Adoption of a New Payment Method: Theory and Experimental Evidence*

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Abstract

We model the introduction of a new payment method, e.g., e-money, that competes with an existing payment method, e.g., cash. The new payment method involves relatively lower per-transaction costs for both buyers and sellers but sellers must pay a one-time fixed fee to accept the new payment method. Due to network effects, our model admits two symmetric pure strategy Nash equilibria. In one equilibrium, the new payment method is not adopted and all transactions continue to be carried out using the existing payment method. In the other equilibrium, the new payment method is adopted and completely replaces the existing payment method. The equilibrium involving only the new payment method is socially optimal as it minimizes total transaction costs. Using this model, we study the question of equilibrium selection by conducting a laboratory experiment. We find that, depending on the fixed fee charged for adoption of the new payment method and on the choices made by participants on both sides of the market, either equilibrium can be selected. More precisely, a lower fixed fee for sellers favors very quick adoption of the new payment method by all participants while for a sufficiently high fee, sellers gradually learn to refuse to accept the new payment method and transactions are largely conducted using the existing payment method.

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1 Introduction

The payments industry has undergone significant changes in the past few decades. Various new means of payments that compete with the traditional payment method – cash – have entered into the payment landscape, including debit cards, credit cards, general purpose prepaid cards such as Visa and MasterCard gift cards, public transportation cards that expand into retail transactions such as the Octopus card in Hong Kong, mobile payments such as M-Pesa in Kenya, online money transfer schemes such as Paypal, and virtual crypto-currencies such as the Bitcoin. The numerous and varied attempts to introduce new payment methods have met with mixed results. The Octopus card in Hong Kong is a notable success. Danmont in Denmark ultimately failed after a few years of limited success. Mondex debuted with much fanfare in several countries but soon failed.

In this paper we study the introduction of a new payment method, focusing on electronic pre-paid schemes. We seek answers to several questions. Will a socially more efficient new payment method take off? Will merchants accept it? How do consumers make portfolio choices between the existing and the new payment method? How do merchants and consumers interact with each other? How do the cost structure associated with the new payment system influence the result?

We first develop a model of the introduction of a new payment instrument, "e-money," that competes with an existing payment method, "cash." We model the new payment method as being more efficient for both buyers and sellers in terms of per transaction costs. Such cost-saving motive lies behind the various attempts to introduce a new payment method: after all, if the new payment method did not offer any such cost savings, there would be no reason to expect it to be adopted (or even introduced). There is also evidence that new developments in electronic payment technology can greatly speed up transactions and save on various handling costs associated with traditional payment methods. According to a study by Polasik et al. (2013), who analyze the speed of various payment methods from video material recorded in the biggest convenience store chain in Poland, a transaction using contactless cards in offline mode without slips costs on average 25.71 seconds, a significant reduction over a cash transaction, which costs 33.34 seconds. Arango and Taylor (2008) suggest that, after the various cash-handling costs – including deposit reconciliation, deposit preparation, deposit trips to banks, coin ordering, theft and counterfeit risk, etc. – are accounted for, a cash transaction costs merchants \$0.25 and a (PIN) debit transaction costs \$0.19.[1] Working against the adoption of the new e-money payment method, we assume that sellers have to pay

[1]The calculation is based on a transaction value of \$36.5. The cost of the debit transaction includes a \$0.12 payment-processing fee.

a fixed setup fee (to rent or purchase a terminal) to process the new payment method.

Given the cost structure of the two payment methods, buyers and sellers play a two-stage game. In the first stage, agents make payment decisions simultaneously. Buyers allocate their budget between the new and existing payment methods. Sellers decide whether to pay the fixed cost to accept the new payment method –they must always accept the existing payment method. The second stage consists of multiple rounds of meetings where buyers and sellers trade with each other. In each meeting, the buyer observes whether or not the seller accepts the new payment method and the trade is successful if the buyer can use a payment method accepted by the seller. Due to network effects, the model admits two symmetric pure strategy Nash equilibria. In one equilibrium, the new payment method is not adopted and all transactions continue to be carried out using the existing payment method. In the other equilibrium, the new payment method is adopted and completely replaces the existing payment method. The equilibrium involving only the new payment method is socially optimal as it minimizes total transaction costs (the reduction in per transaction cost exceeds the fixed cost paid by sellers).

As our model has multiple equilibria, we next conduct a laboratory experiment to assess conditions under which the new payment method replaces the existing payment method, and also conditions where the new payment method fails to be adopted. We find that, depending on the fixed cost for the adoption of the new payment method and on the choices made by participants on both sides of the market, either equilibrium can be selected. More precisely, if sellers face a low fixed cost to adopting the new payment method, then the new payment method is quickly adopted by all participants while for a sufficiently high fixed cost of adoption, sellers gradually learn to refuse to accept the new payment method and transactions are largely conducted using the existing payment method.

We view the experimental approach as a useful complement to theoretical and empirical research on the acceptability of payment methods. The theoretical literature emphasizes the importance of network externalities in the adoption of new payment methods (Rochet and Tirole, 2002; Wright, 2003; McAndrews and Wang, 2012; Chiu and Wong, 2014). For the consumer (merchant), the benefit of adopting (accepting) a new payment method increases if more consumers use (merchants accept) the payment method. These network effects lead to multiple equilibria, which poses a problem for theoretical predictions and thus our experimental study can shed some light on which equilibrium is more likely to occur. While the theory often focuses on equilibrium analysis and ignores transition dynamics, our experimental approach also provides some useful insight about the process by which a new payment method may take off and the speed with which this may occur.

There is a large empirical literature using survey data to explore individual choices among different means of payments.[2] These studies focus mainly on choices among existing payment methods, and the decisions made by a single party, either the consumer or the merchant. In our model and experiment, we develop an environment suitable for the study of new payment methods that considers interactions between *both* sides of the market (buyers and sellers). In addition, survey data are subject to errors due to insufficient incentives for truthful or careful reporting, or misunderstandings about the survey questions; these problems are alleviated to some extent in an incentivized experimental study.[3] Finally, since many factors are at play in the field, isolating the effect of a particular factor may be challenging. In the laboratory, we can exert better control over the environment and thereby isolate the factors that play a role in whether or not a new payment method is adopted.

The closest paper to this one is by Camera, Casari and Bortolotti (2015, hereafter CCB), who also develop a model of payment choice between cash and e-money/card and conduct an experimental study. While we take inspiration from CCB's paper, our project differs from theirs along several important dimensions, including the theoretical model, experimental design, research questions and experimental results. CCB study how the presence of proportional seller fees and buyer rewards affects the adoption of card payments, which are assumed to be more "reliable" than cash.[4] They find that sellers readily adopt cards disregarding the fee and reward structure, while buyers are sensitive to these incentive schemes. More specifically, the buyer's adoption rate is high in the absence of fees or rewards. Imposing seller fees alone reduces card adoption, but adding buyer rewards neutralizes the effect of seller fees and restores high card adoption. CCB also find that there is little feedback effect between the two sides of the market so that network externalities do not matter for payment adoption. However they do not elicit beliefs by market participants about the likely behavior of participants on the other side of the market. Our research question is how the adoption of a new and more socially efficient payment method is affected by the fixed cost born by sellers relative to the

[2] See, for example, Arango et al. (2011) for analysis with the Bank of Canada 2009 Method of Payment Survey, Schuh and Stavins (2013) with the Federal Reserve Bank of Boston 2008 U.S. Consumer Payment Choice Survey, and von Kalckreuth et al. (2014) with the Deutsche Bundesbank 2008 Payment Habits in Germany Survey. Recently, Bagnall et al. (2015) study consumers' use of cash by harmonizing payment diary surveys from seven countries.

[3] Klee (2008) and Cohen and Rysman (2012) study payment choices in grocery stores using scanner data. Misreporting does not pose a problem for scanner data, but it shares other features of the survey data.

[4] CCB model e-money as more efficient in terms of per transaction cost, which is similar to us but in a different sense. They assume that cash payments are "manual" and consequently less reliable than electronic payments. To implement this in the laboratory, they require that buyers using cash must manually click on the correct combination of bills of different denominations within a set time limit, while a card payment is quickly done with a single mouse click. While cash payments can be cumbersome, we rarely see stores turning away customers due to slow payment processing. Stores usually deal with the problem by hiring more cashiers, which we capture by a higher per transaction cost.

potential saving on per transaction costs and as well as by beliefs, which we elicit. We find that choices by both buyers and sellers depend critically on the magnitude of the fixed cost as well as on beliefs about what the other side of the market will do. Thus we find a strong feedback effect between the two sides.

There are several possible reasons why subjects react to the other side's choices so strongly in our experiment, but not in CCB. First, the existence of the fixed setup cost in our model makes sellers respond more strongly to buyers' cash holdings. In particular, they would reject e-money if buyers hold only cash. In CCB, although the homogeneous adoption of cash payments comprises a Nash equilibrium, it is not robust to trembles: sellers are indifferent between acceptance and rejection in this equilibrium and have the incentive to accept cards to minimize payment mismatch if there is no cost to accept cards. This could explain why seller adoption is consistently high in CCB disregarding buyers' choices. Second, in CCB, subjects make both payment and terms of trade decisions. Such multi-tasking may be too challenging for subjects and cause them to focus on the more salient fee/reward structure rather than the coordination problem.[5] For example, consider the treatment with fees and no rewards. Relative to the all-cash equilibrium, the all-card equilibrium is characterized by a higher trading probability (because card transactions are more reliable), a higher price (because sellers pass fees onto buyers) and a lower quantity per trade. In terms of payoffs, buyers are better off in the all-card equilibrium despite the higher price, while sellers are worse off.[6] In theory, buyers should push for card adoption while sellers should resist it. However, the opposite is observed in the experiment, where the buyer's adoption rate is significantly lower. This suggests that the buyers are predominantly concerned that sellers will pass fees to them and fail to take advantage of the high seller acceptance rate. While we agree that the setting of the terms of trade is an interesting question, we think that it is better studied separately. In our experiment, we fix the terms of trade so that subjects can concentrate on the choice of payment methods and the related coordination problem. Third, in our experiment, buyers meet all sellers and vice versa in each period and subjects quickly learn about the aggregate market condition, which boosts interaction between the two sides. In CCB, subjects visit a different partner in every period and observe only their own trading histories. The lack of market-level information may slow down interaction across the two sides.

The rest of the paper is organized as follows. Section 2 develops the theoretical model. Section 3 describes our experimental design. The experimental results are presented in Section 4. Finally, section 5 concludes and points out some directions for future research.

[5]The observation that the price and quantity realized in the experiment are far away from theoretical predictions suggests that subjects have difficulty in fully optimizing during the experiment.

[6]CCB leave it to subjects to figure out their expected payoffs conditional on other players' choices, which may be a daunting task.

2 The Model

In this section, we develop a simple model of the adoption of a new payment method, "e-money," that competes with an existing payment method, "cash." In each trading period, buyers make a portfolio decision, splitting their budget between e-money and cash. Simultaneously, sellers decide whether or not to accept e-money transactions; cash payments must always be accepted. Buyers then meet with sellers and engage in transactions using one payment form or the other. For simplicity (and later experimental implementation) we assume homogeneous buyers and sellers, an exogenously given spending budget for the buyer and fixed terms of trade. As in other models of payment competition, our model has multiple equilibria.

We model the new payment method, e-money, as being more efficient for both buyers and sellers in terms of per transaction costs, but sellers must pay a fixed cost to process e-money. This setup cost, however, can be recovered if each seller succeeds in conducting a sufficient number of e-money transactions with buyers. Thus, both transaction costs and network effects play a role in decisions to adopt the new payment method. In our model, the adoption of an e-money payment method is the socially efficient outcome. We now turn to a detailed description of our model.

2.1 Physical Environment

There are a large number of buyers and sellers (or stores) in the market, each of unit measure. Each seller $i \in [0, 1]$ is endowed with 1 unit of good i. The seller derives zero utility from consuming his own good and instead tries to sell his good to buyers. The price of the good is fixed at one. Each buyer $j \in [0, 1]$ is endowed with 1 unit of money. In each period, the buyer visits all sellers in a random order. The buyer would like to consume one and only one unit of good from each seller, and the utility from consuming each good is $u > 1$.

There are two payment instruments: cash and e-money; we sometimes refer to the latter as "cards." [7] Each cash transaction incurs a cost, τ_b, to buyers, and a cost, τ_s, to sellers. The per transaction costs for e-money are τ_b^e and τ_s^e for buyers and sellers, respectively. Sellers have to pay an up-front cost, $F > 0$, that enables them to accept e-money payments, for example, to rent or purchase a terminal to process e-money transactions.

In the beginning of each trading period, sellers decide whether to accept e-money at the

[7] By "card" we mean a pre-paid payment card or a debit card; we are not considering credit cards to be e-money/cards as credit cards allow unsecured debt.

one-time fixed cost of F, or not. Cash, being the traditional (and legally recognized) payment method, is universally accepted by all sellers. Simultaneous with the sellers' decision, buyers make a portfolio choice as to how to divide their money holdings between cash and e-money. After sellers have made acceptance decisions and buyers have made portfolio decisions, the buyers then go shopping, visiting all of the stores in a random order. When a buyer enters store i, he buys one unit of good i if the means of payment are compatible. Otherwise, there is no trade. At the end of the trading period, both buyers and sellers spend their money balances on a general good. One unit of the general good costs one dollar and entails one unit of utility. Buyers do not wish to consume the general good and any unspent money does not yield them any extra utility.[8]

In what follows, we make the following four assumptions about costs:

A1: $\tau_b^e < \tau_b$ and $\tau_s^e < \tau_s$. In words, e-money saves on per transaction costs for both buyers and sellers.

A2: $u - \tau_b > 0$. Under this assumption, buyers prefer cash trading to no trading.

A3: $F \leq \tau_s - \tau_s^e + \tau_b - \tau_b^e$. This condition implies that the net benefit of investing in the ability to process e-money transactions is positive for the society if all transactions are carried out in e-money.

A4: $F \leq 1 - \tau_s^e$. This assumption ensures the existence of an equilibrium where e-money is used.

2.2 Equilibrium

We will focus on symmetric equilibria, where all buyers make the same portfolio choice decision, and all sellers make the same e-money acceptance decisions. Let $0 \leq m_b \leq 1$ be the e-money balance chosen by the buyer, and let $0 \leq m_s \leq 1$ denote the fraction of sellers who accept e-money. If $0 < m_s < 1$, then sellers play a mixed strategy, accepting e-money with probability m_s.

2.2.1 Buyer's Decision

We will first analyze the buyer's decision, m_b, conditional on the seller's adoption decision m_s. We will carry out the analysis in two cases: (1) $m_b \geq m_s$, and (2) $m_b \leq m_s$.

[8] The assumptions that sellers do not value their own goods and buyers do not value the general good are for simplicity. The model's implications do not hinge on these assumptions.

If $m_b \geq m_s$, then each buyer makes m_s purchases using e-money and $1 - m_b$ purchases using cash. Buyers are not able to transact with a fraction $m_b - m_s$ of sellers due to payment mismatches (buyers want to use e-money but sellers accept cash only). The buyer's expected payoff in this case is:

$$\pi_b = \underbrace{m_s(u - \tau_b^e)}_{\text{e-money transaction}} + \underbrace{(1 - m_b)(u - \tau_b)}_{\text{cash transaction}}$$

Note that

$$d\pi_b/dm_b = -(u - \tau_b) < 0.$$

It follow that for this case, the optimal choice of each buyer is to reduce m_b to m_s so as to minimize the probability of a payment mismatch or no trade outcome.

If $m_b \leq m_s$, then each buyer makes m_b e-money transactions and $1-m_b$ cash transactions (among which $m_s - m_b$ are with sellers who also accept e-money). The buyer's expected payoff is now given by:

$$\pi_b = \underbrace{m_b(u - \tau_b^e)}_{\text{e-money transaction}} + \underbrace{(1 - m_b)(u - \tau_b)}_{\text{cash transaction}}.$$

In this case we have that

$$d\pi_b/dm_b = -\tau_b^e + \tau_b > 0.$$

Thus, if $m_b \leq m_s$, then buyers should increase their e-money balances to m_s so as to minimize transaction costs.

From the analysis above it follows that buyers' optimal portfolio decision is to mimic the sellers' acceptance decision:

$$m_b(m_s) = m_s.$$

2.2.2 Seller's Decision

We now turn to the seller's acceptance decision conditional on the buyer's portfolio decision, m_b. We will carry out our analysis under two parameter settings: (1) $F \leq \tau_s - \tau_s^e$, and (2) $F \geq \tau_s - \tau_s^e$. For each parameter setting, similar to the discussion of the buyer's choice, we analyze the seller's decision in two cases: $m_b \geq m_s$ and $m_b \leq m_s$.

Parameter Setting I: $F \leq \tau_s - \tau_s^e$ If $m_b \geq m_s$, then each seller who accepts e-money engages in a unit measure of e-money transactions (remember that buyers use e-money whenever the seller accepts it), and has a payoff of

$$\pi_s^e = 1 - \tau_s^e - F.$$

Sellers who only accept cash engage in an average of $(1-m_b)/(1-m_s) \leq 1$ cash transactions (the total cash balance in the economy is $1 - m_b$ and this is divided among the $1 - m_s$ sellers who only accept cash). The sellers who only accept cash thus have a payoff of

$$\pi_s = \frac{1 - m_b}{1 - m_s}(1 - \tau_s).$$

In this case,

$$\begin{aligned}
\pi_s^e &= \pi_s \rightarrow \\
1 - \tau_s^e - F &= \frac{1 - m_b}{1 - m_s}(1 - \tau_s) \rightarrow \\
m_s(m_b) &= \left[1 - \frac{(1 - m_b)(1 - \tau_s)}{1 - \tau_s^e - F}\right] \\
&= \frac{1}{1 - \tau_s^e - F}\left[\tau_s - \tau_s^e - F + m_b(1 - \tau_s)\right] \qquad (1)
\end{aligned}$$

If $F < \tau_s - \tau_s^e$, then equation (1) has a positive intercept and lies above the 45^0 line. As long as $m_b \geq m_s$, each seller who accepts e-money is able to trade for e-money in all meetings, which makes it profitable to pay the fixed cost, F, to accept e-money. In equilibrium, it must be the case that $m_b \leq m_s$.

If $m_b \leq m_s$, the e-money balance in the economy can support m_b e-money transactions, which are divided among m_s sellers who accept e-money. Each seller who accepts e-money can trade in all meetings, among which m_b/m_s will be e-money transactions, and the remaining $1 - m_b/m_s$ will be cash transactions. The expected payoff of a seller who accepts e-money is therefore:

$$\begin{aligned}
\pi_s^e &= \underbrace{\frac{m_b}{m_s}(1 - \tau_s^e)}_{\text{e-money transaction}} + \underbrace{\left(1 - \frac{m_b}{m_s}\right)(1 - \tau_s)}_{\text{cash transaction}} - F \\
&= (1 - \tau_s) + \frac{m_b}{m_s}(\tau_s - \tau_s^e) - F.
\end{aligned}$$

Sellers who only accept cash engage in cash transactions in all meetings and have a payoff of

$$\pi_s = 1 - \tau_s.$$

In this case,

$$\begin{aligned} \pi_s^e &= \pi_s \rightarrow \\ m_s(m_b) &= \frac{\tau_s - \tau_s^e}{F} m_b. \end{aligned} \tag{2}$$

If $F < \tau_s - \tau_s^e$, then equation (2) has a slope that is > 1. If $m_b \geq F/(\tau_s - \tau_s^e)$, then it is a dominant strategy for sellers to accept e-money: each seller makes more than $F/(\tau_s - \tau_s^e)$ e-money sales to warrant the fixed investment for e-money acceptance. If $m_b \leq F/(\tau_s - \tau_s^e)$, the number of e-money transactions is not large enough to recover the fixed acceptance cost for all sellers. As a result, sellers play a mixed strategy: $m_s = m_b(\tau_s - \tau_s^e)/F$ fraction of sellers accept e-money, and the rest accept cash only. All sellers earn the same expected payoff ($\pi_s = \pi_s^e$).

To summarize, if $F < \tau_s - \tau_s^e$, then given the buyer's strategy m_b, the seller's strategy is such that

$$m_s(m_b) = \begin{cases} \frac{m_b(\tau_s - \tau_s^e)}{F} & \text{if } m_b \leq \frac{F}{\tau_s - \tau_s^e}, \\ 1 & \text{if } m_b \geq \frac{F}{\tau_s - \tau_s^e}. \end{cases}$$

Parameter Setting II: $F > \tau_s - \tau_s^e$ If $F > \tau_s - \tau_s^e$, in the case where $m_b \geq m_s$, equation (1) has a negative intercept and lies below the 45^0 line. It is a dominant strategy for sellers not to accept e-money if $m_b \leq \hat{m}_b \equiv 1 - [(1 - \tau_s^e) - F]/(1 - \tau_s)$. If $m_b \geq \hat{m}_b$, then accepting e-money gives a higher payoff iff $m_s \leq m_s(m_b)$; in equilibrium, sellers play a mixed strategy choosing to accept with probability $m_s(m_b)$.

If $m_b \leq m_s$, then the slope of equation (2) is < 1. This implies that as long as $m_b \leq m_s$, sellers who do not accept e-money earn a higher payoff. As a result, m_s will decrease. In equilibrium, it must be the case that $m_b \geq m_s$.

To summarize, under the parameter setting $F > (\tau_s - \tau_s^e)$, given the buyer's strategy m_b, the seller's strategy is such that

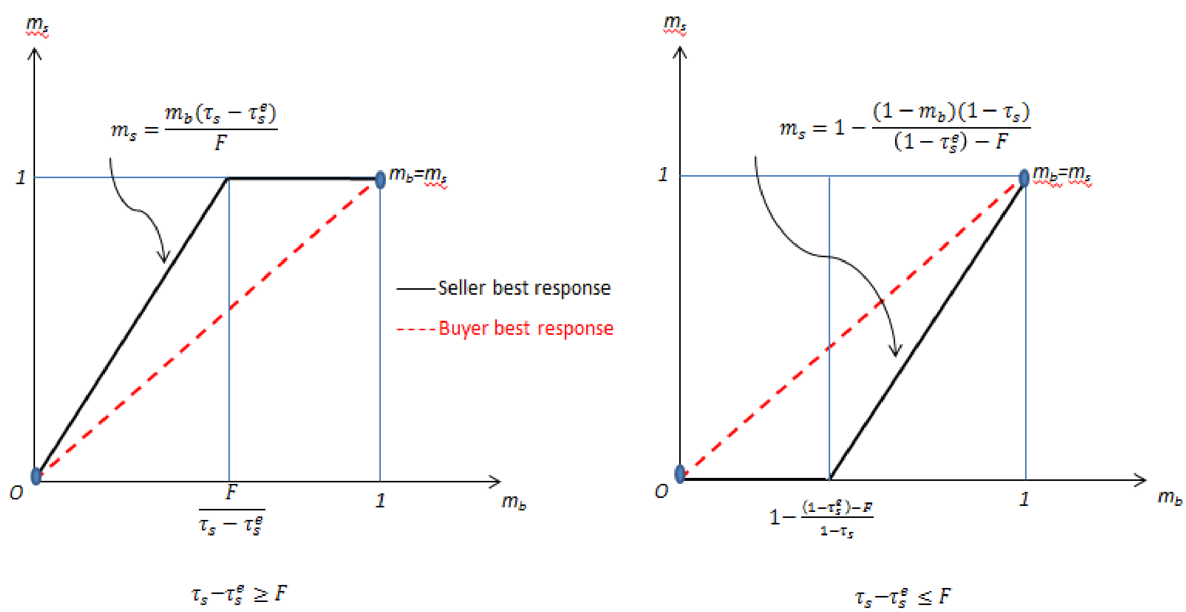
$$m_s(m_b) = \begin{cases} 0 & \text{if } m_b \leq 1 - \frac{(1-\tau_s^e) - F}{1 - \tau_s}, \\ \frac{1}{(1-\tau_s^e) - F} \left[(\tau_s - \tau_s^e) - F + m_b(1 - \tau_s) \right] & \text{if } m_b \geq 1 - \frac{(1-\tau_s^e) - F}{1 - \tau_s}. \end{cases}$$

2.2.3 Equilibrium

Combining the analysis above, we can characterize the symmetric equilibrium of the economy using Figure 1. There are at least two symmetric pure strategy equilibria. In one of these equilibria, $m_b = m_s = 1$: all sellers accept e-money, and all buyers allocate all of their endowment to e-money – call this the all-e-money equilibrium (this equilibrium always exists provided that $F \leq 1 - \tau_s^e$). There is a second symmetric pure strategy equilibrium where $m_b = m_s = 0$ and e-money is not accepted by any seller or held by any buyer – call this the all- cash equilibrium. In both equilibria, there is no payment mismatch, and the number of transactions is maximized at 1. In the case where $F = \tau_s - \tau_s^e$, there exists a continuum of possible equilibria in which $m_s \in (0, 1)$ and $m_b = m_s$.

The e-money equilibrium is socially optimal as it minimizes total transactions cost. Note that buyers are always better off in the all- e-money equilibrium relative to the all cash equilibrium. The seller's relative payoff in the two equilibria, however, depends on the fixed cost, F, and on the savings on per transaction costs from the use of payment 2. If $F = \tau_s - \tau_s^e$, then the seller's payoff is the same in the cash and e-money equilibria; if $F < \tau_s - \tau_s^e$, then the seller's payoff is higher in the e-money equilibrium than in the cash equilibrium; finally, if $F > \tau_s - \tau_s^e$, then the seller's payoff is lower in the e-money equilibrium than in the cash equilibrium.

Figure 1: Symmetric equilibria



3 Experimental Design

The experimental set-up was designed to match the model as closely as possible, but without the continuum of buyer and sellers of unit mass. Specifically, for each session of our experiment, we recruited 14 inexperienced subjects and randomly divided them equally between the buyer and seller roles, so that each market had exactly 7 buyers and 7 sellers. These roles were fixed for the duration of each session to enable subjects to gain experience with a particular role. The subjects then repeatedly played a market game that approximates the model presented in the previous section.

Specifically, subjects participated in a total of 20 markets per session. Each market consisted of two stages. The first stage was a payment choice stage. In this first stage, each buyer was endowed with 7 experimental money (EM) units and had to decide how to allocate his/her 7 EM between the two payment methods. To avoid any biases due to framing effects, we used neutral language throughout, referring to cash and e-money as "payment 1" and "payment 2," respectively. Thus, in the first stage, buyers allocated their 7 EM between payment 1 and payment 2, with only integer allocation amounts allowed, e.g., 3 EM in the form of payment 1 and 4 EM in the form of payment 2. Each seller was endowed with 7 units of goods. Sellers were required to accept payment 1 (cash) but had to decide in this first stage whether or not to accept payment 2 (e-money) for that market. Sellers who decided to accept payment 2 had to pay a one-time fee of T EM that enabled them to accept payment 2 in all trading rounds of that market. As explained below, T is related to the fixed costs of adopting the new payment method (F) described in the model and serves as our main treatment variable.

In addition to making payment choices in the first stage, subjects were also asked to forecast other participants' payment choices for that market. We elicited these forecasts because we wanted to better understand subjects' decision-making process. Specifically, buyers were asked to forecast how many of the seven sellers would choose to accept payment 2 in the forthcoming market. Sellers were asked to supply two forecasts: (1) the average amount of EM that all seven buyers would allocate to payment 2, and (2) how many of the other six sellers would choose to accept payment 2 in the forthcoming market. Forecasts were incentivized; subjects earned 0.5 EM per correct forecast in addition to their earnings from buying/selling goods (also in EM). The seller's forecast of the average of all buyers' payment 2 allocations was counted as correct if it lied within ± 1 of the realized value. The other two forecasts were counted as correct only if they precisely equalled the realized value. Note that no participant observed any other seller or buyer's payment choices or forecasts in this first stage; that is, all first stage choices and forecasts were private information and were made simultaneously.

Following completion of the first stage of each market play immediately proceeded to the second, "trading" stage of the market which consisted of a sequence of seven trading rounds. In these seven rounds, each subject anonymously met with each of the seven subjects who were in the opposite role to themselves, sequentially and in a random order. In each meeting the buyer and seller tried to trade one unit of good for one unit of payment (recall that the terms of trade in our model are fixed). Specifically, when each buyer meets each seller (and not earlier), the buyer learned whether the seller accepted payment 2 or not, and then the buyer alone decided which payment method to use, conditional on the buyer's remaining balance for that market of either payment 1 or payment 2; sellers were passive in these trading rounds, simply accepting payment 1 from the buyer or payment 2 if the seller had paid the one-time fee to accept payment 2 in that market, depending on the choice of the buyer. Thus, provided that a buyer had some amount of a payment type that the seller accepted, trade would be successful. For each successful transaction, both parties to the trade earned 1 EM less some transaction costs for the trading round, where the transaction costs depended on whether payment 1 or 2 was used as detailed below.[9] Notice that the only instances in which a transaction could not take place (was never successful) were those in which the buyer had only payment 2 and the seller did not accept payment 2. In those cases no trade could take place and both parties earned 0 EM for the trading round.

Following completion of the seven trading rounds of the second stage of a market, that market was over. Provided that the 20th market had not yet been completed, play then proceeded to a new two-stage market wherein buyers and sellers had to once again make payment choices and forecasts in the first stage and then engage in 7 rounds of trading behavior in the second stage. Buyers were free to change their payment allocations and sellers were free to change their payment 2 acceptance decisions from market to market but only in the first stage of the market; the choices made in this first stage were then in effect for all 7 rounds of the second trading stage of the market that followed. Thus in total there were 20 markets involving 7 trading rounds each or a total 140 trading rounds per session. In each trading round subjects could earn as much as 1 EM less transaction costs and in the first stage, they could earn 0.5 EM per correct forecast. Following completion of the 20th market subjects

[9] Note that while buyers were endowed with 7 EM at the start of each market, this endowment had to be allocated between payment 1 and payment 2 for the buyers to actually earn EM in each of the 7 trading rounds of the second stage of the market. Buyers could not choose to refuse to engage in trade and redeem their endowment of EM. Unused payment allocations had no redemption value. Further, EM earnings from each market were not transferrable to subsequent markets; instead these earnings were recorded and paid out only at the end of the experiment following the completion of the 20th market. Thus, buyers started each new market with exactly 7 EM and had to make payment allocations and payment choices anew in each market in order to earn EM in that market.

were paid their cumulative EM earnings from all stages and rounds at the known and fixed rate of 1 EM= 0.15 cents and in addition they were paid a $7 show-up payment. Each session lasted for about two hours. The average earnings were between $\$15 - 25$.

To facilitate decision making, we provided subjects with two types of information in stage 1, at the same time that buyers were asked to make their payment allocation choices and sellers were asked to make their payment 2 acceptance decisions and both types had to form forecasts as described above. The first piece of information provided to subjects consisted of payoff tables. The buyer's payoff table reported the buyer's market earnings if the buyer allocated between 0~7 EM to payment 2 (and his/her remaining EM to payment 1) and if 0~7 sellers accepted payment 2. The seller's payoff table reported the expected market earnings the seller could get from the two options (accept/reject payment 2) in cases where *all* buyers choose to allocate between 0~7 EM to payment 2, and where 0~6 of the other six sellers choose to accept payment 2.[10] In addition to these payoff tables, sellers also had access to a "what if" calculator that computed their expected earnings in asymmetric cases where the 7 buyers made different payment allocation choices. The second piece of information that we provided subjects in stage 1 (following the completion of the first market and every market thereafter) was a history of outcomes in all past markets, including the subject's payment choices, the number of transactions using each of the two payment methods, the number of no-trade meetings, market earnings from trading, and the number of correct forecasts. Beginning with market 2, we also reported an aggregate market-level statistic, the number of sellers who had chosen to accept payment 2 in the prior market. We provided this information so that sellers could learn about other sellers' payment 2 acceptance decisions in the just completed market; since all buyers visit all sellers and learn whether each seller accepts payment 2 or not, buyers had this same piece of information by the end of each market. By providing this same information also to sellers, we made sure that both sides of the market had symmetric information about seller choices.

Consistent with assumption A2, we set the per transaction cost to be the same for all buyers and sellers, i.e., $\tau_b = \tau_s = \tau = 0.5$ for payment 1, and $\tau_b^e = \tau_s^e = \tau^e = 0.1$ for payment 2. Thus, it was always the case that $\tau - \tau^e = 0.4$ in all treatments of our experiment. Our only treatment variable was the once per market fixed cost, T, that sellers had to pay to accept payment 2, which corresponds to the parameter F in the model with a continuum of agents via the transformation $T = 7F$. We chose three different values for this main treatment variable: $T = 1.6$, 2.8, and 3.5, respectively.[11]

[10] See the experimental instructions in the appendix which include the payoff tables for both the buyers and the sellers.

[11] The ratio $\tau/\tau^e = 5$ and the various values for the fixed cost, T, were chosen to make the transaction and set-up cost differences sufficiently salient to our subjects (in terms of their earnings) and are not meant to be

Note that, given the lower transaction cost from using e-money, buyers are always better off in the all e-money (all payment 2) equilibrium relative to the all cash (all payment 1). However, seller's relative payoffs depend on the fixed cost, T . If $T < 7(\tau - \tau^e)$, as in our $T = 1.6$ treatment (and represented graphically in the left panel of Figure 1) then the seller's payoff (like the buyer's payoff) is higher in the all e-money equilibrium than in the all cash equilibrium. If $T > 7(\tau - \tau^e)$, as in our $T = 3.5$ treatment (and represented graphically in the right panel of Figure 1), then the seller's payoff is lower in the all e-money equilibrium than in the all cash equilibrium. Finally, if $T = 7(\tau - \tau^e)$, as in our $T = 2.8$ treatment, then the seller's payoffs are the same in both the cash and e-money equilibria.

In terms of theoretical predictions, under our three different treatment conditions, there always exist two symmetric pure-strategy Nash equilibria, one in which no seller accepts payment 2 and all buyers allocate all of their endowment to payment 1 (the all cash equilibrium) and another equilibrium in which all sellers accept payment 2 and all buyers allocate all of their endowment to payment 2 (the all e-money or card equilibrium). Given our parameterization, the symmetric payment 2 equilibrium is always the one the maximizes social welfare.

While our focus is on symmetric equilibria, we note that there may also exist *asymmetric* equilibria where some fraction of sellers accept payment 2 while the remaining fraction does not, and buyers adjust their portfolios of payment 2 and 1 so as to perfectly match this distribution of seller choices. These asymmetric equilibria are always present in the $T = 2.8$, treatment where $T = 7(\tau - \tau^e)$. In particular, any outcome where $m_s \in \{1, 2, ..., 6\}$ sellers accept payment 2, while $7 - m_s$ do not, and all buyers allocate the same m_s units of their endowment to payment 2 and $7 - m_s$ to payment 1 comprises an asymmetric equilibrium for this treatment. Thus, these asymmetric equilibrium characterize dual payment outcomes, where both cash and e-money are used to make transactions. Due to our use of a finite population size of 14 subjects there are also some asymmetric pure strategy equilibria of this same variety in the $T = 1.6$ and $T = 3.5$ treatments, but these asymmetric equilibria are fewer in number than in the $T = 2.8$ treatment and they would disappear completely as the population size got larger and we approached the continuum of the theory, whereas the set of asymmetric equilibria in the $T = 2.8$ case would continue to grow and would eventually reach a continuum as in the theoretical model.

This multiplicity of equilibrium possibilities motivates our experimental study; equilibrium selection is clearly an empirical question that our experiment can help to address. We hypothesize that, as the transaction cost to sellers of accepting payment 2 increases from

empirically accurate, though card transaction costs *are* lower than cash transaction costs as mentioned in the introduction and seller set-up costs for card adoption are non-zero and do vary.

$T = 1.6$ to $T = 2.8$ and on up to $T = 3.5$, coordination on the e-money equilibrium will become less likely and coordination on the cash equilibrium will become more likely, however, this remains an empirical question. In addition, we are interested in understanding the dynamic process of equilibrium selection in terms of the evolution of subjects' beliefs and choices.

The experiment was computerized and programed using the z-Tree software (Fischbacher, 2007). At the beginning each session, each subject is assigned a computer terminal, and written instructions were handed out explaining the payoffs and objectives for both buyers and sellers. See the appendix for example instructions used in the experiment. The instructor read these instructions aloud in an effort to make the rules of the game public knowledge. Subjects could ask questions in private and were required to successfully complete a quiz to check their comprehension of the instructions prior to the start of the first market. Communication among subjects was prohibited during the experiment.

We have four sessions for each of our three treatment conditions, $T = 1.6$, $T = 2.8$ and $T = 3.5$. As each session involved 14 subjects with no prior experience participating in our study, we have data from $4 \times 3 \times 14 = 168$ subjects. The experiment was conducted at Simon Fraser University (SFU), Burnaby, Canada and at the University of California, Irvine (UCI), USA using undergraduate student subjects. Specifically, two sessions of each of our three treatments (one-half of all sessions) were run at SFU and UCI, respectively. Despite our use of two different subject pools, we did not find significant differences in either buyer or seller behavior across these two locations as we show later in the paper.

4 Aggregate Experimental Results

In this section, we present and discuss our experimental results at the aggregate level. The next section will address individual behavior.

Figures 2 to 3 show the evolution of behavior over time in each of the four sessions of our three treatments. In all of these figures, the horizontal axis indicates the number of the market, running from 1 to 20. Figures 2abc, display time series on payment choices and transaction methods in two separate panels for each session. In the first panel the series labeled "BuyerPay2," shows the percentage of the endowment that all buyers allocated to payment 2 averaged across the seven buyers of each session. In this same panel, the percentage of sellers accepting payment 2 is indicated by the series labeled "SellerAccept." The second panel of Figures 2abc show three time series: 1) the frequency of meetings that resulted in transactions using payment 1 labeled as "Pay1," 2) the frequency of meetings that resulted in transactions using payment 2 labeled as "Pay2," and 3) circles indicating the frequency of no-trade meetings labeled as "NoTrade." Figures 3abc also show two panels for each session of the three treatments. The first panel illustrates the average buyer, seller and both buyer and seller (all) payoffs as a percentage of the payoffs that could be earned in the symmetric pure strategy equilibrium where all buyers use payment 2 and all sellers accept payment 2 – the all-payment-2 equilibrium. The second panel is similar but shows the average buyer, seller and combined buyer and seller (all) payoffs as a percentage of the payoffs that would be earned in the symmetric pure strategy equilibrium where all buyers use payment 1 and all sellers refuse to accept payment 2, – the all-payment-1 equilibrium.

Tables 1 and 2 display various statistics for each of the 12 sessions of the experiment using the same time series data that is depicted in Figures 2-3. For each statistic, we show the treatment-level average in bold face. Table 1 provides five statistics on payment choice and usage and transactions. The first part (rows 1 to 10) of Table 1 reports the percentage of endowment allocated to payment 2 averaged across the seven buyers and the percentage of the seven sellers accepting payment 2. In particular, we report the session mean, minimum and maximum, and the mean in the first and the last markets for these two statistics. The second part of Table 1 (rows 16 to 25) shows the percentage of meetings that resulted in trading with payment 1, trading with payment 2 and no trading in a market. Again, we provide the session mean, minimum and maximum, and the mean value in the first and last markets for these statistics. Table 2 provides the same set of statistics on payoff efficiency for buyers, sellers or both ("all") relative to the all-payment-2 or all-payment-1 equilibrium benchmarks. We use the data reported in Tables 1-2 (and depicted over time in Figures 2-3) to characterize the following aggregate findings.

Finding 1 *Across the three treatments, as T is increased from 1.6 to 2.8 to 3.5, there are significant decreases in the buyer's choice of payment 2, the seller's acceptance of payment 2, and successful transactions involving payment 2.*

Support for Finding 1 comes from Table 3 which reports results from a Wilcoxon rank-sum test of treatment differences using session level averages (four per treatment). The test results indicate that the buyer's choice of payment 2 (BuyerChoice) the seller's acceptance of payment 2 (SellerAccept) and successful payment 2 transactions (Pay2Meetings) are significantly higher in the $T = 1.6$ treatment as compared with either the $T = 2.8$ or $T = 3.5$ treatments ($p < .05$). Further, these same means are higher in the $T = 2.8$ treatment as compared with the $T = 3.5$ treatment. Importantly, Table 3 also indicates that initially, using means from just the first market of each session ("First market") there are no differences in these three mean statistics across our three treatments, indicating that all session started out with roughly similar initial conditions and the choices of buyers and sellers then evolved over time to yield the differences summarized in Finding 1. The next three findings summarize aggregate behavior in each of the three experimental treatments.

Finding 2 *When $T = 1.6$, the experimental economies converge to (or nearly converge to) the all-payment-2 equilibrium.*

Support for Finding 2 comes from Table 1 and Figure 2a which report on the evolution of behavior in the four sessions of the $T = 1.6$ treatment. In all four sessions, subjects move over time in the direction of the payment 2 equilibrium, which in this case represents a strict Pareto improvement for both sides. Furthermore, sellers do not suffer much loss from investing on the fixed cost: they can recover the fee if each buyer allocates just 4 EM (57%) or more to payment 2. As a result, sellers maintain high levels of acceptance, and this steadily high acceptance rate encourages buyers to quickly catch up, which, in turn, reinforces the incentives for acceptance of payment 2. As a result, toward the end of all four $T = 1.6$ treatment sessions, subjects have achieved convergence or near-convergence to the payment 2 equilibrium.

Finding 3 *When $T = 2.8$, there is a mixture of outcomes consistent with the greater multiplicity of equilibria in this treatment.*

Support for Finding 3 comes from Table 1 and Figure 2b which report on the evolution of behavior in the four sessions of the $T = 2.8$ treatment. By contrast with the $T = 1.6$ treatment, the data reported in Table 1 and Figure 2b reveal a mixture of outcomes across the four sessions of the $T = 2.8$ treatment. In particular, we observe that the experimental economy either lingers in the middle ground between the all payment 1 and all payment 2 equilibria (sessions 1, 3 and 4) or appears to be very slowly converging toward the all payment 2 equilibrium (session 2). Recall that when $T = 2.8$, sellers are indifferent between the two equilibria as their payoffs are the same in either equilibrium. Further any outcome where all buyers allocate the same proportion of their endowment to payment 2 as the fraction of sellers accepting payment 2 is always an asymmetric equilibrium in this setting. Generally we observe that the fraction of sellers accepting payment 2 hovers above (with some volatility) the fraction of endowment that buyers allocate to payment 2. If, over time, buyers increasingly insist on the new payment method 2, then sellers are likely to accommodate the buyers' choices by accepting it; this seems to be the case in session 2. In the final market of session 2, buyer's payment 2 allocation averages 96%, and six out of seven sellers (86%) are accepting payment 2. The number of payment 2 transactions increases from 55% in the first market to

84% in the last market. Note that compared with the $T = 1.6$ treatment sessions, the process of convergence to the all payment 2 equilibrium is considerably slower, more erratic and incomplete. By contrast, in the other three sessions there is little to no evidence of convergence toward either the all cash or all e-money equilibrium. In session 3 there is a small increase in the number of transactions using payment 2 from 61% in the first market to 76% in the final market, but the economy remains far away from the all payment 2 equilibrium, or any other symmetric equilibrium. In session 1, the number of sellers accepting payment 2 fluctuates between 2/7 (28.5%) and 5/7 (71.4%). Consequently, buyers are not willing to take the lead by acquiring high payment 2 balances, fearing that they will not be able to trade in case some sellers reject it. As a result, the buyer's average payment 2 allocation and the number of sellers accepting payment 2 average between 40-50% throughout the entire session, but there is never coordination on the same rate. Finally, session 4 shows an upward trend in payment 2 usage in the first seven markets, but this trend abruptly halts thereafter, with the average number of payment 2 transactions barely changing from market eight onward (the value fluctuates between 67% and 71%). This outcome represent near (but imperfect) convergence to an interior equilibrium where approximately 5 out 7 sellers are accepting payment 2 and buyers are allocating approximately 5 units of their 7 EM endowment to payment 2. This is the closest instance we have to a dual payments equilibrium outcome.

Finding 4 *When $T = 3.5$, the experimental economy slowly converges to the payment 1 equilibrium, or lingers in the middle ground between the two pure-strategy equilibria.*

Support for Finding 4 comes from Table 1 and Figure 2c which report on the evolution of behavior in the four sessions of the $T = 3.5$ treatment. When $T = 3.5$, sellers do better in the payment 1 equilibrium as compared with the payment 2 equilibrium; by contrast buyers always prefer the payment 2 equilibrium. Nevertheless, in each of the four sessions, more than 50% of sellers start out in the first market accepting payment 2 perhaps fearing that they will lose business in the case where some buyers show up with only payment 2 remaining. With experience sellers learn to resist accepting payment 2 and engage in a tug of war with buyers; the average acceptance rate over all four sessions declines from 75% in the first market to just 21% in the last market. Sellers appear to be winning this contest in sessions 1, 2 and 4, pulling the economy back in the direction of the status quo, payment-1-only equilibrium. For example, in session 1, the buyer's payment 2 allocation falls from 65% in the first market to an average of just 6% in the last market. On the seller's side, 6 of 7 (86%) of sellers accept payment 2 in market 1; by the end of the session, no seller is accepting payment 2. The number of payment 1 transactions increases from 35% in the first market to 94% by the final, 20th market; over the same interval, payment 2 transactions fall from 63%

to 0%. In session 4, the trend works in favor of the seller, but the speed of convergence is very slow; at the end of the session, two sellers (29%) continue to accept payment 2 and 22% of transactions are conducted in payment 2 (however it seems reasonable to conjecture that the economy would get even closer to the payment 1 equilibrium if the session lasted more than 20 markets). In session 3, the tug of war continues throughout the session and neither side is able to gain the upper hand; in that session, the average buyer's payment 2 allocation and the number of sellers accepting payment 2 consistently fluctuates around 50%, but there is no coordination on any asymmetric equilibrium in this setting.

An immediate implication of Findings 1-4 is the following:

Finding 5 *Efficiency losses increase with increases in T.*

Support for Finding 5 comes from Table 2 and Figures 3abc.

When $T = 1.6$, the economy quickly converges to the socially efficient payment 2 equilibrium. All four sessions achieve between 92 and 96% of the socially optimal (payment-2-only) equilibrium payoffs, with the overall average being 94%. The efficiency measure falls as T increases to 2.8, ranging from 75% to 85%, with a treatment average of 81%. Treatment $T = 3.5$ induces a further decrease in the efficiency measure, with efficiency measures ranging from 72% to 75% percent and and a treatment average of 75%. As the fixed cost increases, the economy moves further away from the efficient equilibrium. At the same time, mis-coordination in payment choices becomes more severe, as manifested in the increasing frequency of no-trade meetings, which averaged 0.8% for $T = 1.6$, 5.6% for $T = 2.8$ and 8.6% for $T = 3.5$.

The picture is unchanged if we consider earnings relative to the status quo where only payment 1 is used. The percentage of subjects' earnings relative to the payment 1 equilibrium level serves as a measure of the benefit of introducing the new payment method, payment 2.[12] As revealed in the bottom half of Table 2, there are significant positive welfare benefits to the introduction of payment 2 when $T = 1.6$, moderate benefits when $T = 2.8$, but almost no benefit when $T = 3.5$. Disaggregating by role, Table 2 further reveals that in all three treatments buyers benefit relative to the payment 1 equilibrium, while sellers only benefit in $T = 1.6$ treatment and sellers suffer in the other two treatments relative to the payment 1 equilibrium benchmark. The latter finding is summarized as follows.

Finding 6 *Sellers may choose to accept the new payment method (payment 2) even if doing so reduces their payoffs relative to the status quo where only payment 1 is used.*

[12] Since payment 1, representing cash, has to be accepted by legal restriction, it is natural to think of payment 2 as the new and competing payment method.

Merchants often complain about high costs associated with accepting electronic payments but feel obliged to accept those costly payments for fear of upsetting or losing their customers.[13] We observe a similar pattern in our experiment. For instance, when $T = 3.5$, although sellers understand that they will lose relative to the status quo if the economy moves to the payment 2 equilibrium most sellers still begin the session accepting the new payment method (the average frequency of sellers accepting payment 2 in the first market is 70% in treatment $T = 2.8$ and 76% treatment $T = 3.5$). Figures $3b$ and $3c$ reveal that in all sessions with $T = 2.8$ and 3.5, the seller's average payoff is always below 3.5, the payoff that they would earn were the economy staying in the payment 1 equilibrium.

5 Individual Experimental Results

In this section we explore in further detail individual decision-making in our experiment. In particular, we first examine how the portfolio decisions of buyers depend on outcomes in past markets and their beliefs for the current market. We then do the same for seller's decisions to accept or not accept payment 2.

Table 4 reports regression estimates from a linear, random-effects model of the buyer's payment 2 allocation choice (card choice) where the random effect is at the individual buyer level. Specifically, the dependent variable is the percentage of the buyer's endowment that s/he allocated to payment 2 (card choice %). The two main explanatory variables are: mktAcceptL(%), representing the percentage of sellers accepting payment 2 in the last market, and bBelief%, the buyer's own incentivized belief as to the number of sellers who would be accepting payment 2 in the current market.[14] Additional explanatory variables are the market number, 1,2...20 ("market") to capture learning effects, a location dummy ("location") equal to 1 if the data were collected at SFU and two further treatment dummies, $T16$ and $T35$, to pick up treatment level effects from the $T = 1.6$ and $T = 3.5$ treatments respectively (the baseline treatment is thus $T = 2.8$).

The first column of Table 4 reports results using the pooled data from the entire experiment using all six of these explanatory variables. The results indicate that all variables except

[13]Some evidence in support of this claim comes form Evans (2011, p. vi) who observes that "...the US Congress passed legislation in 2010 that required the Federal Reserve Board to regulate debit card interchange fees; the Reserve Bank of Australia decided to regulate credit card interchange fees in 2002 after concluding that a market failure had resulted in merchants paying fees that were too high; and in 2007 the European Commission ruled that MasterCard's interchange fees violated the EU's antitrust laws."

[14]Buyers learned the percentage of sellers accepting payment 2 in the prior market because they visited all 7 sellers and were informed in every instance whether or not the seller accepted payment 2. In addition, we reported information on the percentage of sellers who accepted payment 2 in all prior markets on buyers' stage 1 portfolio allocation screen. Thus buyers had ready access to the statisitc mktAcceptL.

the location dummy are statistically significant; the latter finding tells us that on the buyer side there was no significant difference in buyer behavior between SFU and UCI and thus rationalizes our pooling of the data from these two populations. We note that among the statistically significant explanatory variables, all but the coefficient on the T35 dummy variable have positive coefficients.

The interpretation of these results is straightforward; buyers increase their allocation to payment 2 the greater is: past market seller acceptance of payment 2; buyers' beliefs about seller's acceptance of payment 2 in the current market; the market number and if $T = 1.6$. If $T = 3.5$, there is a significant drop in buyers' allocations to payment 2, as buyers anticipate the consequences of higher seller fixed costs for seller acceptance of payment 2. The last three columns of Table 4 report on the same regression model specifications but using the data separately from each of the three treatments (thus omitting the T16 and T35 dummies). As these last three columns reveal, buyers' allocation of their endowment to payment 2 is again increasing in both the past market percentage of sellers accepting payment 2 and in buyers' beliefs about the percentage of sellers who will accept of payment 2 in the current market. However, the coefficient on the market variable ranges from a positive and significant 0.699 when $T = 1.6$ to 0.197 when $T = 2.8$ to a negative and significant -0.404 when $T = 3.5$, which indicates that buyer behavior is consistent with Finding 1. Notice further that the location dummy variable is significantly positive for $T = 1.6$ and $T = 2.8$ treatments, but negative in the $T = 3.5$ treatment, which indicates that while there were differences in individual buyer behavior across the two locations at the treatment level, overall, across all three treatments there is no systematic bias (all positive or all negative) in buyers' allocations of endowment to payment 2 (as confirmed again by the insignificance of the location dummy using the pooled data). We summarize these results as follows.

Finding 7 *Buyers' allocations to payment 2 depend on historic market outcomes, their current beliefs about seller acceptance of payment 2 and the value of T.*

As each seller's decision to accept payment 2 or not is a binary choice, Table 5 reports on a random effects probit regression analysis of the factors affecting individual sellers' payment 2 acceptance decisions where the random effect is at the individual seller level. For the pooled data analysis from all three treatments (first column of Table 5) we consider nine explanatory variables, the last four of which are the same ones that were used in the regression analysis reported in Table 4. The five other explanatory variables are: sOtherAcceptL(%), which is the percentage of sellers who accepted payment 2 in the previous market (this information was only revealed to sellers at the start of stage 1 of each new market when they had to make a payment 2 acceptance choice and *not* earlier); sAcceptL*sCardDealL(%), which is the percentage of transactions the seller succeeded in conducting using payment 2 in the previous market conditional on his having accepted payment 2 in that previous market, i.e. if sAcceptL=1; (1-sAcceptL)*sNoDealL(%) is the percentage of no trade outcomes the seller encountered in the previous market conditional on his having refused to accept payment 2 in that previous market, i.e. if sAcceptL=0; and sBeliefB and sBeliefS are the seller's incentivized beliefs about the buyers' average allocation of endowment to payment 2 and of the percentage of the other 6 sellers (excluding themselves) who would accept payment 2, respectively, in the current market.

Table 5 reports marginal effects of these explanatory variables on the seller's probability of accepting payment 2. For the pooled data estimates (first column of Table 5), we observe that the percentage of other sellers accepting payment 2 in the prior market has no statistically significant effect on a seller's current market decision to accept payment 2. However, sellers do respond to their *own* prior market experience from accepting or not accepting payment 2. In particular, sellers who accepted payment 2 in the prior market are more likely to accept it again, the higher were the percentage of transactions they completed using payment 2 in that prior market. Sellers who did not accept payment 2 in the prior market are more likely to accept it in the current market, the larger the number of no trade transactions they experienced in that prior market.[15] The disaggregated treatment-level regression estimates reported on in the last three columns of Table 5 reveal that these latter two effects are coming mainly from the $T = 3.5$ treatment; in that treatment, sellers face the highest fixed cost for adopting payment 2 so they more carefully pay attention to the payoff consequences of prior payment 2 acceptance or non-acceptance decisions in this treatment relative to the other two where the fixed costs of accepting payment 2 were lower. We further observe that sellers' willingness to accept payment 2 is positively affected by their beliefs about the percentage of buyers' endowment that would be allocated to payment 2 in the current market and by their beliefs about the percentage of other sellers' who would accept payment 2 in the current market. The latter finding holds both for the pooled data and for the individual treatment specifications. The market variable is not statistically significant in the pooled seller regression, though it is negative and significant for the $T = 2.8$ treatment alone; sellers in that treatment were more likely to accept payment 2 with experience. There is again an absence of any location effect on the seller side as evidenced by the insignificant estimate on the location dummy variable both in the pooled data and in the individual treatment specifications. However, there is again a strong treatment effect as indicated by the positive and negative coefficients on the T16 and T35 dummies, respectively; sellers in the $T = 1.6$ treatment were more likely to accept

[15]A no-trade outcome can only occur in the case where the seller does not accept payment 2 and the buyer has only payment 2 in his/her portfolio. Sellers must always accept payment 1 (cash).

payment 2 while those in the $T = 3.5$ treatment were more likely to reject payment 2, all relative to the $T = 2.8$ treatment baseline. We summarize our findings for seller behavior as follows:

Finding 8 *Sellers' acceptance of payment 2 depends on historic market outcomes, their current beliefs about buyer allocations to payment 2 and other sellers acceptance of payment 2 and the value of T.*

A potential problem with the analysis presented in Tables 4-5 is that there may be endogenous interaction between explanatory variables such as the seller's lagged acceptance of payment 2 and buyer and seller beliefs in the determination of buyers' and sellers stage 1 payment choices (the dependent variable). To address possible interactions, we re-did the analysis of Tables 4-5 using a conditional mixed process estimator where the specifications of Tables 4 and 5 are jointly estimated. In addition, we considered specifications where we exclude the lagged market acceptance decisions and elicited beliefs. The results from this conditional mixed effects estimation are reported in Table 6. Note first that for the full specification column (4) of both tables, the results (in terms of statistically significant coefficient estimates) are little changed from the corresponding pooled estimation of Tables 4 and 5. Relative to this full specification, the results are also largely unaffected if we remove the endogenous variables from the full specification (compare columns 1-3 of Table 6 with column 4). Finally, the cross-equation correlation of the residuals from two equations is reported at the bottom of Table 6. We observe that the the correlation between the residuals from the buyer and seller regression models is only significant in specification (1). In particular for the full specification, the cross-equation correlation of the errors is not significantly different from zero.

Tables 7-8 reports on whether there is state dependence in buyer and seller payment choices, respectively, by adding the lagged payment choice as an explanatory variable.[16] In Table 7 we observe that the lagged buyer choice term is statistically significant in all four regressions, but the magnitude of the coefficient does decrease significantly when the last market and belief terms (especially the belief term) are added. Table 8 checks state dependence for seller choice. The lagged seller choice term is statistically significant in specifications (1) to (3), but becomes insignificant in regression (4) when both market and belief terms are added. The value of the coefficient also decreases significantly.

Summarizing the results of this section, we have found that past market outcomes and

[16]For these regressions, we didn't use a random effects estimator since adding the lagged term means that the random effect term becomes correlated with other explanatory variables (i.e., the lagged term), and this makes the estimation inconsistent.

beliefs matter for both buyer and seller behavior in a manner that is consistent with our theory. Buyers pay attention to the prior distribution of sellers accepting payment 2 when making portfolio allocations and sellers condition their payment 2 acceptance decisions on their own prior experiences with accepting or not accepting payment 2. Buyers act on their beliefs about the current distribution of sellers accepting payment 2 and sellers act on their beliefs about the current percentage of payment 2 held by buyers and on the current decisions of other sellers to accept payment 2. We have also confirmed the strong treatment effects we report on earlier in 1. Finally, we have not found evidence for any strong location effects in the decisions made by buyers or sellers, despite the fact that we conducted our experiment using student subjects at two different universities, SFU and UCI.

6 An Evolutionary Learning Model of Payment Choice

While our theoretical model is static, the adoption of a payment choice is inherently a dynamic process. Our experiment suggests that this dynamic process involves some learning over the repeated markets of our design. Toward understanding this dynamic learning process, in this section we present and evolutionary learning model approach to payment choice and compare simulation results using that model with our experimental data. The model we use IEL is great (say more about that).

6.1 The IEL model

Can we use the model where the parameters are fixed based on other experiments to tie our hands?

6.2 Simulation Results and Comparison with Experimental Data

Graphs of four simulated sessions + one graph of average of large number of simulations.

Compare large average simulation result with the average of four treatments? But, not calibrated for best fit.

The point is that we have dynamic model of behavior that seems to approximate the dynamic path taken by the subjects in the experiment.

7 Conclusion and Directions for Future Work

We have developed a simple model to understand factors that may contribute to the adoption of a new payment method when there already exists a payment method that all sellers accept. Specifically, we have isolated two factors: network adoption effects and seller transaction costs as determinants of whether or not the new payment method can take the place of the existing payment system. As our model admits multiple equilibria for a wide set of parameter values, we have chosen to study the behavior of human subjects placed in a simple version of that model, incentivize them to make decisions in accordance with the theory and give them ample opportunities to learn how to make choices in that environment.

Our model/experiment involves a two stage game. In the first stage, sellers decide whether or not to accept the new payment method; they must always continue to accept the old payment method. Simultaneously in this first stage, buyers decide how to allocate their endowment between the two payment methods without knowing of seller acceptance decisions. To use the new payment method, the seller has to pay a fixed cost to accept it, but the new payment method saves on per transaction costs for both buyers and sellers. Due to the network effect, the status quo where the existing payment is used and complete adoption of the new payment method are both equilibria.

Our main treatment variable is the fixed cost to accept the new payment method. We find that the new payment method will take off if the fixed cost is low so that both sides benefit by switching to the new payment method. If the fixed cost is high such that the seller endures a loss in the equilibrium where the new payment method is used relative to the equilibrium where it is not accepted, some sellers nevertheless respond by accepting the new payment method initially, fearing to lose business, but they mostly eventually learn over time to resist the new payment method and pull the economy back to the old payment method. If neither side displays much willpower to move behavior toward one equilibrium or the other, then the economy may linger in the middle ground between the two equilibria.

The framework we have developed in this paper can be used to analyze a series of new questions. (1) What are the effects of subsidies and taxes on the adoption of a new payment method? Consider schemes with balanced budgets where subsidies are financed by taxes. Which schemes are more effective in promoting the new payment method? Charging sellers to subsidize buyers or the other way around? (2) In the baseline model, we fix the terms of trade. What will happen if we allow sellers to offer discounts or impose surcharges (i.e., pass-throughs). Will sellers use discounts or surcharges? How will discounts or surcharges affect the diffusion of the new payment method? (3) The baseline model assumes a single new payment method. It is of interest to further explore how the economy evolves if there is more than one new payment method. Imagine the simplest case featuring two new payment methods with the same setup cost. Due to the positive setup cost associated with each new payment method, the most efficient allocation is to use only one new method. Competition between the two new payment methods may make it difficult for agents to coordinate on a single new payment method. As a result, it is possible that neither payment method will take off, or it may take a longer time for the economy to converge to the efficient equilibria. (4) What are the desirable features of the existing payment method, i.e., cash that the new payment method needs to retain in order to make it more competitive? Anonymity? Robustness to network breakdowns? What is the effect of an incidence of identity theft? Suppose the economy has arrived at the equilibrium with the new payment method. Can the economy revert to the cash only equilibrium and if so, under what circumstances? (5) Suppose consumers receive their income in the form of either the old or the new payment method, and assume there is a small cost of portfolio adjustment at the beginning of each trading period. Do these changes matter for the equilibrium that is selected? (6) The baseline model assumes that sellers always accept the old payment method. What would happen if we relax this assumption and allow sellers to decide whether to accept the old payment method? (7) The baseline model assumes that consumers cannot convert between the old and the new payment methods after the initial portfolio choice. As a result, if the consumer has only the new payment method but the seller does not accept it, there will be no trade. In such instances, we could modify the model to allow for conversion opportunities subject to a cost. Note that this new specification does not change the equilibrium outcomes. In equilibrium, consumers' portfolio choice will be fully consistent with the seller's acceptance pattern, and there is no need to convert. However, the conversion cost(s) may affect the speed of convergence to equilibria. We believe that all of these extensions of our model are worth examining theoretically and/or experimentally but we must leave such an analysis to future research.

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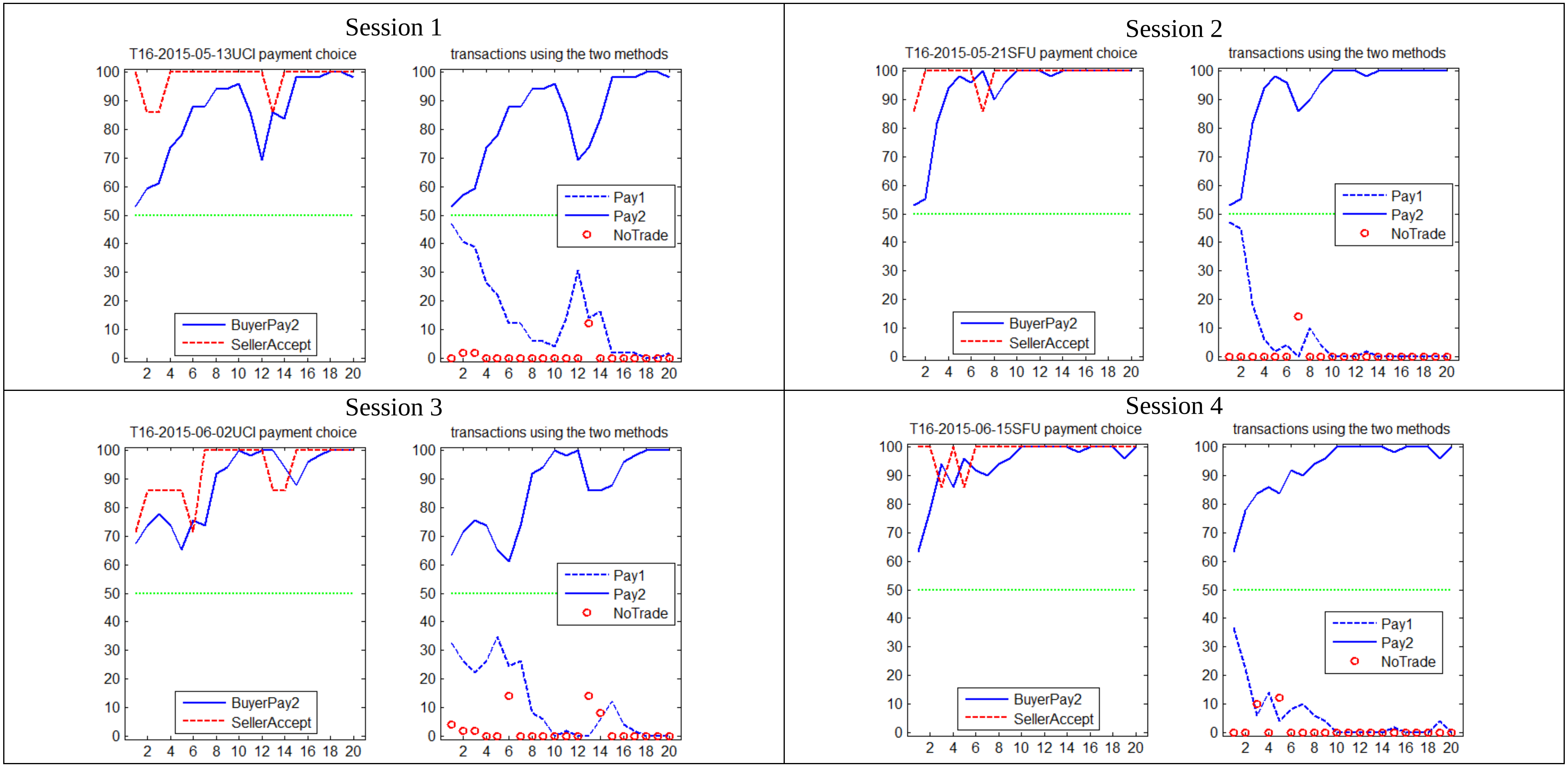
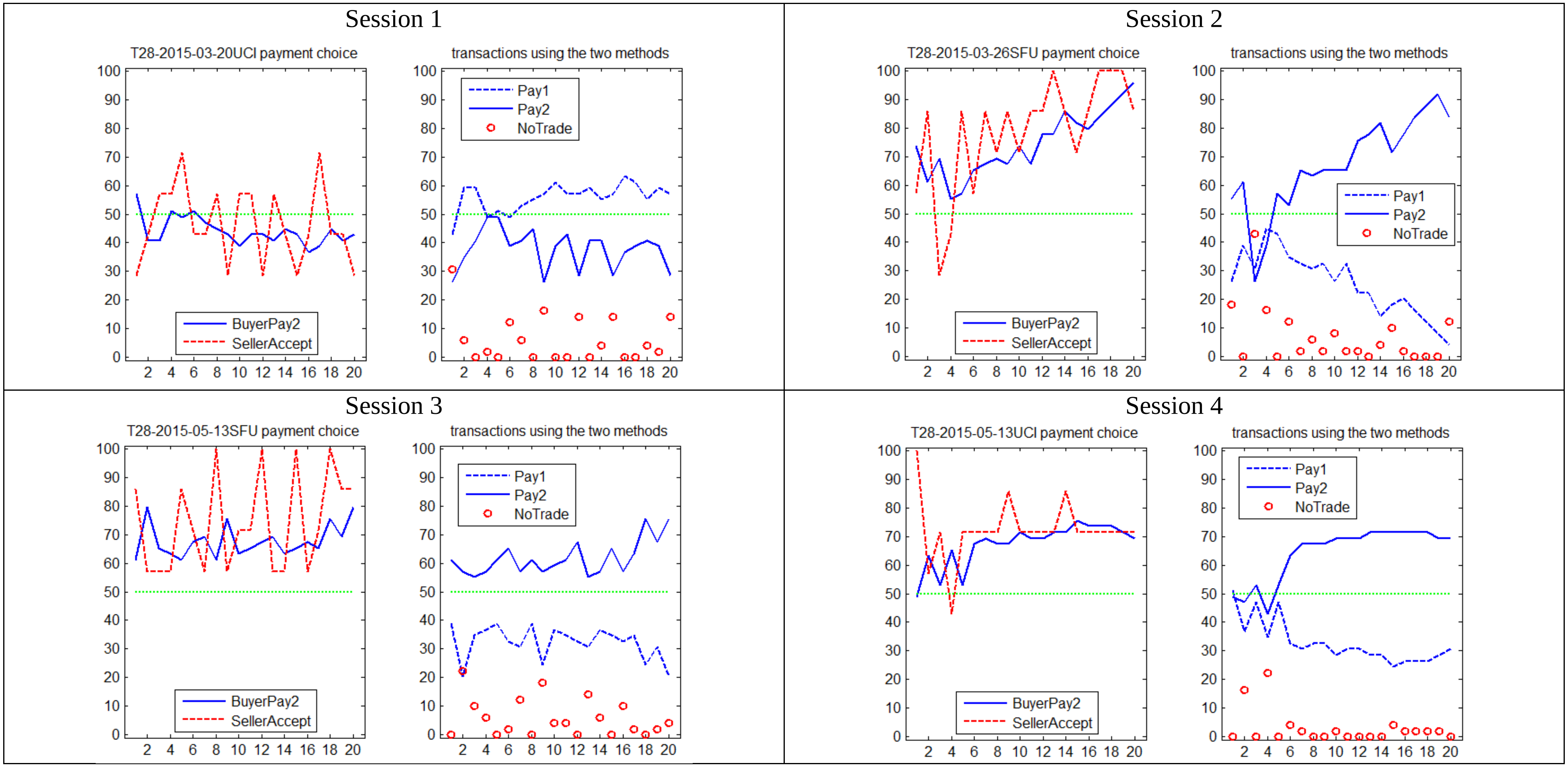
Figure 2a: Payment Choice and Usage T=1.6



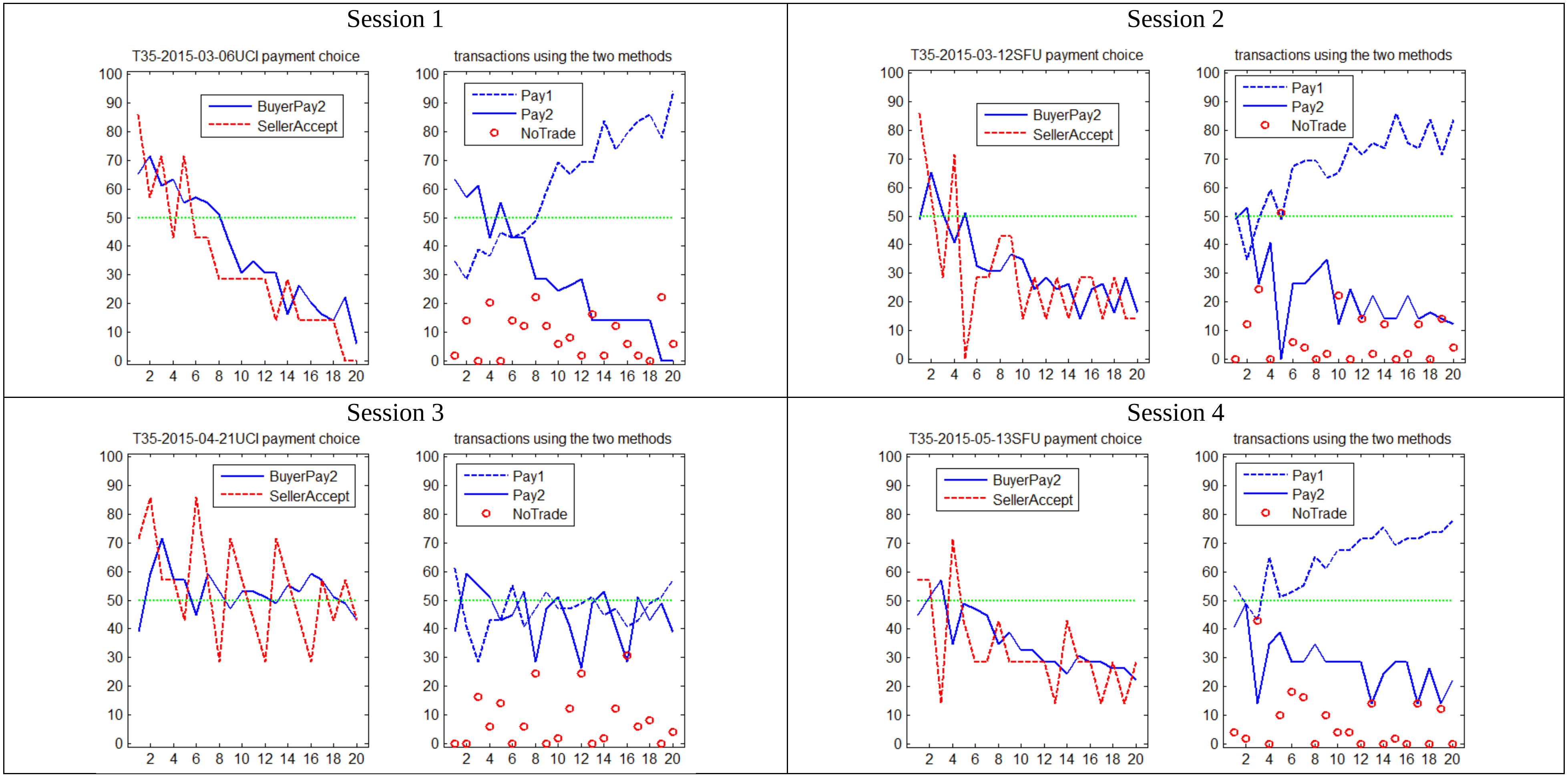
Notes. (1) Horizontal axis: market. (2) There are two figures for each session. The first shows payment choices: the red dashed line represents the percentage of money allocated to payment 2, averaged across the seven buyers; the blue solid line represents the percentage of the seven sellers accepting payment 2. The second figure describes payment usage. The solid blue line is the percentage of meetings using payment 2; the dashed blue line is the percentage of meetings using payment 1; red circles are the percentage of meetings where no trade takes place.

Figure 2b: Payment Choice and Usage T=2.8



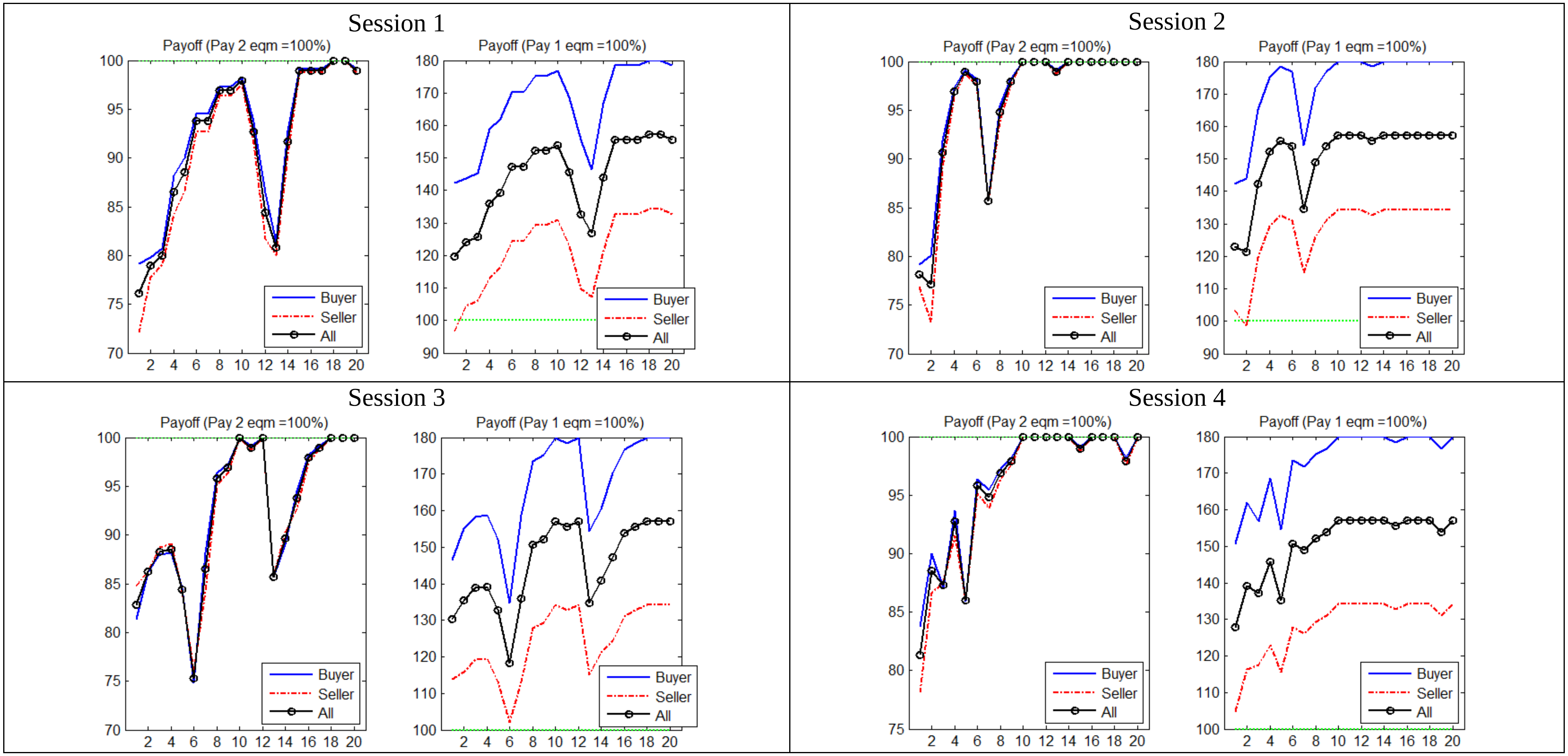
Notes. (1) Horizontal axis: market. (2) There are two figures for each session. The first shows payment choices: the red dashed line represents the percentage of money allocated to payment 2, averaged across the seven buyers; the blue solid line represents the percentage of the seven sellers accepting payment 2. The second figure describes payment usage. The solid blue line is the percentage of meetings using payment 2; the dashed blue line is the percentage of meetings using payment 1; red circles are the percentage of meetings where no trade takes place.

Figure 2c: Payment Choice and Usage T=3.5



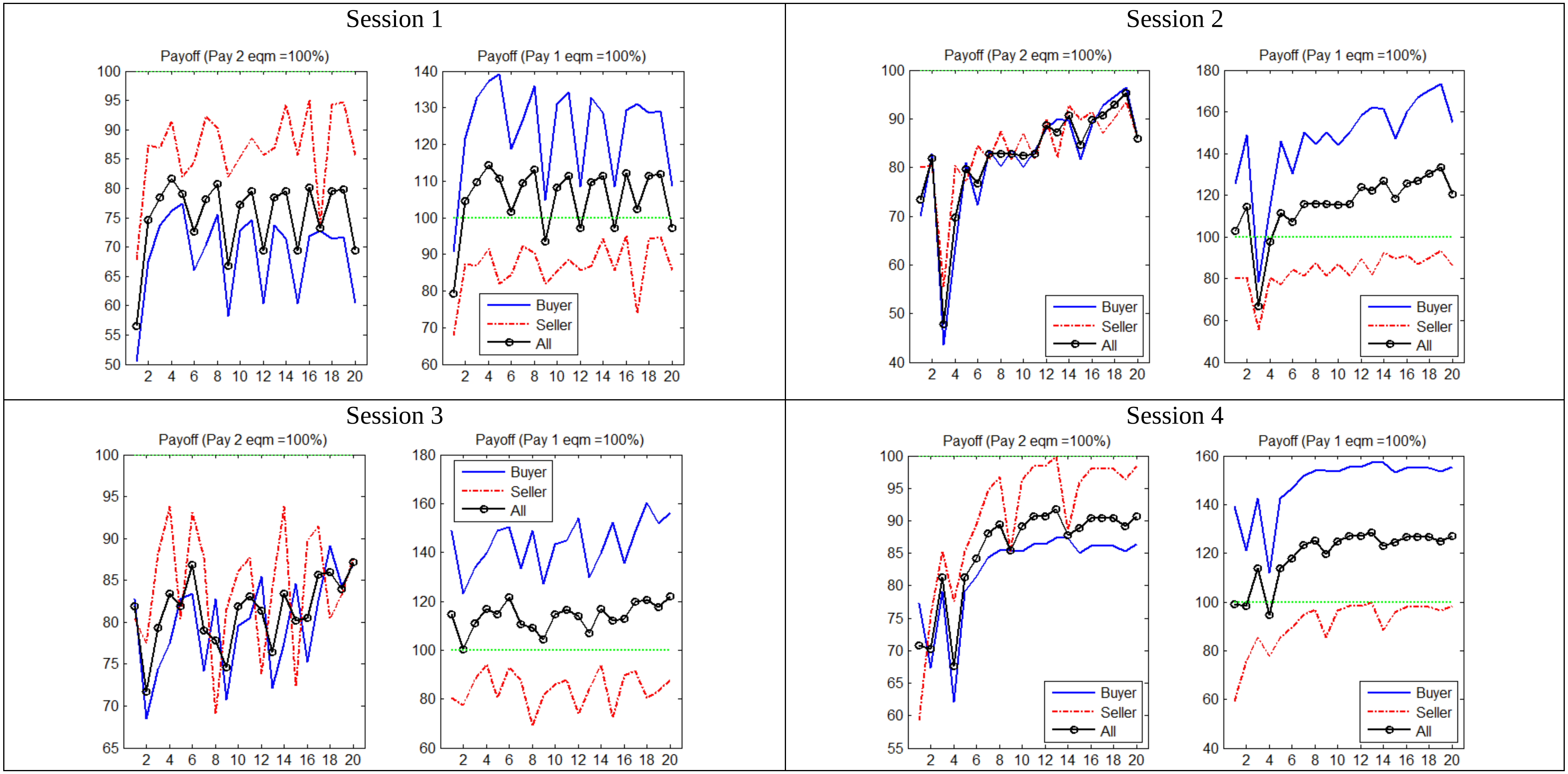
Notes. (1) Horizontal axis: market. (2) There are two figures for each session. The first shows payment choices: the red dashed line represents the percentage of money allocated to payment 2, averaged across the seven buyers; the blue solid line represents the percentage of the seven sellers accepting payment 2. The second figure describes payment usage. The solid blue line is the percentage of meetings using payment 2; the dashed blue line is the percentage of meetings using payment 1; red circles are the percentage of meetings where no trade takes place.

Figure 3a: Efficiency T=1.6



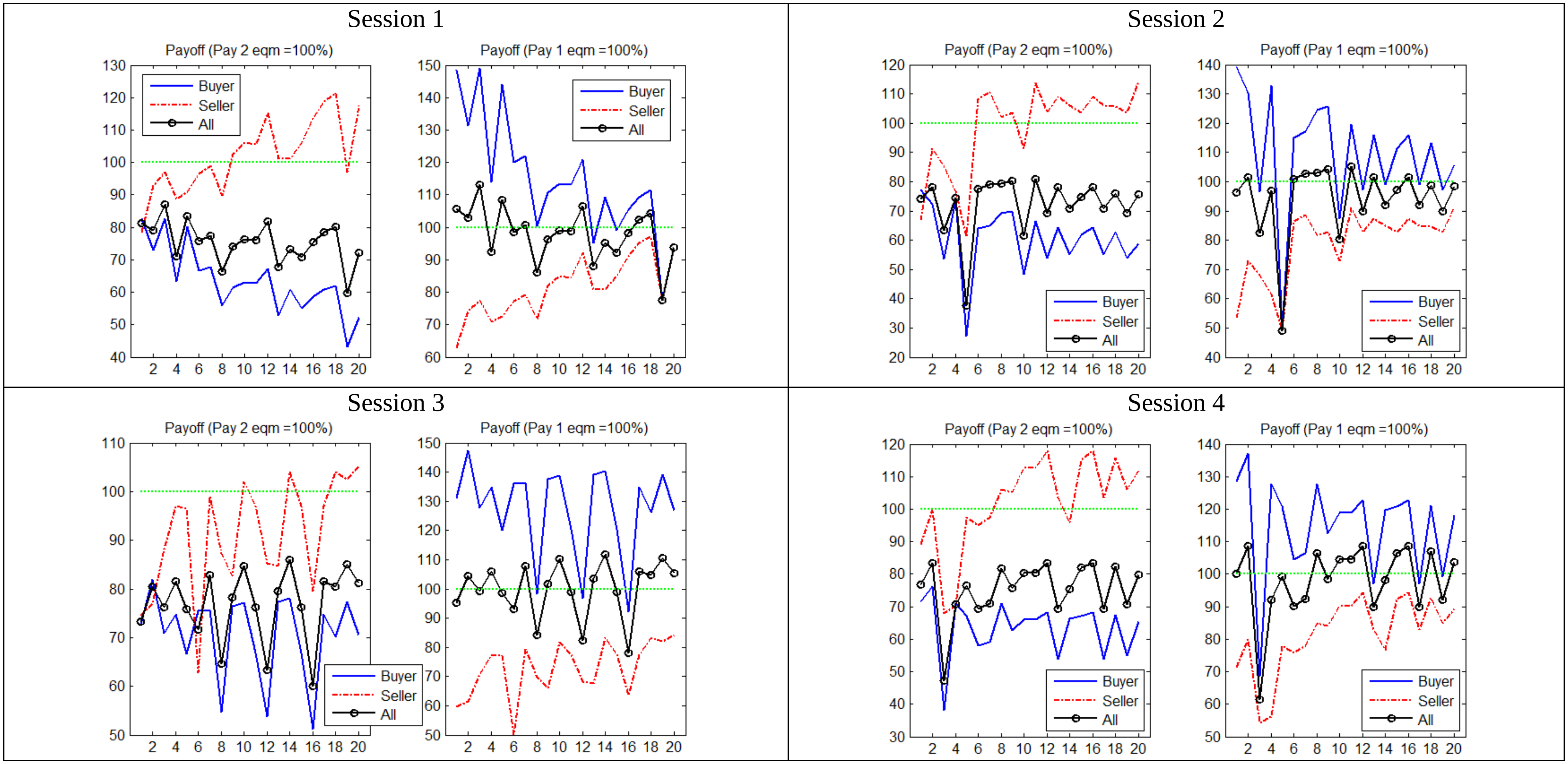
Notes. (1) Horizontal axis: market. (2) There are two figures for each session. The first figure measures efficiency using payoffs in the payment 2 equilibrium as the benchmark (100%). The blue solid line represents sellers, the red dashed line represents buyers and the black line marked with circles represents buyers and sellers together. The second figure measures efficiency using payoffs in the payment 1 equilibrium as the benchmark.

Figure 3b: Efficiency T=2.8



Notes. (1) Horizontal axis: market. (2) There are two figures for each session. The first figure measures efficiency using payoffs in the payment 2 equilibrium as the benchmark (100%). The blue solid line represents sellers, the red dashed line represents buyers and the black line marked with circles represents buyers and sellers together. The second figure measures efficiency using payoffs in the payment 1 equilibrium as the benchmark.

Figure 3c: Efficiency T=3.5



Notes. (1) Horizontal axis: market. (2) There are two figures for each session. The first figure measures efficiency using payoffs in the payment 2 equilibrium as the benchmark (100%). The blue solid line represents sellers, the red dashed line represents buyers and the black line marked with circles represents buyers and sellers together. The second figure measures efficiency using payoffs in the payment 1 equilibrium as the benchmark.

Table 1: Payment choice and usage

	Treatment		T=1.6					T=2.8					T=3.5				
	Session		1	2	3	4	**all**	1	2	3	4	**all**	1	2	3	4	**all**
1	% of money allocated to payment 2	session mean	85	93	88	94	**90**	44	74	68	67	**63**	38	33	53	36	**40**
2		session min	53	53	65	63	**59**	37	55	61	49	**51**	6	14	39	22	**20**
3		session max	100	100	100	100	**100**	57	96	80	76	**77**	71	65	71	57	**66**
4		first market	53	53	67	63	**59**	57	73	61	49	**60**	65	49	39	45	**49**
5		last market	98	100	100	100	**99**	43	96	80	69	**72**	6	16	43	22	**22**
6	% of sellers accepting payment 2	session mean	98	99	93	99	**97**	46	79	74	72	**68**	33	31	54	33	**38**
7		session min	86	86	71	86	**82**	29	29	57	43	**39**	0	0	29	14	**11**
8		session max	100	100	100	100	**100**	71	100	100	100	**93**	86	86	86	71	**82**
9		first market	100	86	71	100	**89**	29	57	86	100	**68**	86	86	71	57	**75**
10		last market	100	100	100	100	**100**	29	86	86	71	**68**	0	14	43	29	**21**
11	% of meetings using payment 2	session mean	84	92	86	93	**89**	38	67	62	64	**58**	29	23	45	28	**31**
12		session min	53	53	61	63	**58**	27	27	55	43	**38**	0	0	27	14	**10**
13		session max	100	100	100	100	**100**	49	92	76	71	**72**	63	53	59	49	**56**
14		first market	53	53	63	63	**58**	27	55	61	49	**48**	63	49	39	41	**48**
15		last market	98	100	100	100	**99**	29	84	76	69	**64**	0	12	39	22	**18**
16	% of meetings using payment 1	session mean	15	7	12	6	**10**	56	26	32	33	**37**	62	67	47	64	**60**
17		session min	0	0	0	0	**0**	43	4	20	24	**23**	29	35	29	43	**34**
18		session max	47	47	35	37	**41**	63	45	39	51	**49**	94	86	61	78	**80**
19		first market	47	47	33	37	**41**	43	27	39	51	**40**	35	51	61	55	**51**
20		last market	2	0	0	0	**1**	57	4	20	31	**28**	94	84	57	78	**78**
21	% of meetings with no trade	session mean	1	1	2	1	**1**	6	7	6	3	**6**	9	9	8	8	**9**
22		session min	0	0	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**
23		session max	12	14	14	12	**13**	31	43	22	22	**30**	22	51	31	43	**37**
24		first market	0	0	4	0	**1**	31	18	0	0	**12**	2	0	0	4	**2**
25		last market	0	0	0	0	**0**	14	12	4	0	**8**	6	4	4	0	**4**

Table 2: Efficiency

Part 1: payment 2 equilibrium as benchmark

	Treatment		T=1.6					T=2.8					T=3.5				
	Session		1	2	3	4	**all**	1	2	3	4	**all**	1	2	3	4	**all**
1		session mean	93	96	93	96	**94**	69	82	80	82	**78**	64	61	71	64	**65**
2		session min	79	79	75	84	**79**	50	44	68	62	**56**	43	27	51	38	**40**
3	buyer	session max	100	100	100	100	**100**	77	96	89	87	**88**	83	77	82	76	**80**
4		first market	79	79	81	84	**81**	50	70	83	77	**70**	83	77	73	71	**76**
5		last market	99	100	100	100	**100**	60	86	87	86	**80**	52	59	71	66	**62**
6		session mean	91	95	92	95	**93**	87	84	84	91	**86**	102	99	91	102	**98**
7		session min	72	73	76	78	**75**	68	56	69	59	**63**	79	61	63	68	**68**
8	seller	session max	100	100	100	100	**100**	95	93	94	100	**96**	121	114	105	118	**115**
9		first market	72	77	85	78	**78**	68	80	80	59	**72**	79	67	74	89	**77**
10		last market	99	100	100	100	**100**	86	86	88	98	**89**	117	114	105	112	**112**
11		session mean	92	96	92	96	**94**	75	82	81	85	**81**	75	72	77	75	**75**
12		session min	76	77	75	81	**77**	57	48	72	68	**61**	60	38	60	47	**51**
13	all	session max	100	100	100	100	**100**	82	95	87	92	**89**	87	81	86	84	**84**
14		first market	76	78	83	81	**80**	57	73	82	71	**71**	81	74	73	77	**76**
15		last market	99	100	100	100	**100**	69	86	87	91	**83**	72	76	81	80	**77**

Part 2: payment 1 equilibrium as benchmark

1		session mean	167	173	167	173	**170**	124	147	144	148	**141**	114	110	127	115	**116**
2		session min	142	142	135	151	**143**	91	78	123	112	**101**	78	49	92	69	**72**
3	buyer	session max	180	180	180	180	**180**	139	173	160	157	**158**	149	139	147	137	**143**
4		first market	142	142	147	151	**146**	91	126	149	139	**126**	149	139	131	129	**137**
5		last market	178	180	180	180	**180**	109	155	156	156	**144**	94	106	127	118	**111**
6		session mean	123	129	124	129	**126**	87	84	84	91	**86**	82	79	73	82	**79**
7		session min	102	104	101	109	**104**	68	56	69	59	**63**	63	49	50	54	**54**
8	seller	session max	134	134	134	134	**134**	95	93	94	100	**96**	97	91	84	94	**92**
9		first market	102	105	111	109	**107**	68	80	80	59	**72**	63	53	60	71	**62**
10		last market	133	134	134	134	**134**	86	86	88	98	**89**	94	91	84	89	**90**
11		session mean	144	151	145	151	**148**	105	115	114	120	**114**	98	94	100	98	**98**
12	all	session min	120	121	118	128	**122**	79	67	100	95	**85**	78	49	78	61	**66**
13		session max	157	157	157	157	**157**	114	133	122	129	**125**	113	105	112	109	**110**
14		first market	120	123	130	128	**125**	79	103	115	99	**99**	106	96	95	100	**99**
15		last market	156	157	157	157	**157**	97	120	122	127	**117**	94	99	106	104	**100**

Table 3: Rank-sum Test – Treatment Effect

		Rank-sum group 1	Rank-sum group 2	z-value	p-value
T=1.6 versus T=2.8					
	BuyerChoice	26	10	2.309	0.021
Session average	SellerAccept	26	10	2.323	0.020
	Pay2Meetings	26	10	2.309	0.021
	BuyerChoice	18	18	0	1
First market	SellerAccept	21.5	14.5	1.042	0.298
	Pay2Meetings	22	14	1.169	0.243
T=2.8 versus T=3.5					
	BuyerChoice	25	11	2.021	0.043
Session average	SellerAccept	25	11	2.033	0.042
	Pay2Meetings	25	11	2.021	0.043
	BuyerChoice	22.5	13.5	1.307	0.191
First market	SellerAccept	18.5	17.5	0.149	0.882
	Pay2Meetings	18.5	17.5	0.145	0.885
T=1.6 versus T=3.5					
	BuyerChoice	26	10	2.309	0.021
Session average	SellerAccept	26	10	2.337	0.019
	Pay2Meetings	26	10	2.309	0.021
	BuyerChoice	23	13	1.452	0.147
First market	SellerAccept	22.5	13.5	1.348	0.178
	Pay2Meetings	23	13	1.488	0.137

Notes: (1) combined sample size for each test is 8

Table 4: Buyer payment 2 choice (%) with random effects

Independent variables	statistics	pooled		T=1.6		T=2.8		T=3.5	
mktAccceptL(%)	**Coef.**	**0.218**	***	**0.328**	***	**0.100**	***	**0.174**	***
	Std.Err.	0.021		0.108		0.027		0.025	
	t	10.33		3.02		3.64		6.82	
	p	0.000		0.002		0.000		0.000	
bBelief(%)	**Coef.**	**0.593**	***	**0.400**	***	**0.624**	***	**0.567**	***
	Std.Err.	0.021		0.048		0.034		0.029	
	t	27.90		8.29		18.34		19.68	
	p	0.000		0		0.000		0.000	
market	**Coef.**	**0.129**	***	**0.699**	***	**0.197**	***	**-0.404**	***
	Std.Err.	0.049		0.124		0.072		0.086	
	t	2.64		5.64		2.75		-4.71	
	p	0.008		0.000		0.006		0.000	
location (SFU=1;UCI=0)	**Coef.**	**1.787**		**4.624**	**	**5.575**	***	**-3.731**	**
	Std.Err.	1.212		2.140		2.151		1.823	
	t	1.47		2.16		2.59		-2.05	
	p	0.140		0.031		0.01		0.041	
T16	**Coef.**	**5.174**	***						
	Std.Err.	1.591							
	t	3.25							
	p	0.001							
T35	**Coef.**	**-4.042**	***						
	Std.Err.	1.578							
	t	-2.56							
	p	0.010							
No. of obs.		1596		532		532		532	
Overall R^2		0.825		0.355		0.687		0.764	

Notes: (1) *p-value<=0.1; **p-value<=0.05; *** p-value<=0.01

Table 5: Seller acceptance (1=accept, 0=reject), probit with random effects

Independent variables	statistics	pooled	T=1.6	T=2.8	T=3.5
sOtherAcceptL(%)	**dy/dx**	**0.032**	**0.043**	**-0.168**	**-0.046**
	Std.Err.	0.054	0.078	0.116	0.123
	t	0.60	0.55	-1.45	-0.38
	p	0.551	0.582	0.146	0.706
sAcceptL*sCardDealL(%)	**dy/dx**	**0.151** ***	**0.033**	**-0.025**	**0.276** ***
	Std.Err.	0.033	0.037	0.071	0.065
	t	4.56	0.91	-0.35	4.22
	p	0.000	0.363	0.723	0.000
(1-sAcceptL)*sNoDealL(%)	**dy/dx**	**0.446** ***	**0.369**	**0.065**	**0.764** ***
	Std.Err.	0.088	0.282	0.184	0.172
	t	5.09	1.31	0.35	4.44
	p	0.000	0.190	0.724	0.000
sBeliefB(%)	**dy/dx**	**0.366** ***	**0.062**	**0.535** ***	**0.470** ***
	Std.Err.	0.0465	0.040	0.097	0.088
	t	7.87	1.57	5.52	5.32
	p	0.000	0.117	0.000	0.000
sBeliefS(%)	**dy/dx**	**0.219** ***	**0.115** **	**0.283** **	**0.208** **
	Std.Err.	0.049	0.052	0.111	0.087
	t	4.47	2.23	2.54	2.39
	p	0.000	0.026	0.011	0.017
market	dy/dx	**0.246**	**0.059**	**0.981** ***	**-0.621**
	Std.Err.	0.159	0.179	0.310	0.448
	t	1.55	0.33	3.17	-1.39
	p	0.121	0.742	0.002	0.165
location (SFU=1;UCI=0)	**dy/dx**	**0.446**	**-0.123**	**3.471**	**0.524**
	Std.Err.	3.582	1.707	10.006	7.373
	t	0.12	-0.07	0.35	0.07
	p	0.901	0.943	0.729	0.943
T16	**dy/dx**	**19.261** ***			
	Std.Err.	5.210			
	t	3.70			
	p	0.000			
T35	**dy/dx**	**-9.874** **			
	Std.Err.	3.944			
	t	-2.50			
	p	0.012			
No. of obs.		1596	532	532	532

Notes: (1) dy/dx represents the marginal effect of the independent variable on the probability (in %) of a seller accepting payment 2; (2) *p-value<=0.1, **p-value<=0.05, *** p-value<=0.01

Table 6: Interaction between buyers and sellers, conditional mixed process estimator

Independent variables	statistics	(1)		(2)		(3)		(4)	
Buyer payment 2 choice (%) with random effects									
MktAcceptL(%)	**Coef.**					**0.534**	***	**0.218**	***
	Std.Err.					0.051		0.047	
bBelief(%)	**Coef.**			**0.712**	***			**0.592**	***
	Std.Err.			0.038				0.046	
market	**Coef.**	**0.054**		**0.066**		**0.212**		**0.129**	
	Std.Err.	0.216		0.119		0.157		0.115	
location (SFU=1;UCI=0)	**Coef.**	**3.645**		**2.045**		**2.368**		**1.794**	
	Std.Err.	2.366		1.306		1.713		1.253	
T16	**Coef.**	**28.181**	***	**8.137**	***	**12.720**	***	**5.197**	***
	Std.Err.	2.898		1.927		2.560		1.927	
T35	**Coef.**	**-24.089**	***	**-7.704**	***	**-8.420**	***	**-4.066**	**
	Std.Err.	2.898		1.824		2.572		1.890	
Seller acceptance (1=accept, 0=reject), probit with random effects									
sOtherAcceptL(%)	**dy/dx**					**0.247**	**	**0.038**	
	Std.Err.					0.104		0.116	
sAcceptL*sCardDealL(%)	**dy/dx**					**0.302**	***	**0.162**	**
	Std.Err.					0.055		0.065	
(1-sAcceptL)*sNoDealL(%)	**dy/dx**					**0.723**	***	**0.478**	**
	Std.Err.					0.186		0.192	
sBeliefB(%)	**dy/dx**			**0.444**	***			**0.396**	***
	Std.Err.			0.100				0.093	
sBeliefS(%)	**dy/dx**			**0.300**	***			**0.235**	**
	Std.Err.			0.104				0.104	
market	dy/dx	**-0.029**		**0.163**		**0.263**		**0.272**	
	Std.Err.	0.486		0.408		0.372		0.004	
location (SFU=1;UCI=0)	**dy/dx**	**3.469**		**0.880**		**1.464**		**0.355**	
	Std.Err.	5.363		4.495		3.990		3.888	
T16	**dy/dx**	**43.428**	***	**23.885**	***	**25.076**	***	**20.860**	***
	Std.Err.	8.643		7.334		7.048		6.704	
T35	**dy/dx**	**-25.692**	***	**-12.245**	**	**-12.495**	**	**-10.556**	**
	Std.Err.	4.345		4.843		5.111		4.880	
No. of obs.		1596		1596		1596		1596	
Cross-equation correlation of residuals		**0.170**	***	**0.028**		**0.055**		**0.034**	
Std.Err.		0.041		0.053		0.045		0.052	

Notes: (1) dy/dx represents the marginal effect of the independent variable on the probability (in %) of a seller accepting payment 2; (2) *p-value<=0.1, **p-value<=0.05, *** p-value<=0.01

Table 7: State dependence – buyer payment 2 choice (%), OLS

Independent variables	statistics	(1)		(2)		(3)		(4)	
bcardL(%)	**Coef.**	**0.672**	***	**0.383**	***	**0.527**	***	**0.372**	***
	Std.Err.	0.018		0.017		0.017		0.017	
MktAcceptL(%)	**Coef.**					**0.404**	***	**0.203**	***
	Std.Err.					0.018		0.019	
bBelief(%)	**Coef.**			**0.546**	***			**0.429**	***
	Std.Err.			0.019				0.021	
market	**Coef.**	**-0.079**		**-0.012**		**0.069**		**0.048**	
	Std.Err.	0.060		0.049		0.053		0.047	
location (SFU=1;UCI=0)	**Coef.**	**1.432**	**	**1.160**	**	**0.943**		**0.973**	*
	Std.Err.	0.661		0.534		0.579		0.517	
T16	**Coef.**	**10.255**	***	**2.615**	***	**2.409**	***	**0.309**	
	Std.Err.	0.935		0.800		0.894		0.804	
T35	**Coef.**	**-9.287**	***	**-3.107**	***	**-0.613**		**-0.075**	
	Std.Err.	0.896		0.755		0.879		0.784	
No. of obs.		1596		1596		1596		1596	

Notes: (1) *p-value<=0.1, **p-value<=0.05, *** p-value<=0.01

Table 8: State dependence – seller acceptance (1=accept, 0=reject), probit

Independent variables	statistics	(1)		(2)		(3)		(4)	
Seller acceptance (1=accept, 0=reject), probit									
sAcceptL	**dy/dx**	**25.587**	***	**18.219**	***	**18.471**	***	**5.262**	
	Std.Err.	1.512		1.624		6.215		5.965	
sOtherAcceptL(%)	**dy/dx**					**0.181**	***	**0.001**	
	Std.Err.					0.044		0.050	
sAcceptL*sCardDealL(%)	**dy/dx**					**0.415**	***	**0.275**	***
	Std.Err.					0.068		0.067	
(1-sAcceptL)*sNoDealL(%)	**dy/dx**					**0.775**	***	**0.593**	***
	Std.Err.					0.079		0.082	
sBeliefB(%)	**dy/dx**			**0.331**	***			**0.291**	***
	Std.Err.			0.040				0.040	
sBeliefS(%)	**dy/dx**			**0.185**	***			**0.150**	***
	Std.Err.			0.041				0.045	
market	dy/dx	**0.022**		**0.140**		**0.219**		**0.204**	
	Std.Err.	0.165		0.158		0.165		0.160	
location (SFU=1;UCI=0)	**dy/dx**	**2.207**		**1.589**		**0.879**		**0.786**	
	Std.Err.	1.815		1.736		1.716		1.677	
T16	**dy/dx**	**26.478**	***	**17.199**	***	**17.527**	***	**15.923**	***
	Std.Err.	2.969		3.057		3.127		3.969	
T35	**dy/dx**	**-13.699**	***	**-7.700**	***	**-7.394**	***	**-7.780**	***
	Std.Err.	1.857		1.876		2.158		2.049	
No. of obs.		1596		1596		1596		1596	

Notes: (1) dy/dx represents the marginal effect of the independent variable on the probability (in %) of a seller accepting payment 2; (2) *p-value<=0.1, **p-value<=0.05, *** p-value<=0.01

Appendix: Experimental Instructions *(T=2.8 treatment only; other treatments are similar)*

Welcome to this experiment in economic-decision making. Please read these instructions carefully as they explain how you earn money from the decisions that you make. You are guaranteed $7 for showing up and completing the study. Additional earnings depend on your decisions and on the decisions of other participants as explained below. You will be earning experimental money (EM). At the end of the experiment, you will be paid in dollars at the exchange rate of 1 EM = $0.15.

There are 14 participants in today's experiment: 7 will be randomly assigned the role of buyers and 7 the role of sellers. You will learn your role at the start of the experiment, and remain in the *same* role for the duration of the experiment. Buyers and sellers will interact in 20 "markets" to trade goods for payment. There are two payment methods, payment 1 and payment 2.

Each market consists of two stages. The first is the payment choice stage. Each buyer is endowed with 7 EM and decides how to allocate it between the two payment methods. Each seller is endowed with 7 units of goods. Sellers have to accept payment 1, but can decide whether or not to accept payment 2. Sellers who decide to accept payment 2 have to pay a one-time fee of 2.8 EM. No participant observes any seller's choice at this stage.

The second stage is the trading stage, which consists of a sequence of 7 rounds. In these 7 rounds, you meet with each of the 7 participants who are in the opposite role to yourself sequentially and in a random order. In each meeting you try to trade one unit of good for one unit of payment. The buyer decides which payment to use and the trade is successful if and only if the seller accepts the payment offered by the buyer. For each successful sale or purchase, you earn 1 EM less some transaction costs. The transaction cost to both sides is 0.5 EM if payment 1 is used, and 0.1 EM if payment 2 is used. If the buyer offers payment 1 (which is always accepted by sellers), then trade is successful and both the buyer and the seller earn a *net* payoff of 1-0.5=0.5 EM. If the buyer offers payment 2 and the seller has decided to accept payment 2 in the first stage, then trade is again successful and both earn a *net* payoff of 1-0.1=0.9 EM. If the buyer has only payment 2 and the seller has decided not to accept it, then no trade can take place and both earn 0 EM. At the end of the market, unspent EMs or unsold goods have no redemption value and do not entitle you to extra earnings.

Task summary

<table>
<tr><td rowspan="2">Market 1</td><td>Stage 1: Payment choice
Buyers allocate 7 EM between the two payments
Sellers decide whether to accept payment 2 at a one-time fee of 2.8 EM</td></tr>
<tr><td>Stage 2: Trading (7 rounds)
Each buyer meets each of the 7 sellers in a random order
Trade with payment 1 → net payoff of 0.5 EM
Trade with payment 2 → net payoff of 0.9 EM
No trade → net payoff of 0 EM</td></tr>
<tr><td rowspan="2">Market 2</td><td>Stage 1: Payment choice</td></tr>
<tr><td>Stage 2: Trading (7 rounds)</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td rowspan="2">Market 20</td><td>Stage 1: Payment choice</td></tr>
<tr><td>Stage 2: Trading (7 rounds)</td></tr>
</table>

More Information for Sellers

As a seller, your earnings in a market (in EM) is calculated as

Option I	Accept payment 2	Number of payment 1 transactions x 0.5 + **Number of payment 2 transactions x 0.9 – 2.8**
Option II	Not accept payment 2	Number of payment 1 transactions x 0.5

The benefit to sellers of accepting payment 2 is to increase the likelihood that you sell goods to buyers (remember no trade can take place if the buyer has only payment 2 and you do not accept it), and to reduce transaction costs and therefore increase net earnings by 0.4 EM each time a buyer pays in payment 2. The cost to sellers of accepting payment 2 is that you have to pay a one-time fee of 2.8 EM at the beginning of the market even if no buyers offer to pay you with payment 2 in that market.

Which option leads to higher earnings depends on all other 13 subjects' decisions. Table 1 on page 7 lists the average market earnings for the seller from the two options (accept / reject payment 2) in cases where all buyers choose to allocate between 0~7 EM to payment 2, and where 0~6 of the other 6 sellers choose to accept payment 2. As you can see, either option can give higher earnings depending on other participants' decisions. During the experiment, please keep Table 1 at hand for reference. In addition, you can use a "what if" calculator on the computer screen to compute the average earnings in situations where buyers make different payment allocations.

Your earnings from accepting payment 2 tend to increase if more buyers allocate more money to payment 2, and if fewer sellers accept payment 2. The opposite is true if you reject payment 2.

More Information for Buyers

As a buyer, your earnings in a market are calculated as

Number of payment 1 transactions x 0.5 + Number of payment 2 transactions x 0.9

As a buyer, the benefit of allocating more money to payment 2 is that you save 0.4 EM each time you use payment 2 instead of payment 1. The cost is the risk that you may not be able to trade if the seller does not accept payment 2 and you run out of payment 1 (which is always accepted). Your market earnings depend on your own payment allocation and the 7 sellers' decisions on acceptance of payment 2. Table 2 on page 7 lists the buyer's market earnings if the buyer allocates 0~7 EM to payment 2 (and the rest to payment 1) and if 0~7 sellers accept payment 2. You should allocate more money to payment 2 if you expect more sellers to accept it. Table 2 will also be on your computer screen when you make payment decisions.

Forecast

At the start of each market before making payment decisions, you are asked to forecast other participants' choices for that market. Buyers forecast how many of the 7 sellers will choose to accept payment 2. Sellers forecast (1) the average amount of EM that all 7 buyers will allocate to payment 2, and (2) how many of the other 6 sellers will accept payment 2. You earn 0.5 EM per correct forecast in addition to your earnings from buying/selling goods.

Earnings

At the end of the experiment, you will be paid your earnings in cash and in private. Your earnings in dollars will be: Total earning (trading + forecasting) in EM x 0.15 + 7 (show-up fee).

Computer Interface

You will interact anonymously with other participants using the computer workstations. You will see three types of screens (Figures 1-6 show sample screens).

Payment choice screen, Figures 1-2. This is where you make payment choices depending on whether you are a buyer (Figure 1) or a seller (Figure 2). Each screen has 4 parts. The upper portion summarizes information about previous markets. To the left of the blank column are your own activities, including your payment choice, the number of transactions using each of the two payment methods, the number of no-trade meetings, market earning from trading, and the number of correct forecasts that you made. To the right of the blank column, there is an aggregate market-level statistic, the number of sellers who accepted payment 2.

The middle section provides information about your average potential earnings from trading in each market. The buyer screen (Figure 1) shows Table 2. The seller screen (Figure 2) has a "what if" calculator. A seller can type in the number of buyers choosing to allocate 0~7 EM to payment 2 and the number of other 6 sellers accepting payment 2 (the default value is 0 in all fields; the first 8 fields must add up to 7; enter an integer 0~6 in the last field), press the "Calculate" button to create a record showing the average market earnings from accepting payment 2 and not accepting it, as well as the average buyers' allocation to payment 2 in that scenario. For example, if you would like to check your potential average earnings in the situation where **5** buyers allocate 2 EM to payment 2, **2** buyers allocate 3 EM, and **3** of the other six sellers accept payment 2, type in "**5**" in the field "# buyers with pay2=2", "**2**" in the field "# buyers with pay2=3", and "**3**" in the field "# other sellers accept pay2." You can create as many records as you wish at the start of each market.

In the lower-left section, you forecast what other participants will do in the new market. Enter an integer within the indicated range for each forecast. The seller's forecast of buyer's average payment 2 allocation is counted as correct if it lies within ±1 of the realized value.

In the lower-right section, you choose how to split your 7 EM between the two payment methods if you are a buyer (Figure 1), and whether to accept payment 2 at a one-time fee of 2.8 EM if you are a seller (Figure 2).

Trading screen, Figures 3-4**.** In each of the 7 trading rounds, buyers decide whether to buy a unit of the seller's good using either payment 1 or payment 2. This decision depends on the buyer's remaining balances of payment 1 and payment 2, and whether or not the seller has agreed to accept payment 2; this information is shown on the buyer's computer screen (see the lower left box in Figure 3). Sellers do not choose at this stage, and can click on the "OK" button to review information on the waiting screen (see Figure 4). From round 2 on, the upper section of the screen reviews your activities in the previous round and in the current market up until then.

Waiting screen, Figures 5-6. At any point in the experiment if you finish your decision sooner than other participants, you will see a waiting screen with information on previous markets and your potential market earnings similar to what you observe on the payment choice screen.

Finally, sellers who invest in the one-time fixed cost to accept payment 2 may have a negative "market earnings" in one or a few rounds. As a result of this, you may see a message screen explaining the situation. After you have been alerted to this situation, you can click on the "continue" button on the screen to proceed.

Figure 1: buyer's payment allocation screen

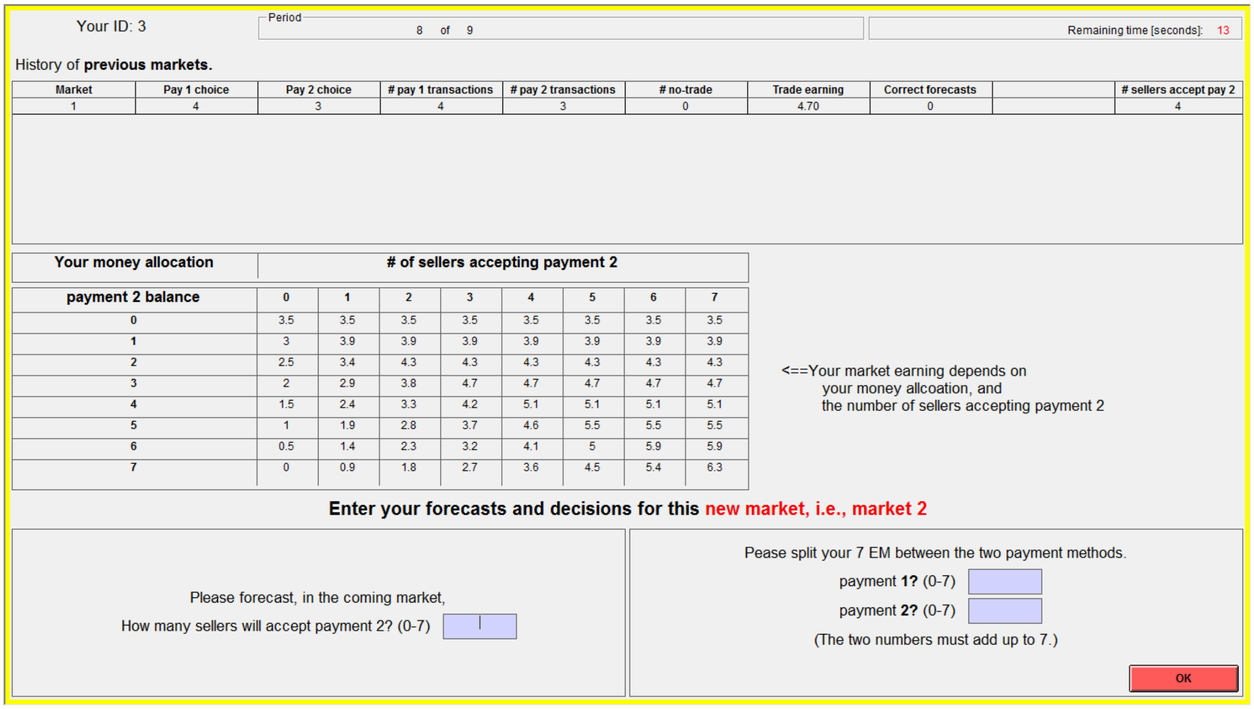


Figure 2: seller's payment 2 acceptance screen

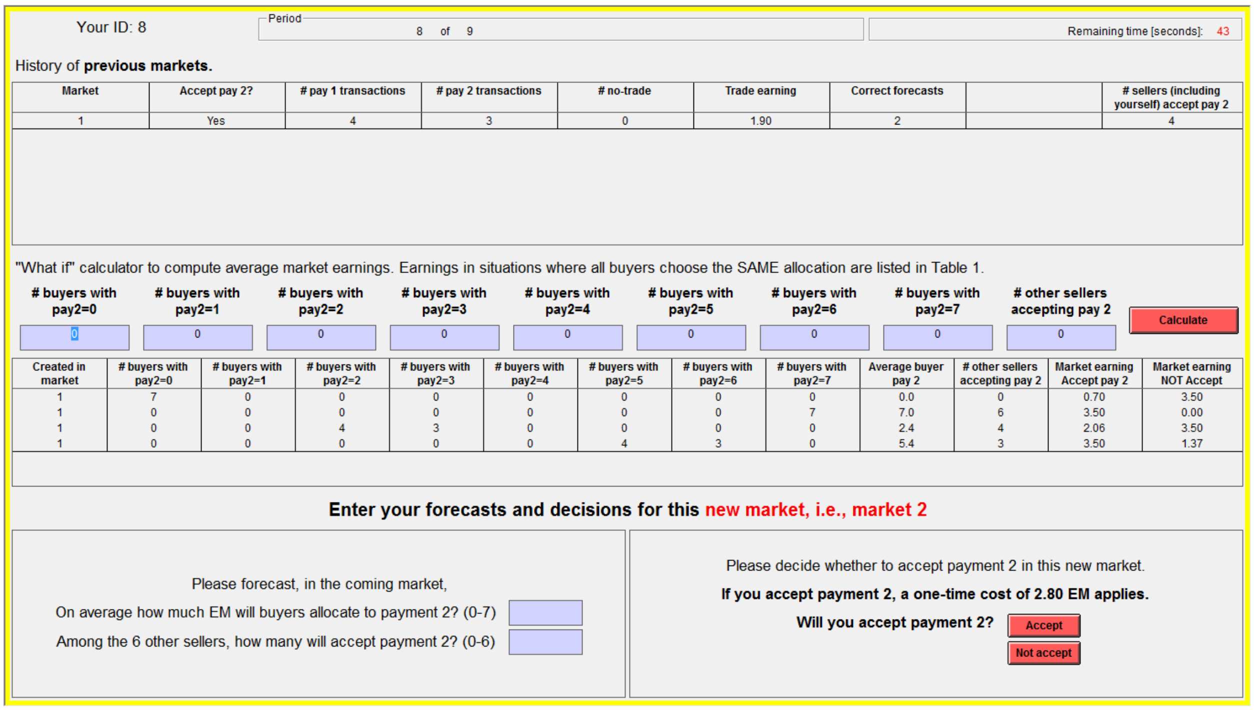


Figure 3: buyer's trading screen

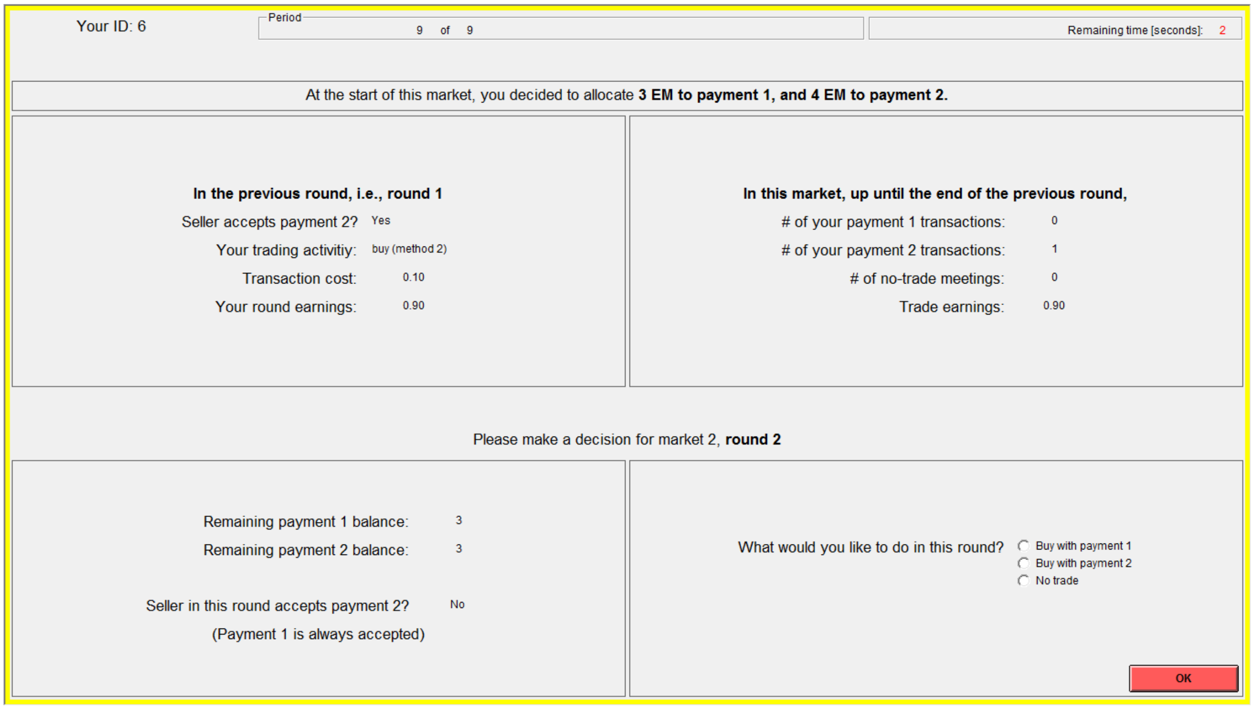


Figure 4: seller's trading screen

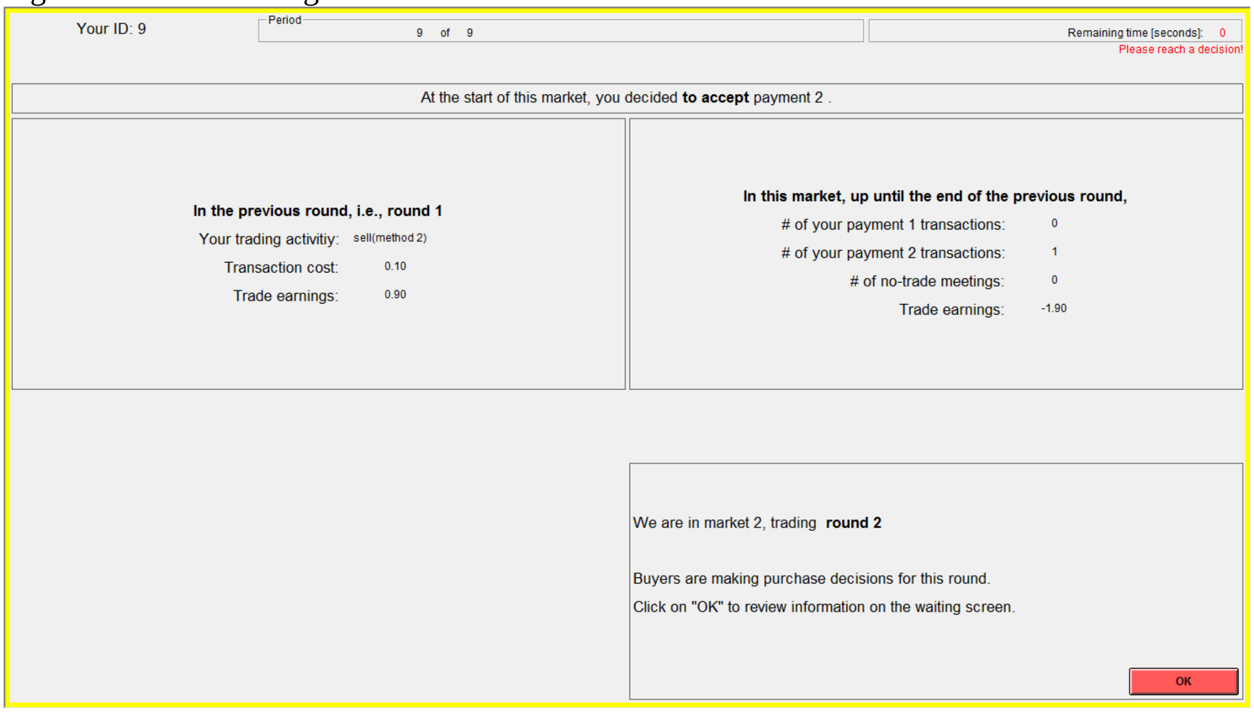


Figure 5: buyer's waiting/information screen

Your ID: 2

Period

8 of 9

History of **previous markets.**

Market	Pay 1 choice	Pay 2 choice	# pay 1 transactions	# pay 2 transactions	# no-trade	Trade earning	Correct forecasts		# sellers accept pay 2
1	5	2	5	2	0	4.30	0		4

Your money allocation	**# of sellers accepting payment 2**							
payment 2 balance	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
1	3	3.9	3.9	3.9	3.9	3.9	3.9	3.9
2	2.5	3.4	4.3	4.3	4.3	4.3	4.3	4.3
3	2	2.9	3.8	4.7	4.7	4.7	4.7	4.7
4	1.5	2.4	3.3	4.2	5.1	5.1	5.1	5.1
5	1	1.9	2.8	3.7	4.6	5.5	5.5	5.5
6	0.5	1.4	2.3	3.2	4.1	5	5.9	5.9
7	0	0.9	1.8	2.7	3.6	4.5	5.4	6.3

<==Your market earning depends on
your money allcoation, and
the number of sellers accepting payment 2

This is the waiting screen ...

We are in **market 2** the payment choice stage ...

You just decided to allocate **2 EM to payment 1, and 5 EM to payment 2.**

Some participants are still making their decisions.
While waiting, you can review the information on the screen.

Figure 6: seller's waiting/information screen

Your ID: 8

Period

8 of 9

History of **previous markets.**

Market	Accept pay 2?	# pay 1 transactions	# pay 2 transactions	# no-trade	Trade earning	Correct forecasts		# sellers (including yourself) accept pay 2
1	Yes	4	3	0	1.90	2		4

The "What if" records you have created.

Created in market	# buyers with pay2=0	# buyers with pay2=1	# buyers with pay2=2	# buyers with pay2=3	# buyers with pay2=4	# buyers with pay2=5	# buyers with pay2=6	# buyers with pay2=7	Average buyer pay 2	# other sellers accepting pay 2	Market earning Accept pay 2	Market earning NOT Accept
1	7	0	0	0	0	0	0	0	0.0	0	0.70	3.50
1	0	0	0	0	0	0	0	7	7.0	6	3.50	0.00
1	0	0	4	3	0	0	0	0	2.4	4	2.06	3.50
1	0	0	0	0	0	4	3	0	5.4	3	3.50	1.37

This is the waiting screen ...

We are in **market 2** the trading stage ...

You just decided **NOT to accept** payment 2 in this market

Some participants are still making their decisions.
While waiting, you can review the information on the screen.

Table 1: Seller’s average market earnings

- This table considers the case where ***all buyers choose the same payment allocation;*** use the “what-if” calculator for cases where buyers make different allocations.
- The earnings for ***accep****ting* payment 2 are in the ***upper-left*** corner,
- The earnings for ***not accep****ting* payment 2 are in the ***lower-right*** corner.

All buyer’s allocation to **payment 2**	# of **other 6 sellers** accepting payment 2							
	0	1	2	3	4	5	6	
0	0.7 3.5	0.7 3.5	0.7 3.5	0.7 3.5	0.7 3.5	0.7 3.5	0.7 3.5	←if accept pay 2 ←if not accept pay 2
1	3.5 3.0	2.1 3.5	1.6 3.5	1.4 3.5	1.3 3.5	1.2 3.5	1.1 3.5	
2	3.5 2.5	3.5 2.9	2.6 3.5	2.1 3.5	1.8 3.5	1.6 3.5	1.5 3.5	
3	3.5 2.0	3.5 2.3	3.5 2.8	2.8 3.5	2.4 3.5	2.1 3.5	1.9 3.5	
4	3.5 1.5	3.5 1.8	3.5 2.1	3.5 2.6	2.9 3.5	2.6 3.5	2.3 3.5	
5	3.5 1.0	3.5 1.2	3.5 1.4	3.5 1.8	3.5 2.3	3.0 3.5	2.7 3.5	
6	3.5 0.5	3.5 0.6	3.5 0.7	3.5 0.9	3.5 1.2	3.5 1.8	3.1 3.5	
7	3.5 0	3.5 0	3.5 0	3.5 0	3.5 0	3.5 0	3.5 0	

Table 2: Buyer’s market earning

Your allocation to **payment 2**	# of sellers accepting payment 2							
	0	1	2	3	4	5	6	7
0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
1	3.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9
2	2.5	3.4	4.3	4.3	4.3	4.3	4.3	4.3
3	2.0	2.9	3.8	4.7	4.7	4.7	4.7	4.7
4	1.5	2.4	3.3	4.2	5.1	5.1	5.1	5.1
5	1.0	1.9	2.8	3.7	4.6	5.5	5.5	5.5
6	0.5	1.4	2.3	3.2	4.1	5.0	5.9	5.9
7	0.0	0.9	1.8	2.7	3.6	4.5	5.4	6.3