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Market Making Theory and Practice (Part 1)
做市理论与实践 (第1部分)

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What is Market Microstructure?
什么是市场微观结构?

- Originally coined by Mark Garman in a1976 *Journal of Financial Economics* paper titled “Market microstructure”
- 最初由Mark Garman于1976年在《金融经济学杂志》中提出，文章名为《市场微观结构》
- Wikipedia: **Market microstructure** is a branch of finance concerned with the details of how exchange occurs in markets.
- 维基百科解释: 市场微观结构是金融学分支，与交易在市场中如何发生的细节相关
- These days market microstructure refers to many aspects of price formation, market making, inventory costs and risk management just to name a few. It’s a broadly defined term that is at the heart of modern day trading practices.
- 目前，市场微观结构指的是价格形成、做市、库存成本和风险管理等的许多方面。该术语定义广泛，是现代日内交易的核心

In this presentation market microstructure is about:
在此次演讲中，市场微观结构将谈及以下几点：

- Price formation
- 价格形成
  - How do supply and demand lead to traded prices?
  - 供应与需求是怎样影响交易价格的?
  - How does information impact prices?
  - 信息是怎样影响价格的?
  - How does strategy enter the picture?
  - 策略是怎样发挥作用的?
- Transaction costs
- 交易成本
  - Bid/Ask spread
  - 买/卖价差
  - Incentives, maker/taker models and other fee structures
  - 奖励措施, 买方做市商/卖方做市商模型和其他费用结构

What's market making
什么是做市

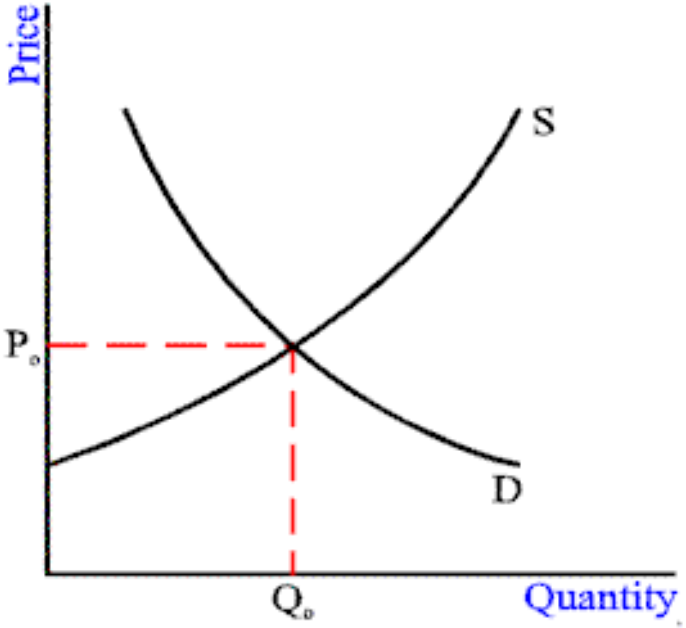
- Liquidity provision
- 提供流动性
- Ability and willingness to be on both sides of the market at all times
- 始终双边交易的能力和意愿
- Ability and willingness to cope with information asymmetry
- 处理信息不对称的能力和意愿
- Inventory management
- 库存管理

Primary challenges of market making
做市面临的主要挑战

- Quoting prices; i.e. at what price to buy and at what price to sell?
- 报价：以什么价格买入和卖出?
- How to modify and adjust the quotes?
- 如何修改和调整报价?
- Managing inventory
- 管理库存
- Managing risk
- 管理风险

Economic mythology
经济学假说

- Efficient markets
- 有效市场
- Perfect and timely information
- 完美、及时的信息
- Rational behavior
- 理性行为
- Similar utility
- 相似的设施
- etc., etc. ….
- 等等
- This is not how prices are formed in the markets
- 这并不是价格在市场中形成的方式



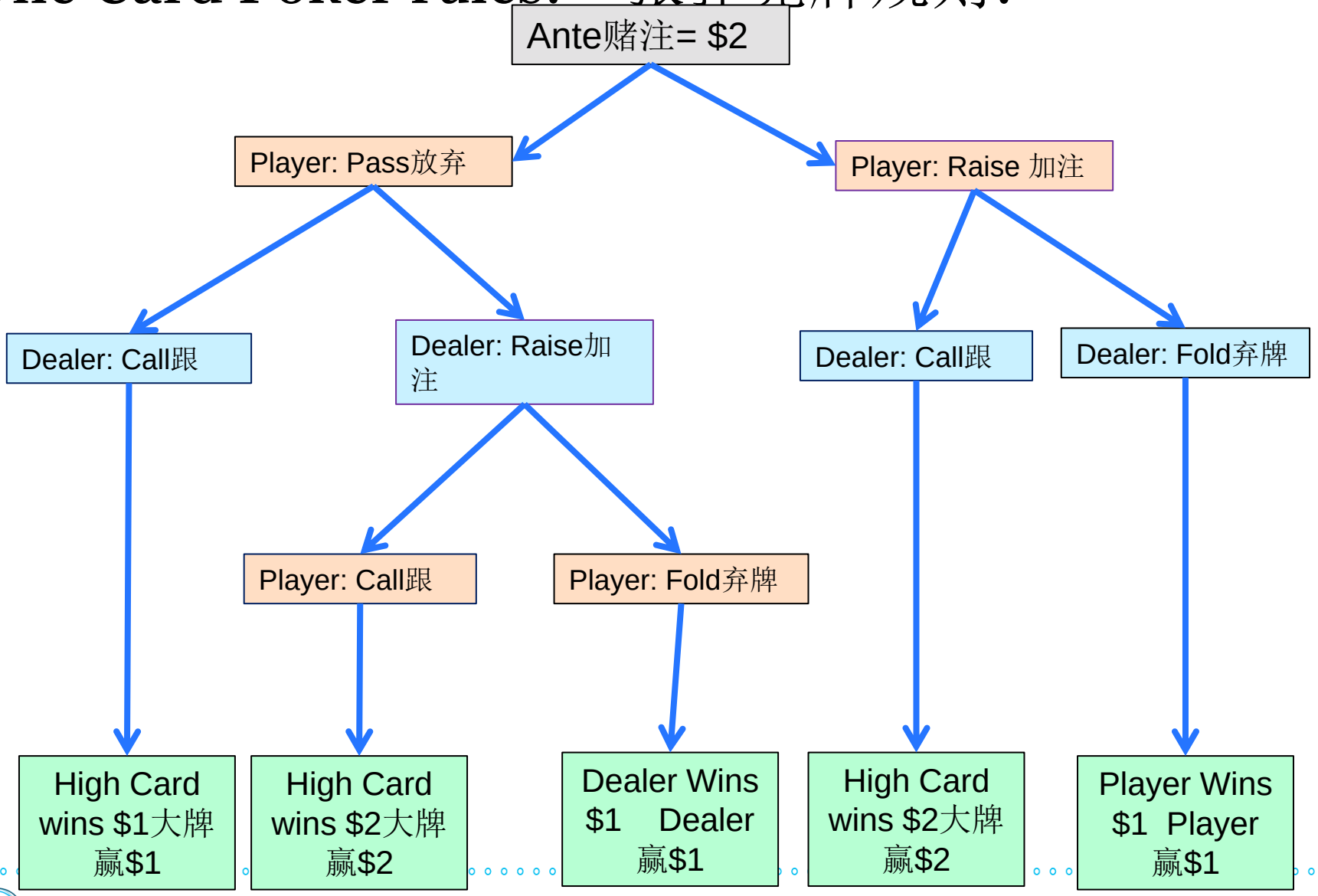
Imperfect information and game theory不完整信息和博弈论

(Koller 和Pfeffer, 1995; Swanson 2005; Gordon: http://www.cs.cmu.edu/~ggordon/poker/)

A useful illustration:说明:

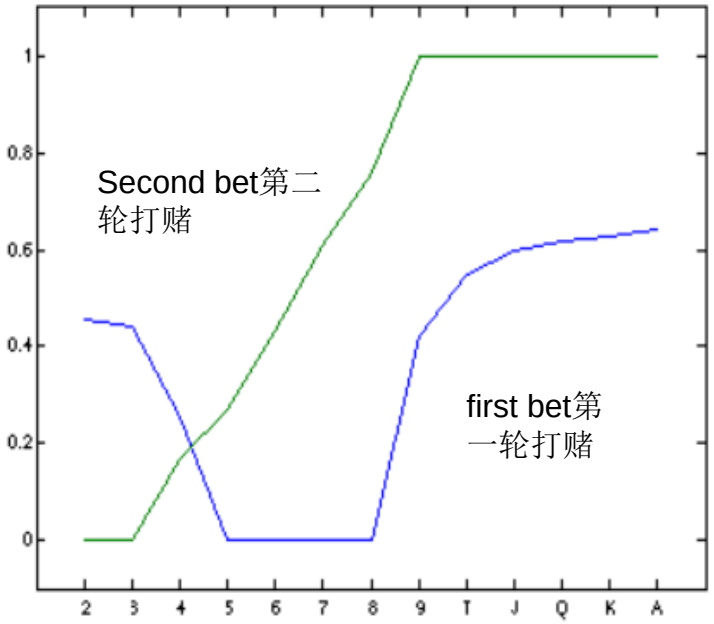
- "High Card" is a simple game where two players draw from a deck and the high card wins the ante. In contrast, in "One Card Poker" each player is dealt a card, however, the cards are not immediately turned over. "大牌"是一种简单的游戏，2名玩家从一副牌中抽牌，持有大牌的赢得赌注。与此相比,在"一张扑克牌"这个游戏中，每个玩家被分配一张牌，但不能立即开牌
- One Card Poker game rules (diagram on the next slide):一张扑克牌游戏规则 (图解在下一页):
  - The game is played with two people, we'll refer to the player that acts first as the "player" and the other as the "dealer"该游戏需2名玩家来进行，我们把先行动的那名玩家称为"player"，另一名则称为 "dealer"
  - each puts in a $1 ante每个人交出1美元的赌注
  - Player has the option of raising $1 or passing玩家可选择追加一美元或者放弃
  - If player raises, dealer can call or fold; if called, high card wins如果player追加一美元，dealer可选择跟或者弃牌;如果跟的话，大牌赢
  - If player passes, then the dealer can raise or pass, if he passes high card wins and if he raises then the player will either call or fold如果player选择放弃，则dealer可选择追加赌注或者放弃。如果他选择放弃，则大牌赢。如果他选择追加赌注，则 player 可选择跟或者弃牌
- High Card is a "fair" game and no strategy is required大牌是一个公平的游戏且不需要策略
- One Card Poker does have an optimal strategy and is not a "fair" game一张扑克牌却有着最优策略且不是一个公平的游戏

One Card Poker rules:一张扑克牌规则：

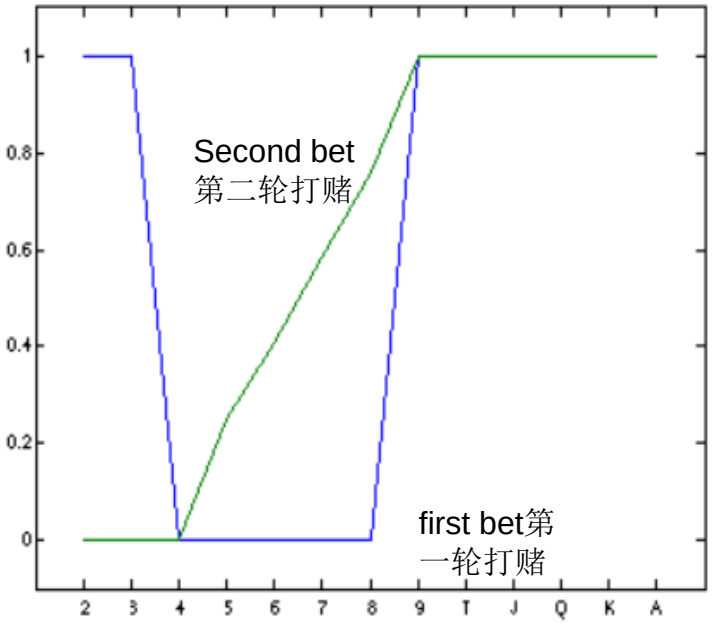


The optimal strategy for One Card Poker一张扑克牌的最优策略

(来自 Gordon: http://www.cs.cmu.edu/~ggordon/poker/)



Player



Dealer

- Note the complex nature of the strategy which uses “bluffing” and other non-obvious variations in betting sequences请注意在赌博顺序中使用“欺骗”和其他不明显的变化策略具有复杂性

Market making involves making decisions with imperfect information做市涉及到使用不完全信息来做决定

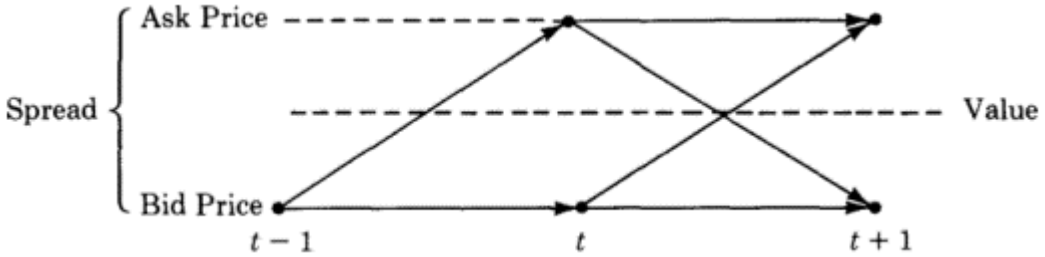
- Information is transmitted through the trading process itself
- 信息是通过交易过程本身来传递的
- Market participants are different because of:
- 市场参与者是各不相同的，因为:
  - Means of accessing and processing information获取和处理信息的方式
  - Risk appetite风险胃纳
  - Availability and cost of capital资本可用性和成本
  - Experience and skills经验和技巧
  - Utility设施
  - Many other differentiators许多其他差异

Microstructure Models微观结构模型

- Mark Garman (1976): coined the term and described Market Microstructure创造了这一术语并描述了市场微观结构
- Richard Roll (1984): simple implicit measure of the bid-ask spread对买卖价差简单、暗示性测量
- Glosten & Milgrom (1985): bid, ask and transaction prices in a specialist market with heterogeneously informed traders有着不同类型的知情交易者的专门市场中的买价、卖价和成交价格
- Kyle (1989): informed speculation with imperfect competition有着不完全竞争的知情的投机
- A good survey of literature: Biais, Glosten and Spatt, 2005. Market microstructure: A survey of microfoundations, empirical results, and policy implications. Journal of Financial Markets, volume 8, issue 2, 217-264.文献纵览: Biais, Glosten和Spatt, 2005. 市场微观结构: 微观基础，实证结构和政策涵义纵览. 金融市场杂志, 第8卷,第2期, 217-264

Roll Model转回模型

- A relatively simple view of the market and price changes:对市场和价格变动的相对简单的概览:



$$\mathrm{Cov}(\Delta p_t, \Delta p_{t+1}) = \tfrac{1}{8}(-s^2 - s^2) = -s^2/4.$$

- Spread is related to the covariance of successive prices价差与连续价格的协方差相关
- Variance is $\frac{s^2}{2}$ and autocorrelation coefficient is -$\frac{1}{2}$方差是$\frac{s^2}{2}$，自相关系数是-$\frac{1}{2}$
- The mean reversion is implied by the model模型得出了均值回归

Limitations of Roll model转回模型的局限性

- Roll model assumes the markets are efficient therefore ignores information and possible asymmetries转回模型假定市场是高效的，因此不考虑信息和可能性不对称
- Roll model does capture certain aspects of the impact of transaction costs转回模型确实说明了交易成本影响的某些方面
- Roll model does not lead to any strategies other than an approximation to the bid-ask spread and the suggestion that price movements are inherently mean reverting转回模型得出了买卖价差近似值，并提出价格变动是固有均值的回复，但是没有提出任何交易策略

Glosten-Milgrom Model Glosten-Milgrom模型

(source来自: Joel Hasbrouck, 2010 http://pages.stern.nyu.edu/~jhasbrou/Teaching/2010%20PhD%20Microstructure/Handouts/SequentialTrade.pdf)

- Belongs to a class of models known as Sequential Trade Models (STM)连续交易模型（STM）其中之一
  - Bid-ask spread is driven by information asymmetries买卖价差是由信息不对称驱动的
  - Can observed bid-ask spreads be used to measure information asymmetries?观测的买卖价差是否可以用于测量信息不对称?
- Orders can “cause” price changes委托单可导致价格变动
- Extreme information asymmetries can cause market disruptions极端的信息不对称可导致市场紊乱

Assumptions: participants and process假设: 参与者和过程

- Participants参与者

  Risk-neutral dealers (market makers without information)中性风险做市商 (没有信息的做市商)

  Traders (agents who want to trade with or without information)交易者(有或没有信息的想要交易的经纪人)

- Process过程

  market makers post bid and ask quotes.做市商发布买卖报.

  A randomly-selected trader arrives and buys or sells one unit一个随机交易者到来并买入或卖出一合约

  If he buys, he pays the market maker's ask.如果他买，则他支付做市商的卖价

  If he sells, he receives the market maker's bid.如果他卖，则他接受做市商的买价

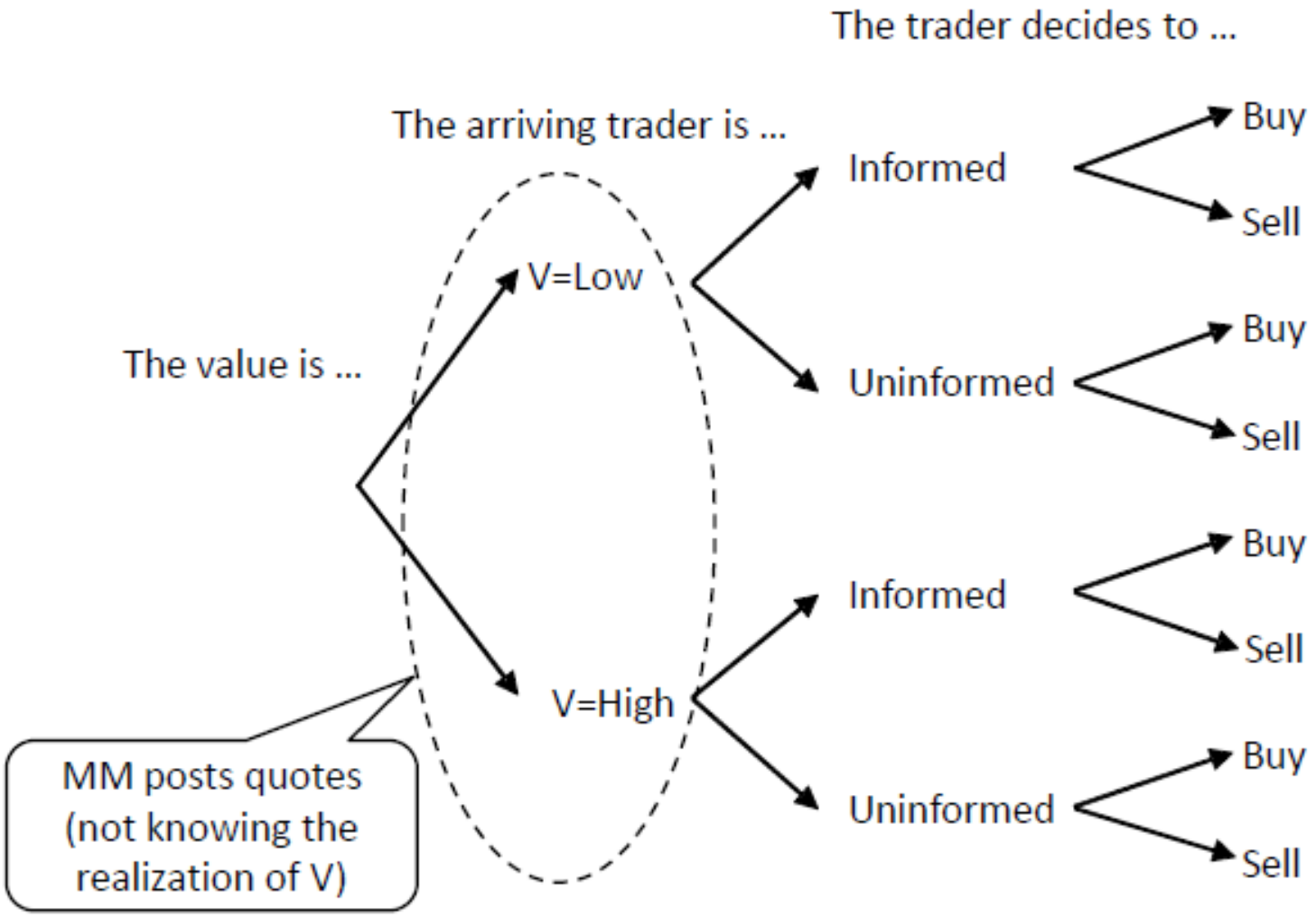
  market makers revise the bid and ask as a result of the trade.交易结束后，做市商修改买价和卖价

  The next randomly selected trader arrives and the process is repeated.下一个随机交易者到来，过程重复

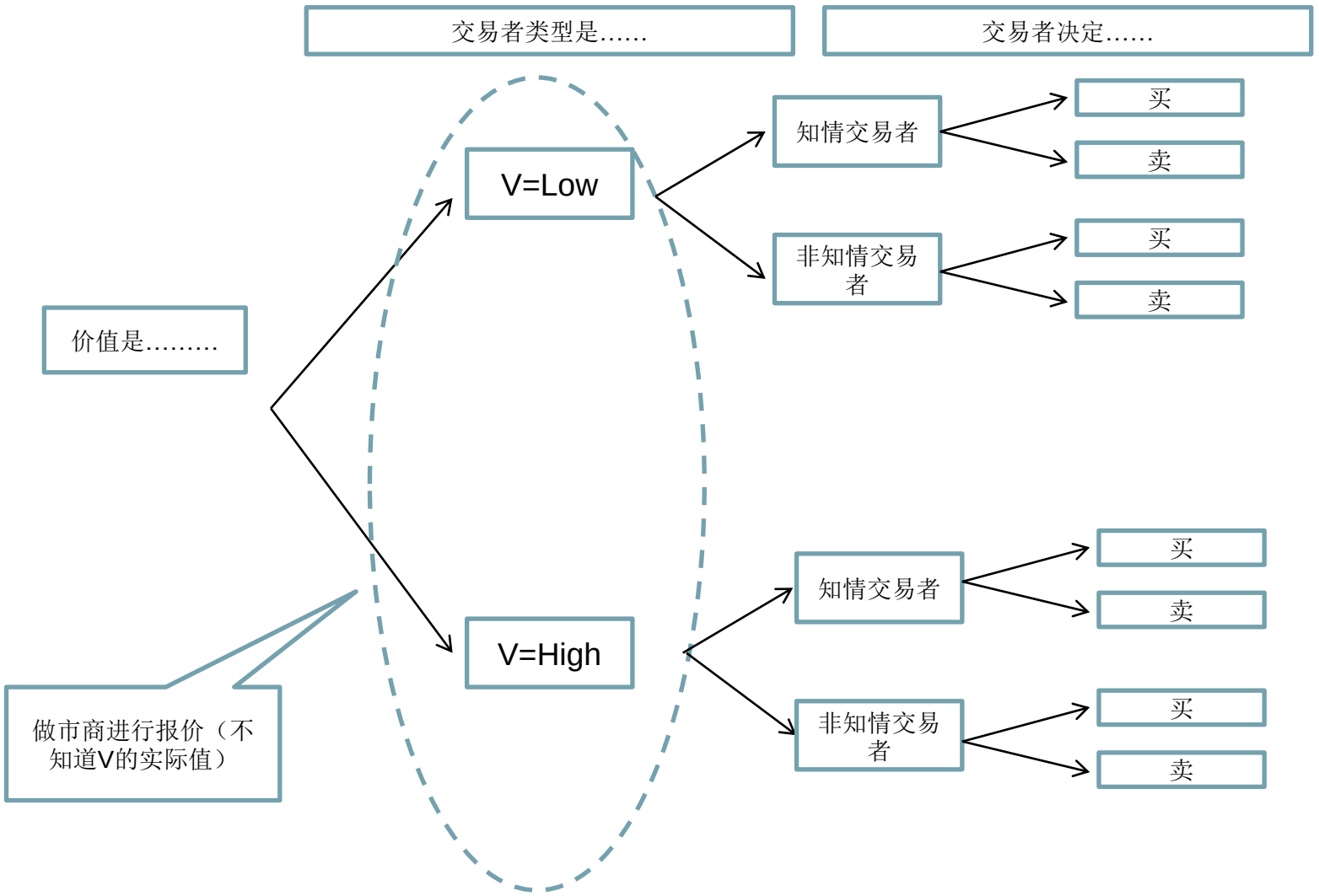
Two types of traders交易者的两种类型

- Informed and uninformed知情交易者和非知情交易者
- Informed traders know in advance whether the outcome is V=Low or High, where V $\in \{Low, High\}$知情交易者可以提前知道结果是否为V=Low或High，其中V $\in \{Low, High\}$
- They will trade to profit on their expectations知情交易者可以按照预期通过交易获利
- Uninformed traders are motivated by idiosyncratic liquidity needs unrelated to the firms value非知情交易者受到与公司价值无关的不规则流动性需求驱动
- The proportion of informed traders in the population is μ.知情交易者在总交易人数中占比设为μ

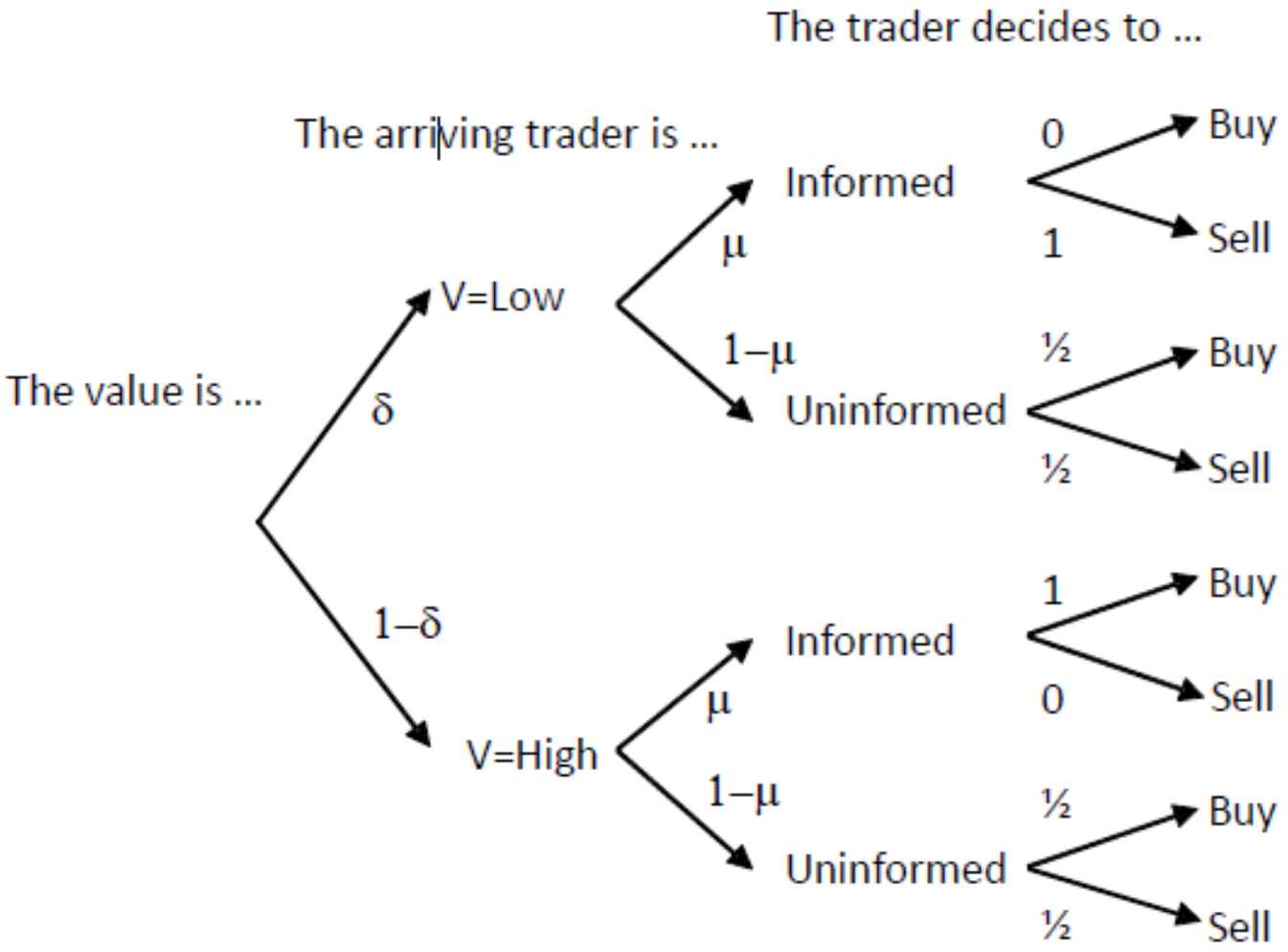
A game theory point of view



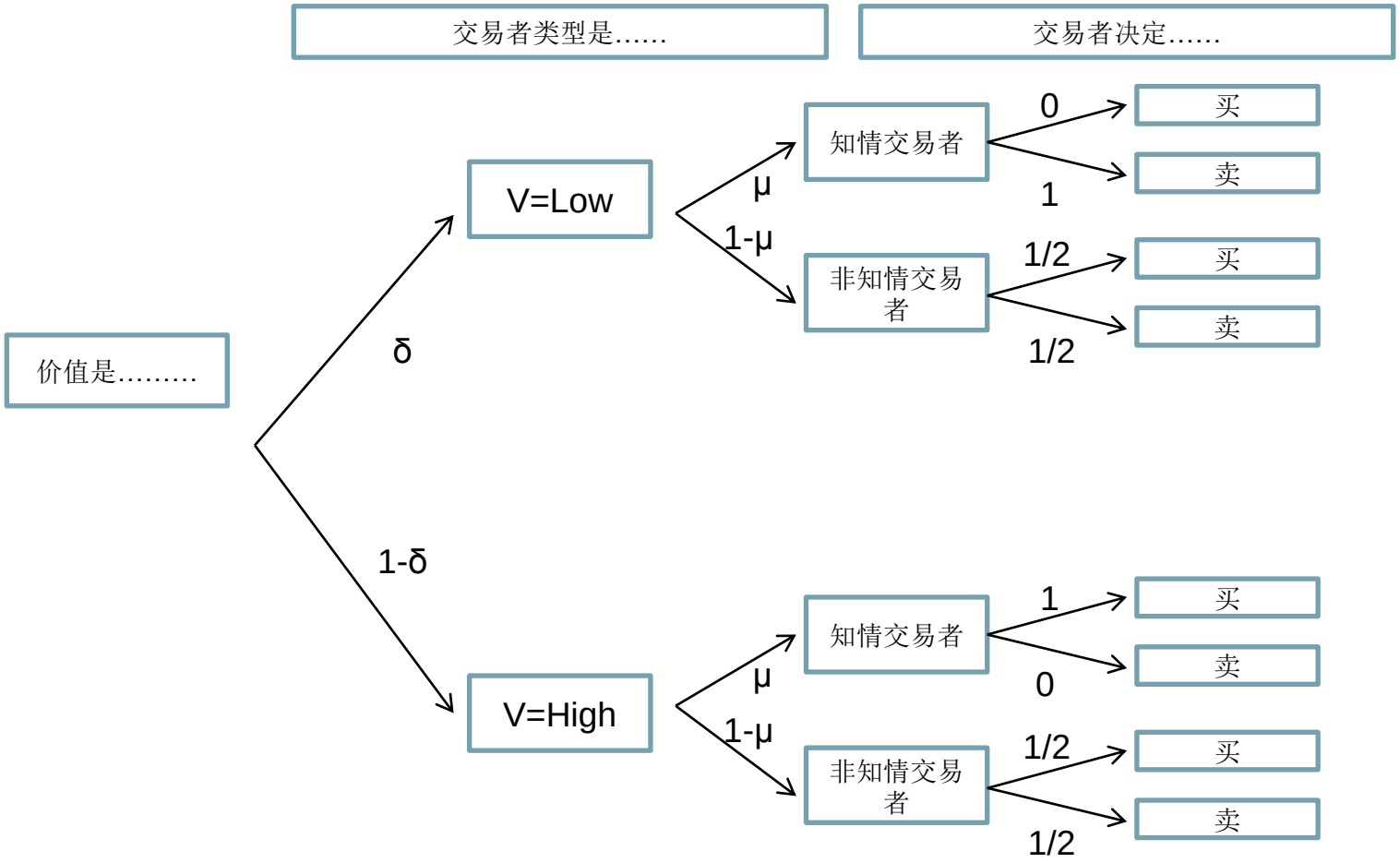
博弈论观点



Transition probabilities



转变可能性



Expectation value calculations期望值计算

$$\Pr(S) = \frac{1}{2} + (-\frac{1}{2} + \delta)\mu$$

$$\Pr(B) = \frac{1}{2}(1 + \mu - 2\delta\mu)$$

$$\Pr(Low, B) = \frac{1}{2}\delta(1 - \mu)$$

$$\Pr(Low \mid B) = \frac{\Pr(Low, B)}{\Pr(B)} = \frac{\delta - \delta\mu}{1 + \mu - 2\delta\mu}$$

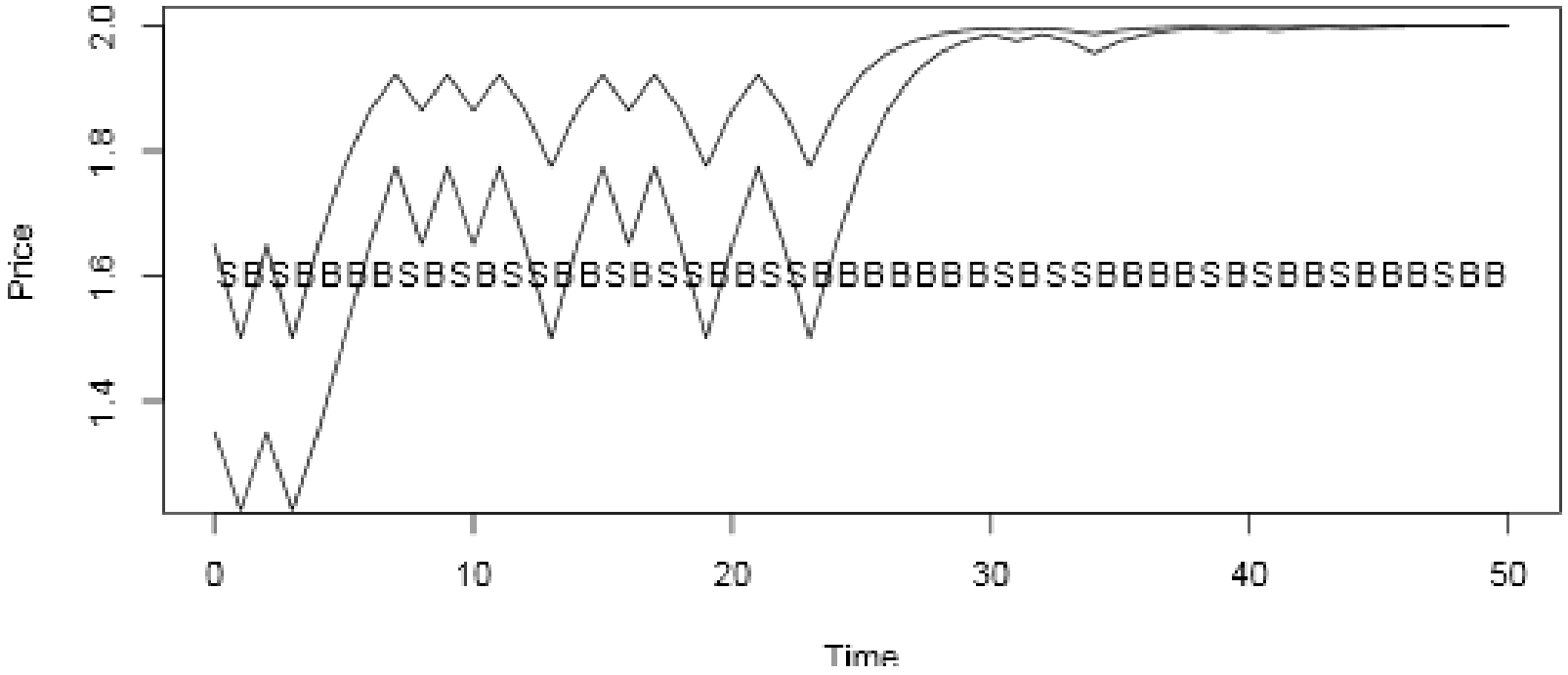
$$E[V \mid B] = \Pr(Low \mid B) \times Low + \left(1 - \Pr(Low \mid B)\right) \times High$$

$$= \frac{Low\,\delta(-1 + \mu) + High(-1 + \delta)(1 + \mu)}{-1 + (-1 + 2\delta)\mu}$$

Simulation example

(source: Dale W.R. Rosenthal: http://www.rinfinance.com/RinFinance2009/presentations/microstructure-tutorial.pdf)

- One simulation for $\mu = 0.3$, $\delta = 0.5$; example bids and asks.
- Simple case: $V = \overline{V} = 2$ (versus $\underline{V} = 1$).
- Can see price impact — especially for sequence of orders.



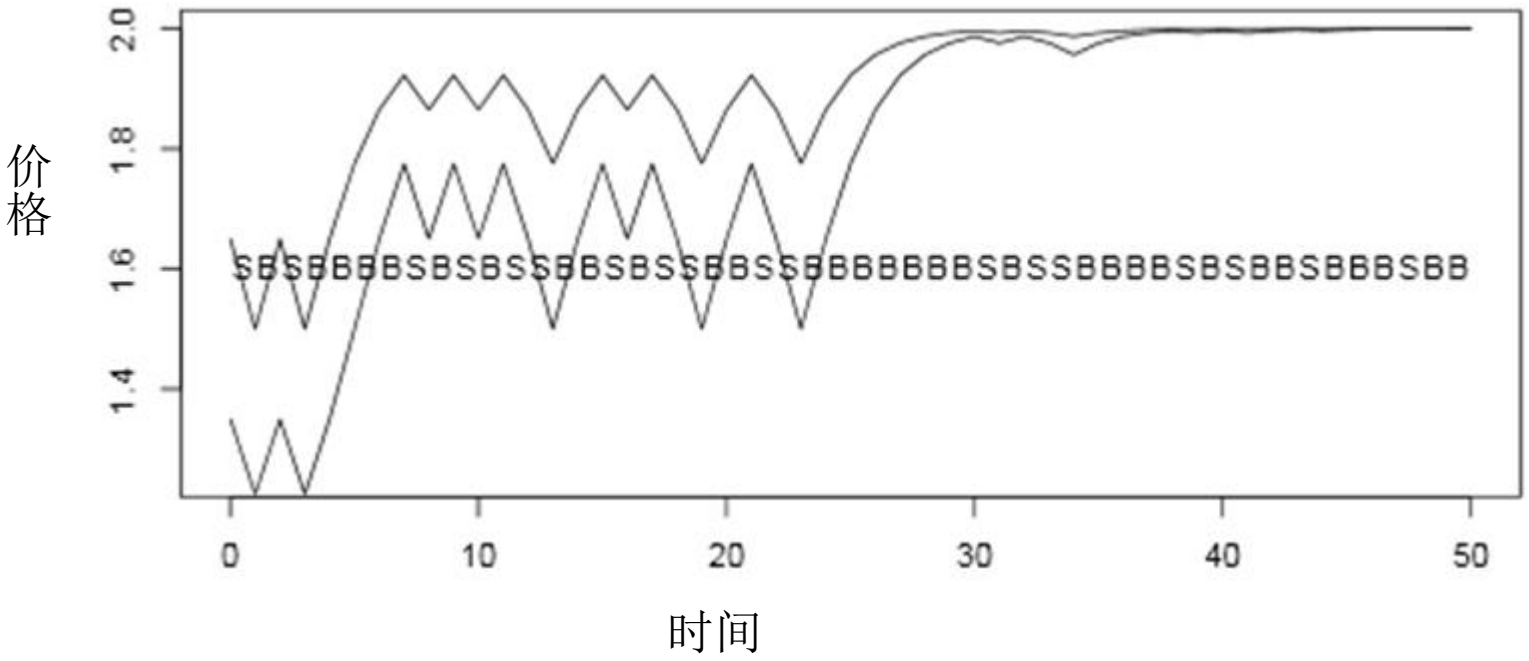
仿真示例

(来源: Dale W.R. Rosenthal: http://www.rinfinance.com/RinFinance2009/presentations/microstructure-tutorial.pdf)

仿真示例一：μ=0.3，δ=0.5；示例买价和卖价

假设V= $\bar{V}$=2（对比：$\underline{V}$ = 1）

可以看到价格影响——尤其是对委托单序列的影响



Market maker profits做市商利润

- Suppose that we set the ask price to A.假设卖价为A
  - If someone buys (lifts our offer), our profit (at the end of the day, when we know V) is A–V如果有人买入（敲掉我们的卖出报价单），我们的利润为A-V（交易日结束时，我们就能知道V值）
  - Immediately following the trade, our expected profit is A – E [V|Buy].交易完成后，我们的期望利润为A-E[V|Buy]
  - Competition among potential dealers reduces profits toward zero.潜在做市商之间的竞争将会减少利润，一直趋近于零
  - A–E[V|Buy] = 0 → A = E[V|Buy] A–E[V|Buy] = 0 → A = E[V|Buy]
- A similar analysis on the bid side shows that B = E[V|Sell]对买入情况进行类似分析可得： B = E[V|Sell]

Market maker's competition and costs做市商竞争和成本

- Competition竞争
- Regulation监管
- If the dealer has to cover costs *c* which include a reasonable profit, then做市商的报价要考虑成本(C)并实现利润则：
  - A = E[V|Buy] + c
  - B = E[V|Sell] – c

Redistribution from uninformed to informed traders利润从非知情者重新分配至知情交易者

$$A - E[V \mid B] = 0$$

$$A - \left(\Pr(I \mid B)\,High + \Pr(U \mid B)\,Low\right) = 0$$

$$\underbrace{\Pr(I \mid B)\,\underbrace{(High - A)}_{\text{Loss to an informed trader}}}_{\text{Expected loss ...}} = \underbrace{\Pr(U \mid B)\;\underbrace{(A - Low)}_{\text{Profit from an uninformed trader}}}_{\text{Expected profit ...}}$$

How does a market maker quote prices?做市商如何报价？

- Positive expectation trades (avoids obvious losers)正期望交易（避免明显的交易失败）
- As profitable (wide) as possible尽量使报价可以盈利（价差越大越好）
- However, competition drives the profitability ever lower但是，竞争降低了做市商的盈利能力
- Market maker will sell at the ask price with the expected P/L from the next trade conditioned on it being a BUY (similar logic for a bid)从下一笔交易做买入单时，做市商将以符合期望盈亏值的卖价挂出报价单（买价报价单也同理)
- The subtle point is that market makers set their quotes at the expected terminal value conditioned on getting the fill (trade)值得注意的是，做市商是基于前一成交单的期望最终价值进行报价

What does Glosten-Milgrom model do?
Glosten-Milgrom模型的作用

- G-M allows us to model the information asymmetries that may exist in the markets G-M模型使我们可以对存在于市场中的信息不对称性进行建模
- Its leads to the conclusion that market makers redistribute profits from the uninformed traders to the informed tradersG-M模型使做市商将利润从非知情者重新分配至知情交易者
- Competition among market makers drives P/L lower for the market makers做市商间的竞争使其盈亏值降低
- Market makers' imperative to trade contributes to a narrowing of the bid-ask spread做市商的交易义务有助于缩小买卖价差
- In this framework we do not consider strategic trading在此，我们不考虑策略组合交易

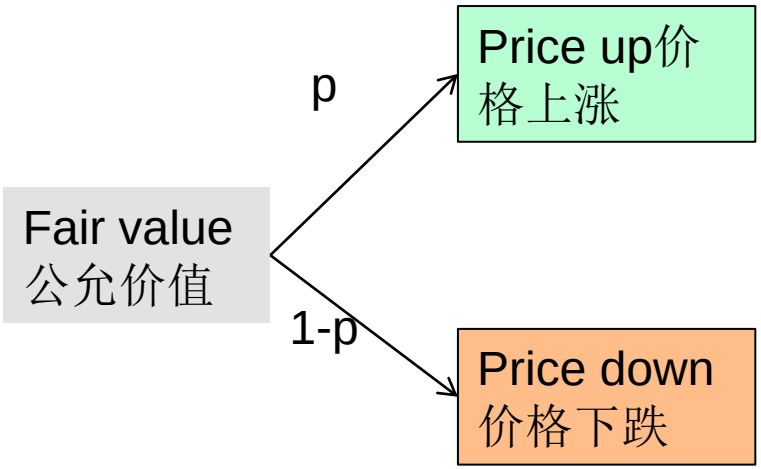
Main challenge of market making: adverse selection做市面临的主要挑战: 不利选择

- Adverse selection is the primary challenge of successful market making不利选择是成功做市的最主要挑战
- Market makers post limit (resting) orders in the market. Adverse selection means that limit orders are more likely to be filled when the prices move against the market maker than when they move in market maker's favor.做市商以限价单在市场中报价。不利选择意味着，当价格以不利做市商的方向变动时，限价单更容易成交
- Some causes of adverse selection不利选择的部分原因
  - Informed market orders知情市价单
  - Competitive limit orders posted by other market makers其他做市商挂出的竞争性限价单
  - Data quality, system performance and other operational issues数据质量、系统性能以及其他运营问题

Simple market making model简易做市模型

(Source来源: Joel Hasbrouck, Empirical Market Microstructure: The Institutions, Economics, and Econometrics of Securities Trading , 2007)

- Begin at fair value从公允价值开始
- Transact one period later at fair value以公允价格执行交易一段时间
- Probability of price increase is p价格可能上涨P
- Spread is 2s价差为2s
- Place a buy limit order 挂出买入限价单
- Probability of fill is q if price rises如果价格上涨，成交概率为q
- Probability of fill is 1 if price falls如果价格下跌，成交概率为1



Market maker's P/L
做市商的盈亏值

$$\mathrm{P/L} = s(pq - p + 1) + pq + p - 1$$

- P/L increases with fill rate, q
- 交易完成率q增加，则盈亏值增加
- P/L increases with spread, s
- 价差s增加，则盈亏值增加
- P/L generally increases with alpha, p
- Alpha值p增加，则盈亏值通常会增加

P/L in the absence of alpha
Alpha为零时，盈亏值的计算

- alpha = 0 corresponds to p=1/2；当alpha = 0时，相当于p=1/2

$$
\begin{aligned}
\mathrm{P/L} &= \frac{1}{2}q(s+1)+\frac{1}{2}(s-1) \\
&= \frac{1}{2}q(s+1)+\frac{1}{2}(1-q)(s+1)-\frac{1}{2}(1-q)(s+1)+\frac{1}{2}(s-1) \\
&= \frac{1}{2}(s+1)-\frac{1}{2}(1-q)(s+1)+\frac{1}{2}(s-1) \\
&= s-\frac{1}{2}(1-q)(s+1)
\end{aligned}
$$

- Market maker's profitability condition becomes:做市商的盈利条件变成：

$$q > 1-\frac{2s}{s+1}$$

Market maker's profitability做市商盈利能力分析

- P/L of a market maker is determined by three quantities做市商的盈亏值由以下三个数量确定：
  - Spread价差
  - Alpha　Alpha值
  - Fill rate交易完成率
- Note that there are interactions, sometimes obvious and at times in a more subtle way, among these parameters.注意，这些参数可以相互作用，有时相互作用很明显，有时不太明显

Market maker's break even spread做市商的保本价差

$$
\begin{aligned}
0 &= s(pq - p + 1) + pq + p - 1 \\
s &= \frac{1 - p - pq}{1 - p + pq} \\
&= \frac{1 - \frac{pq}{1-p}}{1 + \frac{pq}{1-p}}
\end{aligned}
$$

Final remarks最后点评

- Market making in practice做市实践
- Automated market making systems自动做市系统
- Competition做市商竞争
- Regulation做市商监管
- Technology技术
- Research研究

KCG

Thank you