

Appendix A: Theoretical Background and Details

A.1 Optimality and stability for Gale's (1963) example

As discussed in Section 2.2, the expansion path for an agent in Gale's economy is given by the equation $y = ax - b$ for $x, y \geq 0$. This ray is the locus of "corners" of the agent's Leontief indifference curves, restricted to the feasible set. An agent's budget constraint is given by the equation $pw^x + w^y = px + y$. An agent's optimal consumption bundle (x^*, y^*) is given by the intersection of his expansion path and budget constraint, provided the intersection occurs in the feasible set. If this intersection implies negative consumption, the agent's optimal bundle is $(0, pw^x + w^y)$ if $b < 0$, and $\left(\frac{pw^x + w^y}{p}, 0\right)$ if $b > 0$. Focusing on interior solutions, we have

$$\begin{aligned} x^* &= \frac{pw^x + w^y + b}{a + p} \\ y^* &= \frac{a(pw^x + w^y) - pb}{a + p} \end{aligned}$$

By Walras' Law we need only consider the excess demand for good x . Individual excess demand is given by $x^* - w^x = \frac{m}{a+p}$, where $m = w^y + b - aw^x$, so aggregate excess demand is given by the equation

$$Z_x(p) = \frac{m_1}{a_1 + p} + \frac{m_2}{a_2 + p}. \quad (\text{A1})$$

Assuming an interior, positive competitive equilibrium price exists (which is the case in our experiment parameterization by construction), we have:

$$p^* = -\frac{a_1 m_2 + a_2 m_1}{m_1 + m_2}.$$

For instability we need $Z'_x(p) > 0$ when evaluated at p^* (note that excess demand returns to zero as p approaches infinity regardless of whether or not the interior competitive equilibrium is stable). The derivative of excess demand with respect to p is

$$Z'_x(p) = -\frac{m_1}{(a_1 + p)^2} - \frac{m_2}{(a_2 + p)^2}.$$

Evaluating Z'_x at the interior equilibrium price, we have

$$\begin{aligned}
Z'_x(p^*) &= -\frac{m_1}{\left[\frac{m_1(a_1-a_2)}{m_1+m_2}\right]^2} - \frac{m_2}{\left[\frac{m_2(a_2-a_1)}{m_1+m_2}\right]^2} \\
&= -\left(\frac{m_1+m_2}{a_1-a_2}\right)^2 \left(\frac{1}{m_1} + \frac{1}{m_2}\right) \\
&= -\frac{(m_1+m_2)^3}{m_1m_2(a_1-a_2)^2}
\end{aligned}$$

Thus $Z'_x(p^*) > 0$ if and only if

$$\frac{(m_1+m_2)^3}{m_1m_2} < 0.$$

Note from A1 that if $m_1m_2 > 0$ there does not exist an interior competitive equilibrium, because the sign of excess demand does not vary with price. Since we are restricting our attention to economies with multiple equilibria, so that $m_1m_2 < 0$ by construction, the instability condition is met if and only if $m_1+m_2 > 0$.

Intuitively, this instability condition implies that agents have a preference for “home production.” This is most readily seen in the case of corner endowments. If agent 2 (1) is endowed with only good y (x), then $m_2 > 0$ and $m_1 < 0$. Fixing m_2 , we need m_1 sufficiently small to obtain instability, which in turn requires a_1 to be sufficiently small (an agent’s relative preference for x is decreasing in a). Graphically, if the endowment is near the lower-right (upper-left) corner of the Edgeworth box, for instability we need the expansion path for agent 1 to be flatter (steeper) than agent 2’s.

In the 2-good example at the end of Gale (1963), we have the following parameter values:

$$a_1 = \frac{1}{2}, \quad a_2 = 2, \quad b_1 = b_2 = 0, \quad w_1^x = w_2^y = 1 - w_1^y = 1 - w_2^x = 1$$

$$\Rightarrow p^* = 1, \quad m_1 = -\frac{1}{2}, \quad m_2 = 1, \quad m_1 + m_2 = \frac{1}{2}$$

Hence the instability result. As Gale notes, if instead we switch endowments so that

$$w_1^x = w_2^y = 1 - w_1^y = 1 - w_2^x = 0$$

$$\Rightarrow p^* = 1, \quad m_1 = 1, \quad m_2 = -2, \quad m_1 + m_2 = -1$$

In the present paper, we have the following parameter values:

$$\begin{aligned}
a_1 &= \frac{1}{0.028167} \approx 35.5, & a_2 &= \frac{1}{0.00152} \approx 658, \\
b_1 &= -\frac{38}{0.028167} \approx -1349, & b_2 &= \frac{6}{0.00152} \approx 3947 \\
w_1^x &= 15, & w_1^y &= 400, & w_2^x &= 5, & w_2^y &= 5600 \\
\Rightarrow p^* &= 158, & m_1 &\approx -1482, & m_2 &= 6258, & m_1 + m_2 &= 4776
\end{aligned}$$

which implies the unstable interior competitive equilibrium. Excess demand is drawn in Figure A1 below.

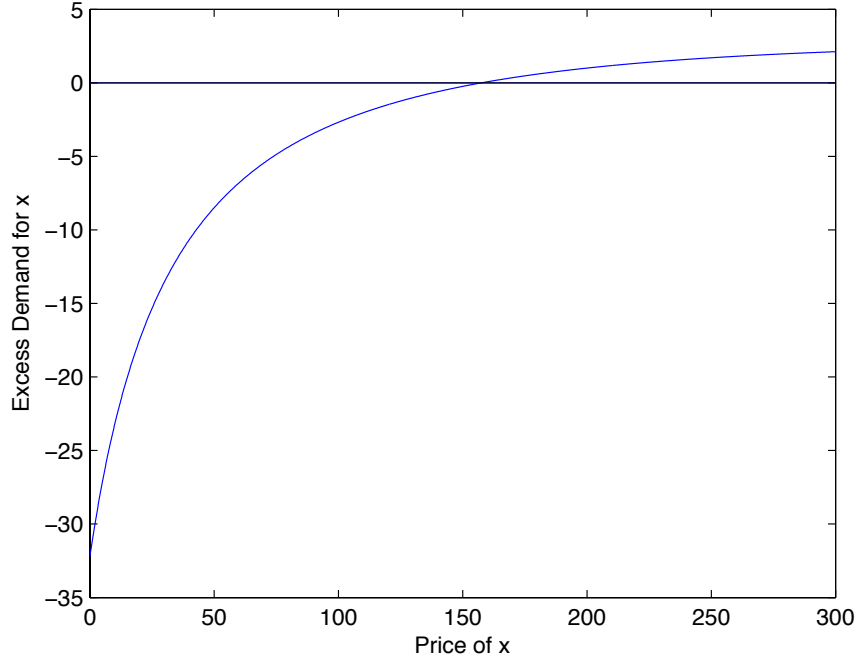


Figure A1: Excess Demand for Good x in the Experiment

A.2 A broader theoretical framework for Gale's example

Gale's example features extreme disequilibrium price paths, but the underlying assumption that goods are perfect complements in consumption is not necessary to produce qualitatively similar dynamics. The Gale example can be viewed as the limiting case of a considerably

broader set of smooth exchange economies.

Alfred Marshall (1879, p. 30) drew the diagram reproduced in Figure A2 below. This is a net trade diagram for a 2-agent, 2-good pure exchange economy, where the current endowment is located at the origin. The (net) offer curve for England is labeled E , Germany's is labeled G . In the example, England will sell good x and Germany will sell good y ; thus any point $H = (H_x, H_y)$ reflects a net trade of $(-H_x, +H_y)$ for England and $(+H_x, -H_y)$ for Germany. The points A , B , and C each represent equilibrium net trades. If we let good y be the numeraire and $p(H)$ be the price of good x implied by net trade H , then $p(A) > p(B) > p(C)$.

Figure A2: Marshall's (1879) Economy

Marshall claims that B is locally unstable while A and C are locally stable. His argument uses what we now call Marshallian (as opposed to Walrasian) adjustment. Consider net trade proposal P , as labeled in Figure A2. To import P_x units of x , Germany is not willing to pay a price greater than $p(Q) < p(P)$, so it is only willing to export fewer than P_y units of y . Similarly, to import P_y units of y , England is willing to accept a price as low as $p(R) < p(P)$, so it is willing to export more than P_x units of x . Thus a new proposal H is made such that $H_x > P_x$ and $H_y < P_y$ (this proposal will occur in the region delineated by arrows in the diagram). Marshall argues that this process of allocation adjustment converges to net trade C . A similar story applies to net trade proposals in the region between A and B , which eventually converge to A .

Walrasian adjustment also implies the stability of A and C (and the instability of B). Consider price $p(Q)$. At this price, Germany's net demand for good x , Q_x , is less than England's net supply of good x , a quantity near R_x . Since aggregate excess demand at $p(Q)$ is negative the price is adjusted downward, eventually converging to $p(C)$ and net trade C .

Offer curves similar to those drawn by Marshall in Figure 8 can be derived from CES or quasi-linear utility functions. For the CES function $u(x, y) = (\alpha x^\rho + \beta y^\rho)^{1/\rho}$, John S. Chipman (1965) provides a necessary condition for instability (and thus multiple equilibria), namely $\rho < 0$, which is intuitive considering that $\rho = 1$ represents perfect substitutes, the limit as ρ approaches zero represents Cobb-Douglas preferences, and the limit as ρ approaches minus

infinity represents the Leontief preferences we study in our experiment.¹ Analogous to our stability condition in the Gale example (i.e., $m_1 + m_2 > 0$), instability for CES preferences generally also requires a taste for “home production” (e.g., England, the “exporter” of good x in Marshall’s example, needs a relatively high α , and Germany a relatively high β).

Now consider Marshall’s economy as parameterized by CES preferences. Increasing the degree to which goods are complements (that is, decreasing ρ) moves the stable equilibrium allocations towards the axes of the net trade diagram, so that $p(A)$ increases, $p(C)$ decreases, and the gains from trade in these equilibria become more asymmetric. Gale’s example is the limiting case where goods are perfect complements (i.e., the limit as $\rho \rightarrow \infty$). The unstable interior equilibrium survives as the only fixed point where markets clear; supply of x exceeds demand whenever $p < p(B)$, pushing prices ever downward, while demand exceeds supply whenever $p > p(B)$, pushing prices ever upward. At a “corner” price of zero or infinity, the sign of aggregate excess demand is still non-zero but prices can move no further. When $p = 0$ (∞), England (Germany) gives away good x (y) for free, while Germany (England) takes at least enough of it to satisfy its own demand but not so much so as to exceed England’s (Germany’s) supply. Such outcomes constitute competitive equilibria of a strange sort where all of the gains from trade accrue to one side of the market, the beneficiary determined entirely by the initial price.

Additional references for Appendix A

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¹John S. Chipman (2010) provides a tighter necessary condition for instability (namely, $\rho < 1$) under the assumption that the CES economy is “supersymmetric” (i.e., endowments and preferences for the two agents are mirror images). Theodore C. Bergstrom et al. (2009) study conditions for multiple equilibria in 2-agent, 2-good economies with quasilinear preferences.

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Appendix B: Additional Empirics

B.1 Econometric Hypothesis Tests

In the paper we report non-parametric tests of the hypothesis that prices movements match the sign of excess demand both within and between periods. In this section we report parametric counterpart tests using standard panel data methods.

First we examine the hypothesis that prices change from period to period according to the sign of excess demand during the Primary phase. We estimate the following linear equation

$$\ln(price_{ip}) = \alpha_i + \beta_1 \times p + \beta_2 \times p \times positive_i + \epsilon_{ip} \quad (A2)$$

where $price_{ip}$ is the mean price in period p of session i , α_i is the session fixed effect and $positive_i$ is a dummy for positive excess demand ². In addition to fixed effects, we cluster standard errors at the session level. We use a log specification because of the vast differences in scale between downward convergence and positive convergence.

Our estimate of β_1 is -.104 (p=0.007), meaning there is a significant 9.8 percent reduction in price each period when excess demand is negative. Our estimate of β_2 is significantly positive at 0.332 (p=0.000), indicating a clear treatment effect (a clear difference between price movements in negative and positive excess demand sessions). Summing the betas and exponentiating we learn that prices rise by an average of 25 percent per period when excess demand is positive (p=0.000). Thus price movements across periods are Walrasian.

To study within period dynamics we estimate the following model

$$\ln(price_{ipt}) = \alpha_{ip} + \beta_1 \times t + \beta_2 \times t \times positive_i + \epsilon_{ipt} \quad (A3)$$

where $price_{ipt}$ is now an individual observed price, t is the time elapsed within the period, α_{ip} is a session by period fixed effect (to capture differences in intercepts in different periods) and standard errors are again clustered at the session level.

²Note that the sign of excess demand never varies within the Primary phase; it is always either positive or negative in our data.

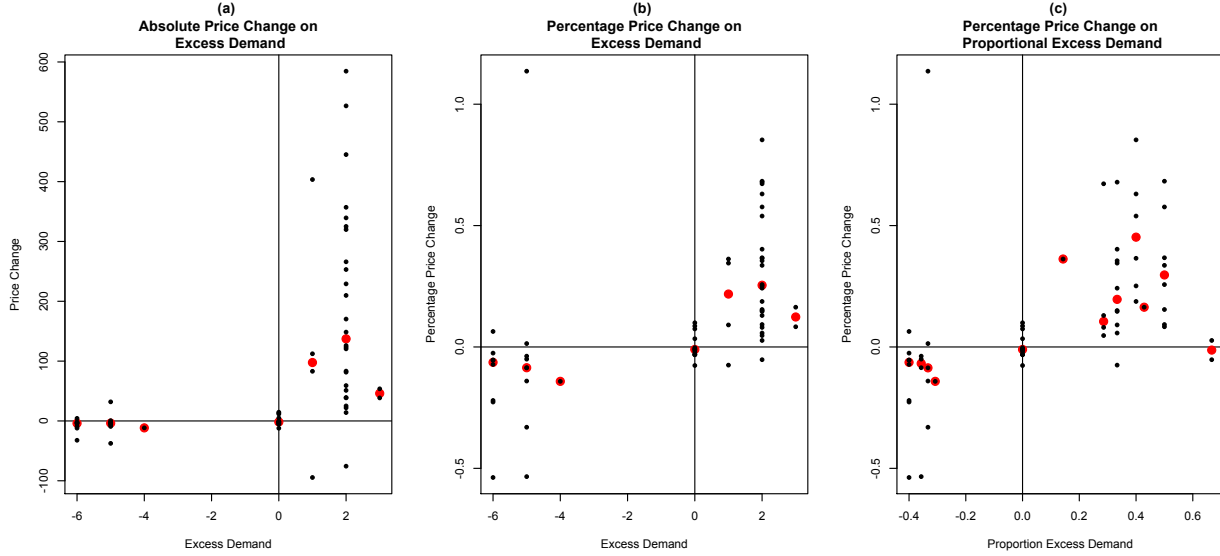


Figure A3: Excess demands and price changes.

We estimate $\beta_1 \times 100$ at -0.125 ($p=0.033$), β_2 at 0.156 ($p=0.009$) and their sum at 0.031 ($p=0.001$). Estimates suggest (after exponentiating) that prices fall an average of 0.12 percent per second when excess demand is negative and rise an average of 0.03 percent per second when excess demand is positive. More importantly, the sign of excess demand is strongly and significantly associated with price movements within period.

B.2 Excess Demand and Price Adjustment

As we explain in the paper, the sign of excess demand has a strong relationship to the sign of price adjustments across periods though our data provides little compelling evidence that the same holds true for the magnitude of excess demand. In this section we provide some evidence to support that claim.

In Figure A3, we plot three specifications of the relationship between excess demand in period t , $z_t = z(p_t)$, and the adjustment in mean price in the following period. Panel (a) plots the excess demand and the absolute change in mean price: $p_{t+1} - p_t$. In panel (b) we plot the proportional change in price $(p_{t+1} - p_t)/p_t$ against z_t . Finally in panel (c) we plot the proportional change in price against excess demand as a (signed) proportion of the maximum individual excess demand. Letting z_t^i be individual excess demand for agent i in

period t , proportional excess demand is defined as

$$\bar{z}_t \equiv \frac{z_t}{\max(|z_t^1|, |z_t^2|)}$$

We consider this measure of excess demand because it is plausible that prices respond more aggressively to larger proportions of unfilled orders than smaller proportions. In the figure, black points are observations and red points are medians at each level of the dependent variable.

Clearly in each case, the data matches sign predictions of tatonnement. When excess demand is negative price changes tend to be negative, and when it is positive they tend to be positive. When excess demand is zero, prices change little and the changes are centered on zero.

	(a)	(b)	(c)
	$p_t - p_{t-1}$	$(p_{t+1} - p_t)/p_t$	$(p_{t+1} - p_t)/p_t$
Intercept	20.310 (23.748)	0.035 (0.036)	0.069 (0.067)
z_t	4.821 (4.396)	0.021 ** (0.007)	
$z_t \times \text{positive}$	68.884 * (26.623)	0.104 * (0.041)	
$\bar{z}_t$			0.411 * (0.191)
$\bar{z}_t \times \text{positive}$			0.081 (0.347)

Table A1: Regressions.

In Table A1 we provide estimates of regressions corresponding to our three panels (with standard errors clustered at the session level). In each case we interact the measure of excess demand (z or $\bar{z}$) with *positive*, a dummy for positive excess demand. This allows the slope to depend on the sign of excess demand.

Results are mixed, though (i) the intercept (at $z_t = 0$) is never significantly different from zero and (ii) proportionate price changes always seem to be impacted by the absolute magnitude of excess demand.

However, these results are somewhat misleading. First, the discretized economy gives us very little variation in excess demand conditional on sign; in any given session we only observe

three levels of excess demand under each sign and in each case they tend to be clumped close together. There is an especially large cluster of excess demands at 2 (panels (a) and (b)). Second, closer scrutiny of Figure A3 shows that conditional on excess demand being of a given sign, the absolute size of price changes do not seem to be monotonically increasing in the absolute value of the excess demand measure. Variations on the regressions reported above confirm this; when we restrict the data to only positive or only negative excess demand sessions (and excluding the zero point), the magnitude of excess demand is never significant.

As we explain in the paper, this lack of effect is likely a consequence of the strange relationship between excess demand and price in Gale’s economy (and probably compounded by lack of variation in excess demand). Excess demand (supply) is largest where the marginal disutility of unfilled demand (supply) is smallest, and where the economy is closest to equilibration. We suspect this drives the non-monotonicity between absolute excess demand and absolute price adjustments observable in the figure.

B.3 Efficiency

In the paper (Figure 6) we document the inequality generated as economies approach corner equilibria. Our parameterization of the Gale economy was calibrated to generate this inequality with minimal effect on the gains from trade generated by the economy. Here we provide evidence that, indeed, gains from trade do not change systematically over periods.

Figure A4 plots the median per-pair payoff by session, phase and period-within-phase. Green horizontal lines show the upper and lower bounds of symmetric optimal payoffs (the interior CE price is the global social optimum, and per-pair symmetric optimal payoffs decrease slowly in both directions as the price moves away from the interior). Realized per-pair payoffs fluctuate little and show no systematic trend and are virtually always within these bounds. This suggests that subjects are typically making close to optimal orders at prevailing prices and that markets are relatively efficient throughout; subjects extract nearly all of the available gains from trade.

For further evidence of efficiency, for a given period consider (1) the sum of all individual profits earned through trading in the period (that is, in excess of endowment profits), and (2) this same number plus the additional profits available through Pareto-improving trades

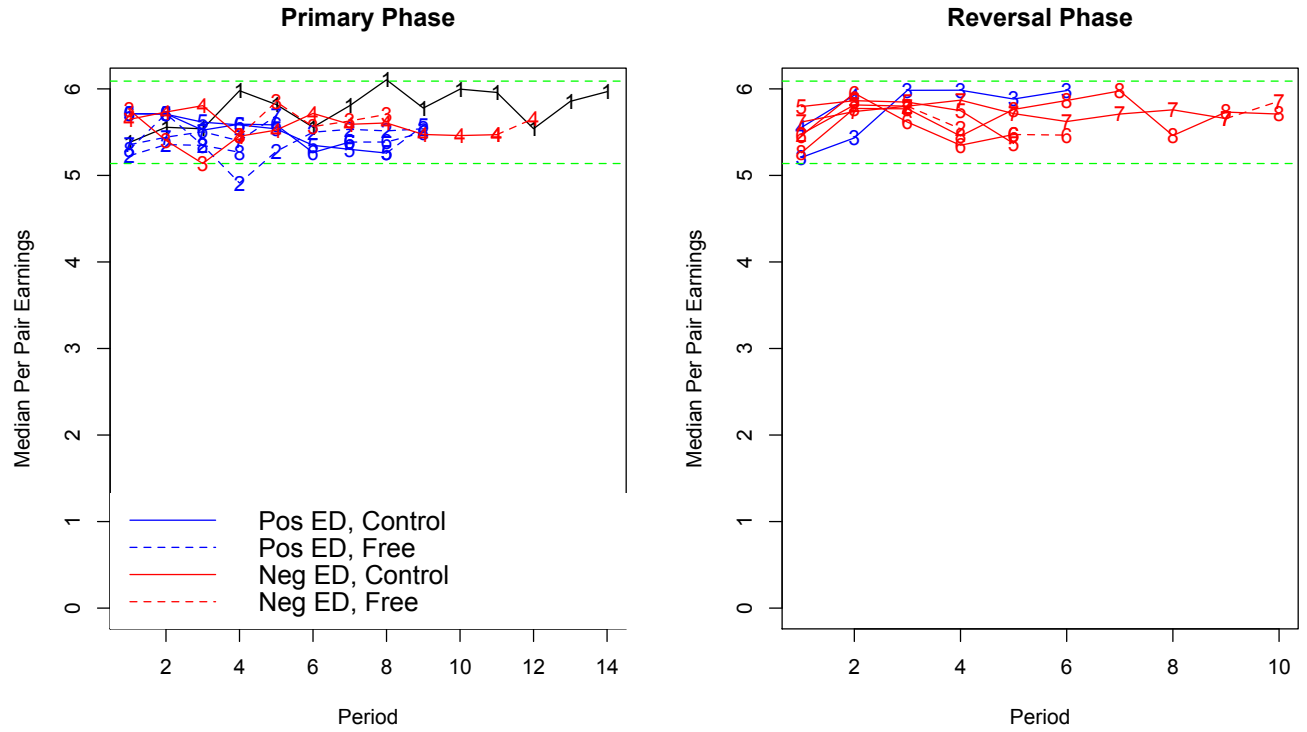


Figure A4: Efficiency by period and session.

at the end of the period (i.e., money left on the table).³ The ratio of the first and second number is a measure of efficiency bounded between zero and one, where autarky equals zero and optimal orders given price equals one. The mean degree of efficiency across all Primary phase periods is 95%, as is the average of session mean efficiency. The fact that gains from trade are virtually exhausted in nearly all periods of all sessions is a strong indicator that most subjects internalized their induced preferences quite well.

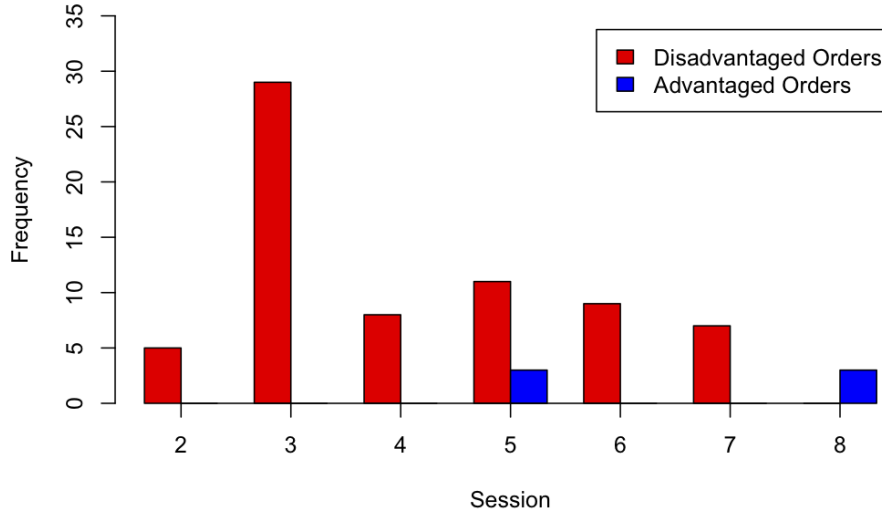


Figure A5: Competitive units left in the order book after the final period of the Primary Phase.

B.4 Evidence on Convergence

We ended the Primary phase of each session when the experimenter made a loose determination that prices had “converged”. Had market prices settled down by the time we ended the Primary phase or were they still moving closer to the corner? A look at the limit order book suggests that we typically closed the Primary phase before Walrasian dynamics had finished influencing the evolution of market prices. In nearly all sessions a large number of the “competitive” orders left in the limit order book at the end of the period were posted by the “price-disadvantaged” side of the market,⁴ suggesting that the disadvantaged side of the market was prepared to transact at even more extreme prices than those observed by the phase’s end. So, while we demonstrated convergence to a reasonably tight neighborhood of corner equilibria in Result 4, there are signs that these economies may have moved even

³We use the following procedure to calculate money left on the table. Let p be the weighted average transaction price during the final minute of the period. Consider the set of bundles that provides each subject his optimal net trade from his final bundle at p . If this set of bundles is feasible, the additional profit available at this reallocation relative to the final realized allocation is our measure of money left on the table. If the reallocation is not feasible, one side of the market must be rationed, and we assume these subjects are rationed proportional to their net demand/supply. The additional profit available at this rationed reallocation is then money left on the table. We maintain the assumption that goods are discrete in this calculation, so several units of the rationed good x may be distributed randomly.

⁴An advantaged (disadvantaged) order is an ask (bid) in a high price period and a bid (ask) in a low price period.

closer to the corner if we had increased the length of the Primary phase.

In Figure A5 is displayed the number of “competitive” units left in the limit order book on the advantaged and disadvantaged sides of the market. Here competitive is defined as a bid (ask) no more than 10% below (above) the final transaction price of the period. In all but one session⁵ the Primary phase ended with a relatively large number of unrequited competitive orders submitted by the disadvantaged side of the market and comparatively few competitive orders from the advantaged side.⁶ Such unfulfilled expressed demand is presumably a driver of price changes across periods; e.g., unaccepted bids at the end of one period are likely to lead to higher bids in the subsequent period. We therefore interpret the closing limit order book as evidence that prices likely would have continued to move even closer to the CCE had we extended the duration of the Primary phase with additional periods.

B.5 Analysis of the Reversal Phase

Relatively quick near-corner convergence in most sessions inspired us to investigate the durability of dynamics. Once established, can Walrasian dynamics be easily reversed? In order to find out, we attempted to reverse Primary dynamics by imposing price controls, forcing a switch in the sign of excess demand in the seven “corner” sessions. Price ceilings at $p = 100$ (session 2) and $p = 90$ (sessions 5, 6, 7 and 8) created excess supply in the Reversal phase while price floors at $p = 275$ (in sessions 3 and 4) generated excess demand.

As we argue in the paper, evidence that dynamics were reversed by the forced changes in excess demand is mixed. In sessions 5 and 6 prices drop substantially over time suggesting successful reversal of dynamics. On the other hand, in sessions 3, 7 and 8 we observe prices hugging the price constraint (the price-controlled Reversal Phase was only 2-3 periods long in sessions 2 and 4, too few periods to assess reversal). In fact, in sessions 7 and 8 the Reversal phase consisted of more periods than the Primary phase and yet prices hugged the price ceiling throughout.

⁵In session 8 the order book in the final period of the Primary phase was dominated by disadvantaged units, as well (31 to 3), but because prices moved so fast near the end of the period (the weighted average price in the period was 1292 but the final transaction price was 3000), the bids left in the book were not categorized as competitive by our metric.

⁶This result is relatively robust to different choices of “competitive,” although at the 20% competitiveness level a cluster of advantaged units in Session 4 becomes competitive and outnumber the disadvantaged units.

In three sessions (2, 6 and 7) we lifted the price controls of the Reversal phase in the final period. The effect is most clearly documented in the right hand panel of the paper’s Figure 5, where the light dashed lines show the price path after price controls are lifted in the Reversal phase of these sessions. In each of these periods we observe prices leaping far past the ICE to the region of excess demand established in the Primary phase. Moreover prices within these periods continued moving upwards within the period in accordance with the dynamics established in the Primary phase. Another view of the effect of lifting the price controls can be found in Figures 3 and 4.

Amazingly, we observe this return to original dynamics even in session 6 where we observe an initial apparent reversal of dynamics while price controls persist. After price controls are lifted this new trajectory is abandoned and the pattern from the Primary phase is reestablished

The difficulty of reversing dynamics demonstrates that price dynamics do not follow mechanically from excess demand. Whatever channel ties excess demand to price motion, the relationship is not a behaviorally trivial outgrowth of the economy’s parameters. We leave the important work of systematically studying such reversals to future research, but we offer preliminary evidence in support of one potential cause of reversal stickiness below. In particular, we report that subjects on the advantaged side of the market “overtrade” in the Reversal phase to a much greater degree than in the Primary phase, absorbing what would have otherwise been excess supply or demand. We also provide a rationalization of this result.

Overtrading in the Reversal phase

Consider a subject’s symmetric optimal excess demand at his final allocation in a period given the period’s weighted average price. Note that a type 1 (2) subject can only have positive (negative) excess demand if he overtrades (that is, if he trades across his expansion path). Ignore for the moment the possibility that a subject might trade across his expansion path because he anticipates a within-period change in the direction of prices (e.g., he is trying to “buy low and sell high”). Then all period-ending excess demand (supply) in high (low) price periods should come from type 2 (1) subjects, and there should be no excess

supply (demand).

Indeed, under-trading by price-advantaged subjects and over-trading by price-disadvantaged subjects is relatively small in both the Primary and Reversal phases. This fact implies that non-zero individual excess demands at the end of a period will generally have the same sign (positive in high-price periods, negative in low-price periods), corroborating the efficiency results in Appendix B3. However, the key difference between the phases is that in the Reversal phase, a substantially larger proportion of excess demand/supply comes from price-advantaged subjects; that is, from subjects who have over-traded.

Why might advantaged subjects over-trade, and why are they more likely to do so in the Reversal phase? We first note that due to the weak monotonicity of Leontief preferences, an advantaged subject pays a relatively small profit penalty for crossing his expansion path. For example if $p = 20$, a myopic optimizing type 2 subject will obtain the bundle (5400,15) and earn a profit of \$4.60 for the period. A type 2 subject who instead “over-buys” by 15 units of x , so that he ends up with (5100,30), will still earn \$4.06. What is the potential reward? If prices happen to move into the high range, say 1500, the subject would earn \$111.36 for the period by selling back only 5 units of x !

Therefore one rationalization for “over-trading” is that the subject expects a large within-period price change. All subjects in the Reversal phase were experienced with extreme prices during the Primary phase. Trade during the Reversal phase began at a price control on the opposite side of the ICE, but there was clearly strong memory of the Primary phase extreme prices (recall the price leaps after the Reversal phase price controls were removed in three sessions). Thus for an advantaged subject in the Reversal phase, over-trading could serve as a relatively cheap option on large within-period price changes that would take the system back to the range of prices experienced during the Primary phase.

Of course, such large price swings were actually not possible with price controls. At the beginning of each high-price Reversal phase period the experimenter announced, “All orders must be posted at a price greater than or equal to 275. This restriction will remain in place for the entire period” (the low-price announcement was the same, but with orders restricted to a price less than or equal to 90 or 100). If the announcement was regarded as credible, over-trading at the price control makes no sense at all. Nevertheless, in the Reversal phase

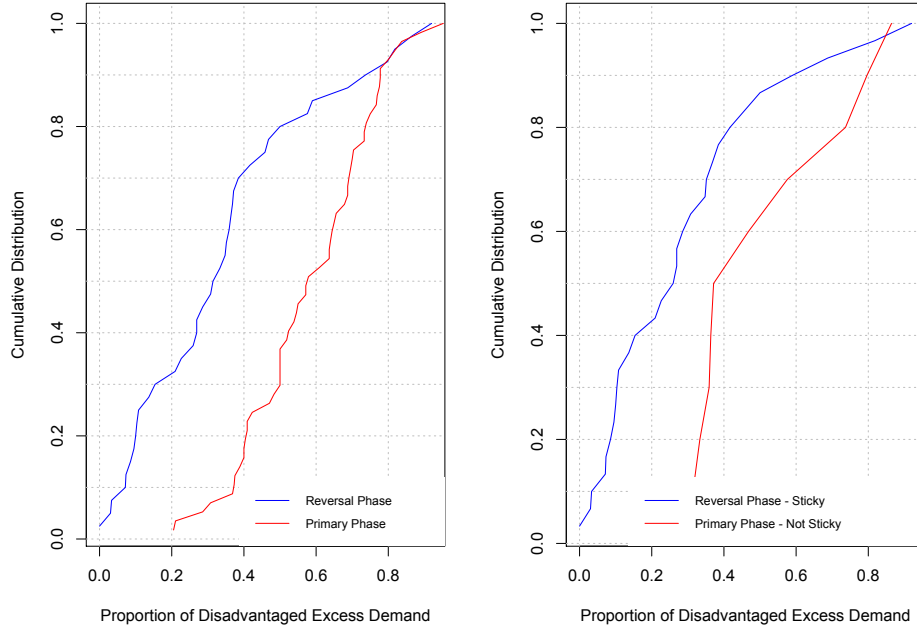


Figure A6: Proportion of excess demand generated by price-disadvantaged subjects.

one or two subjects in each session always over-traded by a large quantity.⁷ Overtrading was certainly not typical behavior; the median absolute value of excess demand for price-advantaged subjects was less than or equal to one in 97% of all Reversal phase periods. But one price-advantaged subject who over-traded by a large quantity was capable of filling what would have been the excess supply/demand of all disadvantaged subjects.

To look more carefully at over-trading, for each period of sessions 2-8 we partition subjects by type, and within each partition we sum the positive (negative) individual excess demands in high (low) price periods. We then calculate the proportion of these summed individual excess demands that comes from the price-disadvantaged partition. This proportion is substantially larger in the Primary phase than in the Reversal phase, and it is larger still in the two Reversal phase sessions where we observe prices moving towards the corner equilibrium (sessions 5 and 6). In Figure A6 we've pooled across sessions the proportion of individual

⁷One such subject (a type 2 subject in session 7 who did not over-trade in the Primary phase) over-traded by 23 units (!) on average during the Reversal phase. This subject was asked after the experiment if he realized he was over-buying. His reply (paraphrasing): "Absolutely. I thought prices would jump back up to where they had been at the beginning of the experiment and I'd make a lot of money." This subject either ignored the announcement that the price control would remain in effect until the end of the period or did not find it sufficiently credible to forego the relatively cheap option on a price reversal.

excess demands that comes from price disadvantaged subjects. In the left panel we observe that in the median period of the Primary pool, nearly 60% of excess demand is generated by price-disadvantaged subjects, double the amount generated by price-disadvantaged subjects in the median Reversal period. The distributions remain far apart throughout; clearly over-trading is far more prevalent in the Reversal phase, despite the fact that subjects in this phase are much more experienced.

In the right panel we consider only the Reversal phase periods in which the price control was in place, and placed sessions 5 and 6 (where there was strong evidence of price reversals) in one pool and the other sessions in a separate pool. We observe a similar pattern to the left panel: Over-trading was more prevalent in the sticky sessions than in non-sticky sessions.

Why should the excess demand of subjects who have over-traded not drive prices in the direction of *tatonnement*? First consider a high-price period, and a type 2 (disadvantaged) subject who finishes the period with positive individual excess demand. We may reasonably infer he would like to have purchased more of good x but was unable to do so. It is his failure to fill his full order that invokes the spirit of *tatonnement*; he is likely to be more aggressive the following period in the attempt to fill his full order, which will help to push prices further upward.

Now consider the same high-price period, but this time a type 1 (advantaged) subject who finishes the period with positive individual excess demand. If his “over-trading” was intentional, we can infer that he weighted the probability of prices dropping by the end of the period sufficiently high to risk over-selling. If he employs the same strategy in the following period, his “excess demand” is by definition only but certainly not intention. He will not exhibit increased aggressiveness in his buying behavior like the aforementioned type 2 subject (because he will not buy at all, only sell), so his individual excess demand at the end of the period will have no impact on subsequent prices. Only if he views his over-trading as a mistake will his behavior in subsequent periods contribute to *tatonnement* price pressure, because he will not supply so much of good x . But over-trading was persistent in the Reversal phase. In some sessions it was the same subject period after period, and in other sessions it was several subjects who alternated experimenting with over-trading (but seldom did more than one subject over-trade in a given period). It therefore seems likely that over-trading by price-advantaged subjects had a substantial influence on price stickiness in the Reversal

phase.

Appendix C: Instructions and Procedures

Subjects were recruited from the Economics and Finance Human Subjects Research Pool at Baruch College. Students who join this research pool elect to receive e-mail announcements of upcoming experiments. The pool draws students from all schools within Baruch College, predominantly undergraduates. Recruitment for this experiment took place via e-mail, and participation was granted on a first come, first serve basis. No subject participated in more than one session of the experiment.

Participants were seated at visually isolated computer terminals. Instructions were distributed electronically in pdf format to each computer terminal, in two separate files. One file (reproduced in C1 below) focused on understanding induced preferences and cash payments in the experiment. These instructions were read aloud to the subjects by the experimenter at the beginning of each session. Following these instructions, subjects took a quiz (distributed on paper, reproduced in C.2 below) so that the experimenter could assess their understanding of induced preferences and answer related questions. Answers to the quiz were based on the Excel induced preference map that each subject was assigned in the experiment. This Excel file was open throughout the session; a screenshot of the two files used in the experiment is reproduced in C.3 below.

After the quiz, a second set of instructions (C.4) was read aloud by the experimenter. These instructions focused on how to use the MarketScape software to trade with other participants in the double auction. After these instructions were completed, the experiment was begun.

C.1 Instructions

Experiment Instructions

Introduction In this experiment you will make decisions to buy, sell, or hold two different commodities, called X and Y, during a sequence of trading periods. All trade takes place in the market for Y. In this market you will be allowed to buy and sell units of Y using your units of X as currency.

The cash you earn during the experiment will depend on the combination of X and Y you

hold at the end of each period. Every combination of X and Y is worth a specific number of points; how many is determined by your Payoff Chart. At the end of the experiment, your points from each period will be added together and converted to U.S. dollars at a constant rate I'll announce shortly, paid in cash.

The Payoff Chart Please look at the interactive payoff chart on your computer, from which you can determine the number of points corresponding to any combination of X and Y. Units of X are shown on the bottom (x-axis) and units of Y are shown on the left (y-axis). Each of the solid red lines is called a point curve. Every combination of X and Y that lies on the same point curve is worth the same number of points. You will finish each period possessing some combination of X and Y, so whichever point curve this combination lies on will determine how many points you have earned for the period.

Payoff charts come in two basic types. In one type there are only L-shaped and vertical point curves, as in Figure 1. In this case the point value corresponding to each point curve will appear at the top of the figure. Notice that combinations A and B lie on the same point curve and are each worth 348 points. So if Figure 1 was your payoff chart (it is not, this is only a sample) and you ended a period possessing combination A or B, you would earn 348 points. Several other examples are also presented in the figure.

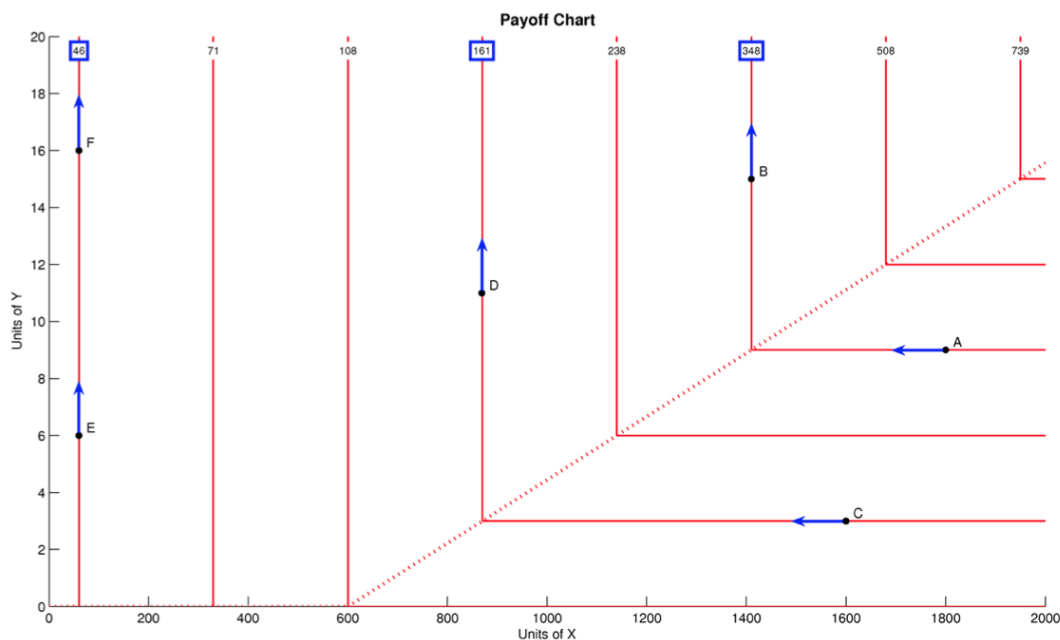


Figure A7: Figure 1.

The other type of payoff chart has only L-shaped and horizontal point curves. In this case the point value corresponding to each point curve will appear on the right-hand side of the figure, as in Figure 2. In this figure combinations A and B lie on the same point curve, and each are worth 175 points. Determine now which kind of payoff chart you have been given.

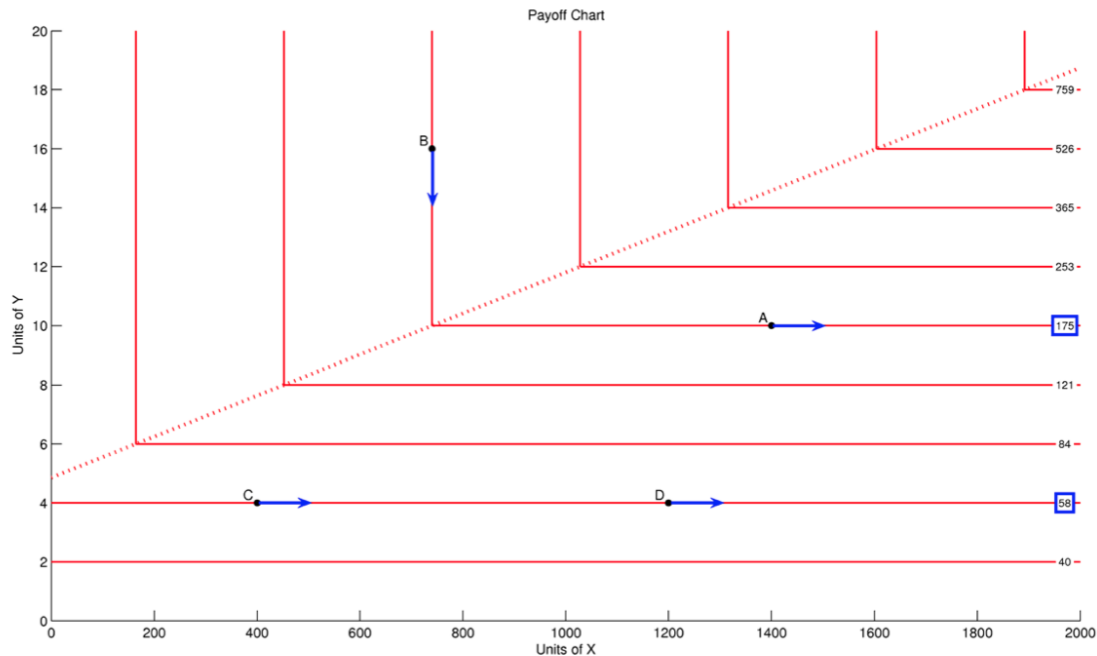


Figure A8: Figure 2.

Some combinations of X and Y do not lie on one of the red point curves. The point curves for these combinations have not been drawn to avoid overcrowding the chart. The payoff chart on your computer has a built-in point calculator to assist you in these circumstances. If you enter a combination of X and Y, the calculator will return the corresponding point value and plot the associated point curve in blue. Right now, enter 1,600 X and 12 Y in the point calculator on your computer. This combination of X and Y and the point curve through it have now been plotted on your payoff chart.

You will notice there is a red dashed line on your payoff chart which connects the corners of the L-shaped point curves and then runs to the origin (where there is zero units of each good). As you move along this line up and to the right, notice that the associated point curves are of increasingly greater value. If your combination of X and Y does not lie on the red dashed line, it means you are “wasting” one type of your goods. Reconsider point A in

Figure 1. Notice if you had fewer units of X but the same amount of Y, you could still earn 348 points. This means if you finish a period at combination A, you have “wasted” some units of X which might have been used to buy more Y and earn more points. Similarly, at point B in Figure 1 you would be wasting units of Y. You could lose up to 6 units of Y and still earn 348 points as long as you retained the same amount of X, so if you sold one unit of good Y in return for some X you would be on a higher point curve.

Summary: You can locate any combination of X and Y on your payoff chart. The point curve through this combination will correspond to a specific number of points you will earn if you end a period possessing 1 this combination. If you end a period with a combination below and to the right of the red dashed line you are wasting some units of X (as at combination A in the figures). This means that by buying Y using some of those “wasted” X you would move to a higher point curve. Alternatively, if you end a period with a combination above and to the left of the red dashed line you are wasting some units of Y (as at combination B in the figures). This means that by selling Y in exchange for X you would move to a higher point curve.

Endowments You will begin each period with a specific combination of X and Y called an endowment. At the beginning of each new period your endowment will be refreshed to this same initial combination. You cannot carry over any goods from one period to the next.

Time and the end of the experiment The market will open for a sequence of trading periods. Period lengths may be change from period to period so you should check the clock regularly. This will be a fairly long experiment. You can expect some periods where you make quite a bit of money, and some periods where you don’t make much money. If you’re in a bad period, just be patient. And remember that seemingly small amounts of money add up over the course of the experiment.

C.2 Quiz

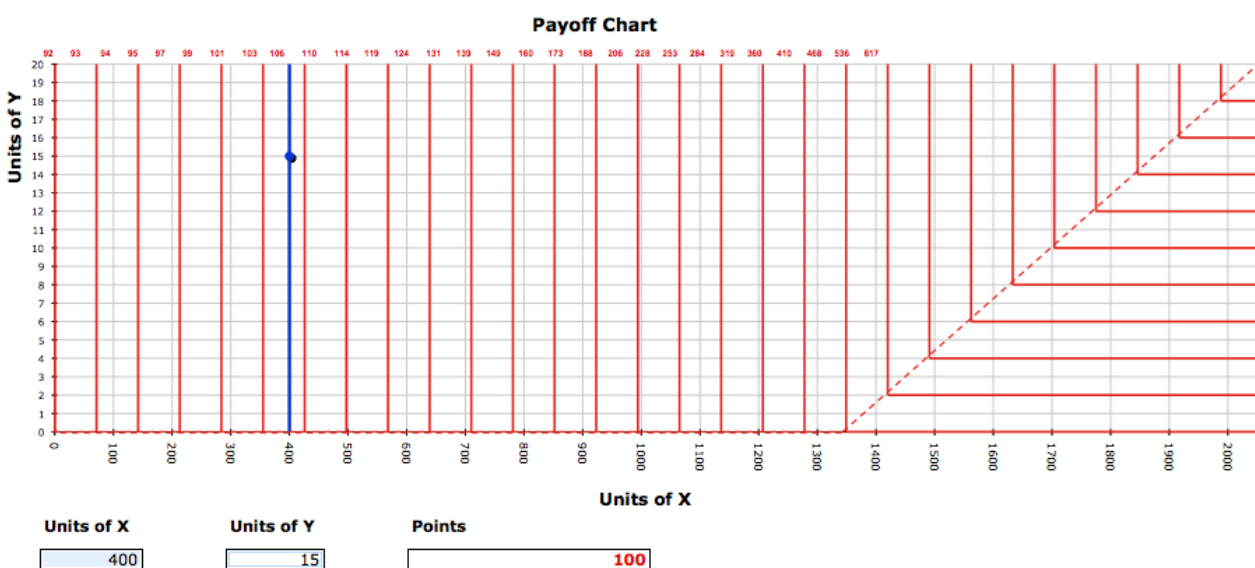
1. On your computer payoff chart, re-enter the combination of 1600 X and 12 Y in the calculator. How many points is this combination worth?
2. If you possessed this combination and would like to make a trade to get to a higher point curve, what would you do? Circle the correct answer.
 - Buy more Y by trading away some X.
 - Sell more Y to acquire some more X.
3. Now enter the combination of 1800 X and 4 Y in the calculator. How many points is this combination worth?
4. If you possessed this combination and would like to make a trade to get to a higher point curve, what would you do? Circle the correct answer.
 - Buy more Y by trading away some X.
 - Sell more Y to acquire some more X.
5. Now enter the combination of 1200 X and 7 Y in the calculator. How many points is this combination worth?
6. If you possessed this combination and would like to make a trade to get to a higher point curve, what would you do? Circle the correct answer.
 - Buy more Y by trading away some X.
 - Sell more Y to acquire some more X.
7. Now toggle to the market trading window on your computer. On the Market Summery frame, click on the Inventory link near the bottom-center of the frame. Under Defaults, you will see a particular combination of X and Y. This will be your starting endowment in each period. Write down your endowment: [] X and [] Y. Now enter your endowment in the calculator. How many points is your endowment worth?

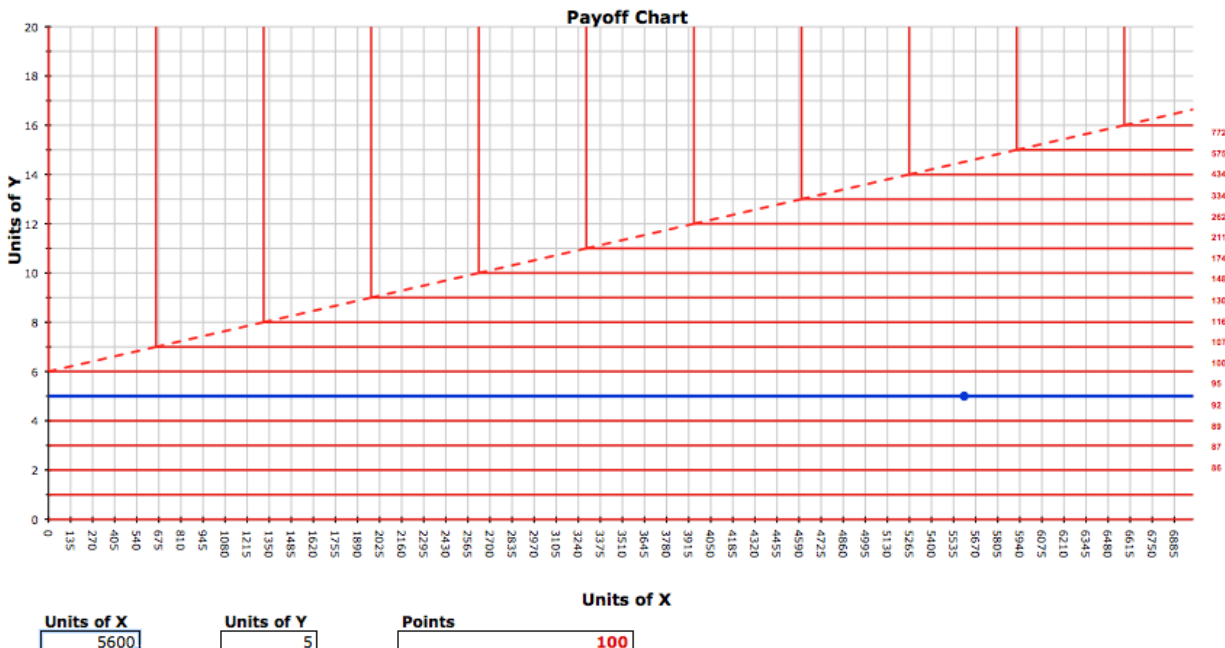
8. If at the beginning of a period (where your starting combination will be your endowment) you would like to make a trade to get to a higher point curve, what would you do? Circle the correct answer.

- Buy more Y by trading away some X.
- Sell more Y to acquire some more X.

C.3 Induced Preference Maps

Below we show screenshots from the interactive induced preference plots used in the experiment. These plots were implemented in Microsoft Excel and show reference indifference curves in red. Subjects entered X and Y amounts in the boxes provided and were shown the corresponding point on the graph, the indifference curve that point lies on and the number of points the subject would earned were the period to end at that allocation. Actual earnings were calculated by the trading software (Marketscape); these maps were used to help subjects visualize their preferences and plan trades.





C.4 Marketscape

The Marketscape window is where you will trade goods X and Y. The Market Summary frame will look similar to this one:

MARKET SUMMARY ID: 65 Tue Apr 8 05:39:35 2008 Period 1 0:09:55 [RELOAD CURRENT DATA](#)

Market	Your Units	Best Buy Offer	Best Sell Offer	Last Trade	My Offers	My Trades	Graph	History
Y	5	-2-	-2-	-	-	-	-	-

Order Form

☐ Buy ☐ Sell Market:

Units: Price:

Time to Expire: (e.g. 1h6m5s; 0=never expire)

Your francs on hand is: [Home](#) [Instructions and Help](#) [Inventory](#) [Personal History](#) [Graph of All Markets](#) [Announcements](#) [LOGOUT](#)

On the top line of the frame is where you can find the time remaining in the current period (in this case 9 minutes and 55seconds), and a Reload Current Data link. It is very important that you click this link frequently during the experiment, because market activity is not updated on your screen automatically; you must manually refresh the window to see the current state of the market.

Suppose we click on the Inventory link near the bottom-center of the frame. This will bring

up a frame below the Market Summary frame that looks something like this:

Information accurate as of Tue Apr 8 06:10:11 2008

Cash and Unit Holdings	
earnings	0
x	2100
y	5

Defaults (your inventory will reset to this at the end of each period)	
x	2100
y	5

Defaults represent your endowment of goods X and Y. In this example you would start each period with 2,100 units of good X and 5 units of good Y. No goods have been traded yet, so your Unit Holdings of X and Y are the same as your Defaults. After you exchange goods in the market these unit holdings will be updated to reflect the transactions (provided you have clicked the refresh button). The earnings line will track your current number of points in the period, although it is disabled in the practice period.

Suppose you want to place an order. You do so by using the Order Form within the Market Summary Frame. If you wish to try to buy some more units of good Y, you would click the “Buy” button and select Market Y using the drop-down arrow. Then you would enter how many units of good Y you wish to buy and at what price. For example, you might decide to try to buy 1 unit of good Y at a price of 150 units of good X:

MARKET SUMMARY
ID: 65
Tue Apr 8 05:57:01 2008
Period 1 0:09:45
[RELOAD CURRENT DATA](#)

Market	Your Units	Best Buy Offer	Best Sell Offer	Last Trade	My Offers	My Trades	Graph	History
Y	5	-@-	-@-	-	-:-	●	●	●

Order Form
☒ Buy ☐ Sell
Market: Y
Units: 1
Price: 150
Time to Expire: 0
(e.g. 1h6m5s; 0=never expire)
Order Clear

Your francs on hand is:
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[Personal History](#)
[Graph of All Markets](#)
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After you click the Order button, your order is submitted and other participants will be able to accept your offer. Note that this order is now listed in the Market Summary frame as the “Best Buy Offer” after the frame was refreshed since it was the first order in the market (1@150 means the current best offer to buy is 1 unit of Y for 150 units of X):

MARKET SUMMARY
ID: 65
Tue Apr 8 06:01:59 2008
Period 1 0:07:58
[RELOAD CURRENT DATA](#)

Market	Your Units	Best Buy Offer	Best Sell Offer	Last Trade	My Offers	My Trades	Graph	History
Y	5	1@150	-@-	-	150:-			

Order Form
☐ Buy ☐ Sell
Market:
Units: Price:
Time to Expire:
(e.g. 1h6m5s; 0=never expire)

Your francs on hand is:
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Now suppose several orders have been placed by various participants in the market. If you click on the Market Y link near the top left of the Market Summary frame, you will see the following frames:

MARKET SUMMARY
ID: 65
Tue Apr 8 06:04:42 2008
Period 1 0:05:14
[RELOAD CURRENT DATA](#)

Market	Your Units	Best Buy Offer	Best Sell Offer	Last Trade	My Offers	My Trades	Graph	History
Y	5	1@160	1@175	-	160:-			

Order Form
☐ Buy ☐ Sell
Market:
Units: Price:
Time to Expire:
(e.g. 1h6m5s; 0=never expire)

Your francs on hand is:
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THE Y MARKET

Note: Market Data is not automatically updated... Information accurate as of Tue Apr 8 06:04:35 2008

You have 2100 x
You have 5 y in this market

Buy Order Book (help)	Sell Order Book (help)
↓ Best Offer ↓ • 1 y for 160 x each by ID# 65 on Tue Apr 8 06:04:31 2008 -- expires never • 1 y for 150 x each by ID# 65 on Tue Apr 8 06:01:33 2008 -- expires never • 1 y for 150 x each by ID# 70 on Tue Apr 8 06:03:35 2008 -- expires never • 1 y for 125 x each by ID# 62 on Tue Apr 8 06:03:23 2008 -- expires never	↓ Best Offer ↓ • 1 y for 175 x each by ID# 68 on Tue Apr 8 06:03:03 2008 -- expires never • 2 y for 200 x each by ID# 59 on Tue Apr 8 06:02:19 2008 -- expires never

Four buy orders have now been placed in the market. The order you initially placed is on the second line of the Buy Order Book. Buy orders appear in descending price order, because the highest price is the best offer to buy that has been posted. If two buy orders share the same price, the one that arrived earliest will be posted above the other.

Two sell orders have been placed in the Sell Order Book. Sell orders appear in ascending order of price, because the lowest price is the best offer to sell that has been made. So the best offers to buy and sell are always listed on the top line of the appropriate order book.

You should also note that in the Market Summary frame the best buy and sell orders have been updated to include the top line orders in the Buy and Sell Order Books. Your best offer has also been updated under “My Offers” (if you click on this link, it will produce a frame that shows only your orders in the order books, and which will give you the option to cancel any of these orders if you wish to do so).

So far no trade has taken place. If you place a new buy order at a price equal to or above the best sell order, or if you place a new sell order at a price equal to or below the best buy order, you will exchange goods at the best price currently posted in the appropriate order book. For example, suppose you would like to accept the best offer to sell. In the Order Form in the Market Summary frame, you would check “Buy”, market Y, 1 unit, and a price of 175 (or any greater price), then click the “Order” button. This results in a transaction. If you now click on the link to Market Y, you will see the following frames:

MARKET SUMMARY
ID: 65
Tue Apr 8 06:05:52 2008
Period 1 0:04:03
[RELOAD CURRENT DATA](#)

Market	Your Units	Best Buy Offer	Best Sell Offer	Last Trade	My Offers	My Trades	Graph	History
Y	6	1@160	2@200	175	160			

Order Form
☐ Buy ☐ Sell
Market:
Units: Price:
Time to Expire: 0
(e.g. 1h6m5s; 0=never expire)

Your frames on hand is:
[Home](#)
[Instructions and Help](#)
[Inventory](#)
[Personal History](#)
[Graph of All Markets](#)
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THE Y MARKET

Note: Market Data is not automatically updated... Information accurate as of Tue Apr 8 06:05:39 2008

You have **1925 x**
You have **6 y** in this market

Buy Order Book (help)	Sell Order Book (help)
↓ Best Offer ↓ 1 y for 160 x each by ID# 65 on Tue Apr 8 06:04:31 2008 -- expires never 1 y for 150 x each by ID# 65 on Tue Apr 8 06:01:33 2008 -- expires never 1 y for 150 x each by ID# 70 on Tue Apr 8 06:03:35 2008 -- expires never 1 y for 125 x each by ID# 62 on Tue Apr 8 06:03:23 2008 -- expires never	↓ Best Offer ↓ 2 y for 200 x each by ID# 59 on Tue Apr 8 06:02:19 2008 -- expires never

The best offer in the Sell Order Book has disappeared because you bought it. Notice that you now have 6 units of Y (rather than 5) and 1,925 units of X (rather than 2,100) because of the transaction. Also notice in the Market Summary frame that “Your Units”, “Best Sell Offer”, and “Last Trade” have all been updated.

Finally, note that orders for multiple units will clear the order book from top to bottom. For

example, if instead of submitting a Buy order for 1 unit at a price of 175 you had submitted a Buy order for 2 units at a price of 200, you would have bought 1 unit at a price of 175 (the top order), and 1 unit at a price of 200 (from the next line in the sell order book). If you had instead submitted a Buy order for 2 units at a price of 175, you would have bought 1 unit at a price of 175, and since there are no more sell orders in the Sell Order Book at a price that low, the balance of your submission would appear on the top line of the Buy Order book.

Certain restrictions may be placed on order prices during this experiment. In the first period you will only be permitted to trade at a price of 275. That is, every order to buy or sell must be posted at a price of 275. This restriction is designed to allow you to focus on what you should be doing at a particular price (that is, should you be buying or selling, and how many units) and not have to worry about what price to set. It is basically a paid training period to make certain you understand your payoff chart. If during this period you are not certain how to determine the number of units of X and Y you currently own, and how many points this combination would be worth at the end of the period, please let me know and I will show you how to find this information.

In the remaining periods of the experiment you will have the flexibility to choose your own prices, although I may set restrictions on the minimum or maximum price. Any such restriction will be announced at the beginning of the period and will remain in effect until the end of the period. It is very important that you obey these price restrictions. I will be monitoring price postings, and if I notice that you are not following the rules I reserve the right to not pay you for the period. If you accidentally post an illegal price, click on the “My Offers” link in the trading window and cancel the order right away. Also make every attempt not to accept anyone else’s illegal offers.