



Effect of Learning and Market Structure on Price Level and Volatility in a Simple Market

Walt Beyeler¹

Kimmo Soramäki²

Robert J. Glass¹

¹Sandia National Laboratories

²Helsinki University of Technology

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The views expressed in this presentation are those of the authors and do not necessarily reflect those of their institutions



Motivation and Objectives

- Infrastructures deliver basic commodities, such as electric power, petroleum products, food, telecommunications, and money
- Markets are widely and increasingly used for allocation
- Markets communicate and reflect the stresses on the system
- Disruptions in the operation of markets, or the composition and disposition of participants, can create extraordinary stresses
- We want to understand how real markets operate, and how their behavior is influenced by the various factors adduced to explain non-ideal behavior, such as volatility:
 - Exogenous shocks – classical economic explanation
 - Endogenous features
 - Market structure – e.g. Doyne Farmer
 - Participant beliefs – e.g. herding

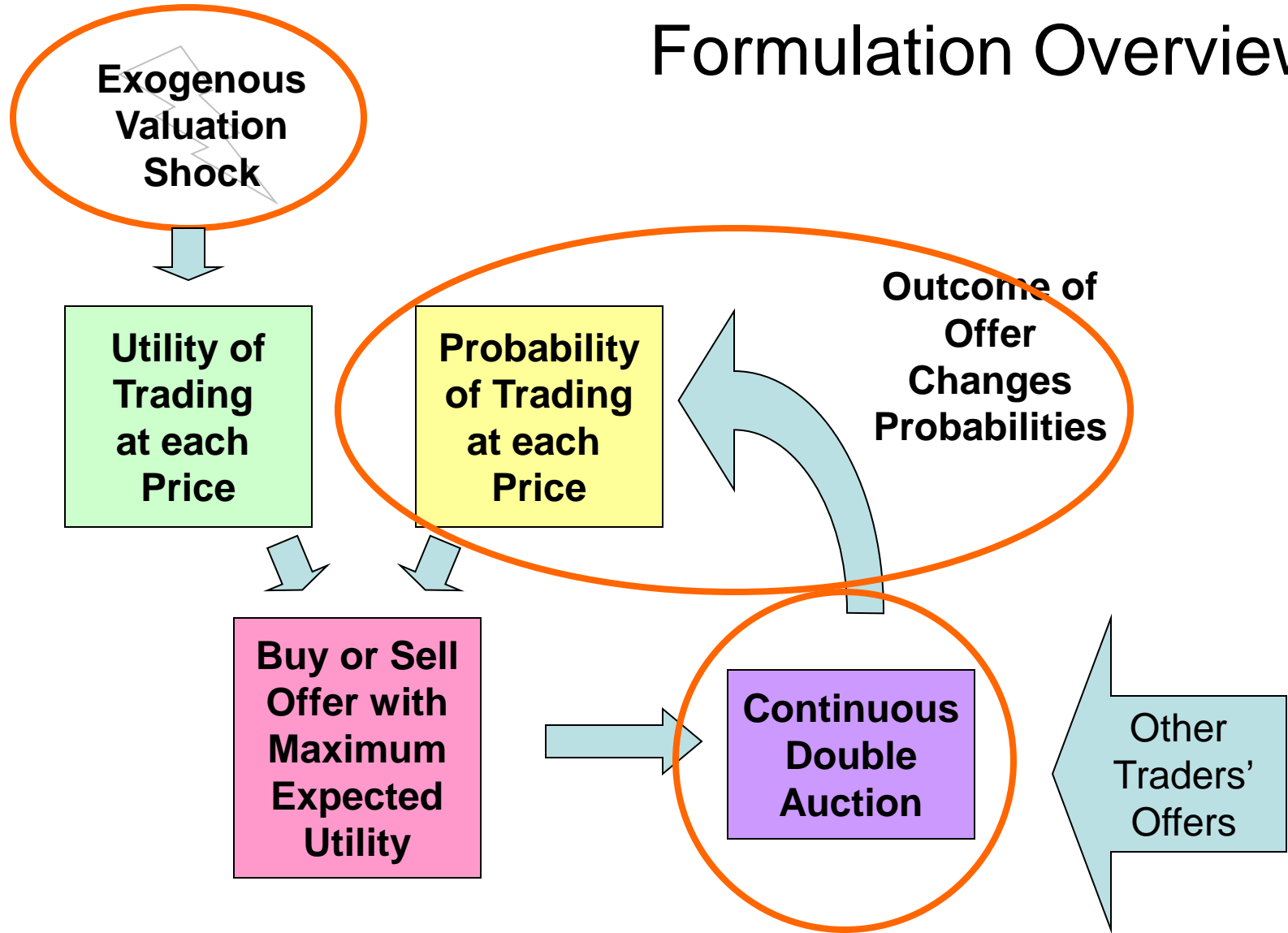


Formulation - Overview

- Traders transfer a unit of a commodity once, at most, in each of a series of trading periods
- In each period ...
 - Traders are paired in a continuous double auction market. One or several rounds of bidding take place in each period
 - In each round r a trader k posts an order to buy or to sell at a discrete price level $x_{r,k}$ of their choosing.
 - Orders enter in a random sequence. The current best buy and sell orders on the book determine the match price
 - Traders choose a role and a price to maximize their expected utility.



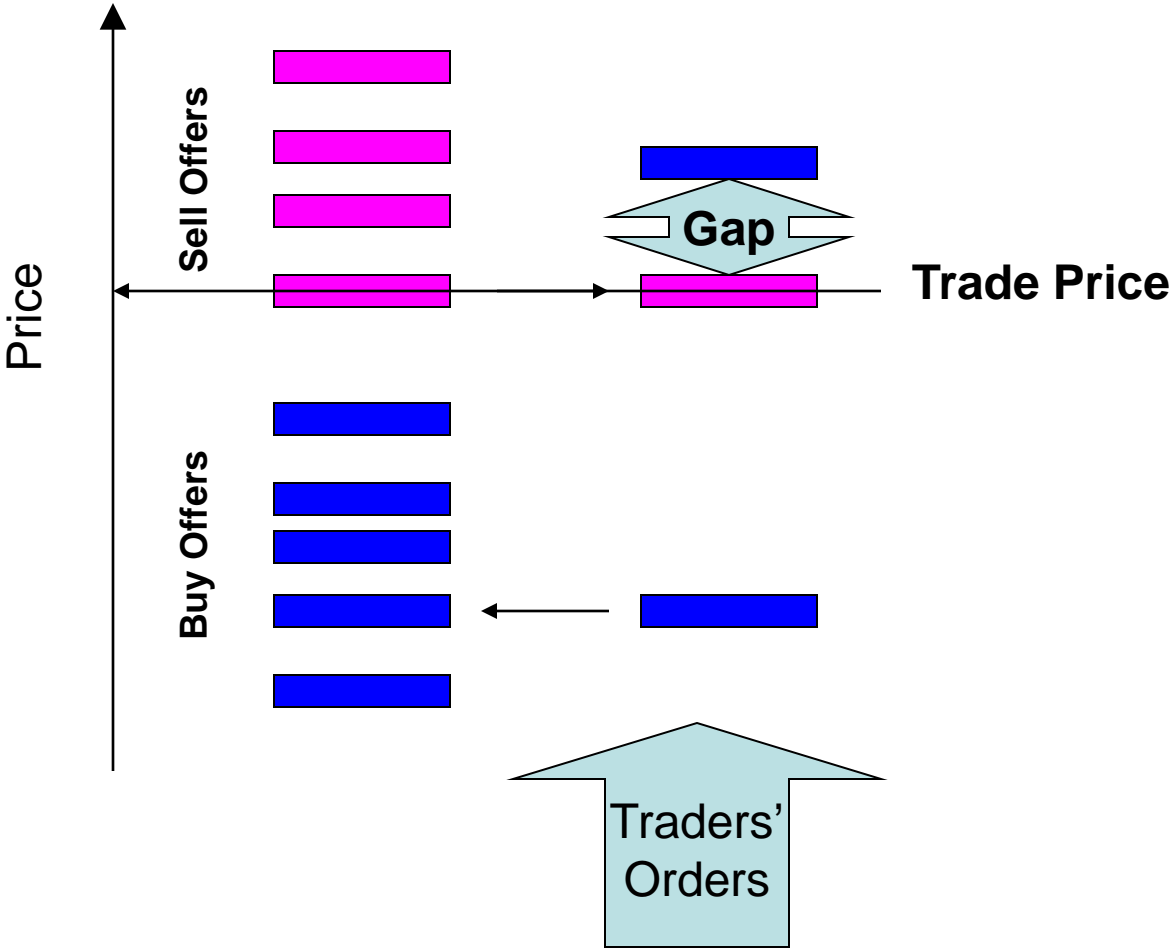
Formulation Overview





Market Structure

Broker's Book





Formulation - Utility

Traders choose a role and a price to maximize their expected utility. The expected utility for an order at x in round r is

$$u_r(x) = P_r(T(x))u_t(x) + (1 - P_r(T(x)))u_{\bar{t}}$$

where $P_r(T(x))$ is the estimated probability for trading at price x in round r

$u_t(x)$ is the utility for completing a trade at price x :

- If they decide to buy $u_t(x) = v - \hat{x} - c_t$
- If they decide to sell $u_t(x) = \hat{x} - v - c_t$
with \hat{x} the actual trading price, c_t trade cost

$u_{\bar{t}}$ is the utility for failing to trade:

- 0 for the final bidding round
- $\max_x(u_{r+1}(x))$ for earlier rounds



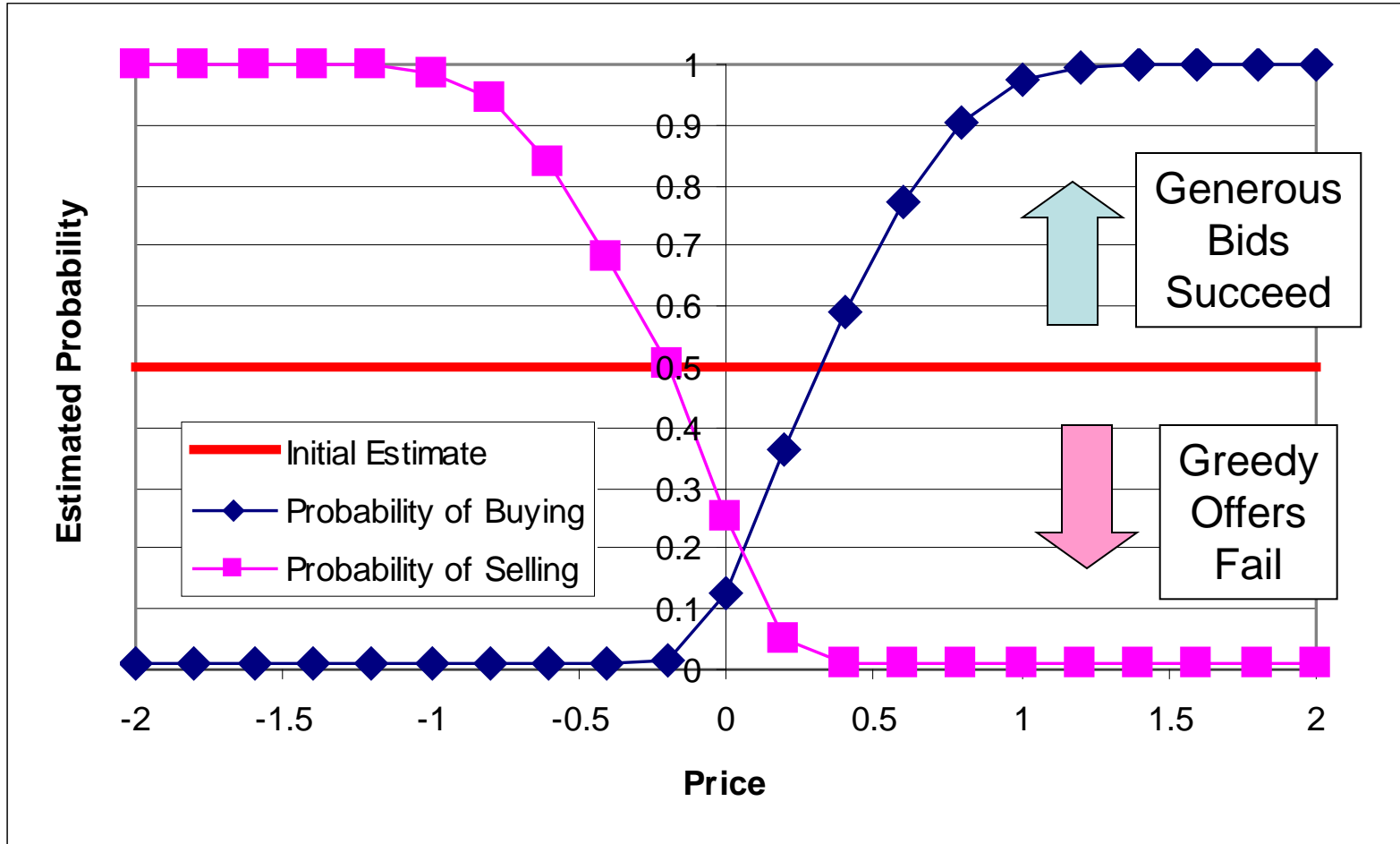
Probability Estimates Define Trader's Beliefs

- Traders track the performance of their orders at each price level to estimate the probabilities that orders at any price level will be matched
- They model matching as a random process with an unknown probability. Counts of successes and trials let them estimate this probability
- Orders and their outcomes at one price level give information about the outcomes of proposals that might have been made:
 - Matched orders would have been matched at better prices too
 - Unmatched orders would also have failed at worse prices



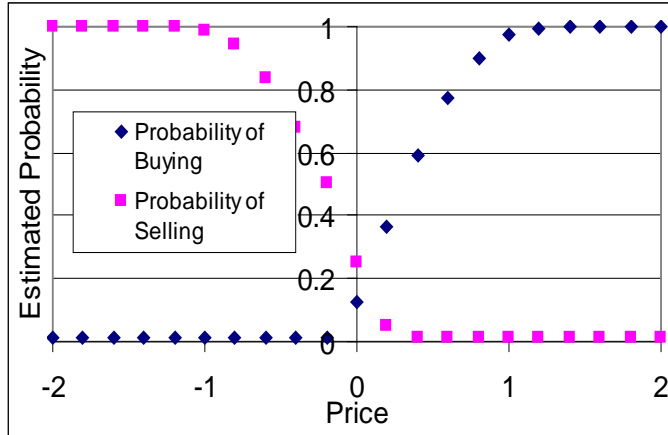
Learning by Updating Probability Estimates

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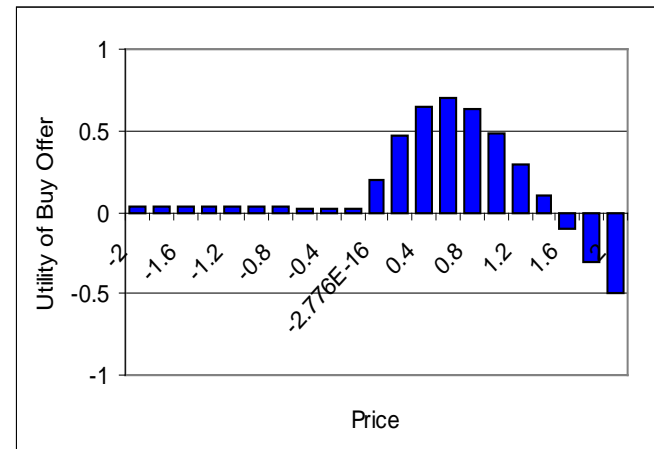
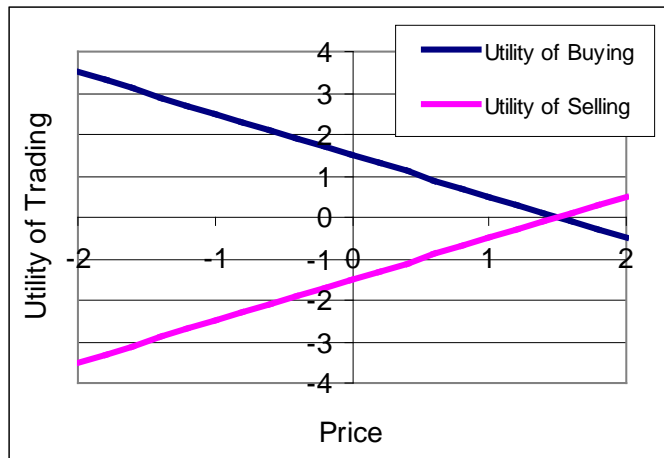
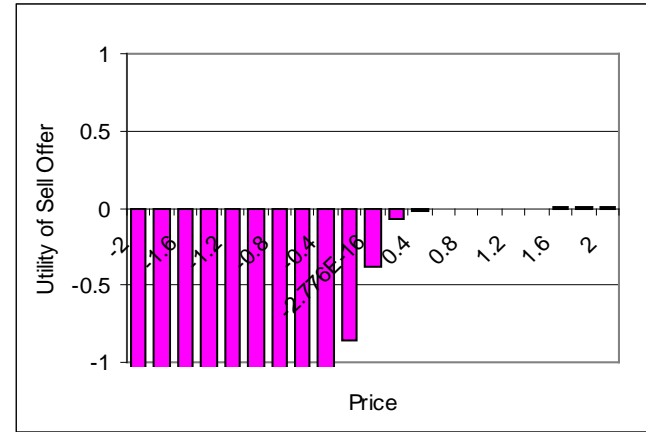




Example Expected Utility Calculation



X





Input Summary

- Inputs varied to study the effect of the three factors of interest:
 - Market efficiency: number of rounds and transaction cost
 - Imperfect and heterogeneous information: uninformed traders (trader lifetime)
 - Exogenous valuation shocks: individual and common element
- Other key inputs
 - 100 traders
 - 21 price levels from -2 to 2
 - 2000 trading periods



Input Details

<i>Factor Influencing Price</i>	<i>Model Parameter</i>	<i>Cases or Values Considered</i>
Exogenous Shocks	Range of Individual Shocks	(-20,20), (-5,5),(-0.5,0.5)
	Range of Common Shocks	(-1,1),(-0.5,0.5),(0,0)
Market Efficiency	Transaction Cost	0,0.1
	Number of market rounds per trading period	1, 2, 5
Trader Information Use	Average trader lifetime	100, 500, infinite



Key Outputs

- Indicators of market efficiency
 - standard dev. of average daily trade prices
 - average gap between buy and sell offers that are matched
 - daily trade volume



Results – No common shock

*Trading Volume, Standard Deviation of Price, Average Price Gap
Common Shock =0, Infinite Lifetime*

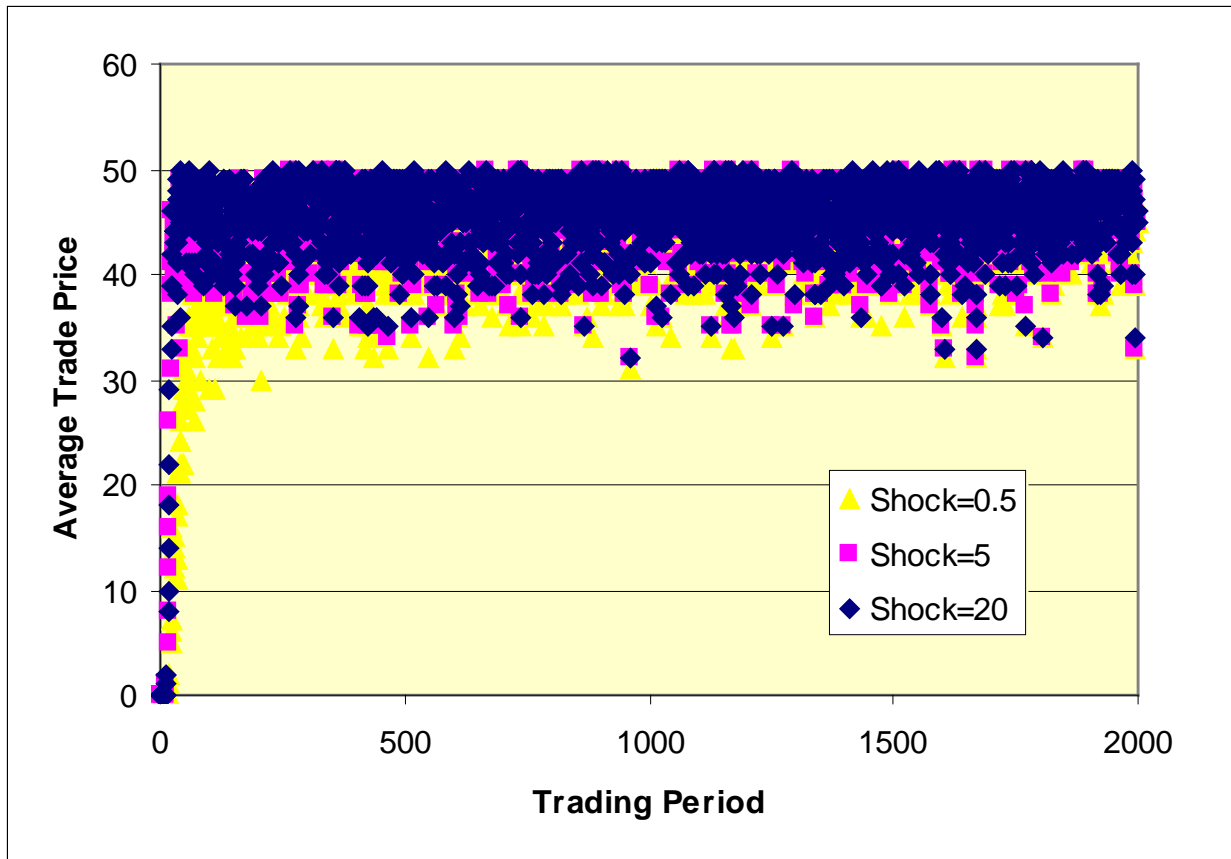
		<i>Individual Shock Range</i>		
		<i>0.5</i>	<i>5</i>	<i>20</i>
Number of Rounds	1	44.9	45.5	45.8
		0	0.209	0.720
		0	0.57	2.00
	2	44.5	45.4	45.7
		0	0.155	0.526
		0	0.36	1.44
	5	43.6	45.4	46.2
		0	0.053	0.198
		0	0.02	0.48

- Traders can learn to trade in one round, but efficiency improves with more rounds
- Traders cope with large shocks by making more attractive orders

Results – Trade Volume for One Round



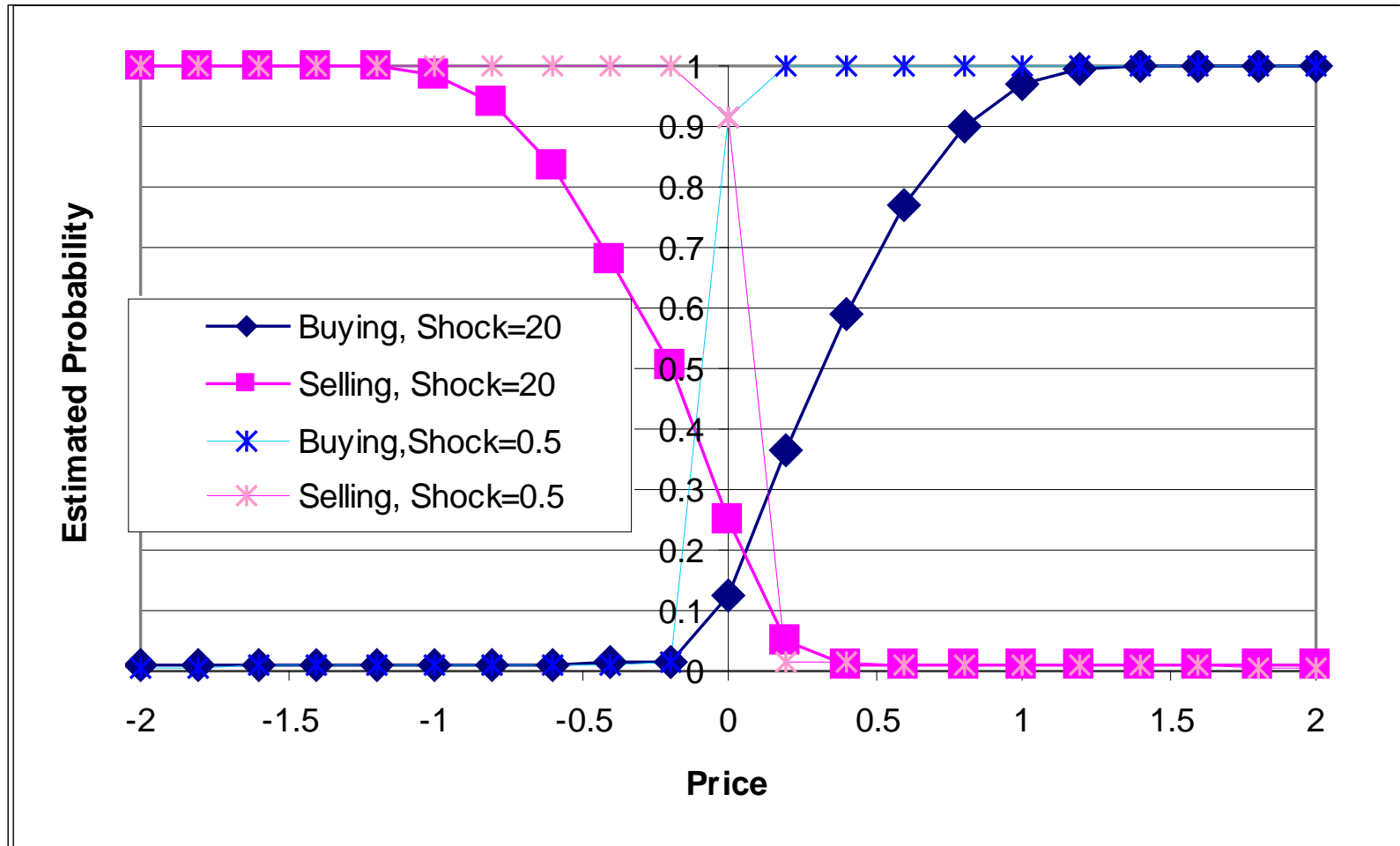
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Larger shocks lead to faster approach to market clearing

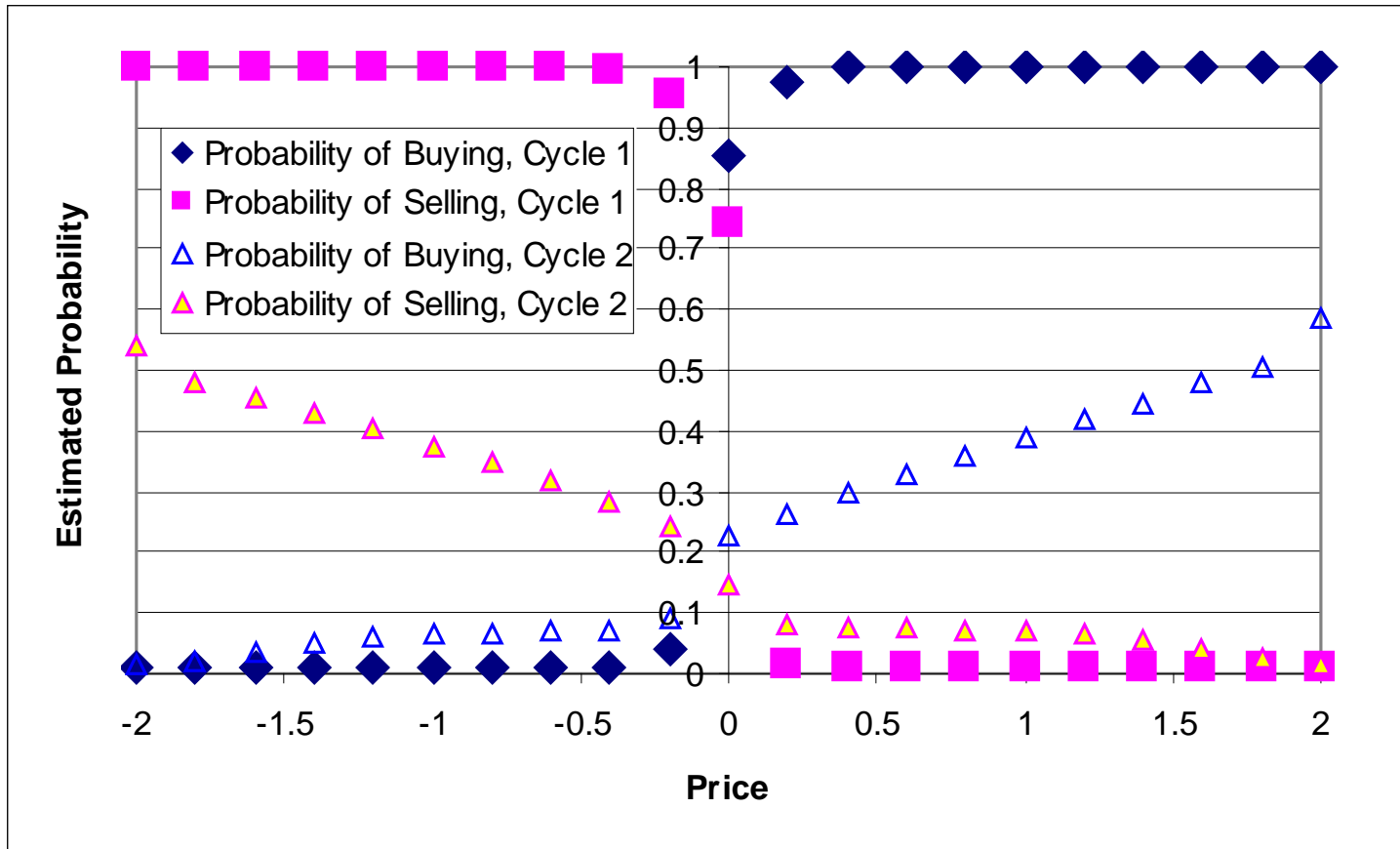


Trading Range is Much Narrower than Range of Individual Shocks





Market Rounds Shape Probability Estimates



Probability of Buying and Selling in the First 2 Rounds of a 5-round Trader
Almost All Trades Happen in the First Round



Results – No common shock

Trading Volume, Standard Deviation of average daily price, Average Price Gap
Common Shock =0, 500 Period Lifetime
(with comparison values for Common Shock=0, Infinite Lifetime)

		<i>Individual Shock Range</i>		
		<i>0.5</i>	<i>5</i>	<i>20</i>
Number of Rounds	1	39.2 (44.9) 0.001 (0) 0.001 (0)	44.1 (45.5) 0.139 (0.209) 0.34 (0.57)	44.9 (45.8) 0.481 (0.720) 1.20 (2.00)
	2	35.0 (44.5) 0.010 (0) 0.003 (0)	43.5 (45.4) 0.080 (0.155) 0.05 (0.36)	45.5 (45.7) 0.254 (0.526) 0.60 (1.44)
	5	36.4 (43.6) 0.007 (0) 0.003 (0)	43.2 (45.4) 0.067 (0.053) 0.02 (0.02)	44.9 (46.2) 0.110 (0.198) 0.05 (0.48)

Finite lifetime can lead to less price variability



Results – No common shock

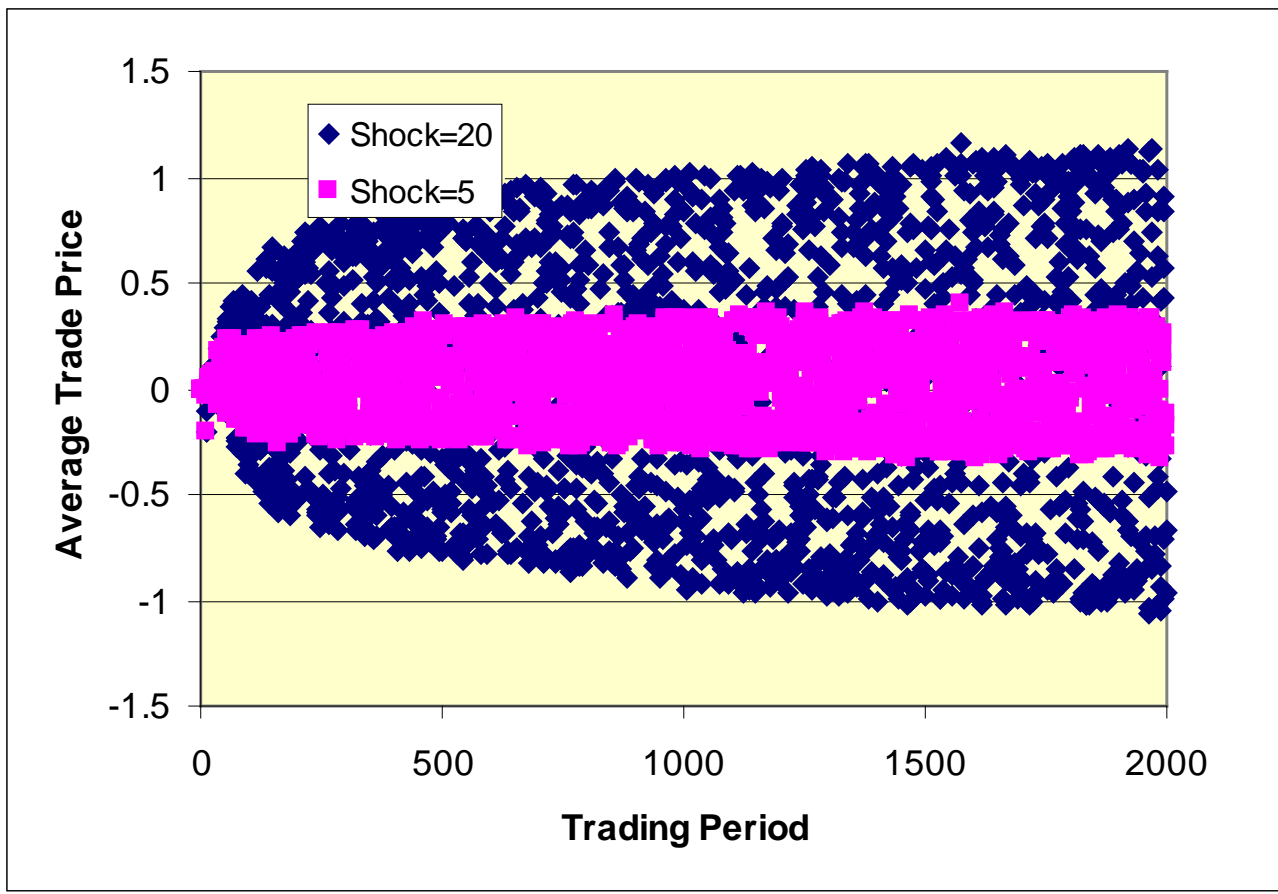
*Trading Volume, Standard Deviation of Price, Average Price Gap
Common Shock =0, 100 Period Lifetime
(with comparison values for Common Shock=0, Infinite Lifetime)*

		<i>Individual Shock Range</i>		
		<i>0.5</i>	<i>5</i>	<i>20</i>
Number Of Rounds	1	26.2 (44.9) 0 (0) 0 (0)	36.6 (45.5) 0.105 (0.209) 0.232 (0.57)	38.2 (45.8) 0.186 (0.720) 0.424 (2.00)
	2	26.5 (44.5) 0.002 (0) 0 (0)	35.9 (45.4) 0.052 (0.155) 0.052 (0.36)	37.8 (45.7) 0.113 (0.526) 0.238 (1.44)
	5	25.9 (43.6) 0.003 (0) 0.001 (0)	35.6 (45.4) 0.052 (0.053) 0.026 (0.02)	38.4 (46.2) 0.079 (0.198) 0.039 (0.48)

... and ultimately to fewer trades



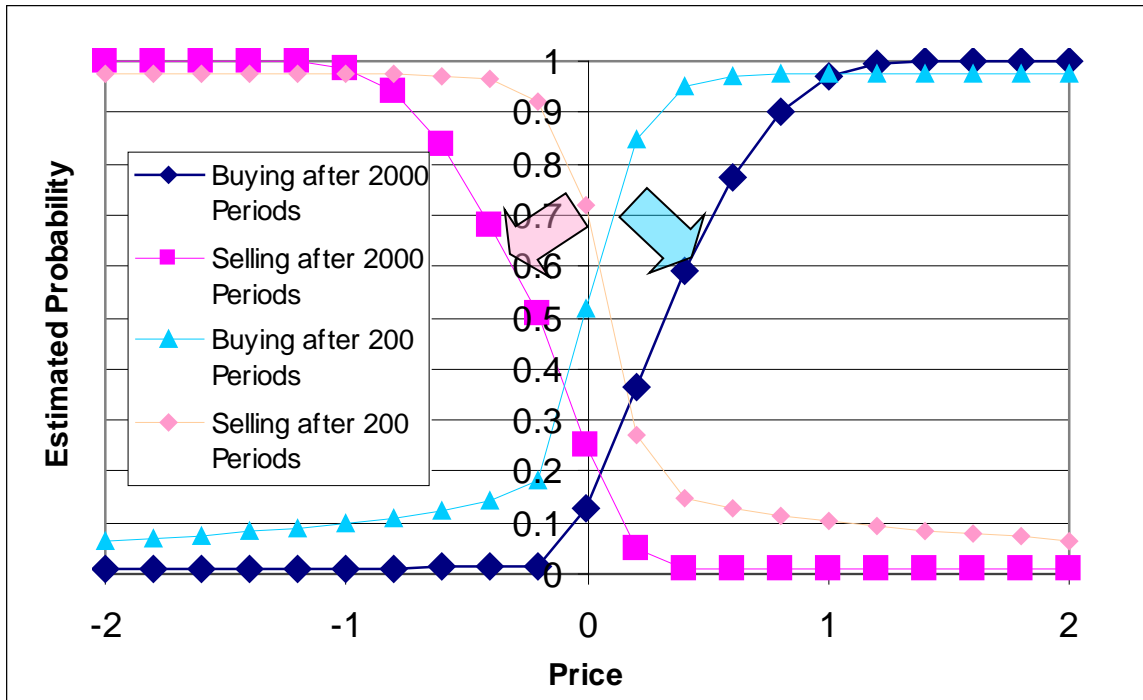
Trade Prices Increase Over Time



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Dynamics of Spreading Trade Prices



1. Trades initially happen at prices near 0
2. Bad timing gives some traders information about the risk of bidding in the middle
3. Large shocks make higher bids (lower offers) more attractive than the formerly successful bids
4. Higher bidding by them lowers the probability that others will succeed at that price



Results – Trading Costs

*Trading Volume, Standard Deviation of Price, Average Price Gap
Common Shock =0, Infinite Lifetime, Trading cost = 0.1
(with comparison values for Common Shock=0, Infinite Lifetime)*

		<i>Individual Shock Range</i>		
		<i>0.5</i>	<i>5</i>	<i>20</i>
Number Of Rounds	1	36.3 (44.9)	44.9 (45.5)	45.5 (45.8)
		0 (0)	0.194 (0.209)	0.728 (0.720)
		0 (0)	0.519 (0.570)	2.00 (2.00)
	2	36.1 (44.5)	44.4 (45.4)	45.2 (45.7)
		0 (0)	0.106 (0.155)	0.542 (0.526)
		0 (0)	0.156 (0.36)	1.42 (1.44)
	5	35.7 (43.6)	45.4 (45.4)	45.8 (46.2)
		0 (0)	0.066 (0.053)	0.167 (0.198)
		0 (0)	0.03 (0.02)	0.38 (0.48)

•Trading costs deter a few trades, especially at low shock ranges



Results – Common shock

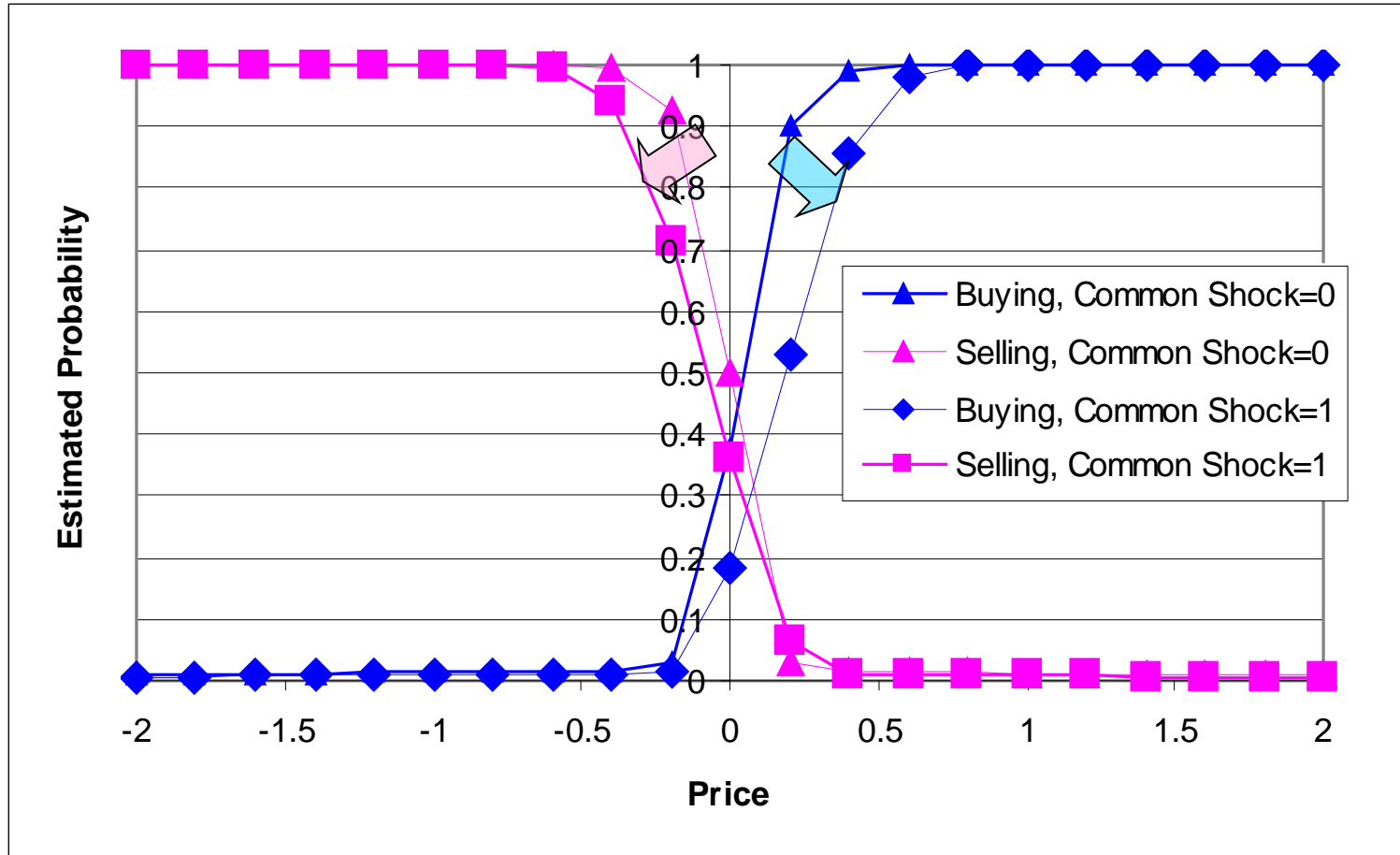
*Trading Volume, Standard Deviation of Price, Average Price Gap
Common Shock =0.5, Infinite Lifetime
(with comparison values for Common Shock=0, Infinite Lifetime)*

		<i>Individual Shock Range</i>		
		<i>0.5</i>	<i>5</i>	<i>20</i>
Number Of Rounds	1	21.4 (44.9)	45.1 (45.5)	45.8 (45.8)
		0.236 (0)	0.25 (0.209)	0.73 (0.720)
		0.104 (0)	0.65 (0.57)	1.98 (2.00)
	2	23.3 (44.5)	44.8 (45.4)	45.7 (45.7)
		0.256 (0)	0.176 (0.155)	0.58 (0.526)
		0.122 (0)	0.40 (0.36)	1.50 (1.44)
	5	24.0 (43.6)	44.3 (45.4)	46.1 (46.2)
		0.260 (0)	0.065 (0.053)	0.17 (0.198)
		0.145 (0)	0.02 (0.02)	0.44 (0.48)

- **Common shock suppresses volume of trade and increases variance**
- **Effect is larger when the common shock is large relative to the individual shocks**



Results – Common Shock Produces More Aggressive Pricing





Results – Common shock

*Trading Volume, Standard Deviation of Price, Average Price Gap
Common Shock =1, Infinite Lifetime
(with comparison values for Common Shock=0, Infinite Lifetime)*

		<i>Individual Shock Range</i>		
		<i>0.5</i>	<i>5</i>	<i>20</i>
Number Of Rounds	1	0 (44.9)	43.4 (45.5)	45.7 (45.8)
		0 (0)	0.384 (0.209)	0.745 (0.720)
		0 (0)	0.57 (0.57)	2.02 (2.00)
	2	0 (44.5)	43.2 (45.4)	45.5 (45.7)
		0 (0)	0.332 (0.155)	0.565 (0.526)
		0 (0)	0.36 (0.36)	1.51 (1.44)
	5	0 (43.6)	43.8 (45.4)	46.0 (46.2)
		0 (0)	0.076 (0.053)	0.223 (0.198)
		0 (0)	0.02 (0.02)	0.55 (0.48)

•Trading is completely disrupted when it drives everyone to one or the other role



Observations

- Traders “learn” to complete a large number of trades in almost all conditions
- Trade prices settle in a narrow range relative to independent shocks
- More rounds lead to more pairing opportunities and narrower price ranges, as expected
- Trading prices increase with time as traders explore boundaries and exploration changes outcome probabilities. Prices are narrower when traders forget
- Common shocks can disrupt trading when their magnitude matches individual shocks
- Probability Estimates -> Behavior -> New Estimates



Complex endogenous dynamics

