Project HighLO and ROOT

May 16th

PPP Meeting

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Project HighLO – Key team

Collaboration: WUR + UM + CERN + CORMEC

HighLO = **High** Energy Physics Tools in **L**imit **O**rder Book Analysis

WUR/UM/CORMEC		CERN
Joost Pennings (WUR/UM)	Marjolein Verhulst (WU/WEcR)	Axel Naumann
Koos Gardebroek (WUR)	Philippe Debie (WU/WEcR)	Lorenzo Moneta
Bedir Tekinerdogan (WUR)	Tarek AlSkaif (WUR)	Jonas Rembser
Cagatay Catal (WUR)		Danilo Piparo
Andres Trujillo-Barrera (CORMEC)		Han Dols

Project HighLO – Background info

Current finance research lacks the tools

- Huge datasets
- Everything is statistically significant

HighLO

- Adapt more capable software tools (ROOT)
- A new perspective on how to analyze data
- Search and detect market manipulation

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Project HighLO – Background info

Limit

Order

Book

Side	Price	Volume
Ask Side (Selling)	15	5 + 3 + 2 = 10
	14	4 + 2 = 6
	13	3 + 1 = 4
Bid Side (Buying)	12	2 = 2
	11	2 + 5 = 7
	10	5 = 5

Project HighLO – Background info

Financial market is governed by supply and demand

- Limit order book = Summary of all limit orders
- More sell limit orders → Price goes down
- More buy limit orders → Price goes up

Spoofing = Placing and cancelling limit orders to push the market (with no intention of execution)

Project HighLO – Research goal

Detect spoofing in the commodity futures market

1. Describe how spoofing works
2. Detect spoofing
3. Help regulators and lawmakers

Spoofing = Placing and cancelling limit orders to push the market
(with no intention of execution)

Int. Expert Group on Market Surveillance (IMS)

The Netherlands:

- Exchange: Euronext
- Regulator: Authority for Consumers and Markets
- Regulator: Authority Financial Markets

UK:

- Exchange: ICE Futures Europe

Germany:

- Exchange: Deutsche Börse (FSE, Eurex)
- Exchange: EEX

Switzerland:

- Regulator: FINMA
- Exchange: SIX Group

Italy:

- Regulator: CONSOB

EU:

- Regulator: ACER
- Regulator: ESMA

USA:

- Exchange: CME Group
- Regulator: CFTC

Into the Microseconds

Paper submitted to Management Science

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Research Questions

1. How to measure relationships on the microsecond level?

2. Can we measure which market is leading?
   And which market is following?

→ This paper is not about market manipulation

Data

	Corn Futures	Wheat Futures	Soybean Futures
CME Globex code	ZC	ZW	ZS
Data range	2019/07/01 – 2020/07/01		
Number of messages	758 Million	723 Million	1605 Million
Raw data	± 100 GB	± 100 GB	± 200 GB
In ROOT	5.3 GB	4.9 GB	9.9 GB

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HighLO

Event-Based Impact Profile – The Concept

Trigger

Impact value

Idea:

Measure the changes in a time series
at fixed intervals before or after an event

Example:

What is the average price change in the Wheat market
50 ms after a price change in the Corn market

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Event-Based Impact Profile – The Construction

1. Collect a set of triggers

   → Price changes in the Corn market (800 k)

2. For each trigger, extract a time series

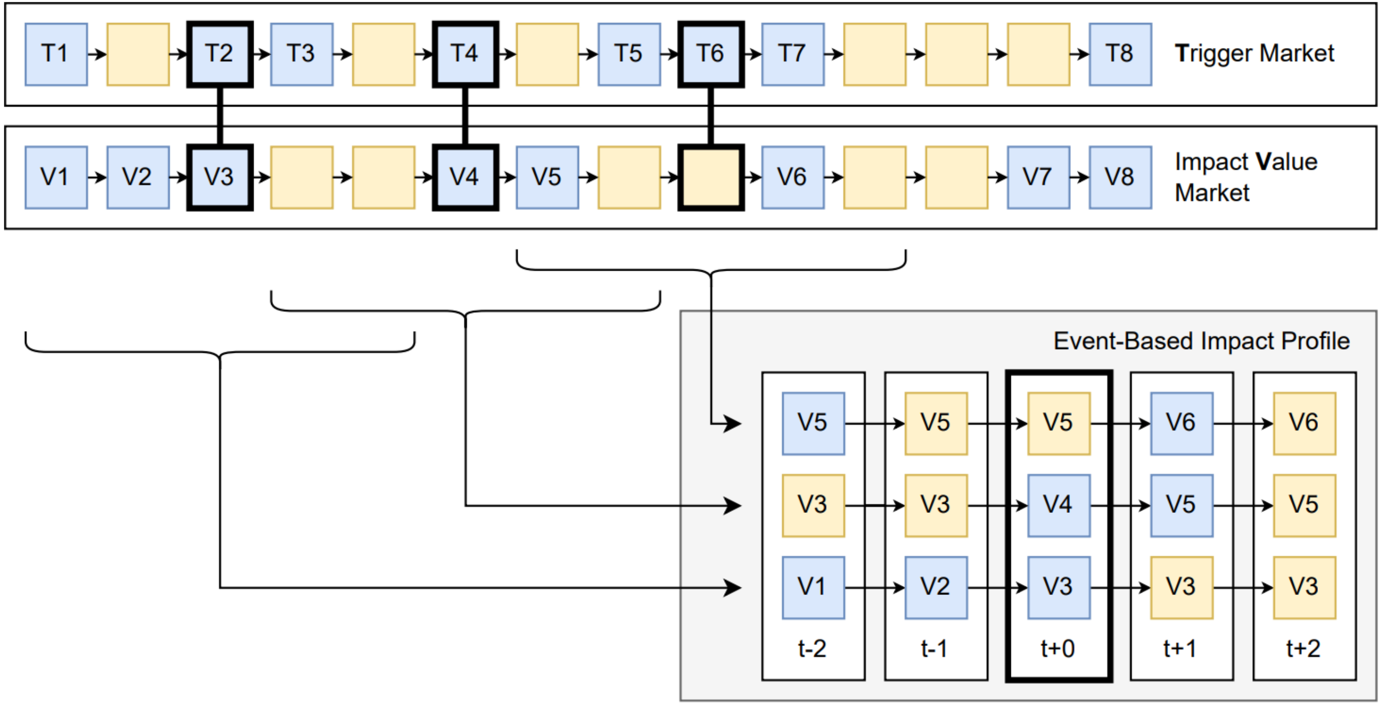
   → 200ms before to 200ms after the trigger

3. Overlap these time series (align the triggers)

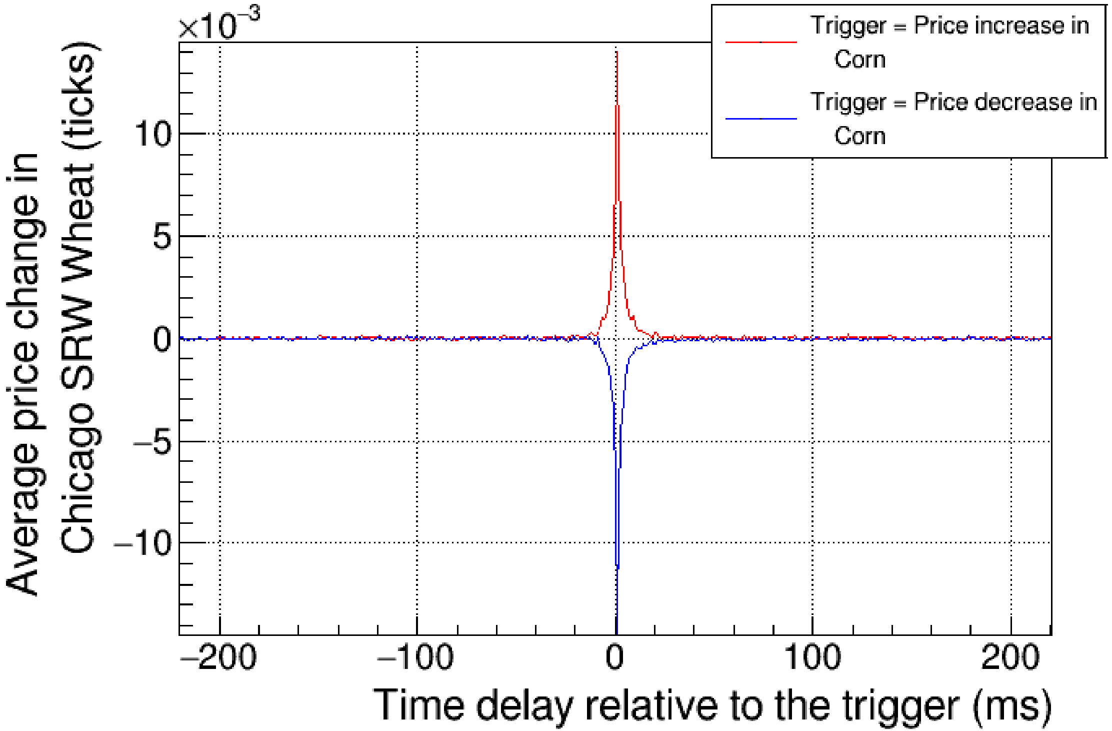
4. For each time delay, build a distribution

   → 401 distributions, sequence of distributions

Event-Based Impact Profile – Diagram

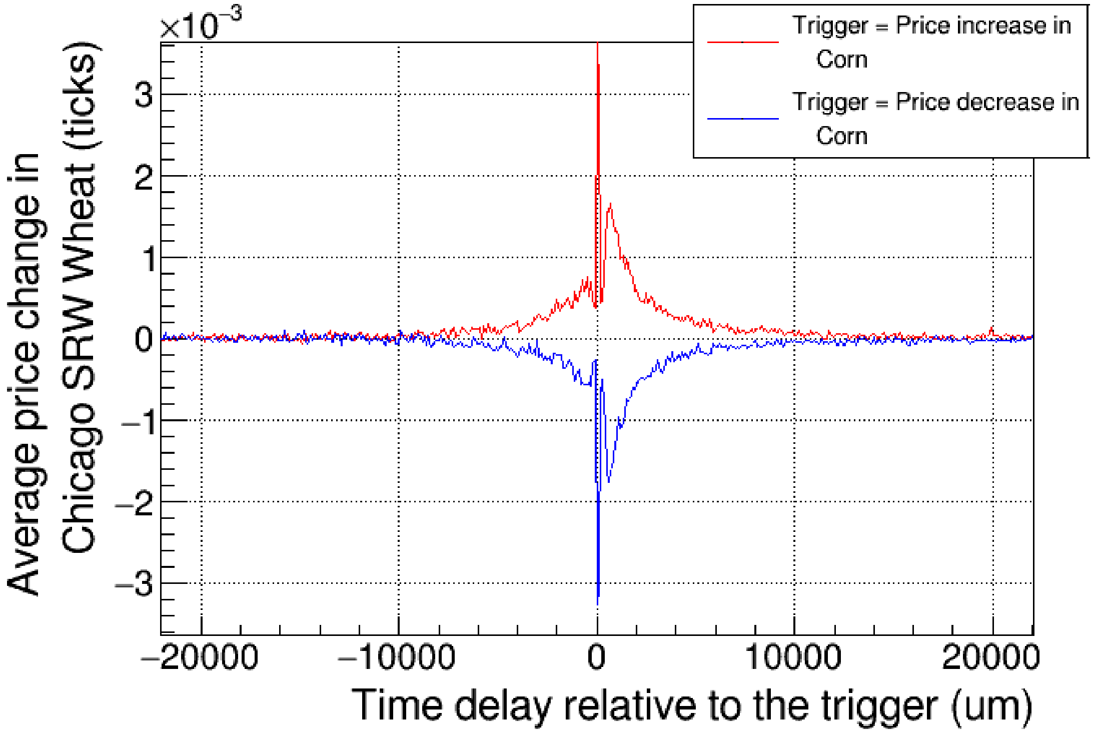


Trigger: Price change in Corn Futures
Impact: Price change in Wheat Futures
Resolution: 1 ms (x-axis spanning 440 ms)



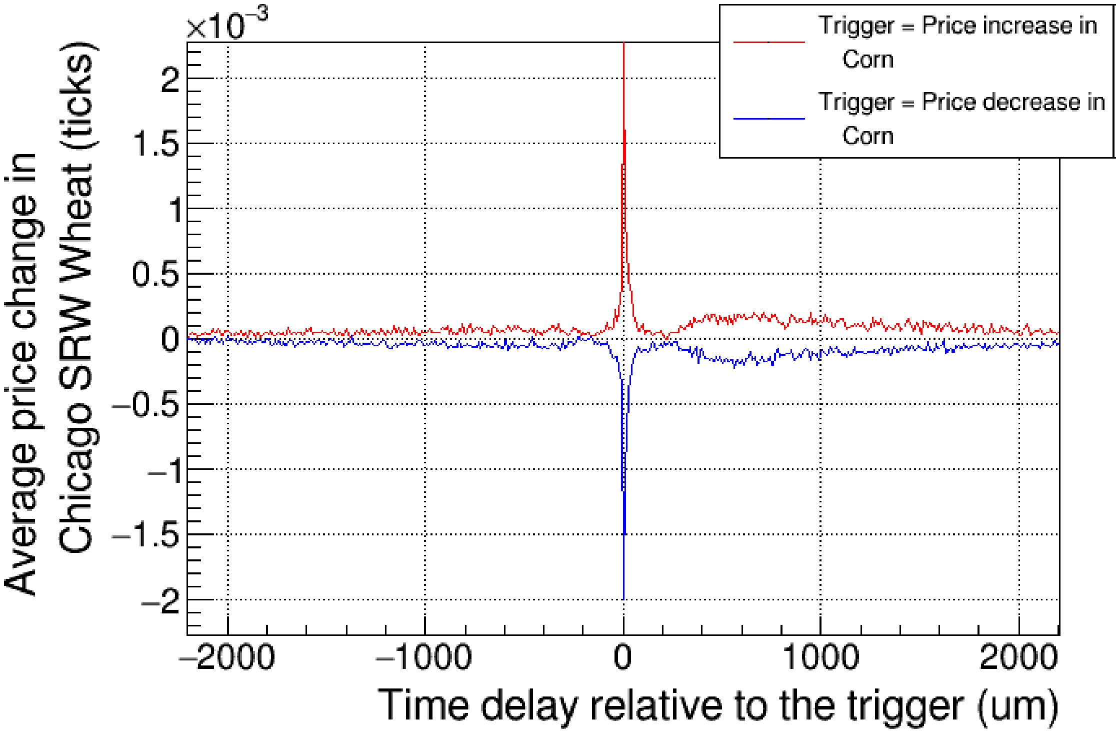
1 tick in Chicago SRW Wheat = 12.5 USD per contract (5000.0 BU)

Trigger: Price change in Corn Futures
Impact: Price change in Wheat Futures
Resolution: 100 µs (x-axis spanning 44 ms)



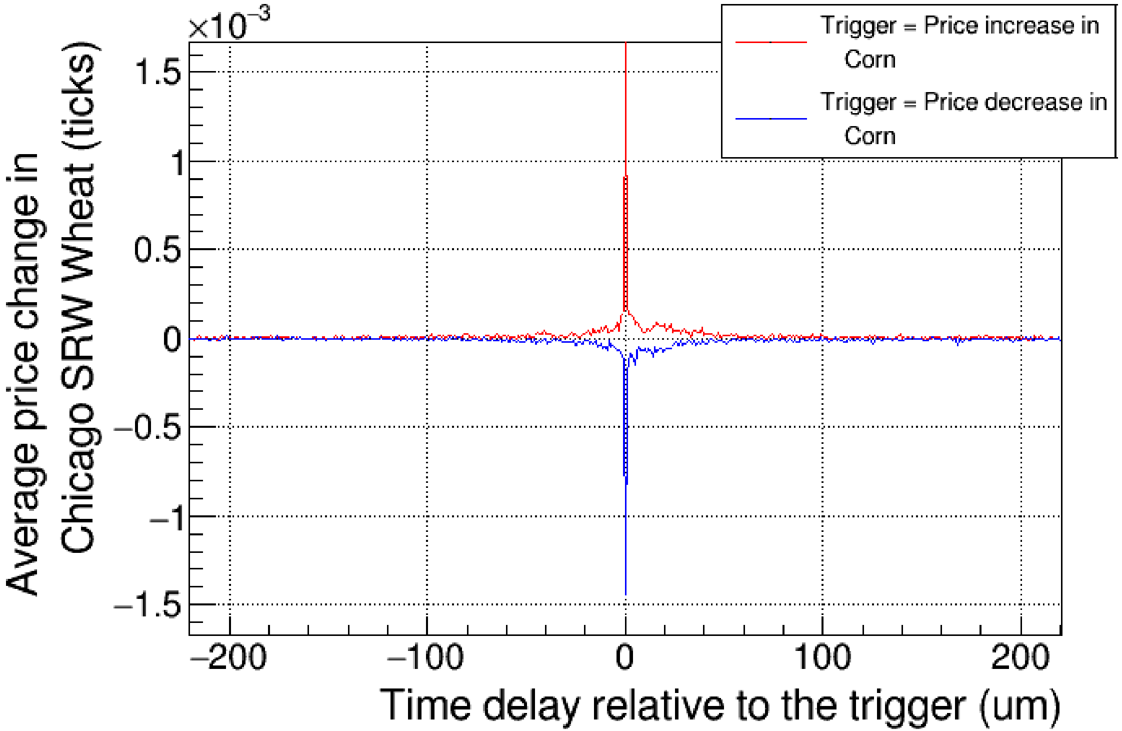
1 tick in Chicago SRW Wheat = 12.5 USD per contract (5000.0 BU)

Trigger: Price change in Corn Futures
Impact: Price change in Wheat Futures
Resolution: 10 µs (x-axis spanning 4.4 ms)



1 tick in Chicago SRW Wheat = 12.5 USD per contract (5000.0 BU)

Trigger: Price change in Corn Futures
Impact: Price change in Wheat Futures
Resolution: 1 µs (x-axis spanning 0.44 ms)



1 tick in Chicago SRW Wheat = 12.5 USD per contract (5000.0 BU)

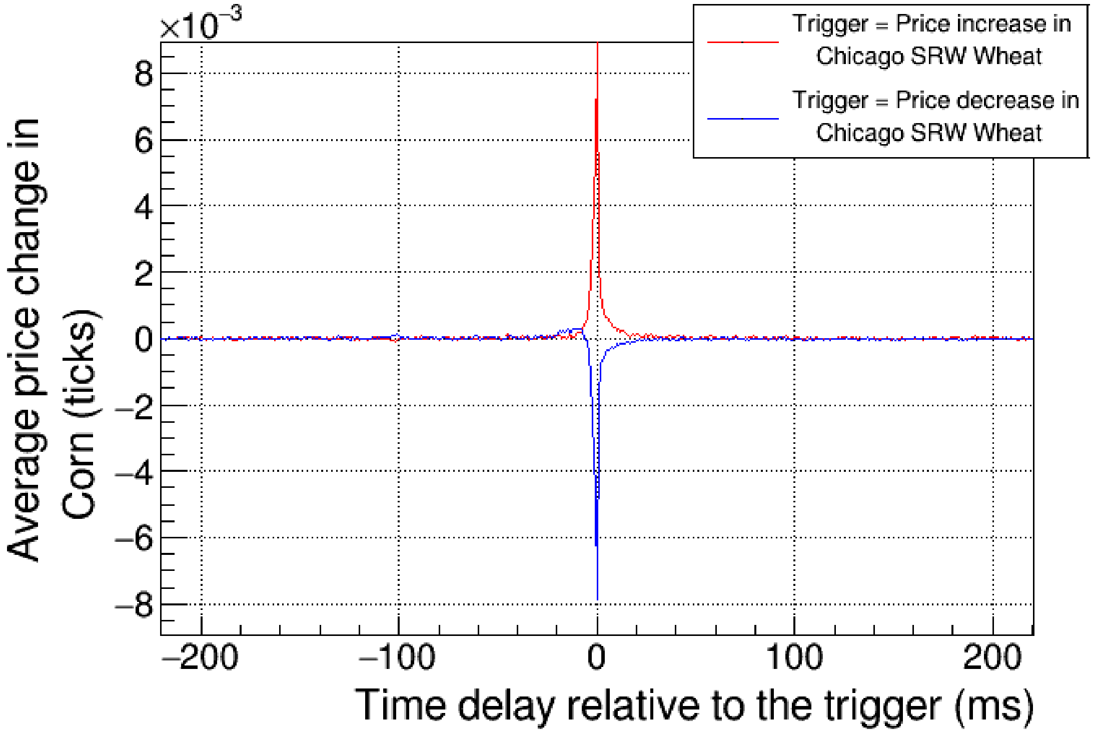
Summary 1: Impact of Corn on Wheat

Summary

1. Price increase occurs in 2 parts
    a. Instantaneously
    b. Starting 0.5 milliseconds after
2. Asymmetric, price increase in Wheat follows price increase in Corn

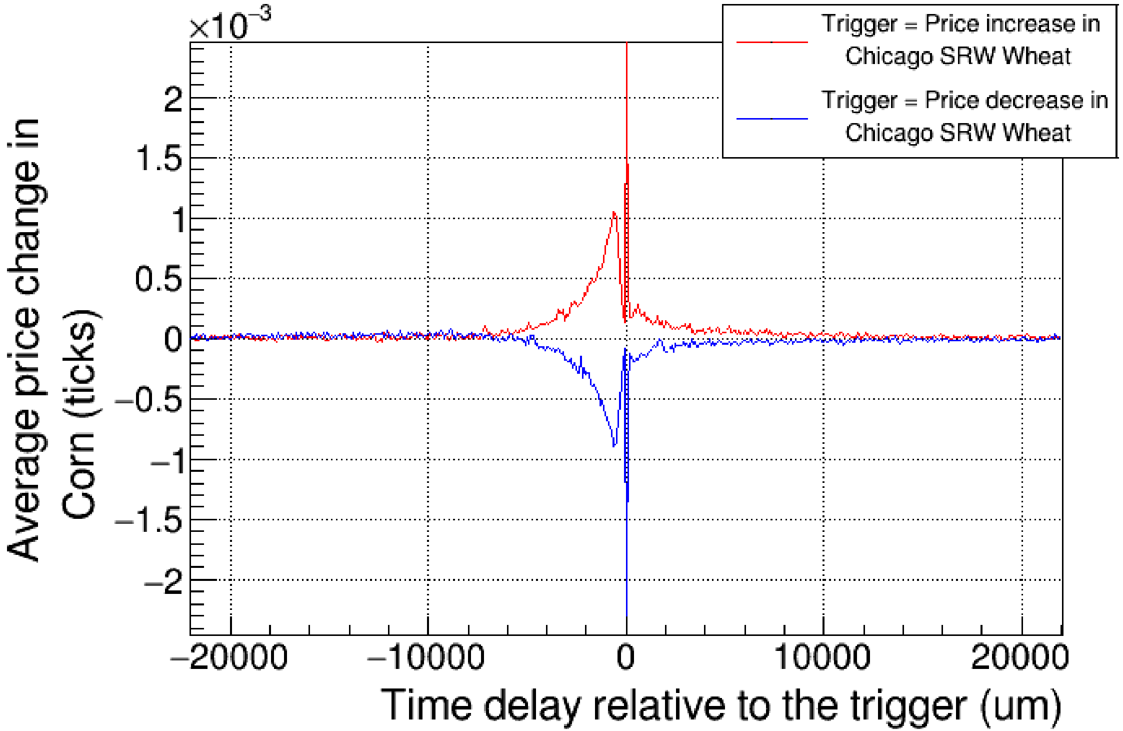
Next question: What if we inverse the trigger and impact contract?

Trigger: Price change in Wheat Futures
Impact: Price change in Corn Futures
Resolution: 1 ms (x-axis spanning 440 ms)



1 tick in Corn = 12.5 USD per contract (5000.0 BU)

Trigger: Price change in Wheat Futures
Impact: Price change in Corn Futures
Resolution: 100 µs (x-axis spanning 44 ms)



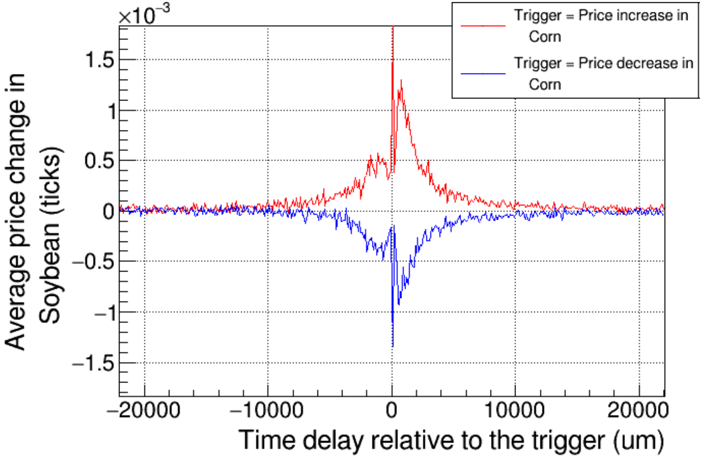
1 tick in Corn = 12.5 USD per contract (5000.0 BU)

Summary 2: Impact of Wheat on Corn

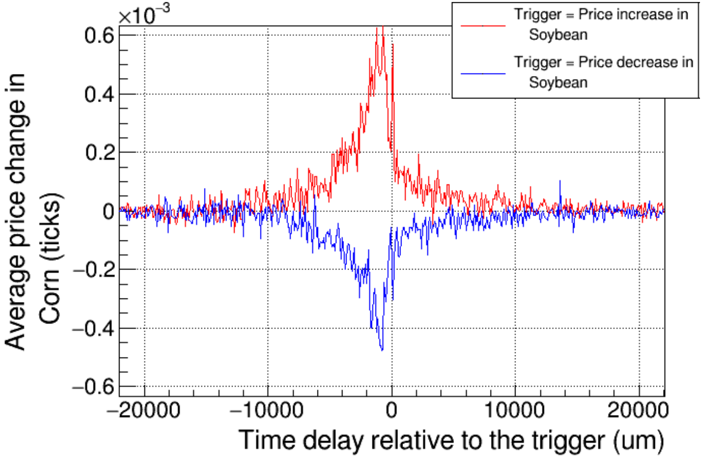
Summary

1. Price increase occurs in 2 parts
2. Asymmetric, price increase in Wheat follows price increase in Corn

Next question: How are relations between other markets?

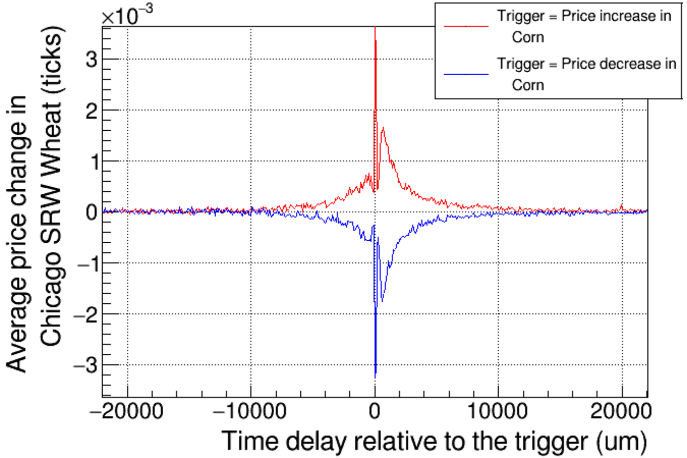


1 tick in Soybean = 12.5 USD per contract (5000.0 BU)

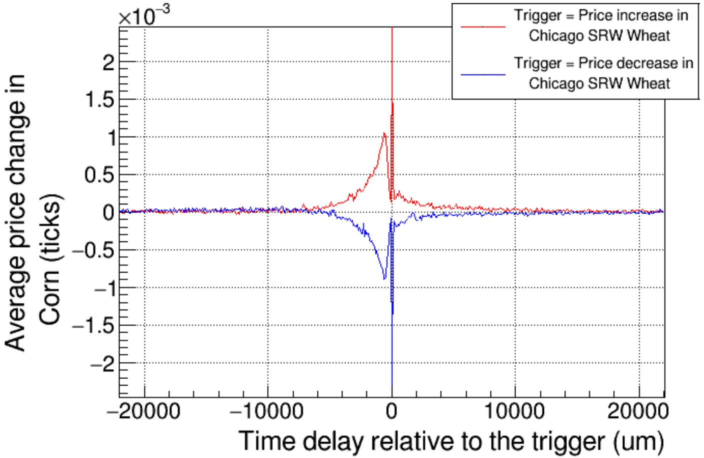


1 tick in Corn = 12.5 USD per contract (5000.0 BU)

Soybean follows Corn

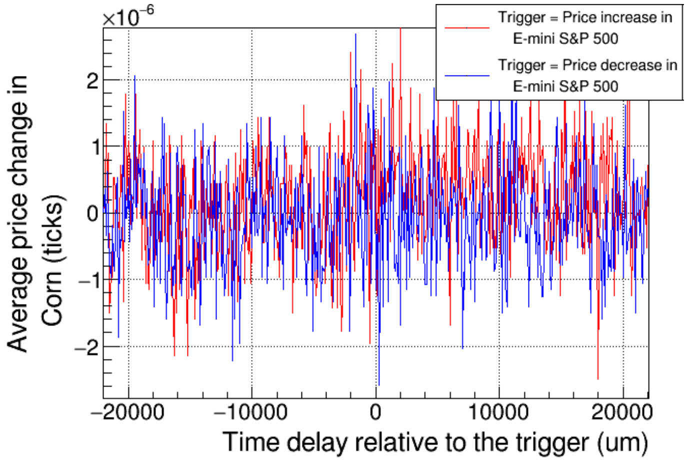


1 tick in Chicago SRW Wheat = 12.5 USD per contract (5000.0 BU)

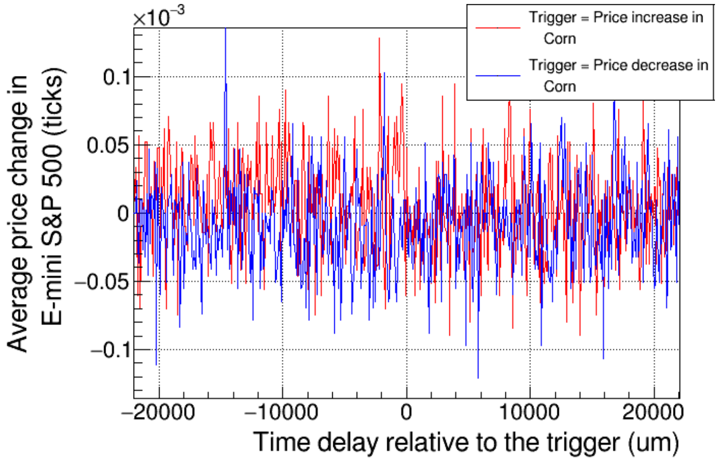


1 tick in Corn = 12.5 USD per contract (5000.0 BU)

Wheat follows Corn



1 tick in Corn = 12.5 USD per contract (5000.0 BU)



1 tick in E-mini S&P 500 = 12.5 USD per contract (50.0 IPNT)

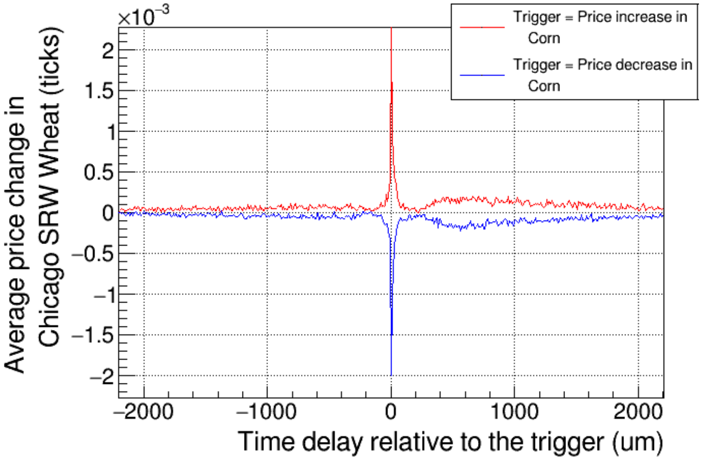
Conclusion: Research question

Observations:

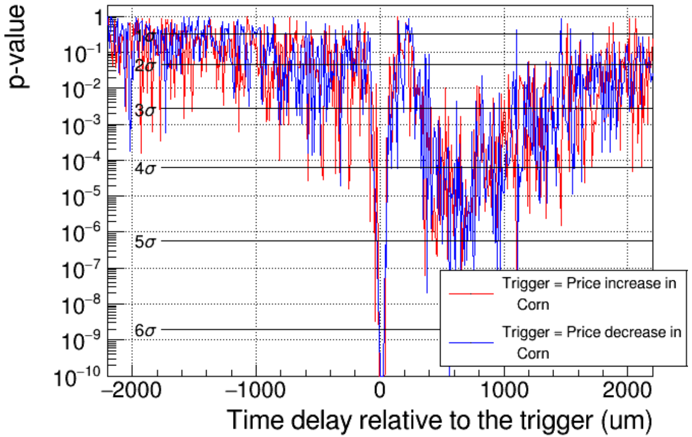
1. The market responds in 2 steps

2. **Price** changes in Wheat and Soybean follow
   Price changes in Corn

Trigger: Price change in Corn Futures
Impact: Price change in Wheat Futures
Resolution: 10 μs (x-axis spanning 4.4 ms)



1 tick in Chicago SRW Wheat = 12.5 USD per contract (5000.0 BU)



Conclusion: The methodology

Advantages compared to an impact analysis using VAR models

1. No data fitting or user-chosen modelling parameters
2. Measure past and future time correlations
3. Linear computational cost and trivial multi-threading
4. Not limited by the complexity of the model

→ Interdisciplinary collaboration led to new techniques

How does HighLO contribute to ROOT?

Project 1: Interactive Dashboard to Explore High-Dimensional Histograms

How does HighLO Contribute to ROOT?

Project 2: RDataframe with Time Series Support

New Operations for RDataframe

Slides from PPP 118

RDataframe operations

- Define using lead and lag (differentiation)
- Persistent data objects (integration and more)
- Resample a time series

Proof of concept: https://github.com/philippe554/root

Lead and Lag

```
ROOT::RDataFrame rdf(50);

auto r = rdf
   .DefineSlotEntry("foo", [](unsigned int slot, ULong64_t entry){return static_cast<int>(entry);})
   .Define("bar", [](int foo){return foo * foo;}, {"foo"})
   .MovingCache<int, int>({"foo", "bar"})
   .Define("D", [](int bar1, int bar2){return bar2 - bar1;}, {"bar", "bar"}, {-1, 0})
   .Display({"foo", "bar", "D"});

r->Print();
```

```
+-----+-----+-----+---+
| Row | foo | bar | D |
+-----+-----+-----+---+
| 1   | 1   | 1   | 1 |               → Note that it skipped the first entry
+-----+-----+-----+---+
| 2   | 2   | 4   | 3 |
+-----+-----+-----+---+
| 3   | 3   | 9   | 5 |
+-----+-----+-----+---+
| 4   | 4   | 16  | 7 |
+-----+-----+-----+---+
```

Persistent Define

```
ROOT::RDataFrame rdf(10);

auto r = rdf
   .DefineSlotEntry("foo", [](unsigned int slot, ULong64_t entry){return static_cast<int>(entry);})
   .Define("D", [](){return gRandom->Exp(1);})
   .DefinePersistent("time", [](double& time, double D){time += D;}, {"D"})
   .DefinePersistent("state", [](std::string& state, int foo){state = state + std::to_string(foo);}, {"foo"})
   .Display({"foo", "D", "time", "state"});

r->Print();
```

```
+-----+-----+----------------+----------------+--------------+
| Row | foo | D              | time           | state        |
+-----+-----+----------------+----------------+--------------+
| 0   | 0   | 0.00025828445 | 0.00025828445 | "0"          |
+-----+-----+----------------+----------------+--------------+
| 1   | 1   | 1.8145581      | 1.8148164      | "01"         |
+-----+-----+----------------+----------------+--------------+
| 2   | 2   | 1.2636598      | 3.0784762      | "012"        |
+-----+-----+----------------+----------------+--------------+
| 3   | 3   | 0.054243873    | 3.1327201      | "0123"       |
+-----+-----+----------------+----------------+--------------+
| 4   | 4   | 1.4624994      | 4.5952195      | "01234"      |
+-----+-----+----------------+----------------+--------------+
| 5   | 5   | 0.72366079     | 5.3188803      | "012345"     |
+-----+-----+----------------+----------------+--------------+
```

Resample a Time Series

Slides from PPP 118

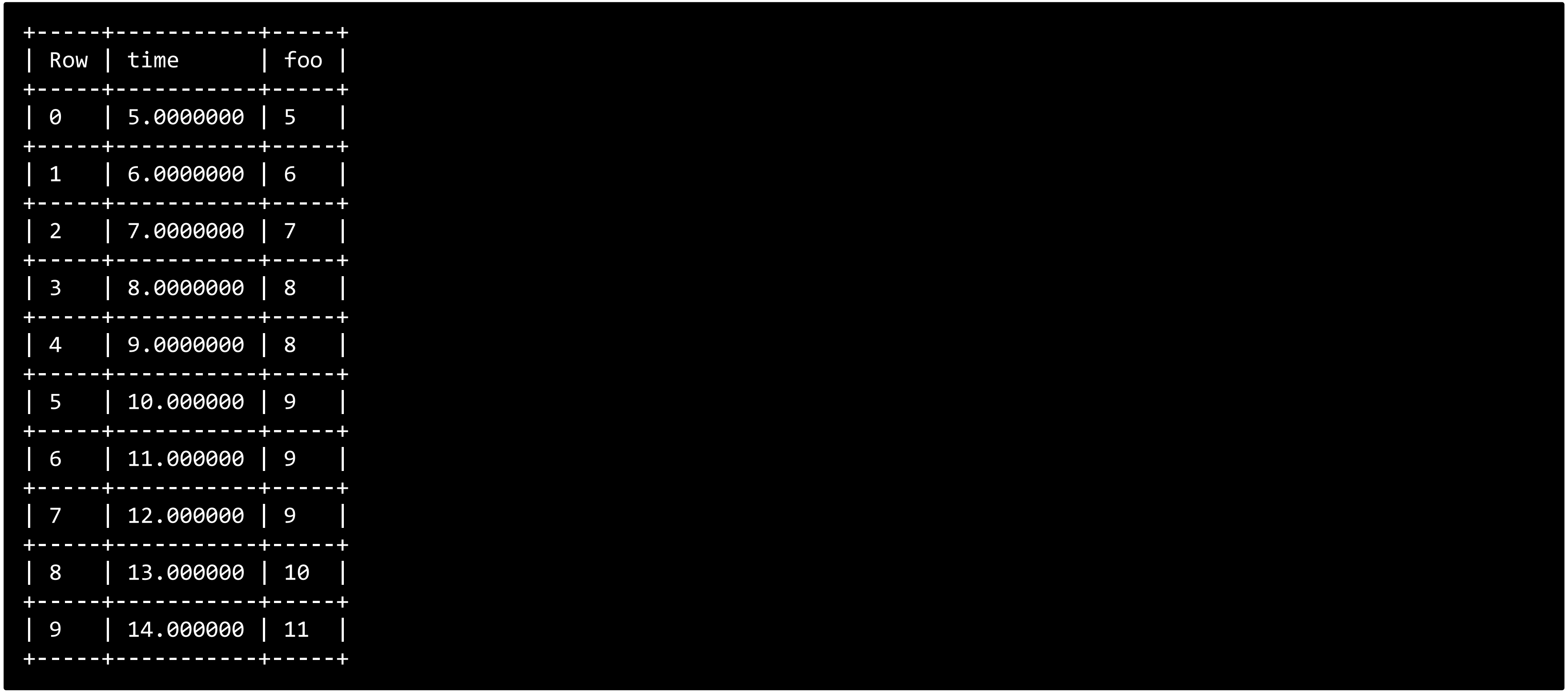
```cpp
ROOT::RDataFrame rdf(50);

auto r = rdf
   .DefineSlotEntry("foo", [](unsigned int slot, ULong64_t entry){return static_cast<int>(entry);})
   .Define("D", [](){return gRandom->Exp(1);})
   .DefinePersistent("time", [](double& time, double D){time += D;}, {"D"})
   .Resample<double, double, int>("time", 1, 5, 15, {"time", "foo"})
   .Display({"time", "foo"}, 10);

r->Print();
```

Resample a Time Series

Slides from PPP 118



```
+-----+-----------+-----+
| Row | time      | foo |
+-----+-----------+-----+
| 0   | 5.0000000 | 5   |
+-----+-----------+-----+
| 1   | 6.0000000 | 6   |
+-----+-----------+-----+
| 2   | 7.0000000 | 7   |
+-----+-----------+-----+
| 3   | 8.0000000 | 8   |
+-----+-----------+-----+
| 4   | 9.0000000 | 8   |
+-----+-----------+-----+
| 5   | 10.000000 | 9   |
+-----+-----------+-----+
| 6   | 11.000000 | 9   |
+-----+-----------+-----+
| 7   | 12.000000 | 9   |
+-----+-----------+-----+
| 8   | 13.000000 | 10  |
+-----+-----------+-----+
| 9   | 14.000000 | 11  |
+-----+-----------+-----+
```

Discussion