When do stock futures dominate price discovery?

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The question

1. The literature finds that the spot market lead derivatives in price discovery for single stocks.
   A lot of the evidence is based on:
   - Aggregate estimates of the *overall* price discovery between derivatives and spot, and
   - Relatively illiquid single stock derivative markets.
2. In this paper, we ask:
   - How does this relationship behave in a very liquid single stock futures market?
   - Can access to high frequency data help to uncover the process of price discovery?

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Background

- Black (1975): when information arrives in the market place, informed traders and speculators prefer to trade using leveraged instruments.

  Hypothesis: Derivatives prices ought to lead spot prices.
- Empirical evidence:
  - Index futures leads index spot in price discovery (Pizzi et al (1998); Hasbrouck (2003); Kurov and Lasser (2004); several others.)
  - No consensus for index options,
  - Spot prices lead price discovery for single stock options or single stock futures. (Chakravarty et al (2004), Shastri et al (2008).)
- Trouble with the popular measure of price discovery:

  Compared to the Information Share (IS) by Hasbrouck 1995, the alternative measure, the Component share by Granger-Gonzalo (1995), frequently gave opposite results. (*Journal of Financial Markets special issue, 2002*)

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Why revisit this issue with single stock futures?

1. Over the last decade, several markets have emerged with much better liquidity on single stock futures and options.
2. New dominant market microstructure – Electronic Limit Order Book markets – with much greater transparency on prices and liquidity costs of trading on derivatives or spot.
3. Allows a closer examination of how prices react in real time as information unfolds.
(Which aggregate analysis, or end-of-day analysis, does not allow.)

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What we find

- The inputs the trader uses to chose between SSF and spot are
  - Leverage and
  - The difference in the cost of trade between the SSF and spot market.
- Stocks with higher leverage and lower costs of trade on the SSF market have price discovery taking place on SSF markets.
  Price discovery for securities with low leverage and high costs of trade on SSF take place on the spot market.
- During periods of high volatility during the trading day, the price discovery shifts to the SSF market *irrespective* of the leverage or the difference in trading costs between SSF and spot.

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Analytic framework

How does the trader choose between leverage and spot?

- Given two existing trading venues with observable liquidity (in the form of the Limit Order Book or LOB):
  Single Stock Futures (SSF) or spot.
- When information arrives, which market does the trader choose?
- Depends upon the *expected net return – risk* of trading in each market.

Expected returns to risk

- Assume a stock with returns: u with probability p and d with probability $(1-p)$
- Assume the trader has Q capital.
- Then spot market trade size = Q and SSF market trade size = λQ where λ is the leverage on the SSF market.
- Cost of trading on the spot market: $c_s(Q)$
- Cost of trading on the SSF market: $c_{ssf}(\lambda Q)$
- Then expected net returns/risk to the trader are:

$$\text{Spot:} \quad \frac{E(r_S)-r_f}{\sigma_S} = \left[\frac{E(r_S)}{\sigma_S} - \frac{r_f}{\sigma_S}\right]$$

$$\text{SSF:} \quad \frac{E(r_{SSF})-r_f}{\sigma_{SSF}} = \left[\frac{E(r_S)}{\sigma_S} - \frac{r_f}{\lambda\sigma_S} + \frac{c_S(\lambda Q) - c_{SSF}(\lambda Q)}{\lambda\sigma_S}\right]$$

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The trader's choice

- The trader will chose to trade in SSF if:

$$\frac{E(r_{\text{SSF}}) - r_f}{\sigma_{\text{SSF}}} > \frac{E(r_{\text{S}}) - r_f}{\sigma_{\text{S}}}$$

- Which is,

$$(\lambda - 1)\frac{r_f}{\lambda\sigma_{\text{S}}} + \frac{c_{\text{S}}(\lambda Q) - c_{\text{SSF}}(\lambda Q)}{\lambda\sigma_{\text{S}}} > 0$$

- Since $\lambda > 1$ and $\sigma_{\text{S}} > 1$, this can be rewritten as:

$$(\lambda - 1)r_f > (c_{\text{SSF}}(\lambda Q) - c_{\text{S}}(\lambda Q))$$

- **Note:** $E(r_{\text{S}}, r_{\text{SSF}})$ and σ_{S} have both dropped out of this choice equation. The only inputs to choosing SSF or spot is the *leverage* λ and the *costs of trading difference* $c_{\text{SSF}}(\lambda Q) - c_{\text{S}}(\lambda Q)$.

Implication

- If λ varies for security i, then
  Higher the λ_i, the trader is more likely to trade SSF.
- If $c_{\text{SSF}}(\lambda Q) - c_{\text{S}}(\lambda Q)$ differs for security i, then
  Lower the $c_{\text{SSF},i}(\lambda Q) - c_{\text{S},i}(\lambda Q)$, the more the trader is likely to trade SSF.

If the trader is more likely to trade SSF, the higher the probability that SSF will lead price discovery.

Econometrics

Robust IS estimation

- Yan and Zivot (2010): high values of IS_{ssf} can arise from:
  - Strong reaction of SSF to information shocks, or
  - Strong reaction of spot to trading / microstructure noise.
- Our approach:
  - Estimate both IS and CS measures for the SSF and Spot markets.
  - Use IS to determine where price discovery takes place, and
  - Supplement inference by using the ration between the IS and CS measures using the following ratio, IS-CS ratio:

$$\frac{|IS_{\text{ssf}} \times CS_{\text{s}}|}{|IS_{\text{s}} \times CS_{\text{ssf}}|}$$

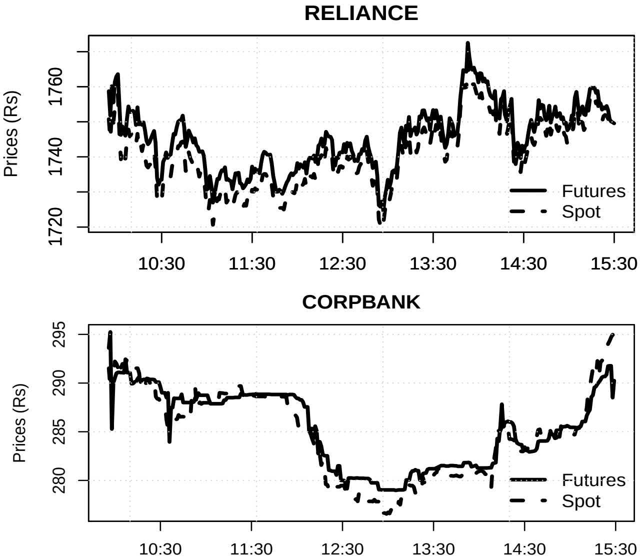
  - When IS-CS ratio$>$ 1, then $\text{IS}_{\text{ssf}} > 0.5$ is in response to information shocks.

Data

Data setting

- *Source:* The National Stock Exchange of India, Ltd., (NSE) ranks third by way of trades on SSFs in the world – unique liquidity in SSF.
- *Microstructure*: Electronic LOB markets, largely retail orderflow.
- *Sample*: Top 97 securities (by market cap).
- *Period:* March 2009 to August 2009, six months.
- *Frequency*: One second data price.
- *Cost measure*: Price impact cost of market order of size Rs.$250,000$ (equivalent to USD 4600).

High-frequency prices for SSF and spot



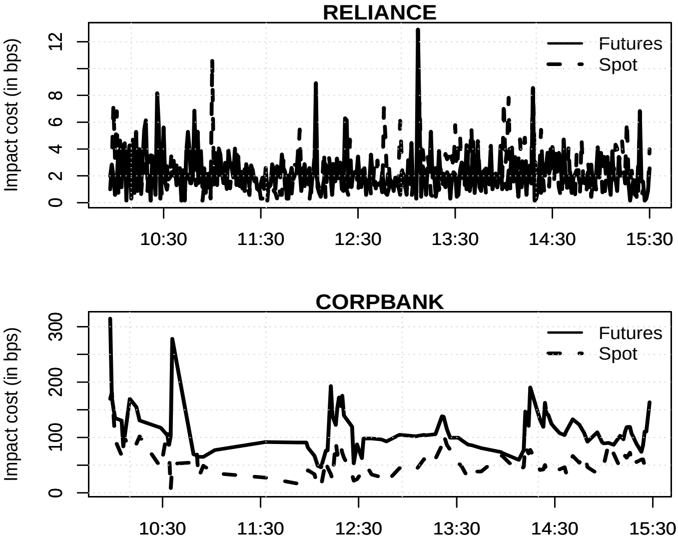
Trading cost measure, impact cost

- Given access to the LOB for each security (spot and SSF),
- The impact cost of a market order of size Q is:

$$IC_Q = \frac{P_Q - P_{MQ}}{P_{MQ}}$$

  where, P_Q is the actual price paid for the market order, P_{MQ} is the midquote price between the bid and the ask.
- The higher the value of IC_Q, the higher the cost of the trade and lower the liquidity of the market.
- Given the access to high frequency data, we calculate IC(Q) at a frequency of one-second.

High-frequency IC for SSF and spot



Hypothesis

- Cross-sectional variation in price discovery:
  - $H_0 : (\mathrm{IS}_{\mathrm{ssf},i} > \mathrm{IS}_{\mathrm{S,j}})$ if $(c_{\mathrm{S},i}(\lambda Q) - c_{\mathrm{SSF},i}(\lambda Q)) > (c_{\mathrm{S},j}(\lambda Q) - c_{\mathrm{SSF},j}(\lambda Q)$ for the same λ_i, λ_j.
  - $H_0 : (\mathrm{Price\ discovery}_{\mathrm{ssf},i} > \mathrm{Price\ discovery}_{\mathrm{S,i}})$ if $\lambda_i > \lambda_j$ for the same costs of liquidity on SSF and spot markets for i and j.
- During times of high volatility, leverage becomes more important. (Brunnermeir and Pederson, 2009)
  - $H_0 : (\mathrm{IS}_{(\mathrm{ssf},i,t})) > (\mathrm{IS}_{(\mathrm{ssf},i,(t-1))})$ When $\sigma_{i,t} > \sigma_{i,(t-1)}$, keeping λ_i and $(c_{\mathrm{S},i}(\lambda Q) - c_{\mathrm{SSF},i}(\lambda Q))$ constant.

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Results

Results: Average IS

- For a liquid SSF market, the overall $\text{IS}_{\text{ssf}} = 49\%$.
- This is much higher than reported elsewhere in the literature.
- Liquid markets have higher price discovery.

Results: Variation by stocks

- Non-parametric - IS by liquidity quartiles:
  Q1 (most liquid firms): $\text{IS}_{ssf} = 61\%$.
  Q4 (least liquid firms): $\text{IS}_{ssf} = 24\%$.
- Parametric - Panel data regression :

$$\text{IS}_{\text{SSF},i,t} = \alpha + \beta_1 \text{LIQUIDITY-DIFF}_{i,t} + \beta_2 \lambda_{i,t} + \epsilon_{i,t}$$

Variable	Estimated coefficients	
Firm fixed effects	No	Yes
Intercept	**0.78****	
	(22.53)	
LIQUIDITY-DIFF	**-1.14****	**-0.82****
	(-10.33)	(-4.54)
λ	**-0.05****	**0.05****
	(-6.80)	(1.69)

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Identification: Variation across time

Identification of high intra-day volatility periods:

- Opening hour of trade: market volatility is significantly higher for the first one hour after market open.
- Earnings announcements: security volatility is higher in the first half hour after earnings announcement.

Results: Opening hour of trade

- Non parametric results: Q1 (most liquid firms): $\text{IS}_{\text{ssf}} = 66\%$ (vs. 61%).
  Q4 (least liquid firms): $\text{IS}_{\text{ssf}} = 35\%$ (vs. 24%).
- Fixed effects regression:

$$\text{IS}_{\text{SSF},i,t} = \alpha + \beta_1 \text{LIQUIDITY-D}_{i,t} + \beta_2 \lambda_i + \beta_3 \text{HIGH}_{i,t,j} + \epsilon_{i,t}$$

where HIGH is a dummy variable taking value 1 in high information periods during the day.

	Estimate	Std. Error	t value	Pr(>|t|)
LIQUIDITY-D	-0.0028	0.0017	-1.63	0.10
HIGH	0.0589	0.0035	16.80	$<$ 2e-16

(In this regression, λ_i becomes insignificant.)

Results: Earnings announcements

- Non-parametric results
  Q1 (most liquid firms): $\text{IS}_{\text{ssf}} = 54\%$ (vs. 61%).
  Q4 (least liquid firms): $\text{IS}_{\text{ssf}} = 44\%$ (vs. 24%).

Conclusions

- The inputs the trader uses to chose between SSF and spot are
  - Leverage and
  - The difference in the cost of trade between the SSF and spot market.
- Stocks with higher leverage and lower costs of trade on the SSF market have price discovery taking place on SSF markets.
- Further, if there are periods of high information during the trading day, the price discovery shifts to the SSF market *irrespective* of the leverage or the difference in trading costs between SSF and spot.
- This indicates a real-time trade-off between leverage and the liquidity differential between the SSF and spot markets.