How Riskless Is “Riskless” Arbitrage?

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Arbitrage

With recent technological advances in financial markets, there is a dramatic increase in algorithmic high-frequency trading

One of the most widely-used strategies of algo traders is high-frequency arbitrage between convertible assets

Examples: CIP, triangular arbitrage, put-call parity

Important characteristic is that they are virtually riskless:

- different from convergence trading
- can be exploited immediately without outlay of endowment

From academic perspective ...

theoretically such arbitrage opportunities may arise but should not persist in an efficient market

Why should such arbitrage persist when it is not regarded as risky?

PUZZLE?

No, there is a limit to arbitrage

In this paper...

- We propose and provide theoretical and empirical support that arbitrage opportunities can persist because of the uncertainty of completing a profitable arbitrage portfolio
- This uncertainty arises due to the crowding trade effect as competing arbitrageurs impose negative externality of each other
- We call this execution risk and it increases with the number of competing arbitrageurs, market illiquidity and inventory costs

Example

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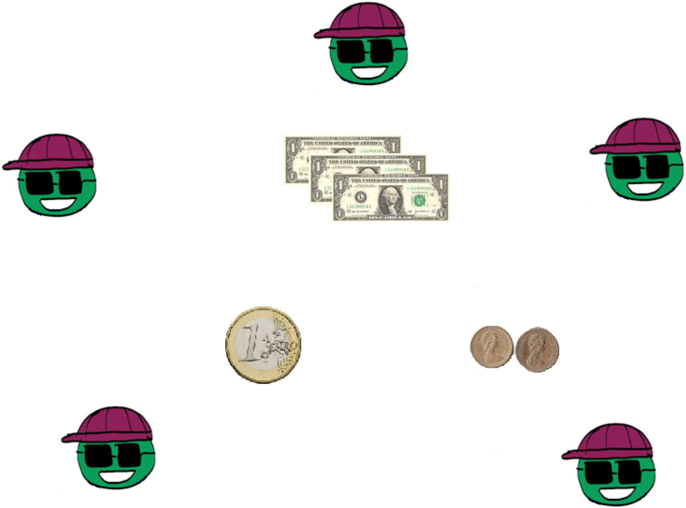

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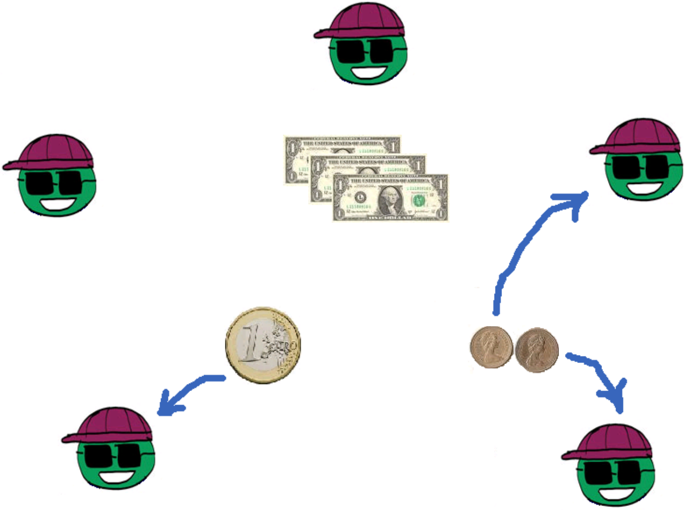

In Equilibrium...

$$A = \sum_{i=1}^{I} \phi_i \left(1 - \mathbf{P}_{i|n_i,k,\pi}\right)$$

A – level of mispricing

ϕ_i – costs of missing the i-th leg

$\mathbf{P}_{i|n_i,k}$ – probability of getting the best price in the market i

k – number of competing arbitrageurs

π – probability of participation

We consider two types of costs ϕ_i:

- illiquidity costs
- inventory costs

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Empirical Implications

- "Riskless" arbitrage opportunities are not eliminated instantly in financial markets
- Existence of competing arbitrageurs induces potential losses in arbitraging
- These losses increase with the number of competing arbitrageurs
- Size of arbitrage deviations increases with market illiquidity and cost of inventory

Data

Triangular arbitrage: GBP/USD/EUR

Data comes from Reuters D3000 trading system

Tick-by-tick high-frequency limit order book

Sample period: from 2 Jan 2003 to 30 Dec 2004

We account for bid-ask spreads and brokerage fees

Number of profitable clusters	**44,166**	
Average arbitrage profit	**1.56**	bps
Average arbitrage duration	**0.77**	sec

Controlling for Latency

We control for latency – arbitrage profit is still economically and statistically significant

We compute average time between order arrival and removal from the system

	Year	EUR/USD	GBP/USD	EUR/GBP
Average execution delay	*2003*	0.037	0.034	0.035
	2004	0.033	0.031	0.032

Arbitrage profit is computed after the average delay

	Without Latency	With Latency
Total Profit (GBP)	6,265,896.07	2,438,758.95
Mean Profit (bps)	1.56^{**}	0.63^{**}
Standard deviation (bps)	1.92	2.07
t-stat (profit without latency=profit with latency)		66.0

Arbitrage profits: Simulation

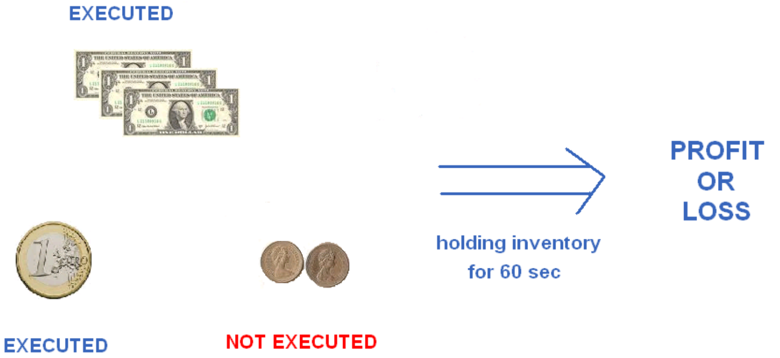
We simulate a trading game to:

- see the effect of crowding trade effect
- create ideal environment free of any other impediments

k	$\pi = 0.1$	$\pi = 0.2$	$\pi = 0.3$	$\pi = 0.4$	$\pi = 0.5$	$\pi = 0.6$	$\pi = 0.7$	$\pi = 0.8$	$\pi = 0.9$	$\pi = 1.0$
2	0.323	0.619	0.881	1.120	1.328	1.498	1.647	1.763	1.846	1.902
4	0.295	0.496	0.598	0.598	0.490	0.271	-0.064	-0.523	-1.109	-1.828
6	0.263	0.364	0.284	0.015	-0.448	-1.128	-2.023	-3.140	-4.495	-6.108
8	0.229	0.223	-0.049	-0.610	-1.472	-2.657	-4.178	-6.046	-8.271	-10.85
10	0.197	0.077	-0.401	-1.271	-2.558	-4.288	-6.477	-9.125	-12.25	-15.86
12	0.164	-0.102	-0.865	-2.168	-4.055	-6.549	-9.675	-13.44	-17.89	-23.04
14	0.127	-0.231	-1.154	-2.693	-4.892	-7.781	-11.38	-15.71	-20.80	-26.64
16	0.091	-0.394	-1.551	-3.446	-6.123	-9.619	-13.96	-19.16	-25.23	-32.14

Arbitrageurs lose money because of crowding trade effect

We proxy inventory risk



Arbitrage deviation is proportional to market illiquidity and inventory risk

$$A = a_0 + a_1 \cdot \phi_{GB/US} + a_2 \cdot \phi_{EU/US} + a_3 \cdot \phi_{EU/GB} + a_4 \cdot Tr.Vol + a_5 \cdot TED$$

$\Delta_{GB/US}$	$\Delta_{EU/US}$	$\Delta_{EU/GB}$	$\lambda_{GB/US}$	$\lambda_{EU/US}$	$\lambda_{EU/GB}$	$IC_{GB/US}$	$IC_{EU/US}$	$IC_{EU/GB}$	Tr.Vol	TED	R^2
0.1837 (90.2)	0.0521 (41.3)	0.0044 (3.00)							1.5964 (6.91)	-0.000029 (-2.30)	24.52
			0.2904 (41.6)	0.1321 (33.4)	0.0912 (6.19)				1.3579 (5.13)	-0.000010 (-0.71)	8.79
						0.0132 (3.75)	0.0239 (8.46)	0.0266 (6.51)	1.0298 (3.87)	-0.000031 (-2.16)	1.97
0.1734 (88.9)	0.0512 (40.2)	0.0043 (2.94)				0.0015 (0.48)	0.0017 (0.69)	0.0139 (3.87)	1.5261 (6.67)	-0.000028 (-2.15)	24.59
			0.2896 (39.6)	0.1184 (31.3)	0.0753 (5.13)	0.0097 (2.84)	0.0134 (4.93)	0.0187 (4.77)	1.0732 (4.12)	-0.000014 (-1.01)	9.52

Main Implications

1. “Riskless” arbitrage can be **very risky**!
2. Risk comes from crowding trade when arbitrageurs compete for scarce liquidity
3. Competition is not always “good” for market efficiency – crowding effect with arbitrageurs imposing negative externality on each other
4. It is also important for any other correlated algorithmic trading

Thank You!