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HIGH-FREQUENCY TRADERS

Need for Speed?
Exchange Latency and Liquidity

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American Economic Association
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Outline

THE WALL STREET JOURNAL. | BUSINESS

TOP STORIES IN BUSINESS

1 of 12

In Germany, Amazon Keeps Unions at Bay

2 of 12

Websites Are Wary of Facebook Tracking

Ne
to Slo
Invers

BUSINESS

NYSE's Fast-Trade Hub Rises Up in New Jersey

REUTERS EDITION: UK

HOME BUSINESS MARKETS WORLD UK TECH MONEY OPINION

LSE goes live with faster trading system

CitiFX launches Velocity 2.0; stakes claim as the fastest platform in market

by Hamish Risk, Laurence Twelvetrees

February 8, 2010

NASDAQ OMX Launches INET Trading System

Question:

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Is an even faster exchange good for liquidity?

Literature on HFT and adverse selection

1. *Theory:*
   HFTs fast/informed speculators...
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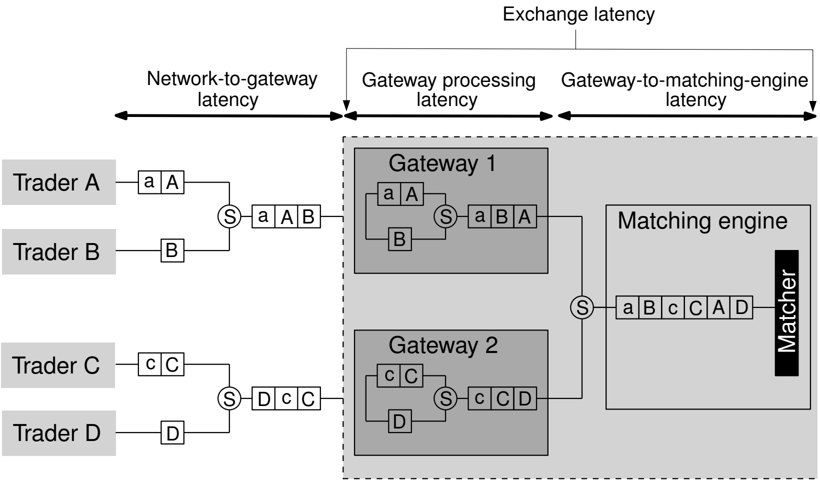
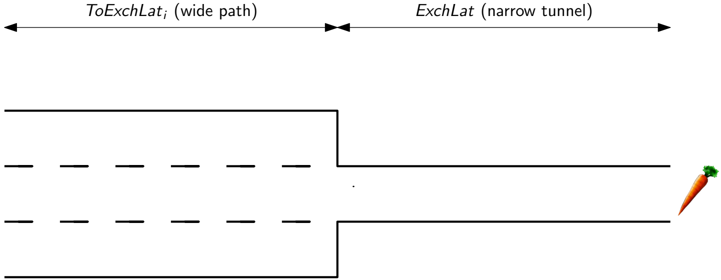
3. Baron, Brogaard, and Kirilenko (2014) and Hagstromer and Norden (2013) find evidence for both market-making and speculative HFT strategies.

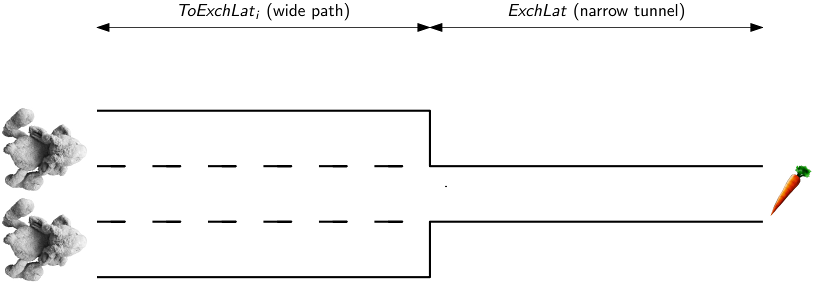
Topology of modern exchanges



Our attempt on exchange speed and liquidity (in pictures)



$ToExchLat_i$ (wide path)
$ExchLat$ (narrow tunnel)



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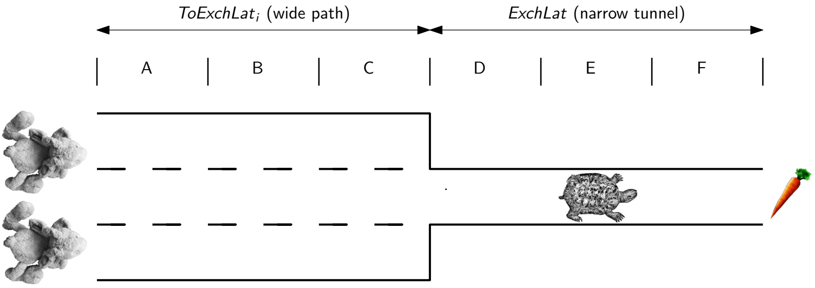
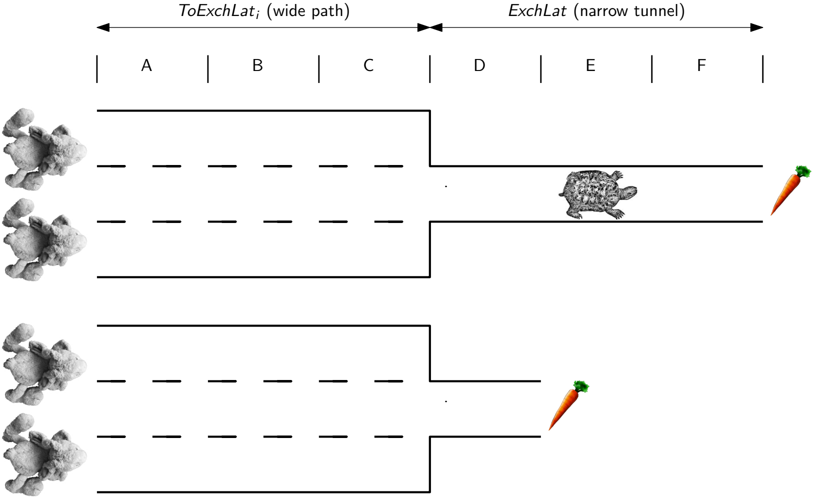


ToExchLat_i (wide path)
ExchLat (narrow tunnel)
A
B
C
D
E
F



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2. A higher exchange speed makes a high-frequency market-maker duel with high-frequency bandits more often.
3. At the same time, a faster exchange allows the high-frequency market maker to update his quotes more quickly and reduce his payoff risk.
4. The net effect on liquidity depends on news-to-liquidity-trader ratio and HFT risk aversion.

Outline

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1. Limit order book.
2. Latency: HFTs send messages at t, processed at $t + \delta$.

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$$v_{t+\delta} = \begin{cases} v_t - \sigma & (\text{“bad” news arrival}) \\ v_t & (\text{no news arrival}) \\ v_t + \sigma & (\text{“good” news arrival}) \end{cases}$$

Timing

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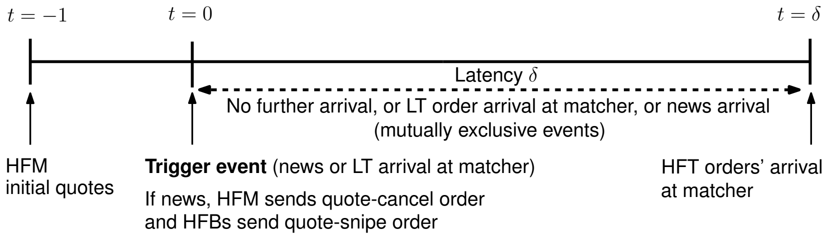

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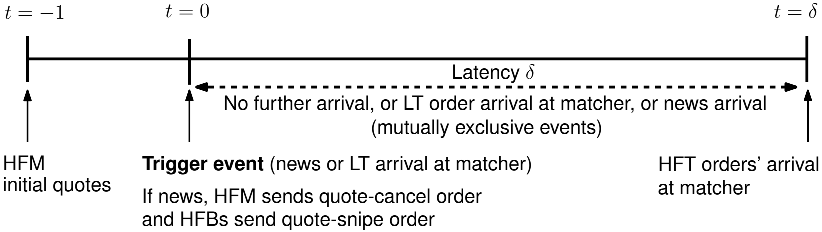

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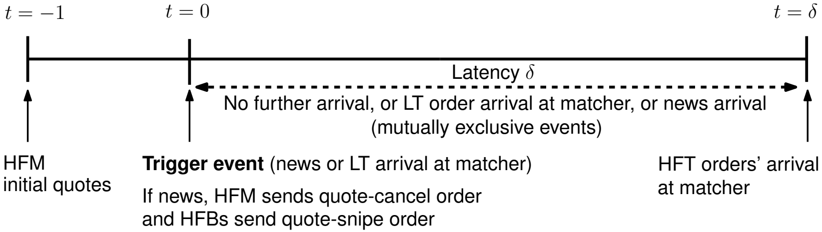

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2. HFTs arrive at the market in random order. Market orders and cancellations execute, new price quotes are submitted.

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Sniping equilibrium (baseline)

1. In equilibrium, HFTs are indifferent between HFM and HFB strategies.
2. Equilibrium half-spread s^* nailed by indifference condition:

$$U_{HFM}\left(s^*\right) = U_{HFB}\left(s^*\right).$$

HFB profit

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The HFB expected profit is:

$$U_{\text{HFB}}(s) = \underbrace{\frac{\alpha}{\mu + \alpha}}_{\text{News before LT}} \underbrace{\frac{1}{H}}_{\text{HFB first}} U_{\text{HFB}}(s|\text{trade}).$$

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$$+\underbrace{\frac{\alpha}{\mu+\alpha}}_{\text{News before LT}}\underbrace{\frac{H-1}{H}}_{\text{HFB first}}\left\{\underbrace{\alpha\delta\left[\frac{1}{2}(s-2\sigma)\gamma+\frac{1}{2}s\right]}_{\text{News arrives during latency delay}}+\underbrace{\left(1-\frac{\mu\delta}{2}-\alpha\delta\right)(s-\sigma)\gamma}_{\text{No event during latency delay}}\right\}$$

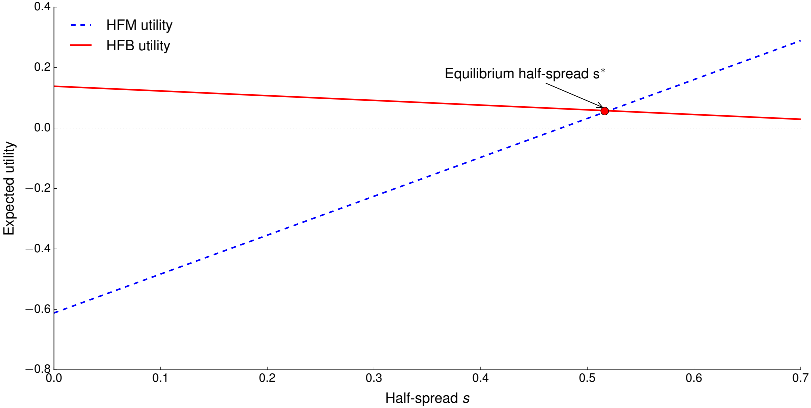
Sure-sniping equilibrium

Proposition 1

The following strategies for HFM and HFB constitute a unique equilibrium for $\gamma < \bar{\gamma}$.

1. At $t = -1$, all HFTs submit one buy limit order at $v_0 - s^*$ and one sell limit order at $v_0 + s^*$. The first arriving HFT (picked randomly) fills the order book; we refer to this HFT as the HFM and to the other HFTs as HFBs.
2. A trigger event occurs at time $t = 0$. If the trigger event is a news arrival (i.e., if $v_0 \neq v_{-1}$), then the HFM submits a quote-cancel order and, at the same time, all HFBs submit a market order aimed at the stale quote on the news side of the book (i.e., the ask side if news was good or the bid side when news was bad).

Sure-sniping equilibrium



Equilibrium spread

The equilibrium spread is

$$s^* = \sigma \frac{\alpha \left[\delta\mu \left(2 + H\right) - 2\gamma \left(H + \delta\mu - 1\right) - 2\right]}{\alpha^2 \delta \left(\gamma - 1\right)\left(H - 2\right) - \mu H \left(2 + \delta\mu\right) - \alpha \left[2 + \delta\mu \left(H - 2\right) + 2\gamma \left(H - 1 + \delta\mu\right)\right]}$$

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1. Comparative statics: $s^* \nearrow \alpha$, $s^* \nearrow \sigma$, $s^* \searrow \mu$, $s^* \nearrow \gamma$.

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1. Comparative statics: $s^* \nearrow \alpha$, $s^* \nearrow \sigma$, $s^* \searrow \mu$, $s^* \nearrow \gamma$.
2. Also, equilibrium spread $s^* \nearrow H$.
   More HFBs lead to higher adverse selection costs for the (unique) HFM.

Equilibrium spread and exchange speed

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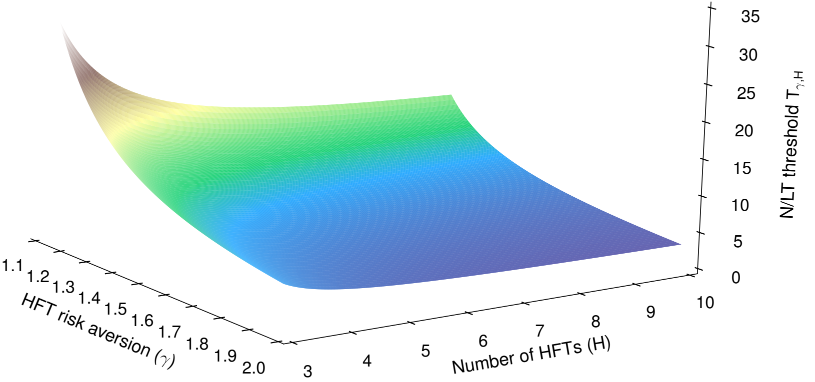
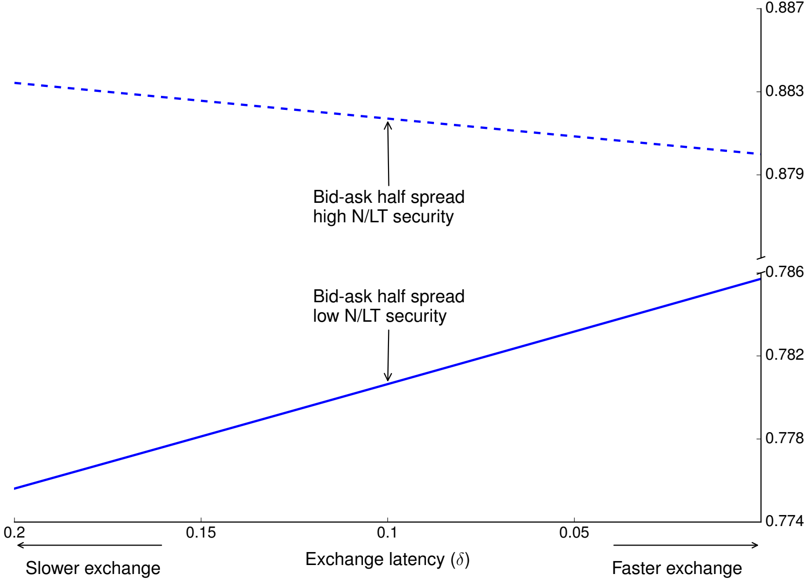
2. decreases in exchange speed (i.e., increases in δ) if $\frac{\alpha}{\mu} > T_{\gamma,H}$;
3. does not depend on exchange speed if $\frac{\alpha}{\mu} = T_{\gamma,H}$,

Threshold $T_{\gamma,H}$



Latency effect on the equilibrium spread



Latency effect on HFT-HFT trade probability

1. HFM-HFB trade probability:

$$\frac{\mathbb{P}\,(\text{HFM-HFB trade})}{\mathbb{P}\,(\text{HFM trade})} = \frac{\frac{\alpha}{\mu+\alpha}\left[\frac{H-1}{H}\left(1-\frac{\mu\delta}{2}\right)\right]}{\frac{\alpha}{\mu+\alpha}\left[\frac{H-1}{H}\left(1-\frac{\mu\delta}{2}\right)\right]+\frac{\alpha}{\mu+\alpha}\frac{\mu\delta}{2}+\frac{\mu}{\mu+\alpha}}.$$

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2. HFM-HFB trade probability conditional on news arrival:

$$\frac{\mathbb{P}\,(\text{HFM-HFB trade — news})}{\mathbb{P}\,(\text{HFM trade — news})} = \frac{\frac{H-1}{H}\left(1-\frac{\mu\delta}{2}\right)}{\frac{H-1}{H}\left(1-\frac{\mu\delta}{2}\right)+\frac{\mu\delta}{2}}.$$

Latency effect on HFT-HFT trade probability

Corollary 4

The probability of an HFT-HFT trade increases in exchange speed (i.e., it decreases in δ).

Mixed-sniping equilibrium

Proposition 3

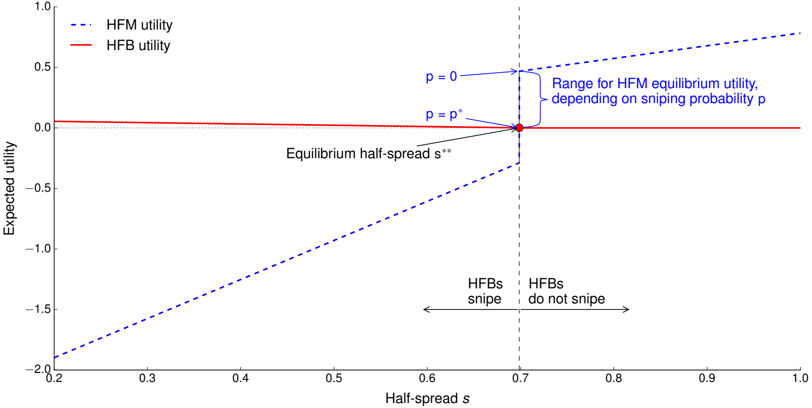
For $\gamma > \bar{\gamma}$ there exist multiple equilibria indexed by the sniping probability of HFBs: p. All these equilibria yield the same unique mixed-sniping spread:

$$s^{**} = \sigma \frac{2 - \delta\mu}{2 - \delta\mu + \alpha\delta(\gamma - 1)}, \quad (2)$$

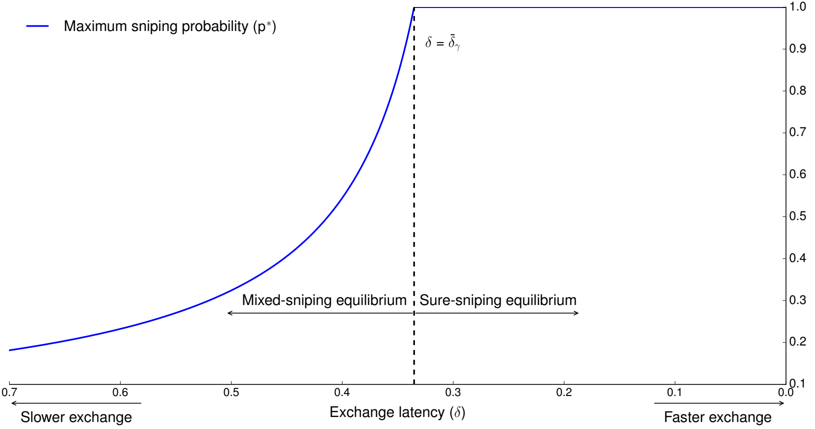
where $0 < s^{**} < \sigma$. The strategies that support these equilibria are:

1. At $t = -1$, all HFTs submit one buy limit order at $v_{-1} - s^{**}$ and one sell limit order at $v_{-1} + s^{**}$.
2. If the trigger event at $t = 0$ is a news arrival, then the HFM submits a quote-cancel order. At the same time, with probability $p \leq p^*$, all HFBs submit a market order aimed at the stale quote on the news side of the book (i.e., the ask side if news was good or the bid side when news was bad).

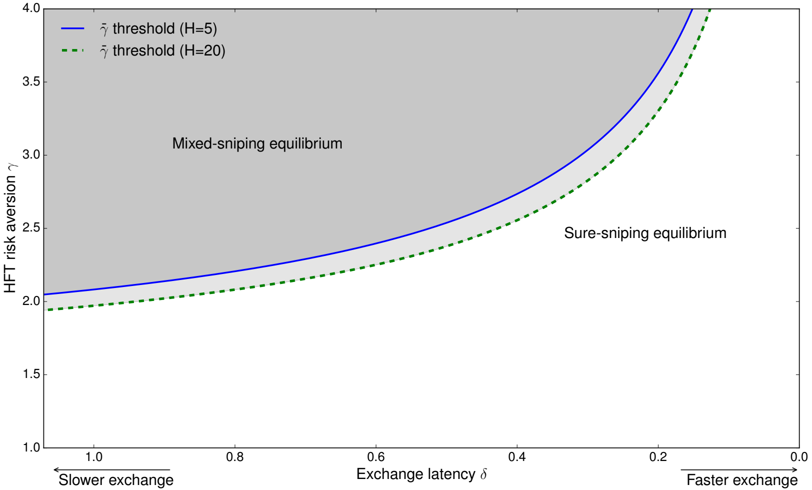
Mixed-sniping equilibrium



Maximum sniping probability and exchange latency



Sure- and mixed-sniping equilibria

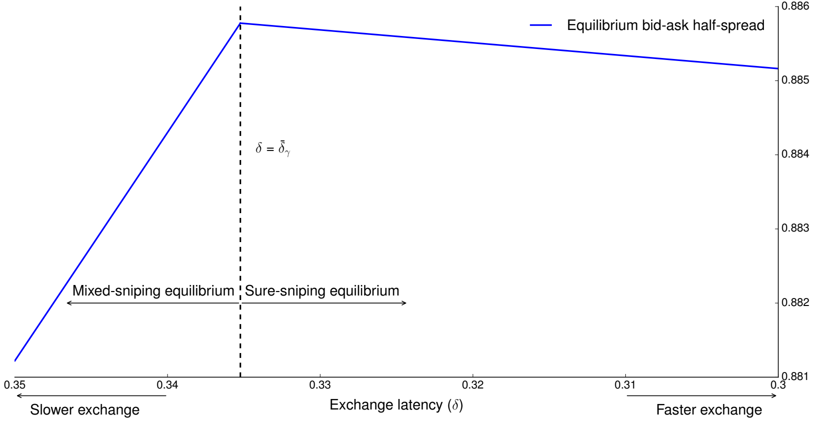


Mixed-sniping equilibrium

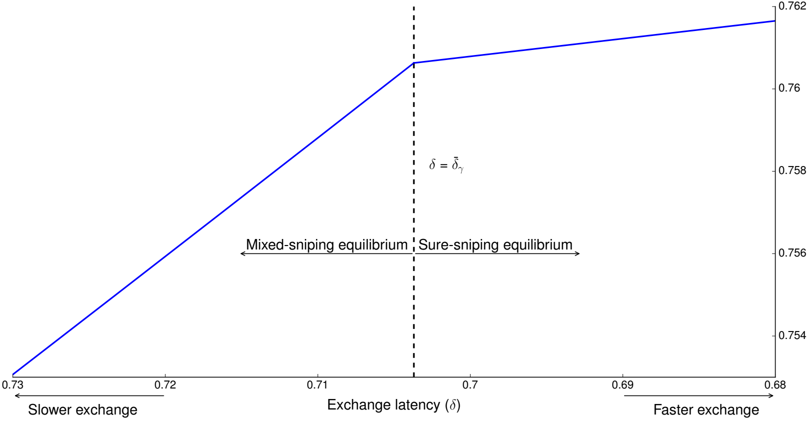
Proposition 4

The mixed-sniping equilibrium half-spread s^{**} increases in exchange speed (i.e., it decreases in δ).

Sure- and mixed-sniping equilibrium spread (high N/LT)



Sure- and mixed-sniping equilibrium spread (low N/LT)



Outline

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Conclusion

1. Lowering exchange latency can reduce liquidity.
2. A higher exchange speed makes a high-frequency market-maker duel with high-frequency bandits more often.
3. At the same time, a faster exchange allows the high-frequency market maker to update his quotes more quickly and reduce his payoff risk.
4. The net effect on liquidity depends on news-to-liquidity-trader ratio and HFT risk aversion.

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