Arbitrage Opportunities in London Stock Exchange

How efficient is the market?

Arbitrage Opportunities

- Futures are obligations to buy or sell at certain prices
- Options are rights to buy at a certain price
- If they are not aligned, one can make risk-free profits
  - Such opportunities should not exist
  - But they do in London

A simplified scenario:

Option price: £0.5 {

- Future selling price: £11
- Option right to buy: £10

Put-call-futures Short Arbitrage

- Say, futures price F is too high

$$Fe^{-r(T-t)} - [C - P + Xe^{-r(T-t)} + TC] > 0$$

T – t is time to maturity, TC is transaction cost

- The following (P-C-F) operation is risk free:
  - Shorting a futures contract at F
  - Buying a call option at C
  - Shorting a put option at P, and
  - Borrowing the present discounted value of F and lending the same for X
- Long Arbitrage can be defined similarly

P-C-F Short Arbitrage, Example

- Info at t=0
  - Exercise price X = £1,000
  - Call option price £2
  - Put option price £8
  - Time to maturity T=60
  - Future price F = £1,080
  - Transaction cost £60
- Operations at t=0
  - Short futureless interest on borrow at 2%, +£1,076.46
  - Buy call option –£2
  - Short put option +£8
- Preparing to exercise:
  - Projected cost of exercising option at time T is £1,000
  - £1,000 set aside may earn interest at 1.8%
  - PV of exercising cost is –£999.95
- Projected Profit:

  Income:

  +£1,076.46 + £8 = £1,084.46

  Less Expenses:

  –£2 – £999.95 = 1,061.95

  Profit (rounded): £22.5

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Scenario 1, X < S

- Info at t=0
  - Exercise price X = £1,000
  - Call option price £2
  - Put option price £8
  - Time to maturity T=60
  - Future price F = £1,080
  - Transaction cost £60
- Operations at t=0
  - Short futureless interest on borrow at 2%, +£1,076.5
  - Buy call option –£2
  - Short put option +£8
- Info at time T:
  - Spot price S = £1,100
- Operations at T
  - Exercise call option, –£1,000
  - Honour future contract to sell at £1,080 (pay interest)
  - Pay transaction cost –£60
- Profit:

  Income £1,076.5 +£8 = £1,084.5

  From previous operations

  –£1,000 –£2 –£60 = –£1,062

  Profit = £22.5

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Scenario 2, X > S

- Info at t=0
  - Exercise price X = £1,000
  - Call option price £2
  - Put option price £8
  - Time to maturity T=60
  - Future price F = £1,080
  - Transaction cost £60
- Operations at t=0
  - Short futureless interest on borrow at 2%, +£1,076.5
  - Buy call option –£2
  - Short put option +£8
- Info at time T:
  - Spot price S = £900
- Operations at T
  - Honour put option, i.e. to buy –£1,000
  - Honour future contract to sell at £1,080 (pay interest)
  - Dispose call option (as X >S)
  - Pay transaction cost –£60
- Profit (same as in X<S):

  Income £1,076.5 +£8 = £1,084.5

  From previous operations

  –£1,000 –£2 –£60 = –£1,062

  Profit = £22.5

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Arbitrage in LIFFE Intraday Data

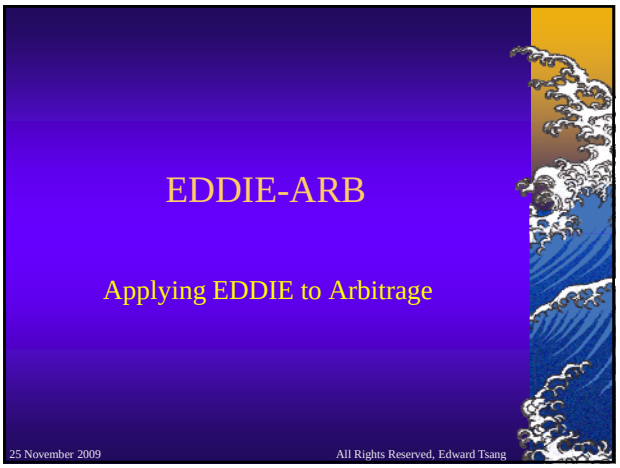
- Pre-processed 1991.03.01 to 1998.06.18 data
  - Millions of records; 9 months' PhD work + interaction
- 15,670 P-C-F opportunities identified
  - 8,073 profitable short arbitrage opportunities
    - 1,641 were followed up by traders
  - 7,410 profitable long arbitrage opportunities
- Assuming total transaction cost of £60
- 2,345 (29%) of the 8,073 short arbitrages were profitable
  - Higher % for market makers / brokers, whose cost is lower

Naïve Rule for Arbitrage

- Act only when profit arises.
- Assume delay time of 1 minute
- Exercise P-C-F in the next 9 minutes
- Execution price risk:
  - Prices may change before execution
  - Hence the rule may not make anticipated profit

The Arbitrage Forecasting Problem

- Why is forecasting needed?
  - Set up time means P-C-F operation may not end up profitable
  - Need to be ahead of others when opportunities arise
- EDDIE-ARB forecasts arbitrage opportunities
  - Use EDDIE
  - To predict opportunities 10 minutes in advance



Variables considered relevant in EDDIE-ARB

- The exercise price of the options, which is also called the strike price
- Price of the security in the spot market, which is also called the ***underlying price***
- Call premium
- Put premium
- Futures price
- Number of days to maturity
- ***profit or loss*** after transaction cost

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Refinement of variables

- Call – put option premiums replace call and put
  - This is likely to be rediscovered repeatedly anyway
- *Moneyness* = Spot ÷ Strike introduced
  - As *in*, *at* and *out of* the moneyness
- *Basis* = Futures price – Spot price, introduced.
  - It helps to capture mis-pricing in the futures leg of the arbitrage.
- "Profit or loss" is replaced by "Profit or loss" ÷ futures price
  - To remove the effect of price changes
- Scaling to avoid precision problem

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The problem with few opportunities

Reality \ Predictions	–	+	
–	9,900	0	99%
+	0	100	1%
	99%	1%	

Ideal prediction
RC = Precision = Recall = 100%

Reality \ Predictions	–	+	
–	9,900	0	99%
+	100	0	1%
	100%	0%	

Easy score on accuracy
RC = 99%, Precision = ?
Recall = 0%

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Handling few opportunities

Reality \ Predictions	–	+	
–	9,801	99	99%
+	99	1	1%
	99%	1%	

Random move from – to +
RC = 98.02%
Precision = Recall = 1%

Reality \ Predictions	–	+	
–	9,810	90	99%
+	90	10	1%
	100%	0%	

Hopefully biased moves from – to +
RC = 98.2%
Precision = Recall = 10%
(RC dropped from 99%)

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Regime Change!

FTSE-100		Training Period (1991.01.29-1996.12.30)			
RC	95.0%	0	1	Opport.:	2.8%
RMC	65.0%	3,894	168	0	4,062
RF	80.0%	75	41	1	116
		3,969	209	5%	4,178
Constrained fitness function:					
FTSE-100		Test Period (1997.01.01-1998.06.18)			
RC	59.0%	0	1		7.3%
RMC	87.8%	867	2,743	0	3,610
RF	21.4%	79	206	1	285
		946	2,949	76%	3,895

- By not buying at all, RC=97.2% (training) 92.7% (testing)
- Besides, market changed; e.g. from 1994, volume up

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More pre-processing for EDDIE

- Problem 1: too few opportunities
- Solution 1: reduced number of negative cases
  - Remove negative cases that were not followed up
  - Final training set: 25% positive instances
  - Tighten constraint to encourage trading
- Problem 2: trading behaviour changed
- Partial Solution 2: pick training/testing data randomly instead of chronologically
  - Worry: rules learned may not fit new data

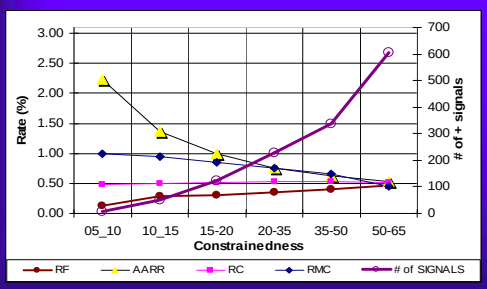
EDDIE-ARB Test Results

EDDIE-ARB	Precision	Recall	RC	# recom.	Avg Profit
5-10%	100%	42%	85.5%	67	£957
10-15%	99%	53%	88.0%	84	£787
15-20%	76%	62%	85.6%	129	£491
20-25%	62%	67%	81.5%	173	£465

3,895 samples, 1 January 1997 to 18 June 1998

- Tight constraint → high precision → high average profit
- EDDIE-ARB could achieve >75% precision

Effect of constraints in FGP-2



DJIA
Training: 1,900 days 07/04/1969 to 11/10/1976
Testing: 1,135 days 12/10/1976 to 09/04/1981
Target: "*rise of 4% within 63 days*"

- Observation: RMC can be traded for RF without significantly affecting RC

EDDIE-ARB vs Naïve Rule

- EDDIE-ARB: average profit: £465 to £957
- Naïve rule: average profit per arbitrage £338
- Naïve rule: ***total profit*** equals best EDDIE-ARB tree
  - As EDDIE-ARB did not pick up all opportunities
  - Improved by the Repository Method
- EDDIE-ARB and Naïve rule do not pick up the same opportunities
  - Could they complement each other?

EDDIE in Arbitrage, Conclusions

- Arbitrage opportunities exist in London
- Naïve approach:
  - Monitor arbitrage opportunities, act when they arise; problem: speed
- Misalignments don't happen instantaneously
  - Do patterns exist? If so, can we recognize them?
- EDDIE-ARB can find some opportunities
  - With high confidence (precision >75%)
- Commercialisation of EDDIE-ARB
  - Need to harvest more opportunities; Need capital
- Research only made possible by close collaboration between computer scientists and economists