The Endogenous Price under Perfect Liquidity

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Outline

- Introduction.
- The model.
- The endogenous price under perfect liquidity.
- The implications on liquidity measuring.
  - Revisited Liquidity-adjusted CAPM.
  - New bid-ask spread measure.
- Empirical investigation.
  - Liquidity-adjusted CAPM.
  - Bid-ask spread estimation.
- Conclusion.

Conceptual Framework

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- Auction theory: the winner of an auction is "cursed" to pay more than the real value of the auctioned asset. The winner is "cursed" to overpay.
- Order-driven market $\Longrightarrow$ the placement of limit orders generates a winner's curse phenomenon.
- Biais, Glosten, and Spatt (2005) argue that liquidity suppliers placing limit orders behave as bidders in an auction.

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  2. Adverse selection risk ("picking-off" risk)
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- The trader placing a limit order is constrained to pay an implicit trading cost.

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1. The perfect liquidity price $\Longrightarrow$ an endogenous derivation of the price under perfect liquidity.
2. The model of the implicit trading cost curve $\Longrightarrow$ a valuation of the transaction cost caused by winner's curse under information asymmetry (winner's curse pricing model).

- The midquote conjecture $\Longrightarrow M = \frac{A+B}{2}$ is the approximation of the perfect liquidity price/fundamental value (Roll - 1984, JoF).

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- Thaler (1988, JEP) - the winner's curse phenomenon would not occur, if the bidders were perfectly rational.
- Garbarino and Slonim (2007, JRU) - the winner's curse is caused by information asymmetry.

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- Foucault, Kadan, and Kandel (2005) identify two types of traders, patient traders and impatient traders, and show that, at equilibrium, patient traders become liquidity suppliers for impatient traders.

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- There are two types of orders on this market: market orders and limit orders.
- There are two main categories of traders on the market: liquidity traders and liquidity suppliers. These traders are either informed or uninformed traders.
- The informed traders hold private information. The informed traders submit market orders. They have a cash-in-the-market strategy.
- There are also noise traders on the market, among both liquidity traders and liquidity suppliers.

The Cash-in-the-Market Strategy

- The limit prices are

$$\begin{cases} K_b = E\left[V \middle| \Omega_t^a; \Theta^{lot}, \Gamma_b\right] \\ K_a = E\left[V \middle| \Omega_t^a; \Theta^{lot}, \Gamma_a\right] \end{cases}$$

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- The profit opportunity could occur in one of the following situations

$$\begin{cases} X \overset{not}{=} X_a > K_a \\ X \overset{not}{=} X_b < K_b \end{cases}$$

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- **Buy limit order**. Example: A trader submits a buy limit order with the limit price of $10. If the private information justifies a future price of $9, the limit order offers to the informed traders a payoff of $1.
- **Sell limit order**. Example: A trader submits a sell limit order with the limit price of $10. If the private information justifies a future price of $11, the limit order offers to the informed traders a payoff of $1.

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$$Payoff = \begin{cases} X_a - K_a, & \text{for sell limit order} \\ K_b - X_b, & \text{for buy limit order} \end{cases}$$

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4. If the replicating option is never exercised,

$$Payoff = 0$$

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- *Assumption 2.* There is at least one uninformed liquidity supplier who will not cancel or modify the limit order, regardless of any new information arriving on the market.
- *Assumption 3.* In a risk-neutral world, the trading price follows a geometric Brownian motion

$$dP(t) = rP(t)\,dt + \sigma P(t)\,d\widetilde{W}(t)$$

Model Setup (con't)

- *Assumption 4.* Let τ_a be a hitting time which is defined as the first time when the process $P(t)$ hits the value $\overline{X}_a$, where $\overline{X}_a$ is a real positive number, $\overline{X}_a > K_a$, and $P(t)$ is an adapted process with continuous paths

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- *Assumption 5.* Let τ_b be a hitting time which is defined as the first time when the process $P(t)$ hits the value $\overline{X}_b$, where $\overline{X}_b$ is a real positive number, $\overline{X}_b < K_b$, and $P(t)$ is an adapted process with continuous paths

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Trading Cost Valuation

- Let K_b be the bid limit price of a buy limit order. The trading cost of the buy limit order caused by the winner's curse and the adverse selection is given by

$$\Pi_b = E_Q \left[e^{-r\tau_b} \left(K_b - \overline{X}_b \right) \right].$$

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- Let K_a be the ask limit price of a sell limit order. The trading cost of the sell limit order caused by the winner's curse and the adverse selection is given by

$$\Pi_a = E_Q\left[e^{-r\tau_a}\left(\overline{X}_a - K_a\right)\right].$$

Winner's Curse Probability

Proposition 1a (Winner's curse probability for a buy limit order).
When a buy limit order with the bid limit price K_b is executed, the probability that the winner's curse effect under information asymmetry does not occur is given by

$$Q\left(\tau_b = \infty\right) = \begin{cases} 1 - \left(\frac{\overline{X}_b}{K_b}\right)^{\frac{2r}{\sigma^2}-1}, \text{ if } r > \frac{1}{2}\sigma^2 \\ 0, \text{ if } r \leq \frac{1}{2}\sigma^2 \end{cases} .$$

Winner's Curse Probability (con't)

Proposition 1b (Winner's curse probability for a sell limit order).
When a sell limit order with the ask limit price K_a is executed, the probability that the winner's curse effect under information asymmetry does not occur is given by

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Trading Cost of a Buy Limit Order

Proposition 2 (Trading cost of a buy limit order).
Let K_b be the bid limit price of a buy limit order. Let B be the quoted best bid at the order submission time. At the order submission time, the trading cost of the buy limit order is defined by

$$\Pi_b = \begin{cases} \left(K_b - \overline{X}_b\right) \frac{B}{\overline{X}_b}, \text{ if } \overline{X}_b \geq B \text{ and } K_b > B \\ \left(K_b - \overline{X}_b\right) \left(\frac{B}{\overline{X}_b}\right)^{-\frac{2r}{\sigma^2}}, \text{ if } \overline{X}_b < B \text{ and } K_b > B \text{ or } K_b \leq B \end{cases}.$$

Trading Cost of a Buy Limit Order (con't)

Corollary 1 (Maximum trading cost of a buy limit order).
Let K_b be the bid limit price of a submitted buy limit order. When $\overline{X}_b < B$ the maximum trading cost of the buy limit order is defined by

$$\Pi_b^* = \frac{\sigma^2}{2r+\sigma^2}\left(\frac{2r}{2r+\sigma^2}\right)^{\frac{2r}{\sigma^2}} K_b^{\frac{2r+\sigma^2}{\sigma^2}} B^{-\frac{2r}{\sigma^2}}.$$

The optimum value of the bid price $\overline{X}_b$ that maximizes the trading cost is given by

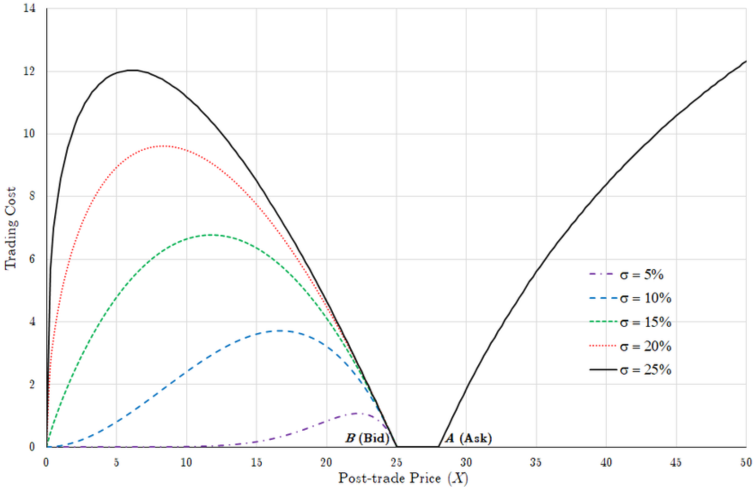
$$\overline{X}_b^* = \frac{2r}{2r+\sigma^2} K_b.$$

Trading Cost of a Sell Limit Order

Proposition 3 (Trading cost of a sell limit order).
Let K_a be the ask limit price of a sell limit order. Let A be the quoted best ask at the order submission time. At the order submission time, the trading cost of the sell limit order is defined by

$$\Pi_a = \begin{cases} \left(\overline{X}_a - K_a\right) \frac{A}{\overline{X}_a}, \text{ if } \overline{X}_a \geq A \text{ and } A > K_a \\ \left(\overline{X}_a - K_a\right) \left(\frac{A}{\overline{X}_a}\right)^{-\frac{2r}{\sigma^2}}, \text{ if } \overline{X}_a < A \text{ and } A > K_a \text{ or } K_a \geq A \end{cases}.$$

Trading Cost Curve Outside the Bid-Ask Spread



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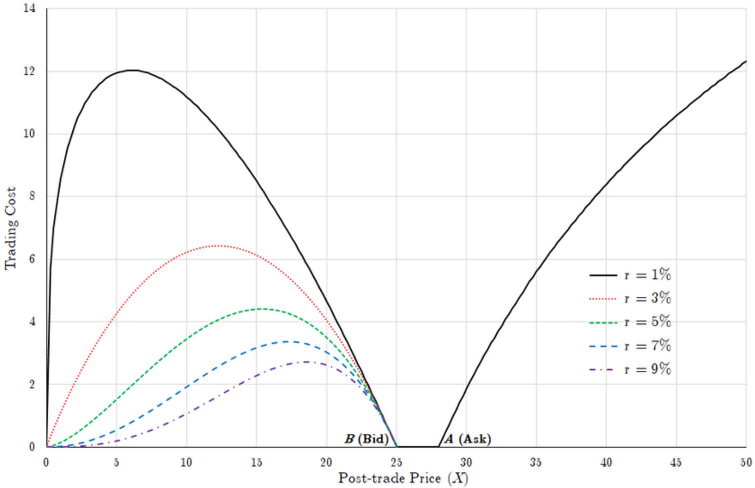

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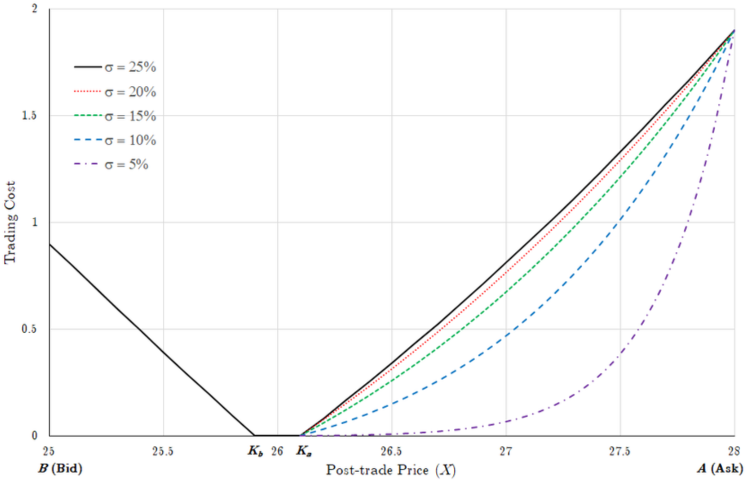

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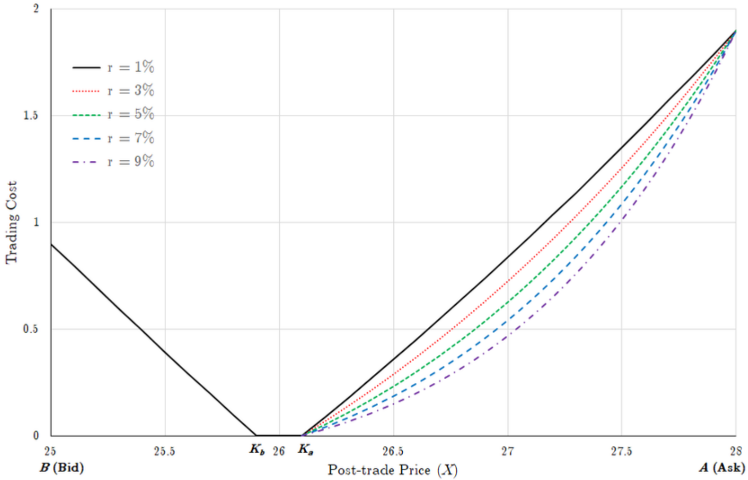

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- In a perfectly liquid market, the bid-ask spread is zero and the trading price is unique. L defines the perfect liquidity price. The price X_L is defined as the estimate of true value of the security under perfect liquidity condition: $\overline{X}_a, \overline{X}_b \rightarrow X_L$. The zero transaction cost condition is given by

$$(L - X_L)\frac{B}{X_L} + (X_L - L)\left(\frac{A}{X_L}\right)^{-\frac{2r}{\sigma^2}} = 0$$

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- When the value X_L approaches the perfect liquidity price $(X_L \to L)$, the illiquidity cost will tend to zero.

The Perfect Liquidity Price (con't)

Proposition 4 (Endogenous price under perfect liquidity). Let A and B represent the best ask and the best bid prices in the order book. Let r be the risk-free interest rate and let σ be the volatility of the trading price. Then, the endogenous price under perfect liquidity is defined by

$$L = A^{\gamma} B^{1-\gamma},$$

where $\gamma = r / \left(r + \frac{1}{2}\sigma^2\right)$ and $0 < \gamma < 1$.

Endogenous Measures of Liquidity

- Revisited Quoted Spread (for small trades)

$$S_q = \frac{A - B}{L} = \left(\frac{A}{B}\right)^{1-\gamma} - \left(\frac{B}{A}\right)^{\gamma}$$

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- Revisited Weighted Quoted Spread (for large trades)

$$\overline{S}_q = \frac{\overline{A}(q) - \overline{B}(q)}{L}$$

Endogenous Measures of Liquidity (con't)

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- Revisited Effective Spread at Bid Price

$$S_e^B = \frac{L - B}{L} = 1 - \left(\frac{B}{A}\right)^{\gamma}$$

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- The relative illiquidity cost (C_{lt}) is the difference between the gross return and the net return

$$C_{lt} = R_{lt} - R_t = \gamma_t R_{st} + (1 - \gamma_{t-1}) R_{st-1} > 0$$

Revisited Liquidity-adjusted CAPM (LCAPM)

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- Using the endogenous relation between gross and net returns and CAPM relation,

$$E\left[R_{li} - C_{li}\right] = r + \beta_i \left(E\left[R_M\right] - r\right)$$

where

$$\begin{aligned} \beta_i &= \frac{COV\left(R_i, R_M\right)}{VAR\left(R_M\right)} = \frac{COV\left(R_{li} - C_{li}, R_M\right)}{VAR(R_M)} \\ &= \frac{COV\left(R_{li}, R_M\right)}{VAR(R_M)} - \frac{COV\left(C_{li}, R_M\right)}{VAR(R_M)} = \beta_{li} - \beta_{ci} \end{aligned}$$

Revisited Liquidity-adjusted CAPM (LCAPM)

- Taking into consideration β_i coefficient decomposition and CAPM translation based on endogenous relation between gross and net returns, the expected gross return given by LCAPM is defined by

$$E\left[R_{li}\right] = r + \beta_{li}\left(E\left[R_M\right] - r\right) + E\left[C_{li}\right] - \beta_{ci}\left(E\left[R_M\right] - r\right)$$

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- The risk premium without liquidity risk is defined by

$$RP_i = \beta_{li}\left(E\left[R_M\right] - r\right)$$

Bid-Ask Spread Measure

- Roll (1984, JoF), Stoll (1989, JoF), George, Kaul and Nimalendran (1991, RFS), Huang and Stoll (1997, RFS), Stoll (2000, JoF), Hasbrouck (2009, JoF), Corwin and Schultz (2012, JoF).

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- *Assumption 1*. The spread is constant over two consecutive trading periods (Corwin and Schultz), $S = S_t = S_{t-1}$.

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- *Assumption 1*. The spread is constant over two consecutive trading periods (Corwin and Schultz), $S = S_t = S_{t-1}$.
- *Assumption 2*. The net return is approximated by the effective return, $R_t \simeq R_{et} = \ln \frac{P_t}{P_{t-1}}$.

Bid-Ask Spread Measure (con't)

Proposition 5 (Bid-ask spread measure).
Let R_{et} be the effective return and let P_t be the trading price of the security. Let r_t be the risk-free interest rate and let σ_t be the volatility of the trading price. Then, the bid-ask spread of the security can be measured by

$$S = \left| \frac{E\left[R_{et}\Phi_t\right]}{E\left[\Phi_t^2\right]} \right|,$$

where $R_{et} = \ln\left(P_t / P_{t-1}\right)$ and $\Phi_t = \gamma_t / P_t + \left(1 - \gamma_{t-1}\right) / P_{t-1}$ with $\gamma_t = r_t / \left(r_t + \frac{1}{2}\sigma_t^2\right)$.

Database

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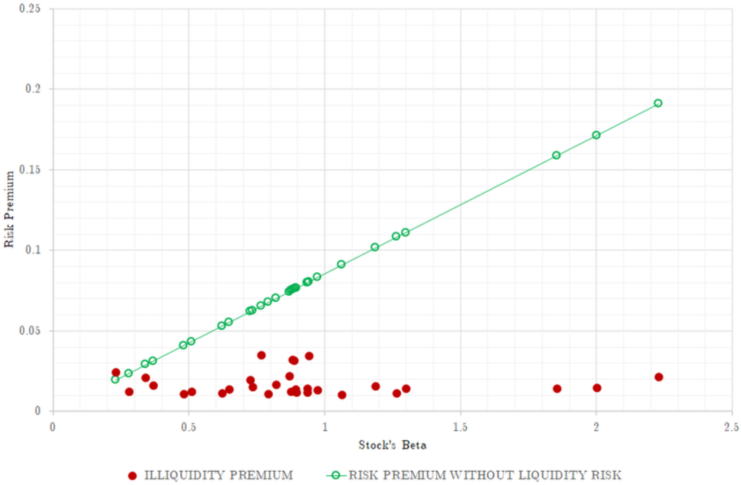
- Period: May 2, 2016 - June 1, 2017
- Stock: 30 component stocks of DJIA and 30 component stocks of CAC40
- Risk-free interest rate: US 10-Year Treasury yield and Germany 10-year Treasury yield
- Variance is computed using the method of Parkinson (1980, JoB) and Garman and Klass (1980, JoB)

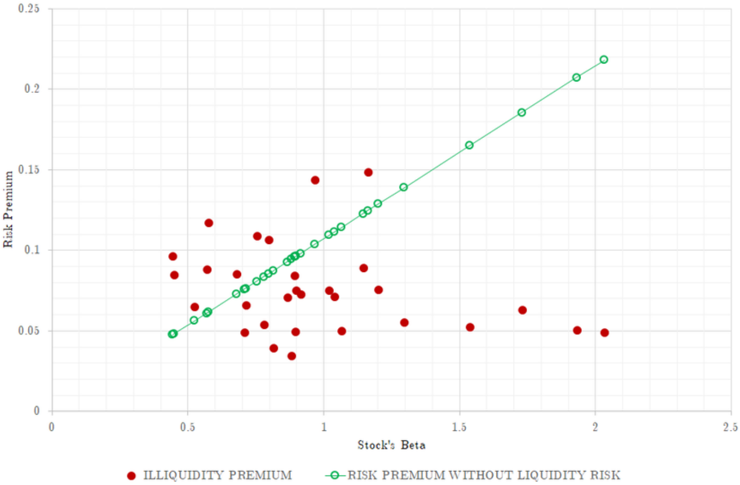
$$\sigma_t^2 = \frac{1}{\theta}\left[\frac{1}{N}\sum_{i=t-N+1}^{t}\left(\ln\frac{H_i}{L_i}\right)^2\right]$$

where $\theta = 4\ln 2$.

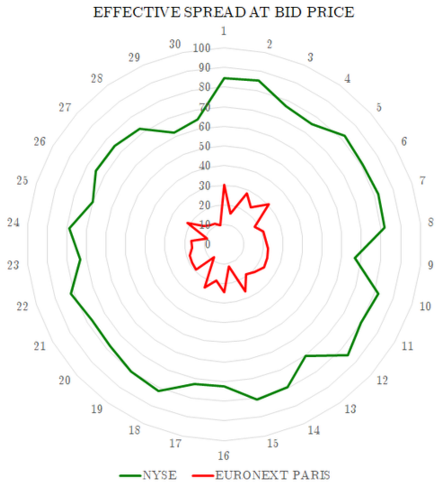
Risk Premiums on NYSE



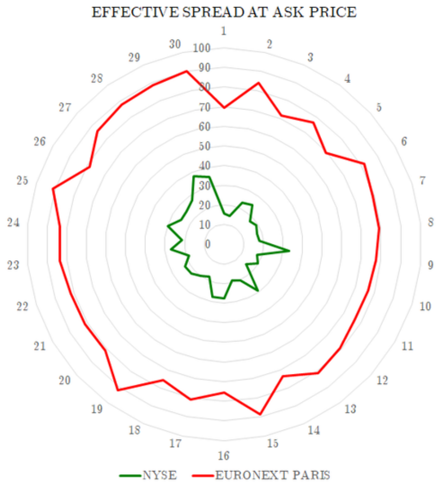
Risk Premiums on Euronext Paris



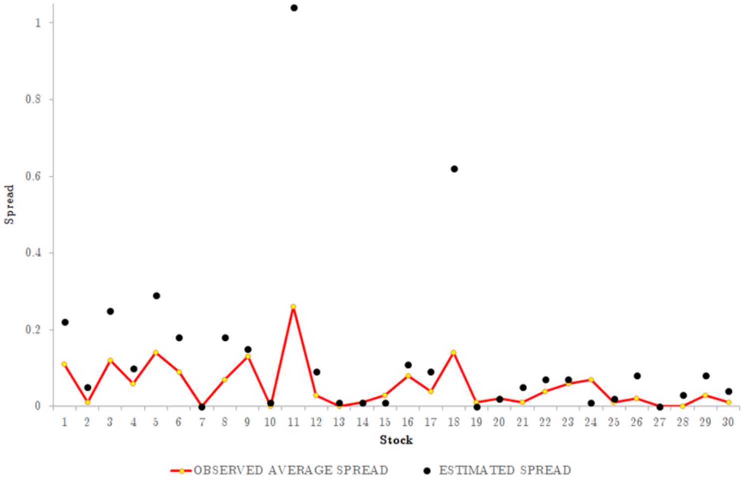
Effective Spread Decomposition



Effective Spread Decomposition (con't)



Estimated Spread vs. Observed Average Spread



Conclusion

- I derive a model for evaluating the trading cost caused by the winner's curse phenomenon and the adverse selection effect.
- The main contribution of the article is the derivation of the endogenous price under perfect liquidity.
- The endogenous security price under perfect liquidity is a weighted average of the best bid and ask prices. The weights depend on the volatility of the security and on the risk-free interest rate.
- The perfect liquidity price is an alternative to the use of the mid-quote price in constructing various illiquidity measures.
- I redefine the quoted spread and the effective spread based on the price under perfect liquidity instead of the mid-quote price.

Conclusion (con't)

- Through the liquidity-adjusted CAPM, I deduce the illiquidity premium by using the gross yield based on perfect liquidity prices and the net yield based on ask and bid prices.
- Based on the endogenous relationship between net and gross yields, I propose a new measure of the bid-ask spread.
- The empirical results indicate an impatient market enter behavior on the American market, as opposed to an impatient market exit behavior on the French market.