and prices not listed in the table you can approximate earnings by looking at the nearby cells. Note that for some prices the seller has a loss.

   Figure C-3 displays the same information contained in the seller's table. In the horizontal axis find the price 390. The corresponding earnings are on the curve labeled quantity = 1 and quantity = 2.

   Now take a moment to find the seller's earning if a quantity=3 is sold at a price of 390 tokens. Any question at this point?

4. After the seller has chosen a price, the buyer must decide how many units of the good to purchase, by typing any number between 0 and 4 (Figure C-2. –The **amount due** is the price multiplied by the quantity requested. Buyers are never endowed with more than 350 tokens to spend in a period. This endowment is placed in the account selected at the beginning of the period (manual or electronic). The endowment leftover after purchases will be redeemed for dollars. –Goods generate a utility value in tokens for the buyer, as shown in the buyer's table. **Earnings** are equal to the **utility**

Figure C-3: Sellers' period earnings

value minus the **amount due** plus any rebate earned. Buyers can use the table to guide their purchases.

Example: if you buy a quantity of 0.5 at a price of 390 tokens, the amount due is 195 tokens, which is 0.5 times 390. If you use manual payments, the earnings are 44.7 tokens. If you use electronic payments, the earnings are instead 54.5 tokens, i.e., 44.7 tokens plus a rebate of 195 x 0.05=9.8 tokens. The computer calculates this for you: type in the quantity requested, then click the **Calculate amounts** button. You can repeat this process as many times as you wish. To finalize your purchase, you must click on the **Proceed to payment** button.

How can a buyer calculate period earnings without the computer? Just look at the buyer's table. Each row indicates a quantity of goods: 0, 0.10, 0.20, ... up to 4. For each quantity the table shows the utility value of those goods. Now, find the row for a quantity of 0.5. The corresponding utility value is 239.7 tokens. Did everyone find it? Suppose the buyer uses manual payments. If the price is 390, as in the example above, then the buyer earns 44.7 tokens, i.e., a utility of 239.7 minus an amount due of $390x0.5$. Consider instead a price of 111 tokens per unit: then the buyer's earnings are 184.2 tokens, i.e., a utility of 239.7 minus an amount due of $(111x0.5)$. If the buyer uses electronic payments you have to add a 5% rebate: 9.8 tokens when the price is 390, and 2.8 tokens when the price is 111.

Figure C-4 displays the same information as in the buyer?s table. Now, please find a quantity = 0.5 on the horizontal axis. The corresponding utility value on the curve is 239.7 tokens, which can be read with some approximation on the vertical axis. Recall that to obtain the buyer?s earnings you need to take this utility value and then subtract the amount paid. displays the same information as in the buyer?s table. Now, please find a quantity = 0.5 on the horizontal axis. The corresponding utility value on the curve is 239.7 tokens, which can be read with some approximation on the vertical axis. Recall that to obtain the buyer?s earnings you need to take this utility value and then subtract the amount paid.

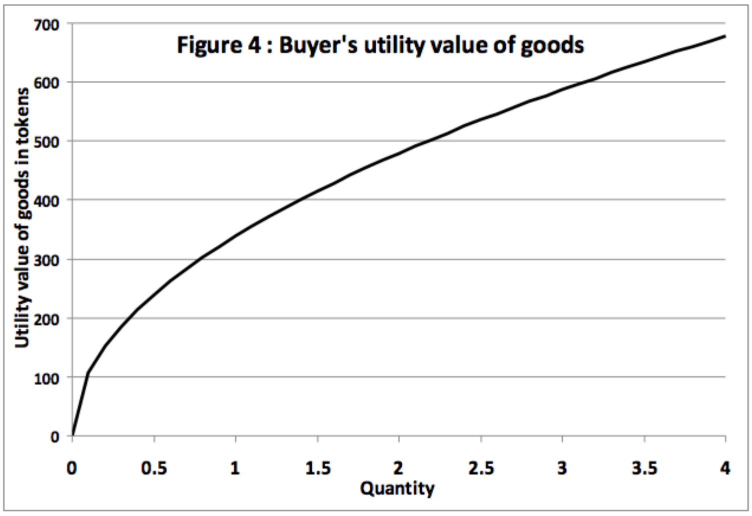

Figure C-4: Buyers' utility value of goods

Any question at this point?

Once a purchasing decision is made, the payment can be carried out. The buyer had already decided earlier in the period whether to pay electronically or manually.

- **Electronic payment:** the buyer must click the ?Proceed to payment? button and tokens are automatically taken from the buyer's electronic account.
- **Manual payment:** the buyer must select a proper combination of tokens from the manual account (Figure C-5).

The choices described in items (3) to (5) above must be completed within the available time.

5. At the end of the period, you will see whether trade took place. Trade **cannot** take place:
(a) if a buyer pays electronically but the seller does not accept electronic payments;
(b) if the buyer has insufficient tokens available in the relevant account;
(c) if the buyer manually selects to transfer less than the amount due;
(d) if the clock runs out before trade is settled.

If trade does not take place within the available time, then cumulative earnings for the buyer increase by the received endowment (between 250 and 350 tokens), and increase by 350 tokens for the seller.

The results screen (Figure C-6) displays details of the trade, for 30 seconds. Seller's earnings reflect the table values minus any applicable payment fee,

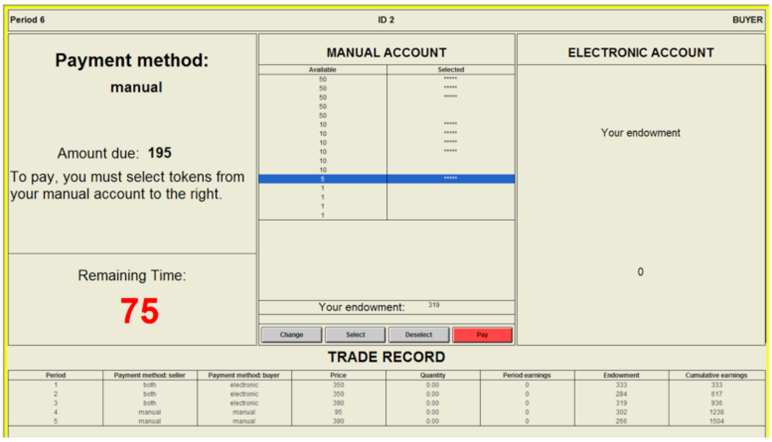

Figure C-5: How to pay a seller from the manual account

Notes: The manual account contains tokens of various sizes. To break a large-size token into a smaller size, select a token and then click the button **Change.** To select the tokens, click on any Available tokens and then press the button **Select.** Selected tokens are indicated with *******.** Press Deselect to undo the selection. To transfer the selected tokens to the seller, a buyer must click the button **Pay**. A trade is completed when a buyer transfers enough tokens, i.e., equal or more than the amount due. It is not completed if the transfer is less than the amount due.

plus possible excess payments. Buyer's earnings reflect the utility values in the table minus the payment, plus any applicable payment rebate. ID is your experimental ID.

The lower part of the screen will always display your trade record for previous periods. This includes the **payment method** selected by you and by the person you encountered, **price** and **quantity** traded, your **period earnings** in tokens, your **endowment** in tokens (only for buyers), and your **cumulative earnings** in tokens. Cumulative earnings will be redeemed for dollars at the end of the experiment. Use the record sheet to record your earnings.

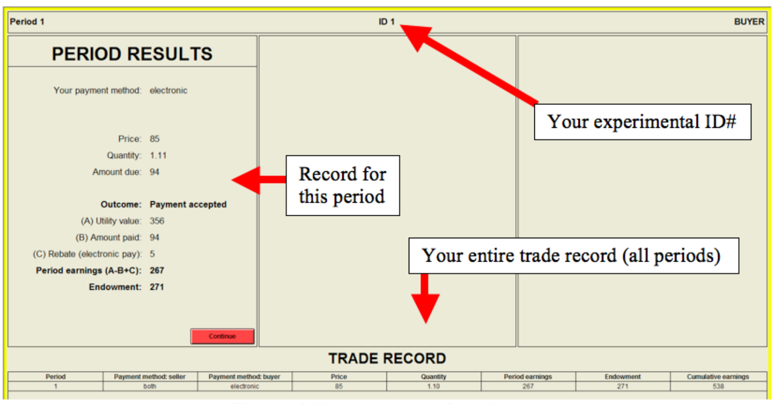

Figure C-6: Results screen for a buyer

Questions? Now is time for questions. Do you have any questions before we begin the experiment?

quantity bought	**utility value in tokens**	**quantity bought**	**utility value in tokens**
0	0.0	**2.1**	491.3
0.1	107.2	**2.2**	502.8
0.2	151.6	**2.3**	514.1
0.3	185.7	**2.4**	525.2
0.4	214.4	**2.5**	536.0
0.5	239.7	**2.6**	546.6
0.6	262.6	**2.7**	557.0
0.7	283.6	**2.8**	567.3
0.8	303.2	**2.9**	577.3
0.9	321.6	**3**	587.2
1	339.0	**3.1**	596.9
1.1	355.5	**3.2**	606.4
1.2	371.4	**3.3**	615.8
1.3	386.5	**3.4**	625.1
1.4	401.1	**3.5**	634.2
1.5	415.2	**3.6**	643.2
1.6	428.8	**3.7**	652.1
1.7	442.0	**3.8**	660.8
1.8	454.8	**3.9**	669.5
1.9	467.3	**4**	678.0
2	479.4		

Figure C-7: BUYER'S TABLE: buyer's utility values in tokens for each quantity purchased of the good

Quantity sold:	0	0.5	1	1.5	2	2.5	3	3.5	4
Price									
0	350	305	275	245	215	185	155	125	95
10	350	310	285	260	235	210	185	160	135
20	350	315	295	275	255	235	215	195	175
30	350	320	305	290	275	260	245	230	215
40	350	325	315	305	295	285	275	265	255
50	350	330	325	320	315	310	305	300	295
60	350	335	335	335	335	335	335	335	335
70	350	340	345	350	355	360	365	370	375
80	350	345	355	365	375	385	395	405	415
90	350	350	365	380	395	410	425	440	455
100	350	355	375	395	415	435	455	475	495
110	350	360	385	410	435	460	485	510	535
120	350	365	395	425	455	485	515	545	575
130	350	370	405	440	475	510	545	580	615
140	350	375	415	455	495	535	575	615	655
150	350	380	425	470	515	560	605	650	695
160	350	385	435	485	535	585	635	685	735
170	350	390	445	500	555	610	665	720	775
180	350	395	455	515	575	635	695	755	815
190	350	400	465	530	595	660	725	790	855
200	350	405	475	545	615	685	755	825	895
210	350	410	485	560	635	710	785	860	935
220	350	415	495	575	655	735	815	895	975
230	350	420	505	590	675	760	845	930	1015
240	350	425	515	605	695	785	875	965	1055
250	350	430	525	620	715	810	905	1000	1095
260	350	435	535	635	735	835	935	1035	1135
270	350	440	545	650	755	860	965	1070	1175
280	350	445	555	665	775	885	995	1105	1215
290	350	450	565	680	795	910	1025	1140	1255
300	350	455	575	695	815	935	1055	1175	1295
310	350	460	585	710	835	960	1085	1210	1335
320	350	465	595	725	855	985	1115	1245	1375
330	350	470	605	740	875	1010	1145	1280	1415
340	350	475	615	755	895	1035	1175	1315	1455
350	350	480	625	770	915	1060	1205	1350	1495
360	350	485	635	785	935	1085	1235	1385	1535
370	350	490	645	800	955	1110	1265	1420	1575
380	350	495	655	815	975	1135	1295	1455	1615
390	350	500	665	830	995	1160	1325	1490	1655
400	350	505	675	845	1015	1185	1355	1525	1695

Figure C-8: SELLER'S TABLE: earnings in tokens if a quantity of the good is sold at the price indicated