

# Cheating in Markets: A Laboratory Experiment\*

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## Abstract

We develop a two-market model under three conditions: autarky, frictionless free trade, and free trade with cheating. Under cheating, in cross market trades the buyer can underpay by  $\pi\%$  and the seller can deliver  $\pi\%$  less than full value. We fully characterize competitive equilibrium with cheating and obtain novel testable predictions on price, volume and surplus. For example, agents with highest value and lowest cost are predicted to trade exclusively in the domestic market, while agents closer to the margin trade only in the cross market and always cheat; the overall volume is higher (!) than in frictionless free trade; and as  $\pi\%$  decreases from 100 to 0, domestic prices move non-linearly from autarky levels to the frictionless free trade level.

We test many of these predictions in a laboratory experiment with human traders using parameters intended to challenge the theory. The results are generally consistent with the competitive predictions, in the cheating treatments as well as in the autarky and frictionless free trade treatments. We find evidence of price unification, market segmentation, and an overall volume of trade higher (but a cross market volume lower) under cheating than in frictionless free trade.

Keywords: Cheating, Missing Trade Puzzle, Frictions, Market Experiment

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# 1 Introduction

A central theoretical proposition in economics, bolstered by laboratory experiments since Smith (1962), is that frictionless markets perform at 100% efficiency. Actual markets, however, face moderate to severe trading frictions. In particular, some buyers or sellers may cheat. The seller might ship an item of lower quality, and the buyer might not pay in full or on time.

Such “cheat frictions” are small (not zero) in well-run modern markets, but they loom large in major markets of the ancient and medieval world (e.g., Greif, 1993) and in some important contemporary markets. For example, according to some observers, eBay’s main competitive advantage in Internet auctions is that its reputation rankings reduce such frictions (e.g., Anderson et al., 2004; Resnick et al., 2004). Many observers believe that Russia’s economic woes in the last 15 years are due largely to uncompetitive markets, in particular to weak legal enforcement of contracts (e.g., Klebnikov, 2000; Leijonhufvud and Craver, 2001).

More generally, international trade economists for years have debated the so-called “mystery of the missing trade.” The observed volume of international trade is far smaller overall than predicted by traditional models, even when formal trade barriers are taken into account (Trefler, 1995; McCallum, 1995; Helliwell, 1998). A leading suspect is the lack of trust in the enforcement of contracts in international markets (e.g., Rauch, 2001; Anderson and Marcouiller, 2002). Hidden transaction costs in international trade include the possible extortion of bribes and corruption or hijacking of shipments, as well as more subtle delays in payment or quality shortfalls. Rodrik (2000) argues that contract enforcement is in fact more difficult where multiple legal jurisdictions are involved, and Marcouiller and Young (1995) argue that informal enforcement mechanisms are also less effective for international transactions. Anderson and Young (2002) show that imperfect contract enforcement in the importer’s country is equivalent to a tariff under risk neutrality.

In the present paper we develop a theoretical two-country model under three conditions: autarky, frictionless free trade, and international trade with cheating.<sup>1</sup> Under cheating, the buyer in international trades has the option to pay only a given fraction  $\pi < 1$  of the agreed price, and the seller has the option to deliver only  $\pi$  of the value. Contracts are fully enforced in domestic transactions. Thus buyers and sellers must trade off better opportunities in international markets against the friction of imperfect contract enforcement.

The model can be solved explicitly to characterize competitive equilibrium with cheating for any value of  $\pi \in [0, 1]$ . At  $\pi = 1.0$ , of course, we have frictionless free trade and, not surprisingly, at  $\pi = 0.0$  the model predicts a reversion to autarky. In between, the model yields novel testable predictions on price, volume and surplus. For example, agents with highest value and lowest cost are diverted to inefficient domestic transactions, while agents closer to the margin trade only internationally and always cheat. The overall volume of trade is higher (!) than in frictionless free trade, but (consistent with the missing trade literature) international trade volume is lower and, of course, overall surplus extraction is lower. As  $\pi$  decreases from 1.0 to 0.0, domestic prices move non-linearly from autarky levels to the frictionless free trade level.

The competitive model is then tested in a new laboratory environment in which human subjects can trade (and keep profits) in a home (“local”) market and also (except in the autarky treatment) in a foreign (“distant”) market. In the cheating treatment, contracts are not perfectly enforceable in the foreign market and traders remain anonymous in the foreign market under the cheating treatment so they cannot establish a reputation. This new laboratory environment allows us to investigate several issues.

First, what is the predictive power of the classic models of autarky and free trade?

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<sup>1</sup>In order to focus sharply on the questions of present interest, the model neglects income effects and production, and so has a partial equilibrium flavor. Noussair, Plott and Reizman (1995) and subsequent work demonstrates that the full general equilibrium model allows laboratory investigation of a different set of issues, such as the impact of international trade on resource allocation and the dynamics of intermarket equilibration.

As explained below, our supply and demand configurations are simple but present a real challenge for the classic models. In particular, does frictionless free trade always produce unified prices, i.e., does purchasing power parity hold between the two markets? More generally, is convergence slowed or stopped by the many options of where to trade, with whom, and whether to cheat? Of special interest, does the new theoretical model predict the outcomes well when cheating is allowed?

The results of our experiment are generally consistent with the predictions of the model in the cheating treatments as well as in the autarky and frictionless free trade treatments. We find strong evidence of price unification and some evidence of market segmentation. When contracts are not enforceable the overall volume of trade is indeed higher than in frictionless free trade (and autarky) while the volume of international trade is somewhat lower than in frictionless free trade, in line with the missing trade literature.

The paper is organized as follows. Section 2 presents the experimental design. Section 3 summarizes the theoretical model. Section 4 presents the results followed by a discussion in Section 5. Mathematical details on the competitive model appear in Appendix A, and complete instructions to subjects are attached as Appendix B.

## 2 Experimental Design

The experiment uses the well-known continuous double auction (CDA) market format. At any instant during a trading period, each buyer can post a public bid (offer to buy a unit at a given price or better) and each seller can post a public ask (offer to sell a unit at a given price or better). Each trader also at any instant can accept another trader's offer and immediately transact at the posted price  $p$ . A buyer with unit value  $v$  earns the profit or surplus  $v - p$  on the transaction, and a seller with cost  $c$  on the unit earns  $p - c$ , so the overall gains on the transaction are  $v - c$ .

Our computerized CDA has several distinctive features, illustrated in Figure 1. Two

markets run simultaneously. Depending on the treatment, a trader may be able to trade only in her home market (“Local Market”), or in both markets (“Local Market” and “Distant Market”). Each trader can transact up to 4 units each period, and different units can have different cost or value. Each trader has a “nickname” that in the autarky and frictionless free trade can be used to identify her to potential transaction partners. In the cheating friction treatment, the nickname is suppressed and only “??” is seen in the distant market. Figure 1 shows the window active during the trading period. Between trading periods traders can view past transactions and profits by clicking the history tabs. All the screens seen by the subjects are shown in Appendix B.

Sixteen human subjects (recruited by email from a list of hundreds of volunteers, most UCSC undergraduates) participated in each laboratory session. Some sessions used only subjects with no prior experience with our laboratory market. Other sessions used only experienced subjects, who had participated in one prior session. Subjects were assigned to two “Local Markets” each comprised of four buyers and four sellers. The discussion below will refer to the two markets as Red and Blue.

Each session began by going through part A of the instructions (reproduced in Appendix B), followed by a practice period. Next came the first block of 3 to 4 periods, and then later parts of the instructions and later blocks of periods using different treatments. Buyer values and seller costs were reshuffled once about half-way through the two-hour sessions with experienced subjects. Each trading period lasted 240 seconds with a 10 second break between periods. After the last period, subjects were paid a \$5 show-up fee plus earnings for all periods; most subjects earned between \$15 and \$35. Tables 2a and 2b report the treatments used in each block in each session.

**Autarky Treatment.** Sessions with inexperienced traders begin with 3 periods of autarky, in which they can buy and sell only in the “Local Market”. As shown in Figure 2 and Table 1, supply and demand are higher in the Red market than in the Blue market.

**Frictionless Free Trade Treatment.** Sessions with inexperienced traders continue

with 3 periods of frictionless free trade. Here each trader can participate in both markets at the same time. Side-by-side color-coded copies of the main window allow each trader to post, observe and accept offers in the distant market as well as in the local market. The third panel of Figure 2 shows the total demand and supply when cross market trade is allowed.

**Cheat Treatment.** The next 4 period block in sessions with inexperienced traders, and the first block of 4 periods with experienced players, features the option to cheat a fixed exogenous degree  $\pi = 0.5$  in trades in the distant market. Cheating is never allowed in local trades, e.g., in the Blue market between two Blue traders. The choices are sequential. First the trader accepting an offer chooses whether to cheat. That choice is observed by the trader who posted the offer, who then decides whether to cheat. Sellers cheat by delivering a good that costs  $\pi c$  instead of  $c$  and that provides value  $\pi v$  instead of  $v$ . Buyers cheat by paying only  $\pi p$  instead of  $p$ . (Instructions avoid the word “cheat,” and just talk about the choice of paying 100 $\pi$ % or 100%, etc.)

For example, suppose that  $\pi = 0.5$  and that a buyer posts bid price  $p = 50$  on a unit he values at  $v = 60$ . If a seller from the distant market with cost  $c = 40$  accepts and decides not to cheat but the buyer then decides to cheat, then the buyer surplus is  $v - \pi p = 60 - 0.5 * 50 = 35$  and the seller surplus is  $\pi p - c = 0.5 * 50 - 40 = -15$ .

It should be emphasized that in this treatment, cross market transactions are anonymous. Traders’ nicknames are shown in all-local market transactions, but are replaced by “??” when they post or accept bids and asks in distant markets. The idea to avoid the complications of international reputation and first-degree price discrimination.

### 3 Theoretical Predictions

Computing the competitive equilibrium (CE) predictions is straightforward under autarky and free trade. A careful examination of Figure 2 will convince the readers that in Red

market autarky, the CE price is  $p_{RA}^* = 65$ , and quantity is  $q_{RA}^* = 8$ . Since the price is set by the marginal sellers, buyer surplus of 100 is larger than seller surplus of 60, resulting in total Red market surplus of 160. The autarky CE in the Blue market has the same quantity and surplus but at CE price  $p_{BA}^* = 25$ . Overall surplus in autarky is  $S_A = S_{RA} + S_{BA} = 320$ , as indicated in the first row of Table 3.

The supply and demand curves in frictionless free trade are the (horizontal) sum of supply and demand in Red and Blue markets, as depicted in the third panel of Figure 2. The CE is seen to have  $p_{FT}^* = 45$ , quantity  $q_{FT}^* = 16$ , and a resulting surplus  $S_{FT} = 640$ . In the second row of Table 3, these predictions are entered in the cross-market column because in the frictionless free trade CE, Blue sellers will “export” and sell units to Red buyers. See Appendix A for details of the CE computations.

Note that CE trade volume in frictionless free trade remains the same as in autarky, but the CE surplus doubles to 640, of which 360 is Blue seller surplus and 280 is Red buyer surplus. The environment is a challenge for theory, especially because CE surplus falls to 0 for Blue buyers and for Red sellers. This extreme redistribution may retard convergence to CE and may encourage violations of purchasing power parity.

Competitive equilibrium with cheating is not covered in textbooks and so deserves a full explanation. The option to cheat means that there are additional markets. Besides domestic transactions in Red and Blue markets where no cheating is allowed, there are international transactions in each market that may or may not involve cheating. At first glance, then, it might seem that there are four additional markets. However, in equilibrium these collapse to just one additional market: international transactions where both parties cheat. The full explanation appears in Appendix A. In brief, the idea is (a) cheating is always the best response in international transactions so the non-cheating international markets disappear, and (b) arbitrage eliminates price differences in international trade, so international trades (all involving cheating) should take place at the same price in both Red and Blue markets.

The upshot is that there are three distinct markets in equilibrium, denoted R (Red

domestic), B (Blue domestic) and C (cheat or cross). In any competitive equilibrium, traders take as given a vector of prices and choose quantities so as to maximize profit. The resulting supply and demand schedules then must clear at the given prices. A CE with cheating  $\pi \in (0, 1)$  thus is a price vector  $p^* = (p_R^*, p_B^*, p_C^*)$ , together with the associated trades, such that

- Every Blue trader transacts each unit in market B or C or holds the unit, whichever is more profitable. Given  $\pi$  and  $p^*$ , this condition yields the quantity supplied and demanded in market B, and Blue traders' portion of supply and demand in market C.
- Every Red trader transacts each unit in market R or C or holds the unit, whichever is more profitable. Given  $\pi$  and  $p^*$ , this condition yields the quantity supplied and demanded in market R, and Red traders' portion of supply and demand in market C.
- Supply equals demand in each of the three markets, given  $\pi$  and  $p^*$ .

Using a close linear approximation of the laboratory parameters, Appendix A derives closed form expressions for an essentially unique CE for arbitrary  $\pi \in [0, 1]$ . The expressions coincide with the autarky CE for  $\pi = 0$  and coincide with the frictionless free trade CE for  $\pi = 1$ . In between, the CE varies smoothly but non-linearly between the two extremes. It allows some traders that are extramarginal in autarky and frictionless free trade to be able to earn profits.

The last row in Table 3 summarizes the CE outcomes for  $\pi = 0.5$ . Because of the discrete supply and demand, one of the price predictions is no longer unique but still lies in a narrow interval. CE prices are: 45 in the cross-market, 32.5 – 35 in the Blue market, and 60 in the Red market. CE trading volume increases from 16 to 22 units: 10 units trade across markets and involve cheating by both buyer and seller, while 6 units trade domestically in each home market.

Despite the higher overall trading volume, the CE surplus decreases to 425. An intuitive explanation is that relative to frictionless trade, actual cheating cuts the surplus in half in each transaction in C. Moreover, the threat of cheating in C causes high-surplus traders to retreat to their home markets where they transact with low surplus traders (high cost sellers in R and low value buyers in B). Transactions involving these low surplus traders are inefficient, so the mere threat of cheating also reduces the surplus while reducing the volume of cross market trade.

Besides the specific predictions in Table 3 we shall test three more general hypotheses.

**H1. Price unification, or purchasing power parity.** Under frictionless free trade, mean transaction price is the same in the Red market as in the Blue market. The natural alternative to this null hypothesis is that inertia allows Blue prices to remain lower than Red.

**H2. Market segmentation.** When cheating is allowed, traders with highest value and lowest cost trade exclusively in the domestic market, and traders closer to the margin trade only in the cross market. The null hypothesis is that value and cost are unrelated to choice of domestic vs cross market.

**H3. Trade volume.** Overall volume is higher when cheating is allowed than under either frictionless free trade or Autarky. The null hypothesis is that trading volume is independent of treatment. An alternative research hypothesis (suggested by behavioral economics and by some intuitions on missing trade) is that volume is lower when cheating is allowed.

## 4 Results

We ran ten sessions with inexperienced traders and seven sessions with experienced traders, with treatments summarized in Tables 2a and 2b. We begin by summarizing the outcomes under the three treatments, and then examine tests of the main hypotheses.

**Autarky.** Figure 3 shows the real-time sequence of transactions in all Autarky periods. With inexperienced traders, actual prices converge towards CE from above in the low price Blue market, and converge from below in the high price Red market. Table 4 shows that the standard deviation of prices declines in both markets; the only exception is due to a few outliers in the Red market for period four. By the final period, this measure of price dispersion is down to 3.0 for the Blue market and 5.1 for the Red, while the average price is within 0.3 of the CE predictions. Over all periods and in both markets, average price is within a fourth or less of a standard deviation of the CE prediction. Thus price convergence is quite sharp in both high and low price markets.

Average trading volume is within 1.0 unit of the CE prediction in every period in both markets, and the overall average volume of 8.1-8.3 is very close to the 8.0 prediction. Average gains from trade are 286.4, about 89.5% of the CE prediction 320.0.

**Frictionless Free Trade.** Table 5 and Figures 4 and 5 show behavior in Frictionless Free Trade. As predicted, domestic trade volume shrivels, averaging 1.3 unit or less each period in both Red and Blue markets. Average volume in the cross market reaches 15.4 in the fourth period and averages 15.2 overall, quite close to the CE prediction of 16.0. Average prices in the cross market (and overall) are within 0.3 of the CE prediction 45. Price dispersion declines dramatically in the cross market; the standard deviation falls from 11.6 to 3.6. A key prediction is that CE surplus doubles to 640. The average realized surplus also rises sharply. It is above 600 in 3 of 4 periods, and efficiency reaches at  $619.3/640=94.8\%$  in the last period, and  $619.3/640=94.8\%$  overall.

We conclude that actual behavior tracks the extreme CE predictions surprisingly well in the first two treatments.

**Trade with Cheating Frictions.** Tables 6ab and 7ab and Figures 6-9 show behavior when cheating is allowed in cross market trade. With inexperienced subjects who have just finished the frictionless free trade treatment, the actual average number of cross-market trades with no cheating falls from 15.2 to 1.7, compared to the CE predicted fall from 16.0

to 0. Meanwhile, the average number of cross-market trades with cheating rises to 13.2, beyond the CE forecast of 10.0. With experienced traders, the average number of cross-market trades with no cheating falls to 2.3, and the average number with cheating rises to 9.0. Thus cheating is indeed rampant in cross-market trade (89% of trades for inexperienced and 80% for experienced traders), and deviations from the CE quantity predictions diminish with time for inexperienced traders. (The trend for experienced traders is less clear, a point we shall return to later.)

The predicted price is 45 for cross market trades, and average prices are 45.9 for inexperienced and 48.2 for experienced traders. Standard deviation of price declines over time, and averages about 6 for inexperienced and less than 5 for experienced traders. Thus there is approximate price convergence to CE, in some respects even tighter than in the frictionless free trade treatment.

The CE model overpredicts trade volume in the two domestic markets. Actual volume in both local markets averages about a third of the predicted 6.0 for inexperienced subjects and around half the predicted value with experienced subjects. The trend is upward but slow. Slow convergence is also seen in domestic prices which remain less extreme than predicted, and fairly dispersed, even later periods with experienced subjects. Average price stays about 5 points above the predicted band in the Blue market and 3.5 below in the Red market with inexperienced traders, while with experienced traders the prices are a bit closer in the Blue but a little further in the Red.

Total surplus is quite variable in this treatment:  $385.6 \pm 56.8$  with inexperienced traders and  $428.7 \pm 81.7$  with experienced, versus the CE prediction of 425. The no-cheat cross-market trades increase surplus beyond the CE prediction, but the other departures from CE more than offset.

The CE predictions for this treatment again are rather extreme, and again behavior moves strongly in the predicted direction. We have less than complete convergence, however, and in particular the domestic trade volume does not recover to the predicted level.

Table 8 reports the test statistics for the three general hypotheses.

**H1. Price unification.** The average price for the 373 trades executed in the Red market (including both domestic and cross market transactions) in frictionless free trade was 45.5, versus 45.1 for the 268 Blue market trades. The two sample t-test statistic for equality of these averages is -0.50 (p-value 0.62), and the non-parametric Mann-Whitney test statistic is -0.14 (p-value 0.89). We cannot reject the null hypothesis of price unification and we conclude that prices are quickly unified under frictionless free trade.

**H2. Market segmentation.** When cheating is allowed in inexperienced sessions, Red buyers acquire units domestically in the Red market with average value 76.4 versus average value 60.3 for units they acquire in the cross market. The t-test statistic is 8.30 (p=0.00), and the MW test is 8.12 (p=0.00). In experienced sessions the value averages are 70.4 for the domestic market and 64.9 for the cross market, with  $t=3.32$  (p=0.00) and  $MW=3.56$  (p=0.00). Segmentation is therefore quite significant and in the predicted direction for Red buyers.

For inexperienced sellers, units sold domestically in the Blue market have average cost 21.9 versus 28.9 for units sold by Blue sellers in the cross market. The associated t-statistic is -3.94 (p=0.00) and the MW statistic is -3.68 (p=0.00). For experienced subjects, the averages are 19.9 in the domestic Blue versus 27.2 in the cross market;  $t=-5.85$  (p=0.00) and  $MW=-6.60$  (p=0.00). Thus the segmentation hypothesis also prevails for Blue sellers.

**H3. Trade volume.** Overall volume averages for inexperienced subjects are 16.3 units per period in autarky, versus 17.3 in frictionless free trade and 18.5 when cheating is allowed. As predicted, the difference between cheating and frictionless free trade is significant:  $t=3.11$  (p=0.00) and  $MW=3.13$  (p=0.00), as well as the difference between cheating and autarky:  $t=6.26$  (p=0.00)  $MW=5.23$  (p=0.00). Thus the data support a distinctive implication of the theoretical model.

## 5 Discussion

In this paper we extend the competitive equilibrium (CE) model to predict the impact of an important friction, weaker contract enforcement in international trade. We then subject the basic and extended CE model to a laboratory stress test. The laboratory parameters are chosen to deliver violent dislocations in CE prices, trading partners, transaction volume and total surplus as we change treatments from autarky to frictionless free trade to trade with enforcement frictions. The laboratory data nevertheless follow the CE predictions rather closely. In particular,

1. In autarky with inexperienced subjects, both Red and Blue markets converge rapidly to the CE price and trading volume. Efficiency, i.e., surplus extraction as a fraction of the maximum possible, averages 89.5%, somewhat lower than in typical double auction markets (which usually run for more than 4 periods).
2. In frictionless free trade, convergence to CE prices and quantities is surprisingly rapid given the choice of extreme parameters that sideline all Blue buyers and all Red sellers. Surplus extraction is quite good, and average efficiency rises to 94.8%.
3. Price unification (or purchasing power parity) is essentially complete in frictionless free trade.
4. Outcomes when traders can cheat on international transactions are predicted well by a new extension of the competitive equilibrium model. Trading volume indeed increases significantly, cheating predominates in foreign trade, and higher valued buyers and lower cost sellers retreat to their domestic markets. The precise quantitative predictions of the model are quite accurate for average prices in all markets, quantities in the cross market, and overall surplus. The model overpredicts the level of domestic trade although sessions with experienced subjects move in the right direction.

Although the CE model does a remarkably good job overall of explaining the data, there is one quirk or anomaly that might be worth pursuing. Both experienced and inexperienced traders completed an average of 2.8 units of completely honest transactions in the first period without full contract enforcement. In later periods with inexperienced traders, that number declined steadily to 1.1 by the fourth and last period, seemingly headed to the CE prediction of 0.0. But with experienced traders, such honesty decayed more slowly, and increased back to 2.3 in the last period. This does not represent a large fraction of the cross market transactions, but it is large enough to raise the question of whether convergence to the CE prediction with cheating would ever be complete. There is evidence from a variety of non-market experiments beginning with Berg, et al. (1995) that some individuals, even with complete anonymity, seek fairness and are willing to trust anonymous counterparties, who in turn often reward their trust. Such behavior may also have some role in our market setting.

Clearly, however, the enforcement friction leads to a major deterioration in market performance, in the laboratory as well as in the CE model. What market (or interpersonal) institutions might evolve to mitigate such trading frictions? We plan to explore that question in subsequent work.

## **6 Appendix A: Theoretical Derivation**

First we derive competitive equilibrium (CE) predictions, focusing on the case of linear demand and supply that closely approximate the parameters used in the experiment. Then we derive the predictions for the actual step functions used in the experiment.

### **6.1 Linear Demand and Supply**

#### **Autarky**

The Red market inverse demand function is

$$p_{RA}^D = \begin{cases} 85 - \frac{5}{2}q, & q \in [0, 16]; \\ 0, & q > 16, \end{cases} \quad (1)$$

and the inverse supply function is

$$p_{RA}^S = \begin{cases} 45 + \frac{5}{2}q, & q \in [0, 16]; \\ \infty, & q > 16. \end{cases} \quad (2)$$

Autarky CE in the Red market  $(p_{RA}^*, q_{RA}^*)$  is characterized by the supply = demand condition  $p_{RA}^S(q) = p_{RA}^D(q)$ . The unique solution for the functions (1) and (2) is  $q_{RA}^* = 8$ , so  $p_{RA}^* = p_{RA}^S(8) = 65$ . The associated buyer surplus is  $\int_0^{q^*} (p^D(q) - p^*)dq = 80$ , while seller surplus is  $\int_0^{q^*} (p^* - p^S(q))dq = 80$  and so CE surplus in the Red market is  $S_{RA} = 160$ .

Similarly in the Blue market, the autarky inverse demand is  $p_{BA}^D = 45 - \frac{5}{2}q$  for  $q \in [0, 16]$  and is 0 for larger  $q$ , while inverse supply is  $p_{BA}^S = 5 + \frac{5}{2}q$  for  $q \in [0, 16]$  and is unbounded for larger  $q$ . The associated CE price is  $p_{BA}^* = 25$  with CE quantity  $q_{BA}^* = 8$ . Again buyer surplus and seller surplus both are 80, so  $S_{BA} = 160$ . Overall CE autarky surplus is  $S_A = S_{RA} + S_{BA} = 320$ .

### Free Trade

Summing the direct demand functions obtained from the inverse demand functions given above, one can verify that the total inverse demand function is  $p_{FT}^D = 85 - \frac{5}{2}q$  for  $q \in [0, 32]$ , and is 0 for larger  $q$ . Likewise, the total inverse supply function is  $p_{FT}^S = 5 + \frac{5}{2}q$  for  $q \in [0, 32]$  and is unbounded for larger  $q$ . Frictionless free trade CE is the unique solution to total supply = total demand, namely price  $p_{FT}^* = 45$  and quantity  $q_{FT}^* = 16$ . Now buyer surplus is 320, and by (1), it all goes to Red buyers. Likewise, seller surplus is also 320, all of which goes to Blue sellers. Overall CE surplus in frictionless free trade is  $S_{FT} = S_{RFT} + S_{BFT} = 640$ .

### Cheating Frictions

The analysis of cross-market trade with frictions is less familiar and more complex, so we proceed in small steps. Recall that cheating is an option for each party in a cross market transaction, but is not an option for either party in a domestic transaction. Recall also that cross-market transactions are anonymous. Under the usual competitive assumption, decisions on cheating have no consequences regarding one's own future trading opportunities. (The assumption is reasonable here because of anonymity.) Therefore rationality dictates maximizing profit separately on each transaction.

In the main protocol in the experiment, the trader posting the accepted price observes the acceptor's decision on whether or not to cheat before making her own decision. Cheating is a dominant strategy for her. For example, suppose she is a seller with cost  $c$  who posted ask price  $p$ , and the buyer cheated. Then she will receive revenue  $\pi p$  whether or not she cheats. She will incur cost  $\pi c$  if she cheats, or cost  $c$  if she doesn't. For any  $\pi < 1$  she maximizes profit by cheating. If the buyer didn't cheat the revenue is higher but the argument is the same. The argument is essentially the same if she is a buyer with value  $v$  who posted bid price  $p$ : her revenue is fixed (at  $\pi v$  if the seller cheated or at  $v$  if not) but cheating always reduces her cost and increases her profit. Since the party posting the price has a dominant strategy, there is a unique subgame perfect equilibrium, and in it the party accepting the price also cheats. Some early pilot experiments used a simultaneous decision protocol, equivalent to the classic prisoner's dilemma. Here cheating is a dominant strategy for both parties.

Hence in any equilibrium, cheating is universal in cross-market transactions. One convenient consequence is that there is only one cross-market in equilibrium. If cross-market transaction prices were higher in the Blue market, for example, then more sellers and fewer buyers would go there. Such shifts in cross-market supply and demand would equalize prices and thus unify the cross-market.

Another convenient consequence is that profit (or surplus) is easy to characterize. In a domestic transaction at price  $p$  between a buyer with value  $v$  and a seller with cost

$c$ , the buyer's surplus is  $v - p$  and the seller's surplus is  $p - c$ , since cheating is not an option. By contrast, in a cross-market transaction with cheating, the buyer's surplus is  $\pi v - \pi p = \pi(v - p)$  and the seller's surplus is  $\pi(p - c)$ .

Now we can characterize supply and demand. Fix  $\pi \in (0, 1)$ , and suppose traders take as given the price vector  $(p_R, p_B, p_C)$ . Then a Red Buyer with value  $v = v^*$  is indifferent between a domestic and cross market transaction, where  $v^*$  satisfies the equal profit condition

$$\pi(v - p_C) = v - p_R \quad (3)$$

The left hand side of (3) increases more slowly in  $v$  than the right hand side. Hence for  $v > v^*$  a domestic transaction is more profitable, while for  $v < v^*$  a cross-market transaction is more profitable. Thus in equilibrium the inverse demand curve in the Red market is truncated below at  $p_R^D = v^*$ , and inverse demand in the cross-market is truncated above at the same point.

Likewise, a Blue seller's indifference condition is

$$\pi(p_C - c^*) = p_B - c^*. \quad (4)$$

Sellers with higher cost prefer the foreign market C and sellers with lower cost prefer the domestic market B. The Blue inverse supply curve thus is truncated above at  $p_B^S = c^*$ , and inverse supply in the cross-market is truncated below at the same point.

### **Equilibrium with Cheating Frictions**

We seek a price vector  $(p_R, p_B, p_C)$  such that supply = demand simultaneously in the three interdependent markets. Assuming (to be checked later) that the truncation binds in the Red market, equate Red supply at  $p_R$  to Red demand at  $v^*$  to obtain  $p_R = 45 + \frac{5}{2}q = 45 + \frac{5}{2}[\frac{2}{5}(85 - v^*)] = 130 - v^*$ . Solve (3) to obtain  $v^* = \frac{1}{1-\pi}p_R - \frac{\pi}{1-\pi}p_C$ . Insert this into the

previous expression for  $p_R$  and simplify to obtain

$$(2 - \pi)p_R = \pi p_C + (1 - \pi)130. \quad (5)$$

Likewise, assume that the truncation binds in the Blue market, equate Blue demand at  $p_B$  to Blue supply at  $c^*$  to obtain  $p_B = 45 - \frac{5}{2}q = 45 - \frac{5}{2}[\frac{2}{5}(c^* - 5)] = 50 - c^*$ . Solve (4) to obtain  $c^* = \frac{1}{1-\pi}p_B - \frac{\pi}{1-\pi}p_C$ . Insert into the previous expression for  $p_C$  and simplify to obtain

$$(2 - \pi)p_B = \pi p_C + (1 - \pi)50. \quad (6)$$

Finally, consider direct supply and demand in the cross market. Supply is the residual from the Blue market,  $S_C(p_C) = S_B(p_C) - S_B(c^*) = \frac{2}{5}(p_C - c^*)$ . Demand is the residual from the Red market,  $D_C(p_C) = D_R(p_C) - D_R(v^*) = \frac{2}{5}(v^* - p_C)$ . Equate the two expressions and simplify to obtain  $p_C = \frac{1}{2}(c^* + v^*)$ . Insert the expressions for  $v^*$  and  $c^*$  obtained earlier and simplify to obtain

$$p_C = \frac{p_R + p_B}{2}. \quad (7)$$

We now have a full characterization of the equilibrium. To obtain explicit expressions, insert (7) into (5) and (6) and solve to get, for all  $\pi \in [0, 1]$

$$p_C = 45, \quad (8)$$

$$p_R = \frac{130 - 85\pi}{2 - \pi}, \quad (9)$$

$$p_B = \frac{50 - 5\pi}{2 - \pi}, \quad (10)$$

$$v^* = \frac{130 - 45\pi}{2 - \pi}, \text{ and} \quad (11)$$

$$c^* = \frac{50 - 45\pi}{2 - \pi} \quad (12)$$

It is straightforward to check that the truncations bind at  $v^*$  and  $c^*$  when  $\pi \in (0, 1)$ .

For  $\pi = 1$  the expressions reduce to the frictionless free trade CE,  $p_R = p_B = p_C = 45$ . For  $\pi = 0$  we obtain the autarky CE,  $p_R = 65$  and  $p_B = 25$ ; since also  $v^* = 65$  and  $c^* = 25$  the units that trade in autarky all trade domestically. Of course, with  $\pi = 0$ , nobody can earn a positive equilibrium profit in the cross market anyway.

The transition between autarky and frictionless free trade is non-linear as  $\pi$  varies in  $(0, 1)$ . For instance,  $\frac{dp_R}{d\pi} = \frac{-40}{(2-\pi)^2} < 0$ , and  $\frac{d^2p_R}{d\pi^2} = \frac{80}{(2-\pi)^3} > 0$ , so  $p_R$  is a decreasing convex function of  $\pi$ . Likewise,  $p_B$  is increasing and concave in  $\pi$ .

## 6.2 Step Functions

With the actual step functions used in the experiment, it is routine to compute competitive equilibrium (CE) under autarky and frictionless free trade. One simply draws the usual supply and demand curves as in Figure 2 (and Table 1) and analyzes them as in the text.

### Equilibrium with Cheating Frictions

The previous section introduced all the ideas necessary to compute CE in the cheating treatment, but obtaining exact results with step functions requires some extra work. The work is simplified by noting:

- Demand and supply in market B depend on  $p_C$  but not on  $p_R$ , and likewise demand and supply in market R depend on  $p_C$  but not on  $p_B$ . This follows from the earlier observation that in equilibrium all cross market transactions involve cheating.
- The only possible equilibrium price in Market C is  $p_C = 45$ . This result arose from symmetry in the linear case, and it is true *a fortiori* in the step function case because there is an extra-wide step in the demand function (four units) at that price.

Due to those simplifications, in computing CE it suffices to compute supply and demand (or excess demand) in the domestic markets as functions only of own price, and the resulting

spillovers of demand and supply into market C, under the maintained assumption that  $p_C = 45$ . Such computations are reported in the following two tables.

Blue market $p_B$	# Blue units offered in			# Blue units demanded Domestically up to
	Cross-market $\Pi_C > \Pi_B$	Indifferent $\Pi_C = \Pi_B$	Domestic (Blue) $\Pi_C < \Pi_B$	
< 27.5	16	0	0	8 if (20, 27.5)
27.5	14	2	0	8
(27.5, 30)	14	0	2	8
30	12	2	2	8
(30, 32.5)	12	0	4	6
32.5	10	2	4	6
(32.5, 35)	10	0	6	6
35	6	4	6	6
(35, 37.5)	6	0	10	4
37.5	4	2	10	4
(37.5, 40)	4	0	12	4
40	2	2	12	4
(40, 42.5)	2	0	14	2
42.5	0	2	14	2
> 42.5	0	0	16	2 if (42.5, 45] 0 if > 45

Red market $p_R$	# Red units demanded			# Red units offered
	Cross-market $\Pi_C > \Pi_R$	Indifferent $\Pi_C = \Pi_R$	Domestic (Red) $\Pi_C < \Pi_R$	Domestically (up to)
< 45	0	0	16	0
45	0	2	14	0
(45, 47.5)	2	0	14	0
47.5	2	2	12	0
(47.5, 50)	4	0	12	0
50	4	2	10	2
(50, 52.5)	6	0	10	2
52.5	6	2	8	2
(52.5, 57.5)	8	0	8	2 if (52.5, 55) 4 if [55, 57.5)
57.5	8	2	6	4
(57.5, 60)	10	0	6	4
60	10	2	4	6
(60, 62.5)	12	0	4	6
62.5	12	2	2	6
(62.5, 65)	14	0	2	6
65	14	2	0	10
> 65	16	0	0	10 if (65, 70) 12 if [70, 75) 14 if [75, 80) 16 if $\geq 80$

Inspection of the tables, row by row, discloses that there is excess demand in the Red market at prices below  $p_R = 60$  and excess supply at higher prices, so the only candidate for equilibrium is  $p_R = 60$ . In the Blue market there is excess demand at prices below  $p_B = 32.5$  and excess supply at prices above  $p_B = 35$ . Hence the only candidate CE price vectors are  $p_C = 45$ ,  $p_R = 60$ ,  $p_B \in [32.5, 35]$ . The corresponding supply and demand quantities balance at  $q_C = 10$ ,  $q_R = 6$ , and  $q_B = 6$ . These result in surpluses  $S_C = 125$ ,  $S_R = 150$ , and  $S_B = 150$ .

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Table 1. Parameters

Market BLUE					Market RED				
Buyers' Values					Buyers' Values				
Buyer ID	Unit 1	Unit 2	Unit 3	Unit 4	Buyer ID	Unit 1	Unit 2	Unit 3	Unit 4
B1	45	45	20	20	<b>B1*</b>	85	85	80	80
B2	40	40	15	15	<b>B2*</b>	60	60	55	55
B3	35	35	10	10	<b>B3*</b>	75	75	50	50
B4	30	30	5	5	<b>B4*</b>	70	70	45	45
Sellers' Costs					Sellers' Costs				
Seller ID	Unit 1	Unit 2	Unit 3	Unit 4	Seller ID	Unit 1	Unit 2	Unit 3	Unit 4
S1	10	10	15	15	<b>S1*</b>	50	50	65	65
S2	25	25	30	30	<b>S2*</b>	55	55	70	70
S3	20	20	35	35	<b>S3*</b>	60	60	75	75
S4	25	25	40	40	<b>S4*</b>	65	65	80	80

Table 2a. Experimental Design - Inexperienced Subjects

Session	Periods	Treatment	Session	Periods	Treatment
CHEAT05 (Jan16, 2004)	1-3	A	NETCHEAT04 (Mar03, 2005)	1-4	A
	4-6	FT		5-8	FT
	7-9	C		9-12	C
	10-15	N		13-16	N
CHEAT06 (Feb06, 2004)	1-3	A	NETCHEAT06 (Mar10, 2005)	1-4	A
	4-6	FT		5-8	FT
	7-10	C		9-12	C
	11-14	N		13-16	N
CHEAT07 (Feb13, 2004)	1-3	A	NETCHEAT08 (Mar31, 2005)	1-4	A
	4-6	FT		5-8	FT
	7-10	C		9-12	C
	11-15	N		13-16	N
NETCHEAT01 (Feb10, 2005)	1-4	A	NETCHEAT09 (Apr07, 2005)	1-4	A
	5-8	FT		5-8	FT
	9-12	C		9-12	C
	13-16	N		13-16	N
NETCHEAT02 (Feb24, 2005)	1-4	A	NETCHEAT11 (May05 2005)	1-4	A
	5-8	FT		5-8	FT
	9-12	C		9-12	C
	13-16	N		13-16	N

Legend:

A=Autarky; FT=Frictionless Free Trade; C=Cheat Friction with Anonymity;

N= Network treatment not analyzed here.

Table 2b. Experimental Design - Experienced Subjects

Session	Periods	Treatment	Session	Periods	Treatment
CHEAT08	1-4*	C	NETCHEAT10	1-4	C
(Feb20, 2004)	5-16	N	(Apr07, 2005)	5-16	N
	17-20	C**		17-28	N**
	21-28	N	NETCHEAT12	1-4	N
CHEAT09	1-4	C	(May11, 2005)	5-8	C
(Feb27, 2004)	5-16	N		9-16	N
	17-28	N**		17-20	C**
NETCHEAT05	1-4	C		21-32	N
(Mar10, 2005)	5-16	N	NETCHEAT13	1-12	N
NETCHEAT07	1-4	C	(May18, 2005)	13-16	C
(Mar31, 2005)	5-16	N		17-28	N**
	17-28	N**			

Legend:

A=Autarky; FT=Frictionless Free Trade; C=Cheat Friction-Anonymity;

N=Network treatment not analyzed here.

\* These four periods were discarded because of a software problem.

\*\* Buyer values and seller costs were reshuffled just before period 17.

Table 3. Testable Predictions

	Red Market			Blue Market			Cross-market					
	$p_R$	$q_R$	$S_R$	$p_B$	$q_B$	$S_B$	No Cheating			Cheating		
							$p_{NC}$	$q_{NC}$	$S_{NC}$	$p_C$	$q_C$	$S_C$
Autarky	65	8	160	25	8	160	N/A	N/A	N/A	N/A	N/A	N/A
Free Trade	-	0	0	-	0	0	45	16	640	N/A	N/A	N/A
Cheat Friction	60	6	150	32.5-35	6	150	-	0	0	45	10	125

**Table 4. Autarky Results**

	Blue Market			Red Market		
	$p_B$	$q_B$	$S_B$	$p_R$	$q_R$	$S_R$
<b>Predicted</b>	<b>25</b>	<b>8</b>	<b>160</b>	<b>65</b>	<b>8</b>	<b>160</b>
Period 1	27.3	8.1	142.0	63.8	8.1	130.0
Std. Dev.	4.4	0.7	15.3	7.9	1.2	17.8
Obs.	81	10	10	81	10	10
Period 2	25.5	8.0	146.0	64.4	7.8	152.0
Std. Dev.	4.0	0.9	15.6	3.7	0.6	8.6
Obs.	80	10	10	78	10	10
Period 3	25.1	8.5	141.5	64.9	8.1	146.5
Std. Dev.	3.2	0.5	23.9	3.5	1.0	17.0
Obs.	85	10	10	81	10	10
Period 4	25.1	8.6	154.3	65.3	8.29	133.6
Std. Dev.	3.0	0.5	6.1	5.1	1.1	27.7
Obs.	60	7	7	58	7	7
<b>Overall</b>	<b>25.8</b>	<b>8.3</b>	<b>145.3</b>	<b>64.6</b>	<b>8.1</b>	<b>141.1</b>
Std. Dev.	3.8	0.7	17.1	5.4	1.0	19.6
Obs.	306	37	37	298	37	37

Tab 5. Frictionless Free Trade Results

	Blue Market			Red Market			Cross Market			Combined		
	$P_B$	$q_B$	$S_B$	$P_R$	$q_R$	$S_R$	$P_C$	$q_C$	$S_C$	$P$	$q$	$S$
<b>Predicted</b>	-	0	0	-	0	0	45	16	640	45	16	640
Period 1	34.2	1.0	13.5	57.8	1.2	24.0	45.0	15.9	573.5	45.3	18.1	611.0
Std. Dev.	11.1	1.3	17.3	7.9	0.8	24.8	11.6	1.8	87.8	12.0	1.9	73.7
Obs.	10	10	10	12	10	10	159	10	10	181	10	10
Period 2	41.9	1.3	17.0	61.0	1.0	13.0	44.5	14.5	569.0	45.3	16.8	599.0
Std. Dev.	8.0	1.0	13.4	8.1	0.8	16.4	6.6	1.3	36.2	7.9	1.0	25.6
Obs.	13	10	10	10	10	10	145	10	10	168	10	10
Period 3	43.2	1.3	23.0	61.4	1.0	11.5	45.2	15.2	567.5	45.9	17.5	602.0
Std. Dev.	6.4	0.8	18.0	11.2	1.1	13.8	6.1	1.2	33.9	7.5	1.3	26.4
Obs.	13	10	10	10	10	10	152	10	10	175	10	10
Period 4	41.0	0.6	13.6	63.2	0.7	13.6	43.9	15.4	592.1	44.6	16.7	619.3
Std. Dev.	2.2	0.5	13.5	13.6	0.8	18.4	3.6	0.8	39.5	5.8	0.8	19.5
Obs.	4	7	7	5	7	7	108	7	7	117	7	7
<b>Overall</b>	40.3	1.1	17.0	60.4	1.0	15.7	44.7	15.2	574.2	45.3	17.3	606.9
Std. Dev.	8.6	1.0	15.7	9.5	0.9	18.8	7.8	1.4	53.7	8.9	1.4	42.6
Obs.	40	37	37	37	37	37	564	37	37	641	37	37

**Table 6a. Free Trade with Cheating: Price Results  
(Inexperienced Subjects)**

	<b>Blue Mkt</b>	<b>Red Mkt</b>	<b>Cross Market</b>		<b>Combined</b>
	$p_B$	$p_R$	Cheat $p_C$	No Cheat $p_{NC}$	$p$
<b>Predicted</b>	<b>32.5-35</b>	<b>60</b>	<b>45</b>	<b>-</b>	<b>46.02</b>
Period 1	43.1	55.8	47.0	46.2	47.2
Std. Dev.	7.7	6.7	7.7	7.1	7.9
Obs.	16	13	137	28	194
Period 2	39.1	54.4	44.6	45.9	45.1
Std. Dev.	3.3	7.6	6.0	4.7	6.6
Obs.	13	15	139	17	184
Period 3	39.7	58.1	46.1	45.6	46.7
Std. Dev.	2.9	8.4	5.6	6.3	7.3
Obs.	18	20	132	12	182
Period 4	39.5	56.7	46.0	47.8	47.0
Std. Dev.	4.5	5.6	4.5	6.3	6.7
Obs.	20	25	105	10	160
<b>Overall</b>	<b>40.3</b>	<b>56.5</b>	<b>45.9</b>	<b>46.3</b>	<b>46.5</b>
Std. Dev.	5.1	7.0	6.2	6.2	7.2
Obs.	67	73	513	67	720

**Table 6b. Free Trade with Cheating: Quantity and Surplus Results (Inexperienced Subjects)**

	Blue Market			Red Market			Cross Market						Combined		
	$q_B$	$S_B$		$q_R$	$S_R$		$q_C$	$S_C$		$q_{NC}$	$S_{NC}$		$q$	$S$	
<b>Predicted</b>	<b>6</b>	<b>150</b>		<b>6</b>	<b>150</b>		<b>10</b>	<b>125</b>		<b>0</b>	<b>0</b>		<b>22</b>	<b>425</b>	
Period 1	1.6	28.5		1.3	29.5		13.7	204.7		2.8	132.5		19.4	395.2	
Std. Dev.	0.7	22.4		1.3	34.9		3.4	85.4		3.0	140.6		1.5	77.8	
Obs.	10	10		10	10		10	10		10	10		10	10	
Period 2	1.3	26.0		1.5	29.0		13.9	272.1		1.7	61.5		18.4	388.6	
Std. Dev.	1.3	28.8		1.7	32.9		2.4	54.4		1.3	42.1		1.7	45.6	
Obs.	10	10		10	10		10	10		10	10.0		10	10	
Period 3	1.8	34.0		2.0	44.5		13.2	246.2		1.2	57.0		18.2	381.7	
Std. Dev.	1.5	37.0		1.6	40.6		2.2	65.3		1.5	71.1		1.9	55.3	
Obs.	10	10.0		10	10.0		10	10		10	10		10	10	
Period 4	2.2	46.7		2.8	64.4		11.7	220.4		1.1	44.4		17.8	376.0	
Std. Dev.	1.9	45.9		1.4	39.5		1.6	70.3		1.3	53.4		1.8	49.9	
Obs.	9	9		9	9		9	9		9	9		9	9	
<b>Overall</b>	<b>1.7</b>	<b>33.5</b>		<b>1.9</b>	<b>41.28</b>		<b>13.2</b>	<b>236.3</b>		<b>1.7</b>	<b>74.62</b>		<b>18.5</b>	<b>385.6</b>	
Std. Dev.	1.4	33.8		1.5	38.33		2.5	71.9		2.0	90.14		1.8	56.8	
Obs.	39	39		39	39		39	39		39	39		39	39	

**Table 7a. Free Trade with Cheating: Price Results  
(Experienced Subjects)**

	<b>Blue Mkt</b>	<b>Red Mkt</b>	<b>Cross Market</b>		<b>Combined</b>
	$p_B$	$p_R$	Cheat $p_C$	No Cheat $p_{NC}$	$p$
<b>Predicted</b>	<b>32.5-35</b>	<b>60</b>	<b>45</b>	<b>-</b>	<b>46.02</b>
Period 1	37.7	54.7	48.2	46.9	47.2
Std. Dev.	7.1	6.0	5.0	5.6	7.3
Obs.	21	17	71	22	131
Period 2	37.1	54.6	47.7	44.6	46.5
Std. Dev.	4.6	7.0	5.1	6.1	7.6
Obs.	25	24	73	20	142
Period 3	37.5	52.9	48.4	46.3	46.8
Std. Dev.	6.2	7.8	4.9	5.3	7.5
Obs.	27	22	78	12	139
Period 4	35.9	53.8	48.8	45.2	46.7
Std. Dev.	5.4	8.5	3.5	3.7	7.9
Obs.	28	26	65	18	137
<b>Overall</b>	<b>37.0</b>	<b>54.0</b>	<b>48.2</b>	<b>45.7</b>	<b>46.8</b>
Std. Dev.	5.8	7.4	4.7	5.3	7.6
Obs.	101	89	287	72	549

Table 7b. Free Trade with Cheating: Quantity and Surplus Results (Experienced Subjects)

	Blue Market			Red Market			Cross Market						Combined	
	$q_B$	$S_B$		$q_R$	$S_R$		$q_C$	$S_C$		$q_{NC}$	$S_{NC}$		$q$	$S$
<b>Predicted</b>	<b>6</b>	<b>150</b>		<b>6</b>	<b>150</b>		<b>10</b>	<b>125</b>		<b>0</b>	<b>0</b>		<b>22</b>	<b>425</b>
Period 1	2.6	63.8		2.1	45.6		8.9	194.5		2.8	115.0		16.4	418.9
Std. Dev.	2.0	51.3		1.3	40.9		3.6	87.6		2.9	130.8		2.8	91.4
Obs.	8	8		8	8		8	8		8	8		8	8
Period 2	3.1	73.1		3.0	71.3		9.1	191.6		2.5	103.1		17.8	439.1
Std. Dev.	1.7	47.7		0.8	28.3		3.1	72.5		2.7	113.7		1.0	85.6
Obs.	8	8		8	8		8	8		8	8		8	8
Period 3	3.4	76.3		2.8	60.0		9.8	205.6		1.5	68.1		17.4	410.0
Std. Dev.	1.1	35.3		1.0	33.3		2.7	56.4		1.9	91.4		2.3	73.8
Obs.	8	8		8	8		8	8		8	8		8	8
Period 4	3.5	81.9		3.3	76.3		8.1	190.5		2.3	98.1		17.1	446.8
Std. Dev.	1.6	49.5		1.6	42.7		4.2	125.6		3.2	124.8		1.8	86.3
Obs.	8	8		8	8		8	8		8	8		8	8
<b>Overall</b>	<b>3.2</b>	<b>73.8</b>		<b>2.8</b>	<b>63.28</b>		<b>9.0</b>	<b>195.6</b>		<b>2.3</b>	<b>96.1</b>		<b>17.2</b>	<b>428.7</b>
Std. Dev.	1.6	44.6		1.2	36.91		3.3	85.1		2.6	111.8		2.0	81.7
Obs.	32	32		32	32		32	32		32	32		32	32

Table 8. Hypotheses Tests

<b>Price Unification</b>				
$H_0 : p_{B,FT} - p_{R,FT} = 0$ *				
T-Test	-0.50 (0.62)			
MW** Test	-0.14 (0.89)			
Obs.	(268, 373)			
<b>Market Segmentation</b>				
	Red Market (Buyers' Values)		Blue Market (Sellers' Costs)	
	$H_0 : v_{R,C} - v_{RC,C} = 0$		$H_0 : c_{B,C} - c_{BC,C} = 0$	
	Inexperienced	Experienced	Inexperienced	Experienced
T-Test	8.30 (0.00)	3.32 (0.00)	-3.94 (0.00)	-5.85 (0.00)
MW Test	8.12 (0.00)	3.56 (0.00)	-3.68 (0.00)	-6.60 (0.00)
Obs.	(73, 580)	(89, 359)	(67, 580)	(101, 359)
<b>Trade Volume</b>				
	$H_0 : Q_C - Q_{FT} = 0$		$H_0 : Q_C - Q_A = 0$	
T-Test	3.11 (0.00)		6.26 (0.00)	
MW Test	3.13 (0.00)		5.23 (0.00)	
Obs.	(39, 37)		(39, 37)	

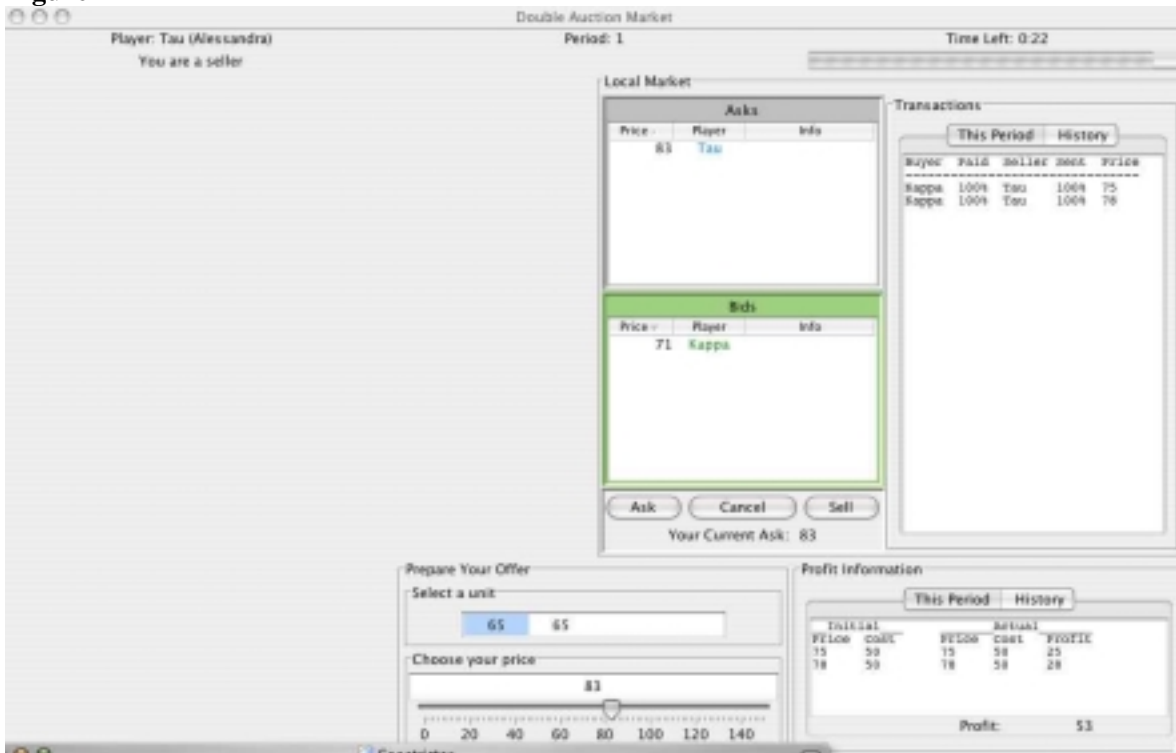
\*Tested for all transactions executed in B and R markets in all FT periods listed in Table 2a

\*\* Two-sample Wilcoxon rank-sum (Mann-Whitney) test

A=Autarky; FT=Frictionless Free Trade; C=Cheat Friction with Anonymity

P-values in parentheses

**Figure 1**



**Autarky trading screen** is shown for a seller (ID code Tau, actual name Alessandra) in her “Local Market”. She can post an offer by either typing the desired price or by dragging the slider to the desired value in the “Prepare Your Offer” box and then clicking the **Ask** button.

The “Select a unit” part of the “Prepare Your Offer” box shows Tau’s costs for the current unit (highlighted, 65) and the remaining ones (here another one at 65).

Similar to “Asks”, “Bids” appear in the green coloured box of her “Local Market” (here there is only one bid at 71 from buyer Kappa).

The “Transactions” box shows the current period transactions in her local market; by clicking on the History tab the previous periods transactions are shown. Under autarky, all prices and trader ID’s are shown.

A seller can transact a single unit in two ways: Either by clicking on an existing bid and then clicking on the **Sell** button (and the buyer confirms it), or by waiting until some buyer clicks on the seller’s ask (and she confirms it).

The “Profit Information” box at the bottom right of the screen shows Tau’s previous transactions and profit. The History tab details trading profits and transactions in all earlier periods (always accessible to players).

Buyers’ trading screens are similar, with **Bid** and **Buy** buttons in the center box, values instead of costs in the “Prepare Your Offer” box, etc.

**Figure 2.**

Demand and Supply Schedules

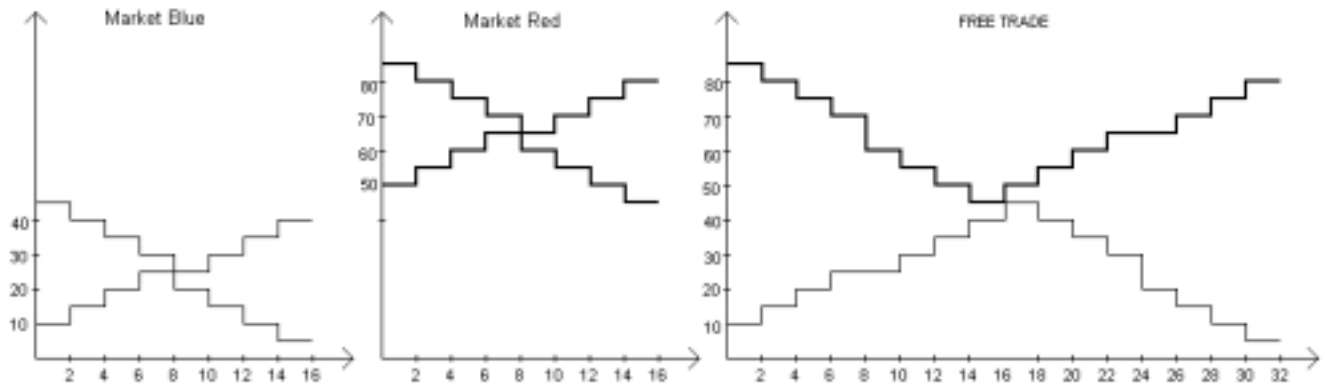


Figure 3.

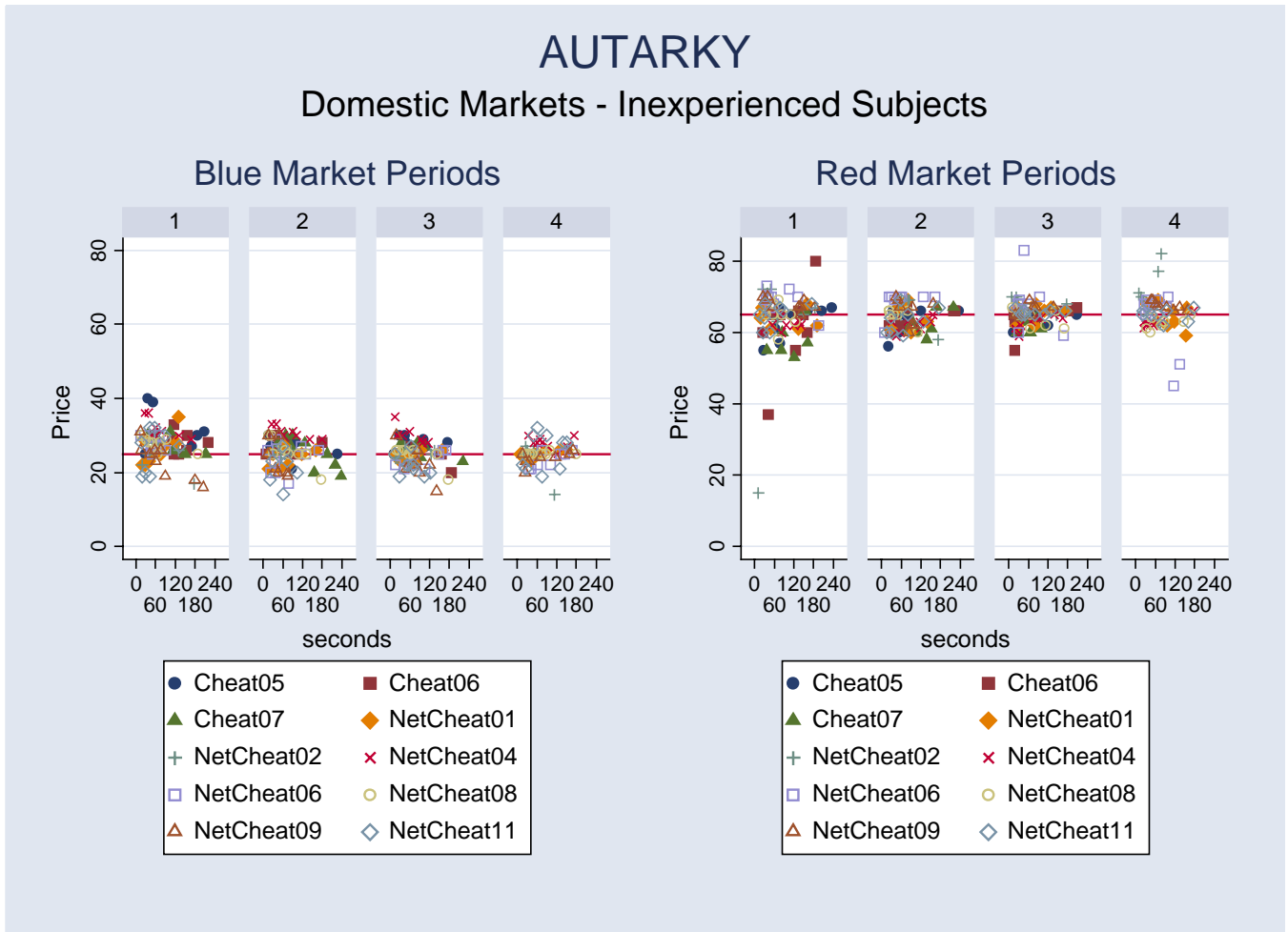


Figure 4.

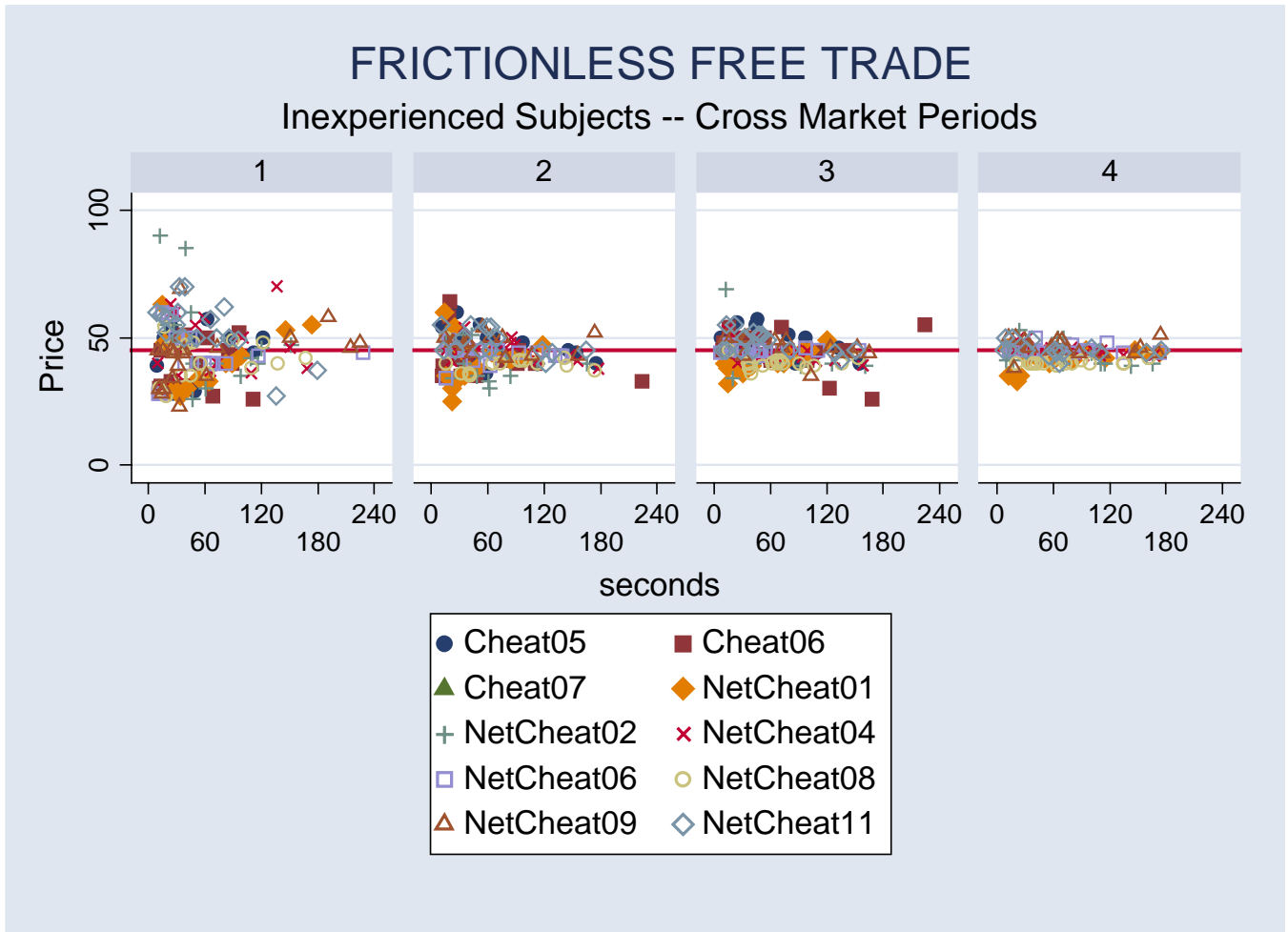


Figure 5.

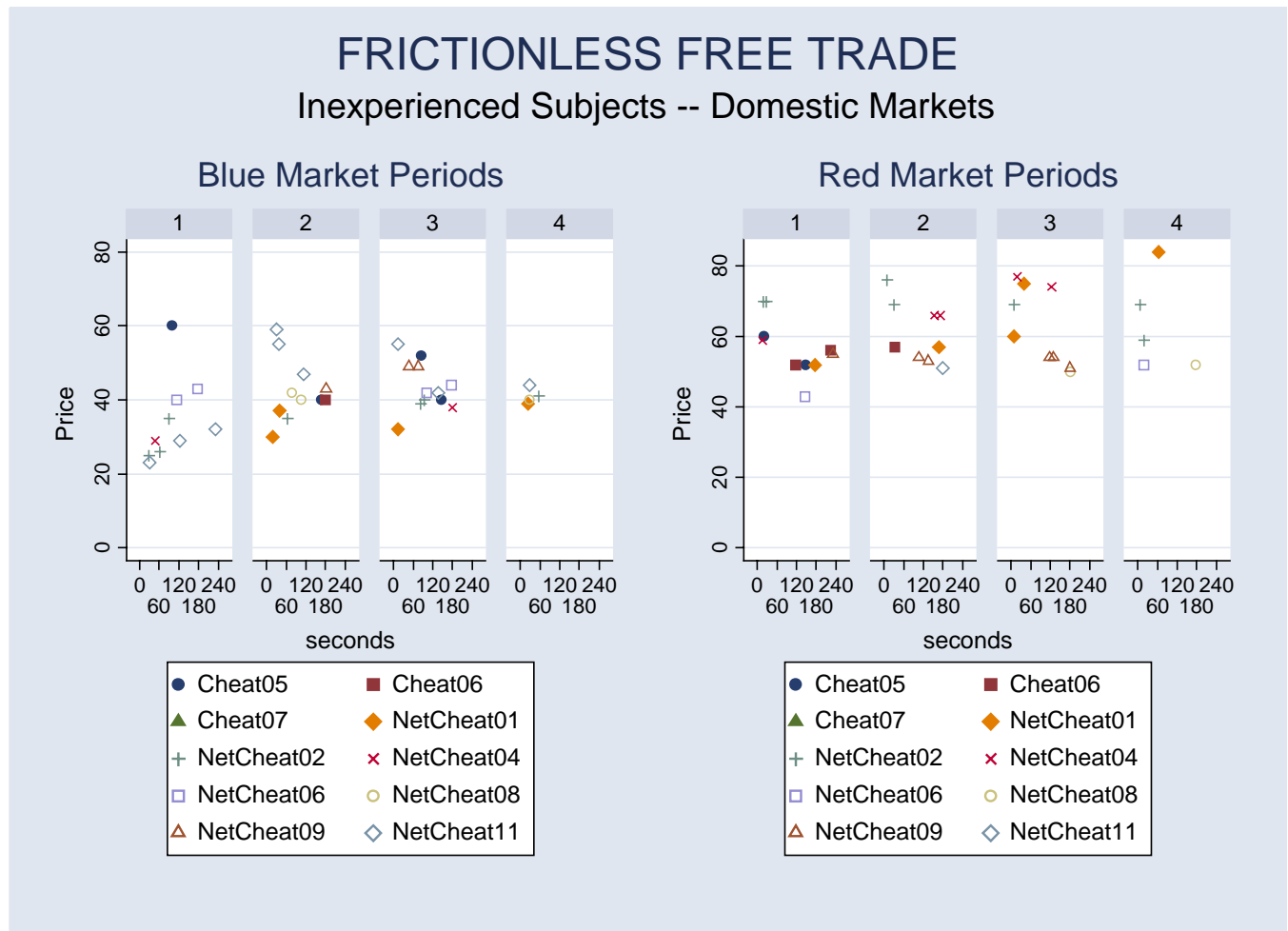


Figure 6.

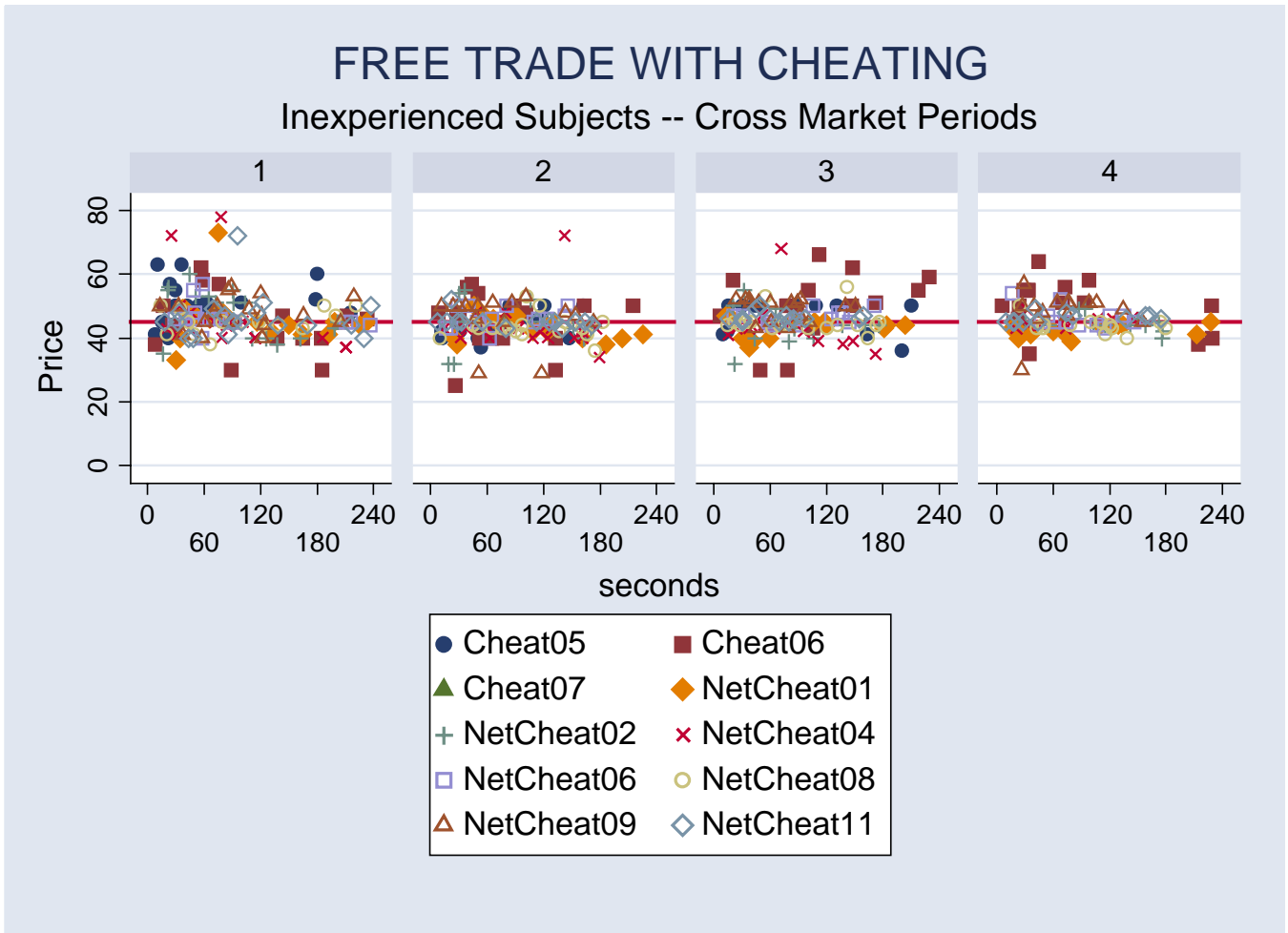


Figure 7.

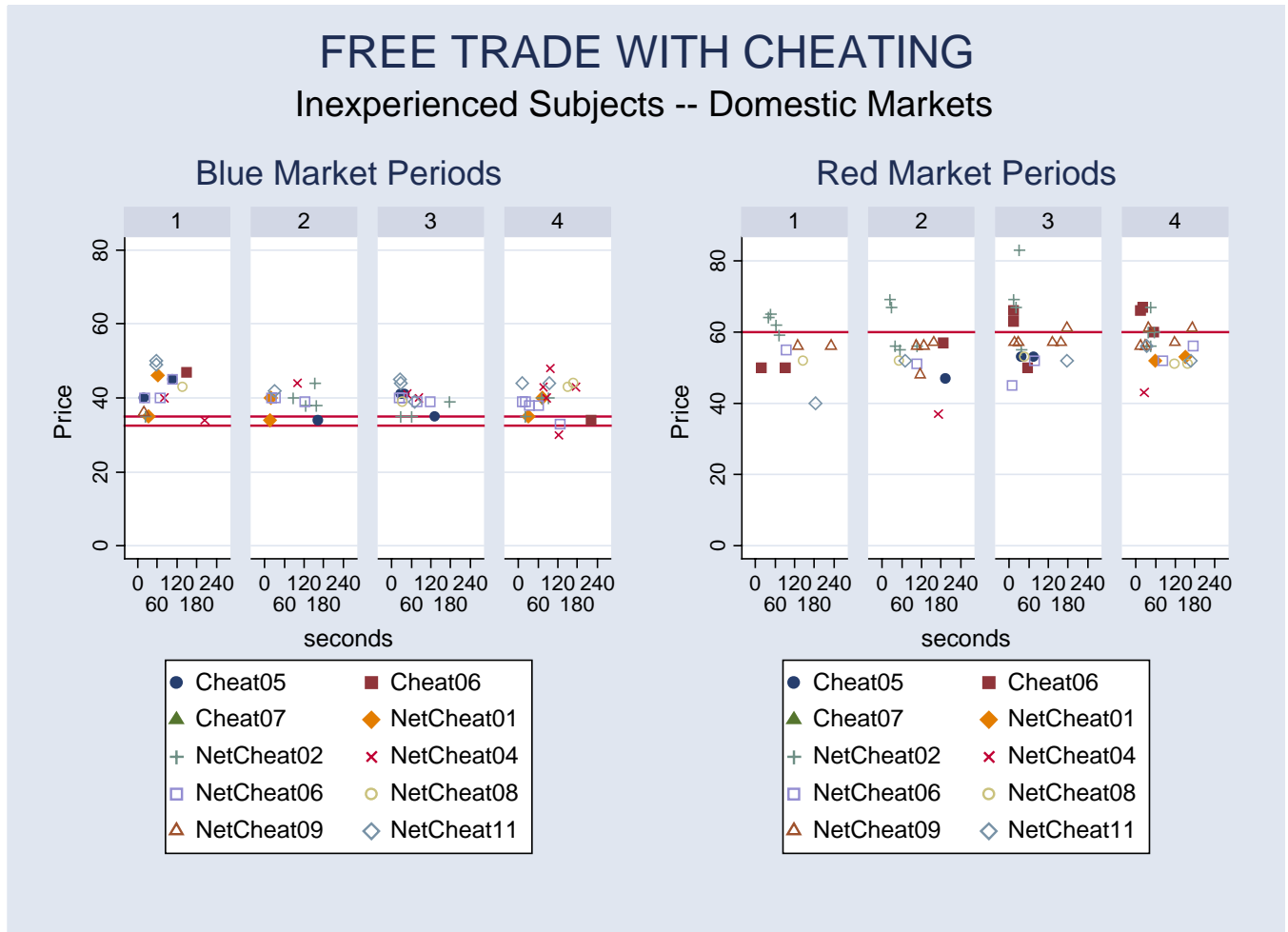


Figure 8.

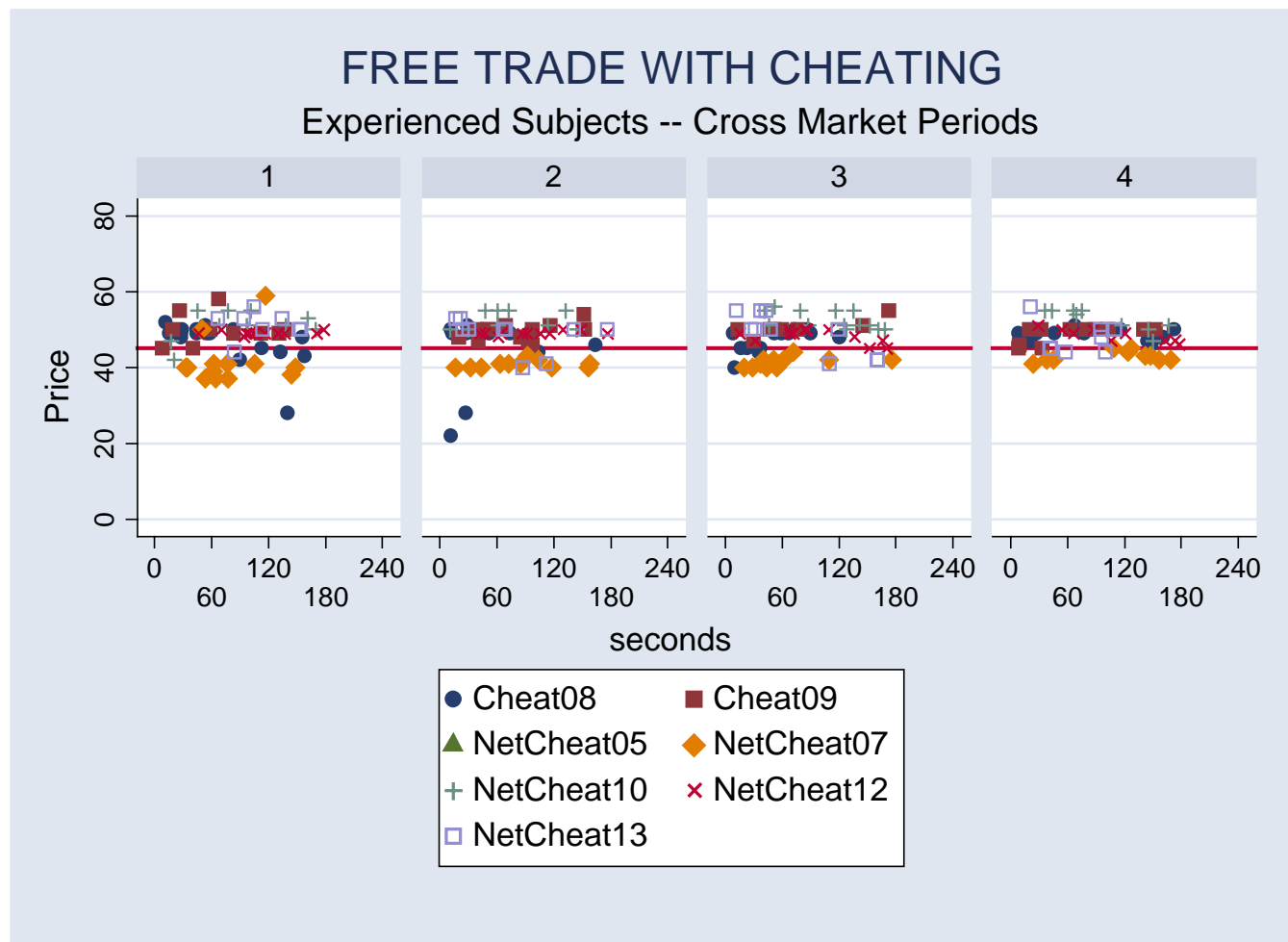


Figure 9.

