LIMITS TO ARBITRAGE IN SOVEREIGN BONDS PRICE AND LIQUIDITY DISCOVERY
IN HIGH-FREQUENCY QUOTE-DRIVEN MARKETS

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Our paper

We study:

- Price discovery.
- Liquidity (discovery) under stressful environment.

Our special focus is

- Arbitrage activity: Linkage of the two market, indicated by Cash-Futures Basis.
- It requires an analysis using High-Frequency Data.

Concepts

Price discovery

- Information shock can transmit between markets without order flow.

- Which market incorporates the information first and transmits it to the other?

Liquidity discovery

- Two markets linked by arbitrage: cash and futures.

- Liquidity has to be brought about by orders.

- How does the other market react?

Motivation 1/2

1. Price discovery:
- Does the futures price lead the cash bond price or vice versa?
  - How does this lead-lag relationship change during periods of crisis, and especially after important policy announcements by the European Central Bank (ECB)
  - Security Market Programme (SMP): direct purchase in the open market
  - Long-Term Refinancing Operation(LTRO): does not access to the open market.

Motivation 2/2

2 Liquidity discovery and spillover:

- Do shocks to the liquidity of one market spill over to the other?

- Is the liquidity of one market driving that of the other?

Contribution   1/2

We show that:

- Even though the futures market leads the cash market in price discovery, the cash market leads the futures market in liquidity discovery.

- The liquidity in the cash market, and not that in the futures market, leads the futures-bond basis. This is related to asymmetry (imbalance) of depth.

- The interventions of the ECB widens the magnitude of the basis and affects the liquidity transmission between the markets

Contribution   2/2

Advantages of tick-by-tick data:

- An impediment to arbitrageurs?

  → We introduce "Executable Basis"

- The willingness of the market maker to take the opposite side of a trade

  → "Lambda ask/bid"
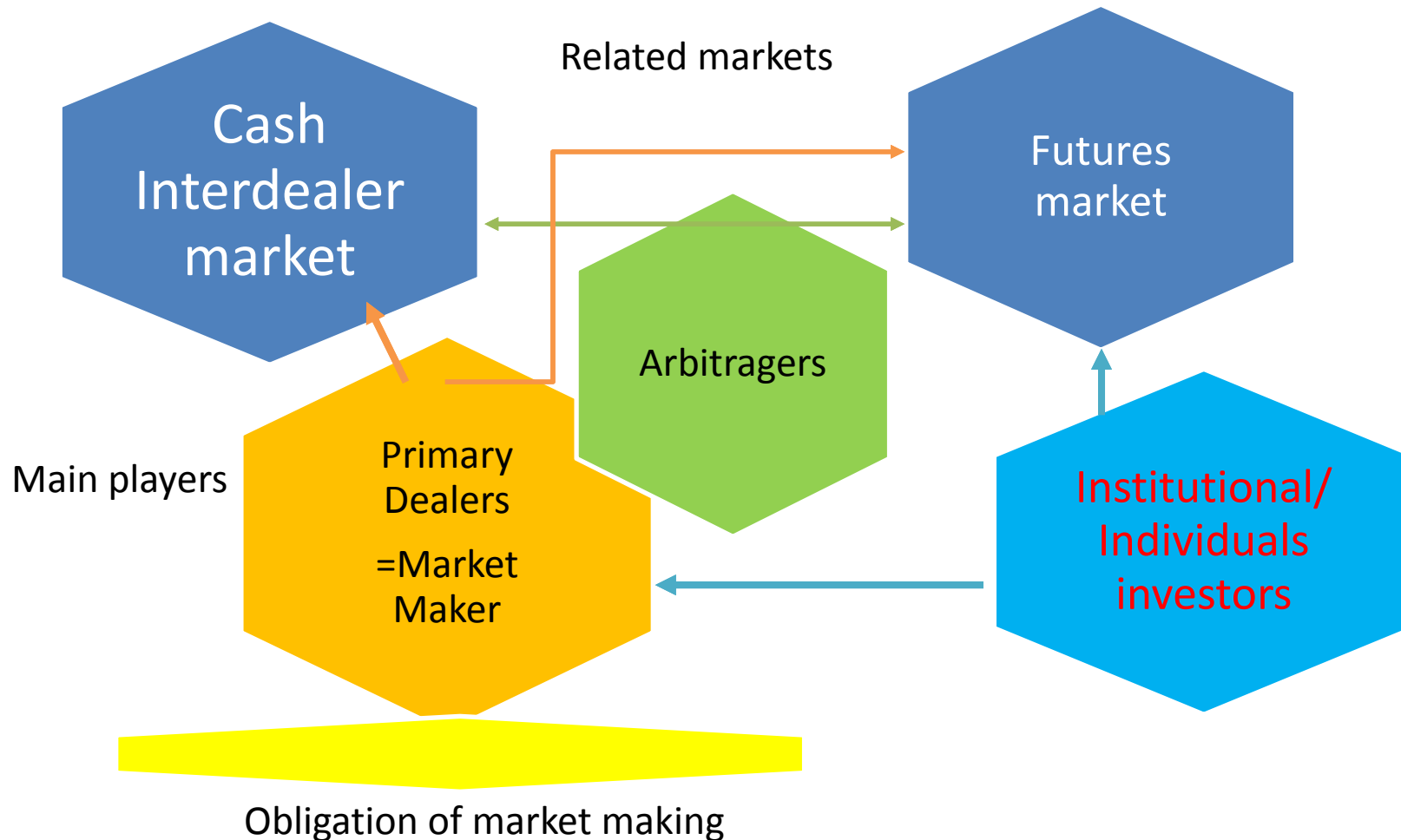
MARKET STRUCTURES

MTS:
- Electronic, Inter-Dealer market.
- Large share of secondary market for European government bonds.
- Domestic and European Markets: Several, connected.
- Primary Dealers: Market-makers (around 25).

EUREX:
- Continuous, electronic trading platform.
- Only one designated market maker, but several informal market makers.
- Everyone can supply liqudity through placing limit orders.

- Three futures contracts on Italian sovereign bonds: Long-, Mid-, Short-term. The underlying bonds are debt instruments issued by the Republic of Italy.

- We focus on the current Long-Term Euro-BTP futures contract, first introduced in 2009 and the most liquid.
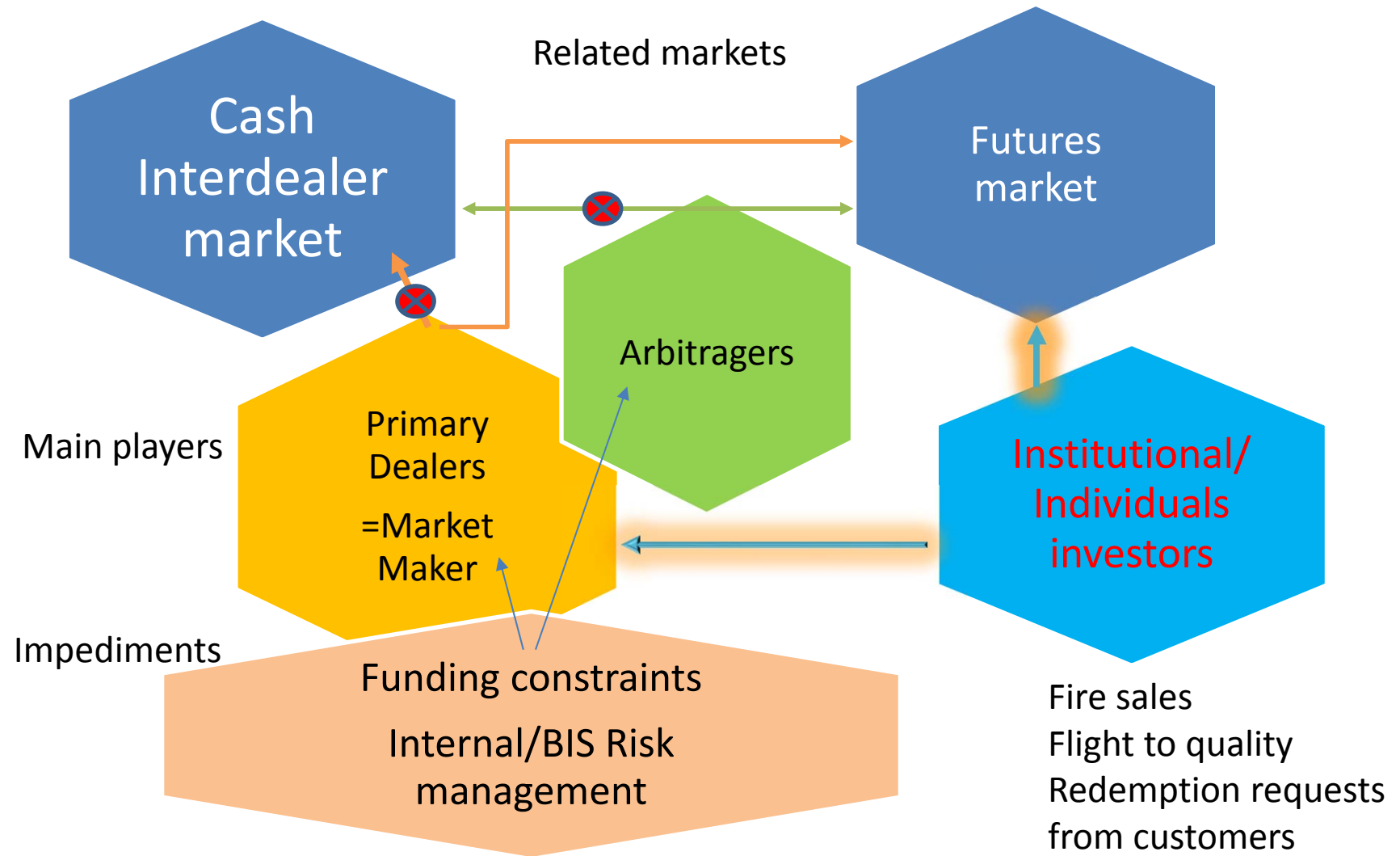
Price and Liquidity Discovery

Related markets

Cash Interdealer market

Futures market

Arbitragers

Main players

Primary Dealers

=Market Maker

Institutional/ Individuals investors

Obligation of market making

Liquidity Discovery: While arbitrageurs gain from exploiting the mispricing between securities X and Y by trading them, they add liquidity to the side against price move. This mitigates imbalance between buy and sell

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Impediments of Liquidity Discovery

Related markets

Cash Interdealer market

Futures market

Arbitragers

Main players

Primary Dealers
=Market Maker

Institutional/ Individuals investors

Impediments

Funding constraints

Internal/BIS Risk management

Fire sales
Flight to quality
Redemption requests from customers

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LITERATURE OVERVIEW 1/2

- On the future cash basis: Brenner, Subrahmanyam, Uno (1989).
- On the law of one price: Chan, Hong, Subrahmanyam (2008), Garleanu and Pedersen (2011).
- On the CDS-Bond basis: Nashikkar, Subrahmanyam, Mahanti (2011), Shachar and Choi (2013), Bai and Collin-Dufresne (2012).
- On the relation between liquidity in markets: Brunnermeier and Pedersen (2009), Cespa and Foucault (2014).
- On Euro-zone sovereign bonds: Beber, Brandt, Kavajecz '08, Cheung, de Jong, Rindi '05
- Various interventions and bond basis: Corradin/Rodriguez-Moreno(2014),Buraschi et al.(2014), etc.
- SMP: Pooter et al.(2014), Ghysels et.al.(2012) etc.

LITERATURE OVERVIEW 2/2

- Commonality in Liquidity 1: Market makers' funding liquidity determines the liquidity in the futures and bond cash market. When a market maker, who is dealing in securities X and Y, is hit by a funding liquidity shock, the liquidity of both security X and Y plummets (Brunnermeier and Pedersen, RFS 2009).

- Commonality in Liquidity 2: The price of security Y is used in the pricing of security X. If security Y is hit by a liquidity shock, its price is less informative. This affects the inventory cost for security X's market makers, who reduce their exposure. (Cespa and Foucault, RFS 2014).

THE DATA: A UNIQUE DATASET IN A UNIQUE PERIOD

Bond Data:
- Trade-by-Trade data.
- Order-by-Order data, uniquely linked to the trades.
- Every quote, every update, un-netted.

Futures:
- Trade-by-Trade data.
- Best quotes updates.

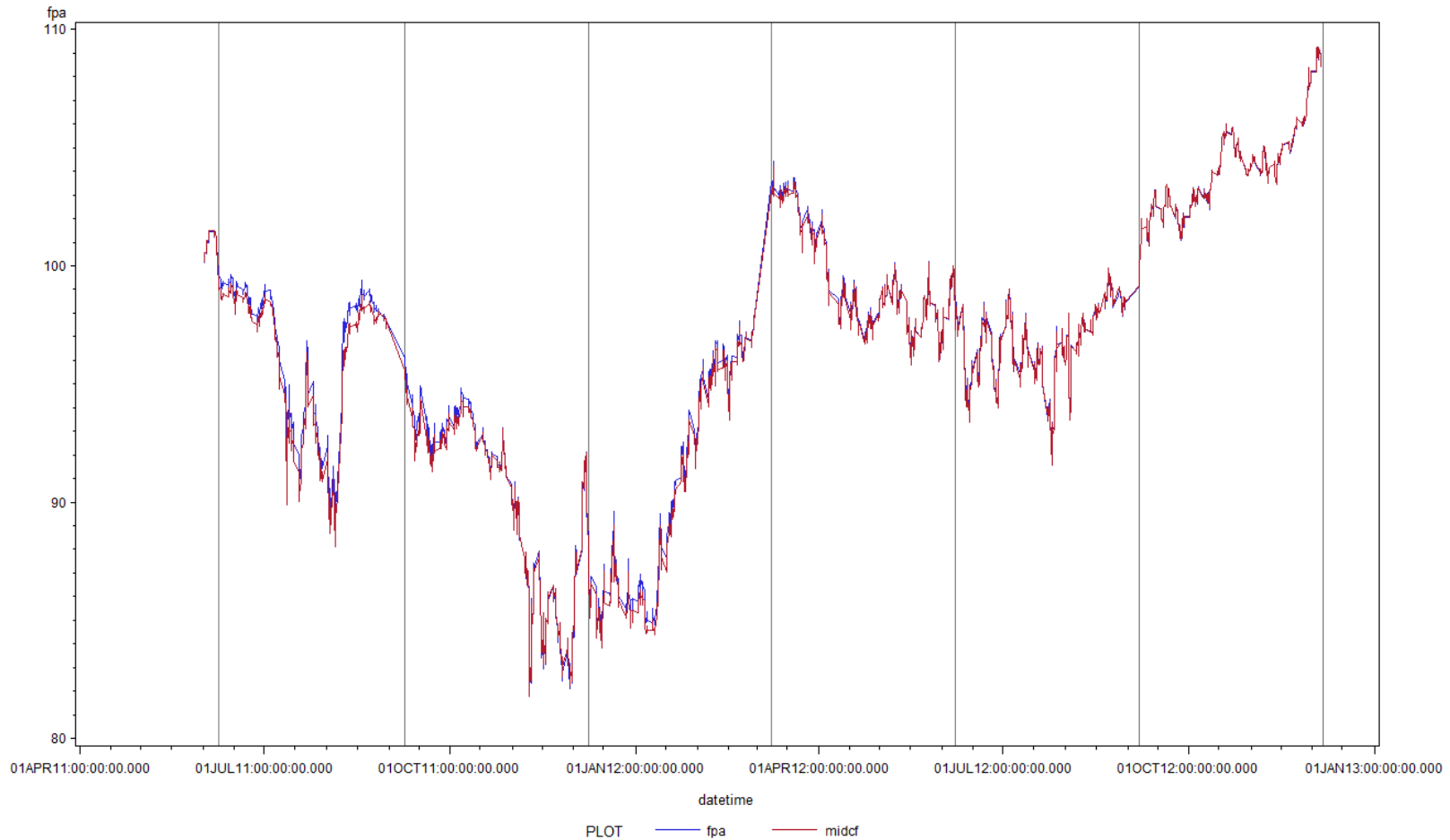Sample Period:
- June 2011 to December 2012.

Our liquidity measures:
- QUOTED SPREAD: Best ask-Best bid per 100e of face value.
- LAMBDA: How much a trader would move the best bid (ask) if she were to trade e 15 million

The price of the CTD bond and Scaled Futures

Cheapest to deliver (CTD) calculations based on Conversion Factors.
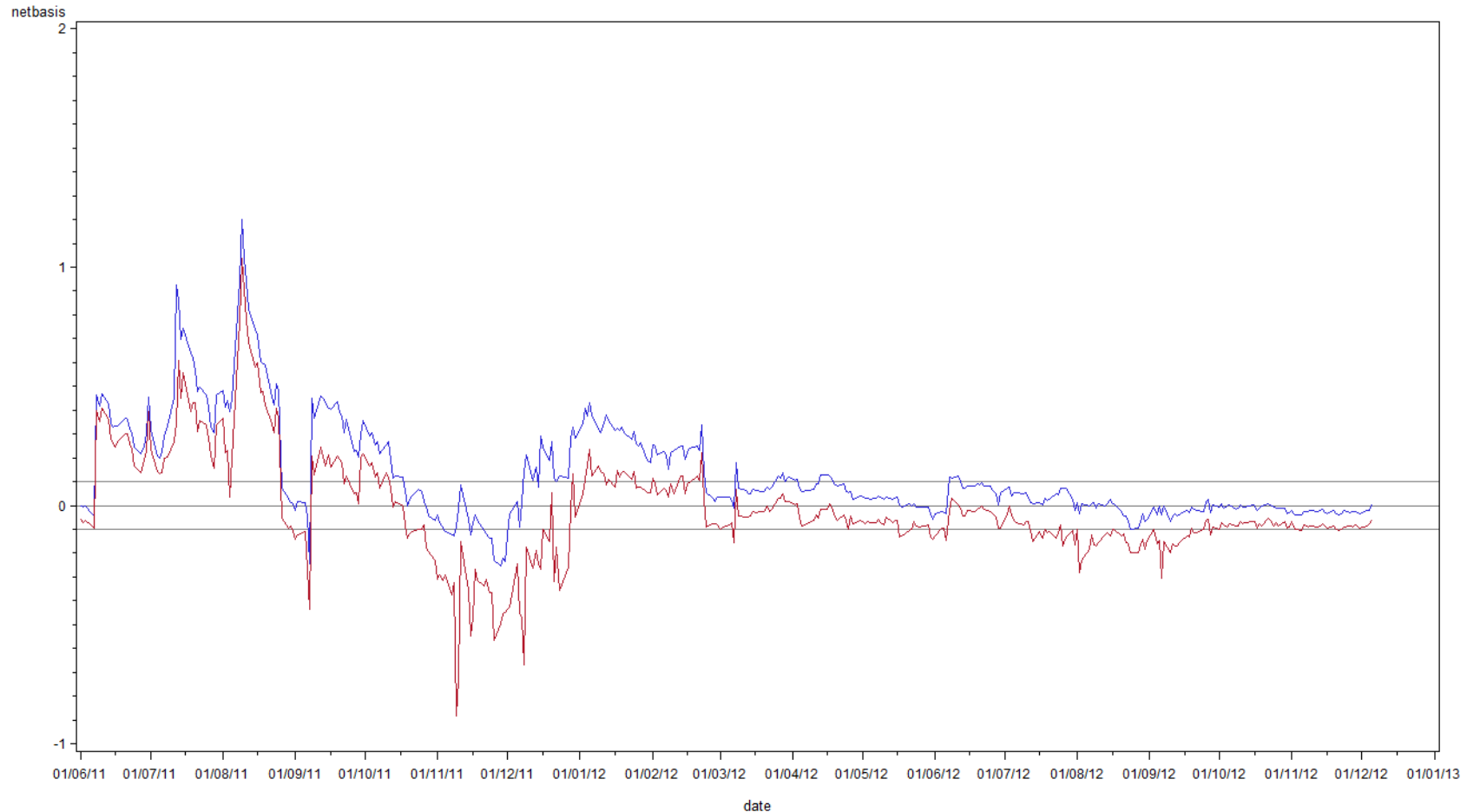The difference between the series is the basis.

THE FUTURES-BOND BASIS FOR THE CTD

Basis is high (above 100bps) in June 2011.
It turns negative during the depths of the crisis in November 2011, particularly around the resignation of Berlusconi.

THE FUTURES-BOND EXECUTABLE BASIS FOR THE CTD

The executable basis is computed by assuming the purchase of the futures (cash) contract at the ask and the sale of the CTD cash bond (futures) at the bid. (This is a conservative estimation.)

The blue graph represents the basis using mid-quotes, while the red graph uses the CTD bid- and the futures' ask-price.

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THE FUTURES-BOND EXECUTABLE BASIS FOR THE CTD
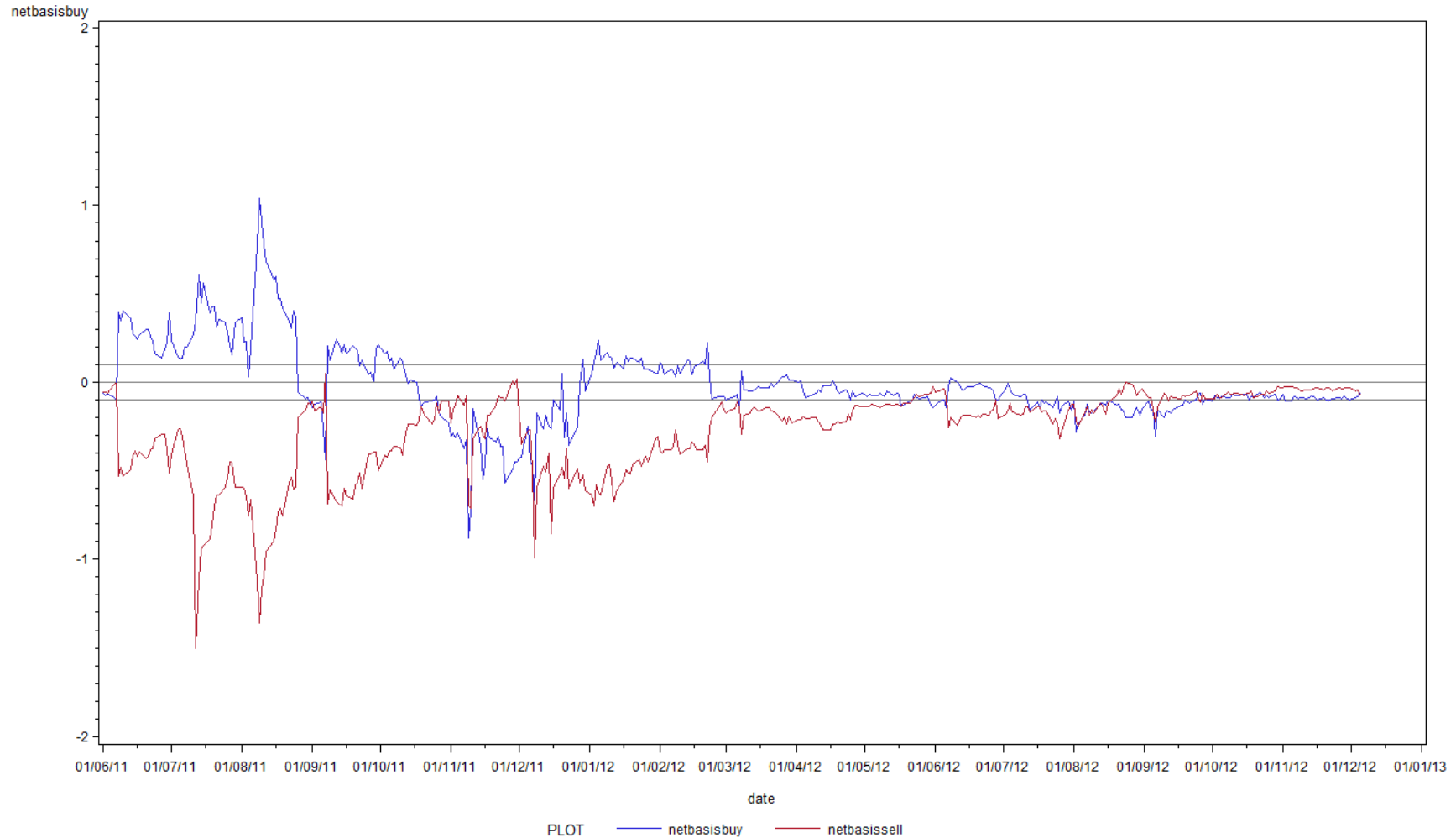
Blue graph represents buy futures-sell cash and the red graph buy cash-sell futures differences: executable basis.

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THE BID-ASK SPREADS OF THE CTD BOND AND THE FUTURES CONTRACT
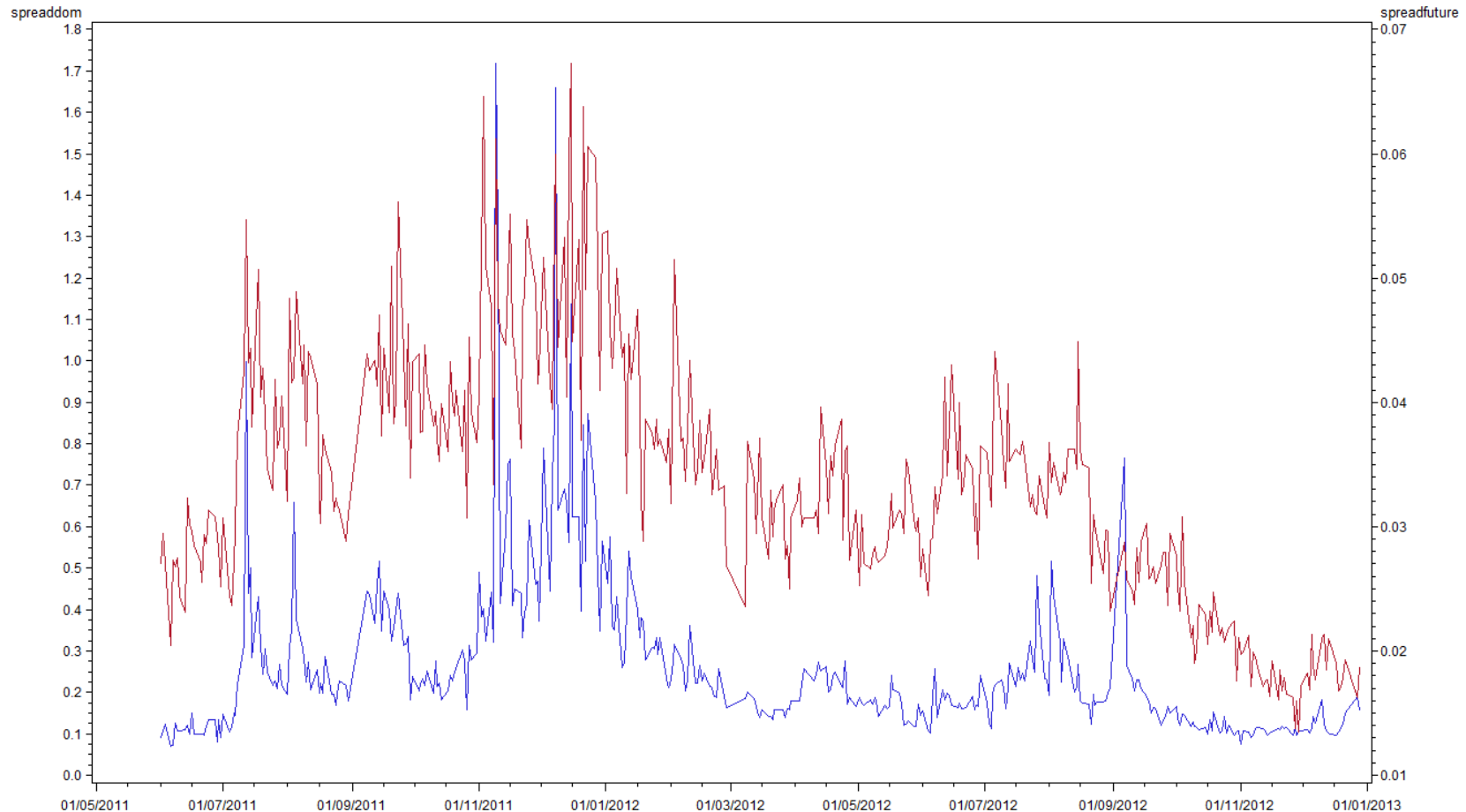
Bid-ask spread of the cash CTD bond (left) is always larger than that of the futures contract (right).

Their levels and the difference are the largest in the first half of the sample.

THE QUOTE SPREAD AND THE LAMBDA MEASURES

Comparison between cash bond liquidity measures. Lambdas on the left axis, in blue and red, and quoted spread on the right axis, in green

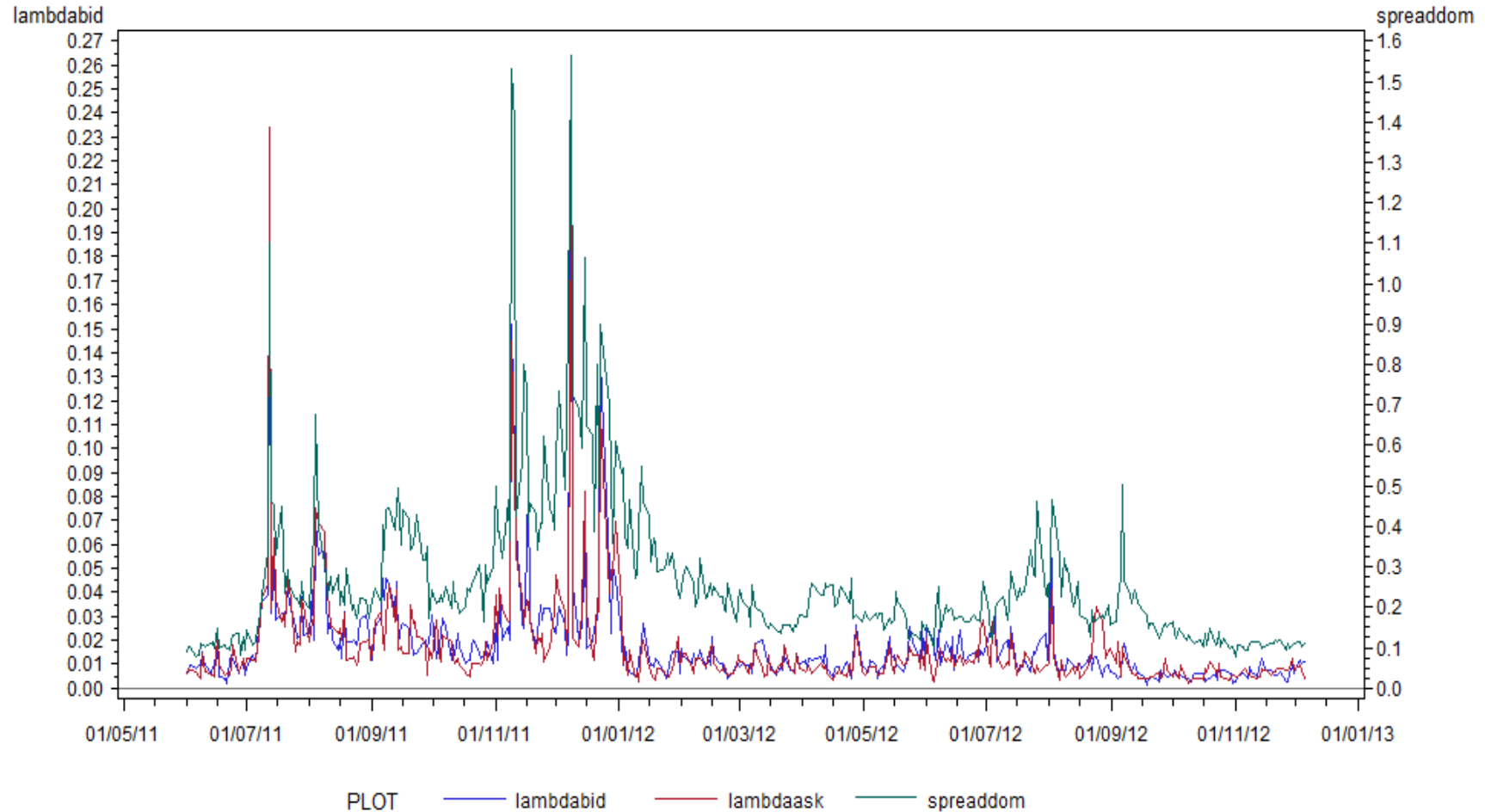| | Bond Market | | | | | |
	Five-minute Intervals			Daily Data		
Variable	Mean	Median	SD	Mean	Median	SD
Price	97.3406	97.8650	6.00901	97.3504	97.8224	6.01731
Bid-Ask Spread	0.2535	0.1900	0.23660	0.2585	0.2030	0.19624
λ^A	0.0158	0.0083	0.04714	0.0168	0.0105	0.02443
λ^B	0.0166	0.0083	0.04377	0.0179	0.0119	0.03033
$\lambda^A - \lambda^B$	-0.0010	0.0000	0.04574	-0.0014	-0.0013	0.01654

	Futures Market					
	Five-minute Intervals			Daily Data		
Variable	Mean	Median	SD	Mean	Median	SD
Price	101.8778	101.5650	5.32480	101.8873	101.5706	5.32629
Bid-Ask Spread	0.0338	0.0300	0.01964	0.0338	0.0332	0.00992

	Bases					
	Five-minute Intervals			Daily Data		
Variable	Mean	Median	SD	Mean	Median	SD
Net Basis	0.1315	0.0550	0.2194	0.1321	0.0557	0.2133
Net Basis Buy	-0.0151	-0.0621	0.2373	-0.0154	-0.0676	0.225
Net Basis Sell	-0.2783	-0.1875	0.2632	-0.2796	-0.1875	0.2474

▶ Bid-ask spread is much larger for cash bonds than for futures contract.
▶ Their SDs are comparable to their means.
▶ Median λs are equal: fair price.

Bond Market						
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Variable	Mean	Median	SD	Mean	Median	SD
Price	97.3405	97.8650	6.00901	97.3504	97.8224	6.01731
Bid-Ask Spread	0.2535	0.1900	0.23660	0.2585	0.2030	0.19624
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- Bid-ask spread is much larger for cash bonds than for futures contract.
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The prices of the futures and the underlying bonds are bound by a tight arbitrage condition.

- ▶ Cointegration framework.
- ▶ Allow the data to indicate the cointegration rank and space.
- ▶ Statistically test a net-zero-basis hypothesis.

$$\begin{pmatrix} \Delta P_{cash,t} \\ \Delta P_{Fut,t} \end{pmatrix} = \alpha\beta' \begin{pmatrix} P_{cash,t-1} \\ P_{Fut,t-1} \\ 1 \end{pmatrix} + \sum_{i=1}^{p} \phi_i \begin{pmatrix} \Delta P_{cash,t-i} \\ \Delta P_{Fut,t-i} \end{pmatrix}$$

RESULTS:

- ▶ Futures and cash bond prices are cointegrated of order 1.
- ▶ At a 5 min interval frequency, the futures price leads the cash bond price.
- ▶ At a daily level, there is no short term adjustment.

What is the dynamic relation between the liquidity in the two markets?

We distinguish between:

- ▶ the change in the liquidity that comes from a change in the information set.
  - ▶ We show that the futures market is leading in price discovery

- ▶ shocks to liquidity that originate purely from asset liquidity changes.
  - ▶ In the case of ECB intervention, we expect it to affect the cash market first since it is the market chosen for intervention.

Regarding the behavior of the arbitrageurs, we need to take into account the level of the basis.

To distinguish between long- and short-term adjustments, we analyze the relationship at a daily level (in levels):

$$QS_{cash,t} = \alpha + \sum_{i=1}^{p} \beta_i QS_{cash,t-i} + \sum_{i=1}^{p} \gamma_i QS_{future,t-i} + \sum_{i=1}^{p} \delta_i B_{t-i}$$

$$QS_{fut,t} = \alpha + \sum_{i=1}^{p} \beta_i QS_{cash,t-i} + \sum_{i=1}^{p} \gamma_i QS_{future,t-i} + \sum_{i=1}^{p} \delta_i B_{t-i}$$

and at the intra-day level (in differences):

$$\Delta QS_{cash,t} = \alpha + \sum_{i=1}^{p} \beta_i \Delta QS_{cash,t-i} + \sum_{i=1}^{p} \gamma_i \Delta QS_{future,t-i} + \sum_{i=1}^{p} \delta_i \Delta B_{t-i}$$

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	Daily (Levels)		
Causing/Caused	Basis	Bid-Ask Bond	Bid-Ask Futures
Basis	2527.74***	3.04	0.72
Bid-Ask Bond	12.01**	38.14***	17.24***
Bid-Ask Future	2.56	6.84	220.02***
	Five-minute (Changes)		
Causing/Caused	Basis	Bid-Ask Bond	Bid-Ask Futures
Basis	155.65***	21.92	13.28
Bid-Ask Bond	13.42	138.89***	11.88
Bid-Ask Future	14.16	19.41	12392.59***

▶ Illiquidity of the bond market leads the mispricing between the markets.

▶ At the intraday level, there is no relation (in changes).

▶ To capture changes in the propensity to buy/sell, we need a better measure.

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- At the intraday level, there is no relation (in changes).
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Is low market liquidity in the cash or futures market an impediment to arbitrage?

$$B_t = \alpha + \sum_{i=1}^{p} \beta_i QS_{cash,t-i} + \sum_{i=1}^{p} \gamma_i QS_{future,t-i} + \sum_{i=1}^{p} \delta_i B_{t-i}$$
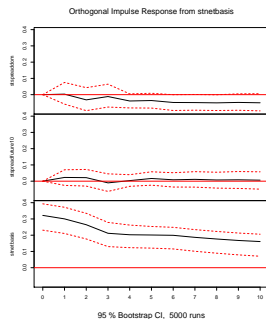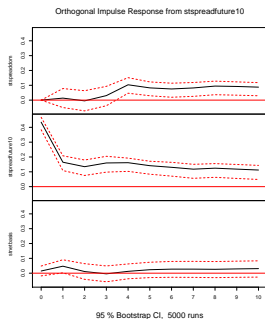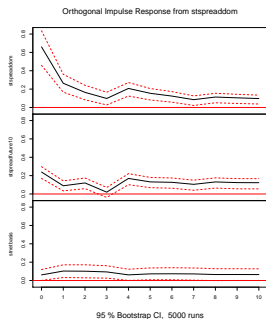
- ► As the cash bond illiquidity goes up, the net basis follows and the shock lasts 3 days.

- ► The futures illiquidity has no effect on the basis and a marginal effect on the cash bond market.

- ► A shock in the basis has no effect on the liquidity.

We re-estimate the VAR with the intraday data using λ^A and λ^B as liquidity measures.

$$\Delta\lambda_t^A = \alpha + \sum_{i=1}^p \beta_i^A \Delta\lambda_{t-i}^A + \sum_{i=1}^p \beta_i^B \Delta\lambda_{t-i}^B + \sum_{i=1}^p \gamma_i \Delta QS_{future,t-i} + \sum_{i=1}^p \delta_i \Delta B_{t-i}$$

$$\Delta\lambda_t^B = \alpha + \sum_{i=1}^p \beta_i^A \Delta\lambda_{t-i}^A + \sum_{i=1}^p \beta_i^B \Delta\lambda_{t-i}^B + \sum_{i=1}^p \gamma_i \Delta QS_{future,t-i} + \sum_{i=1}^p \delta_i \Delta B_{t-i}$$

$$\Delta QS_{fut,t} = \alpha + \sum_{i=1}^p \beta_i^A \Delta\lambda_{t-i}^A + \sum_{i=1}^p \beta_i^B \Delta\lambda_{t-i}^B + \sum_{i=1}^p \gamma_i \Delta QS_{future,t-i} + \sum_{i=1}^p \delta_i \Delta B_{t-i}$$

$$\Delta B_t = \alpha + \sum_{i=1}^p \beta_i^A \Delta\lambda_{t-i}^A + \sum_{i=1}^p \beta_i^B \Delta\lambda_{t-i}^B + \sum_{i=1}^p \gamma_i \Delta QS_{future,t-i} + \sum_{i=1}^p \delta_i \Delta B_{t-i}$$

▶ λs combines information from prices and quantities of the quotes.

▶ It is a measure of the depth of the market.

▶ It is superior to the bid-ask spread because it involves quantity, and also, can be asymmetric, in general.

		Five-minute		
Causing/Caused	Basis	λ^{ASK}	λ^{BID}	Bid-Ask Futures
Basis	456.18***	26.88**	23.01	17.32
λ^{ASK}	26.27*	326.43***	21.32	21.27
λ^{BID}	23.74*	52.26***	80.12***	32.58***
Bid-Ask Future	21.00	24.17*	20.36	12375.13***

		Five-minute	
Causing/Caused	Basis	$\lambda^{ASK} - \lambda^{BID}$	Bid-Ask Futures
Basis	450***	21.35	17.45
$\lambda^{ASK} - \lambda^{BID}$	27.86**	79.46***	30.12**
Bid-Ask Future	20.58	15.02	12367.41***

- λ^{BID} leads all measures, including the liquidity in the futures market.
- λ^{BID} is the relevant variable when the basis is positive.
- $\lambda^{ASK} - \lambda^{BID}$, i.e., the "deep" midquote, leads changes in the basis and the liquidity in the futures market.

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Basis	450***	21.35	17.45
$\lambda^{ASK} - \lambda^{BID}$	27.86**	79.46***	30.12**
Bid-Ask Future	20.58	15.02	12367.41***

► λ^{BID} leads all measures, including the liquidity in the futures market.

► λ^{BID} is the relevant variable when the basis is positive.

► $\lambda^{ASK} - \lambda^{BID}$, i.e., the "deep" midquote, leads changes in the basis and the liquidity in the futures market.

|		Five-minute		
Causing/Caused	Basis	λ^{ASK}	λ^{BID}	Bid-Ask Futures
Basis	456.18***	26.88**	23.01	17.32
λ^{ASK}	26.27*	326.43***	21.32	21.27
λ^{BID}	23.74*	52.26***	80.12***	32.58***
Bid-Ask Future	21.00	24.17*	20.36	12375.13***

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During the Euro-zone crisis, the ECB intervention took many forms:

- ▶ Securities Market Programme (SMP).

- ▶ Outright Monetary Transactions (OMT).

- ▶ Long Term Refinancing Operations (LTRO).

- ▶ Policy Guidance.
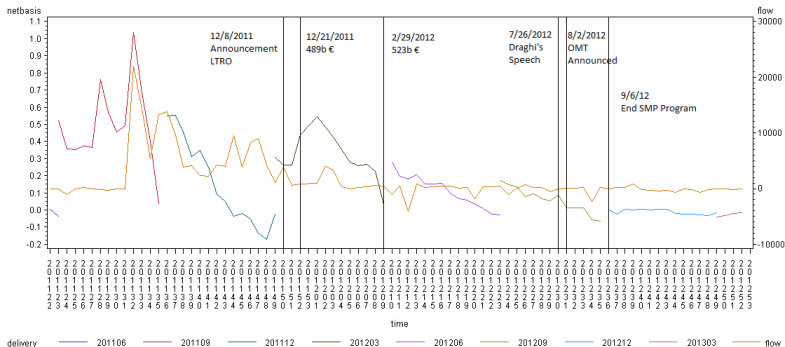
- The net basis spikes up as large repurchase programs are initiated.
- When the program stops, the basis slowly converges to zero.
- Draghi's speech has little effect on the basis, although it affects yields and liquidity

Panel A: 2011			
Causing/Caused	Basis	$\lambda^{ASK} - \lambda^{BID}$	Bid-Ask Futures
Basis	270.85***	21.98	20.13
$\lambda^{ASK} - \lambda^{BID}$	32.7***	533.13***	28.17**
Bid-Ask Futures	17.36	18.42	2710.61

Panel B: 2012			
Causing/Caused	Basis	$\lambda^{ASK} - \lambda^{BID}$	Bid-Ask Futures
Basis	1101.5***	18.99	15.42
$\lambda^{ASK} - \lambda^{BID}$	20.25	288.23***	19.59
Bid-Ask Futures	20.28	14.67	9315.89***

▸ The results for the whole sample are driven by the first period.
▸ The higher liquidity in the second half of the sample means that market liquidity does not impede the arbitrage.

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- ▶ In the Italian market, cash bonds are characterized by greater illiquidity than the futures contract.

- ▶ The futures market leads the cash market in price discovery.

- ▶ This imposes a clear limit to the arbitrage mechanism between the cash and futures markets.

- ▶ There is a spillover of liquidity from one market to the other in market, which are linked by arbitrage.

- ▶ This explains why it is the liquidity of the most illiquid market that drives both the basis and the liquidity discovery.

- Monetary policy and Central Banks:
  - Open-market asset-repurchase actions have an impact on the liquidity of the inter-dealer market for government bonds.

  - Massive central bank operations, particularly in the context of quantitative easing, are bound to substantially affect liquidity.

  - New unconventional instruments of monetary policy on the markets can be improved by including the usage of the futures markets as one of the intervention tools.

- Market regulators: the presence of arbitrage opportunities is a matter of concern. The identification of the sources of such limits to arbitrage is a step towards ensuring the efficient transmission of central bank actions to market.

- Euro-zone national treasuries: the relationship between market liquidity in the cash and futures markets implies strong consequences for the pricing of their sovereign debt issues in the auctions.

- ▶ Characterize the dynamics of the executable basis.

- ▶ Investigate the direct effect of funding liquidity in the daily analysis.

- ▶ Relate the basis to the trading activities of the markets.

- ▶ Implement robustness in daily measures.

- ▶ Autocorrelation robust IRF for intraday data.

- ▶ Formally testing for structural breaks.

- ▶ Investigate the effect of magnitude of ECB intervention.

Thank you for your attention!