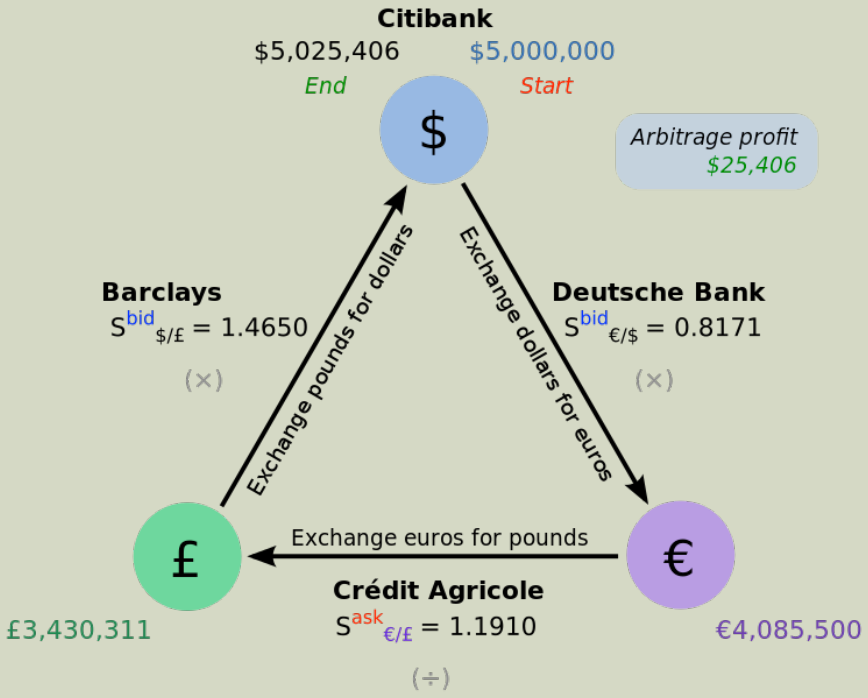
CURRENCY ARBITRAGE AND YOU

Adrian Law
Benjamin Li

WHAT IS ARBITRAGE AND WHY DO WE CARE

- Brief discrepancies in the foreign exchange market (Forex) due to rounding errors or high activity Using at least 3 currencies to trade in a cycle to lock in “riskless” profit
- Largest financial market by a wide margin ($5.3 trillion a day in 2013)
- Market participants are by large multinational banks, and hedge fund/investment managers as smaller participants



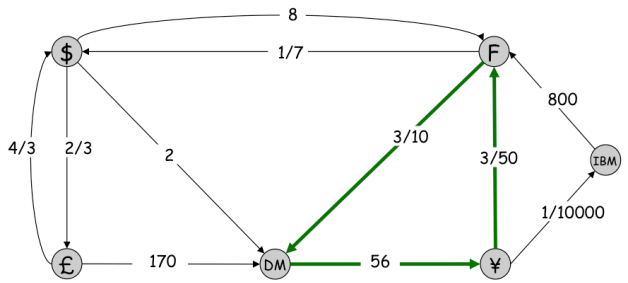
HOW TO FIND FREE MONEY

- Use predictive analysis i.e. corresponding factors, indicators, seasonality
- High Frequency Trading = Bellman Ford (CS330)

Detecting Negative Cycles: Application

Currency conversion. Given n currencies and exchange rates between pairs of currencies, is there an arbitrage opportunity?

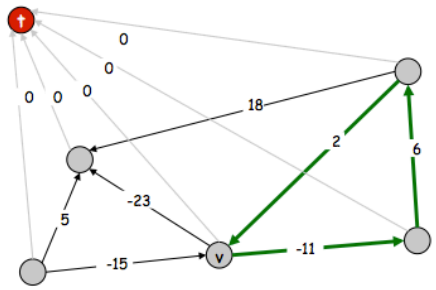
Remark. Fastest algorithm very valuable!



Detecting Negative Cycles

Theorem. Can detect negative cost cycle in O(mn) time.

- Add new node t and connect all nodes to t with 0-cost edge.
- Check if OPT(n, v) = OPT(n-1, v) for all nodes v.
  - if yes, then no negative cycles
  - if no, then extract cycle from shortest path from v to t



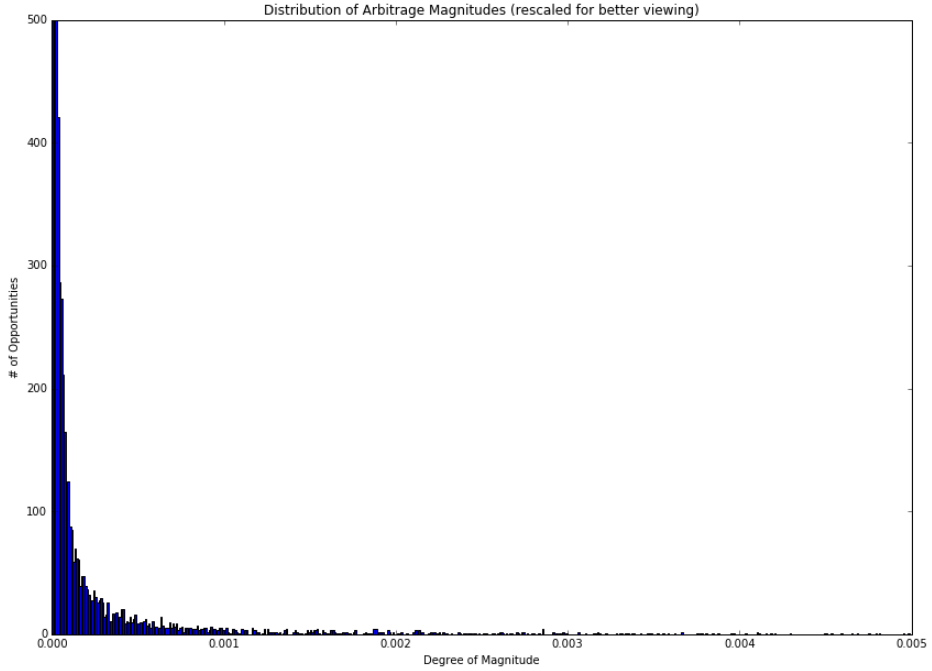
PROJECT GOALS

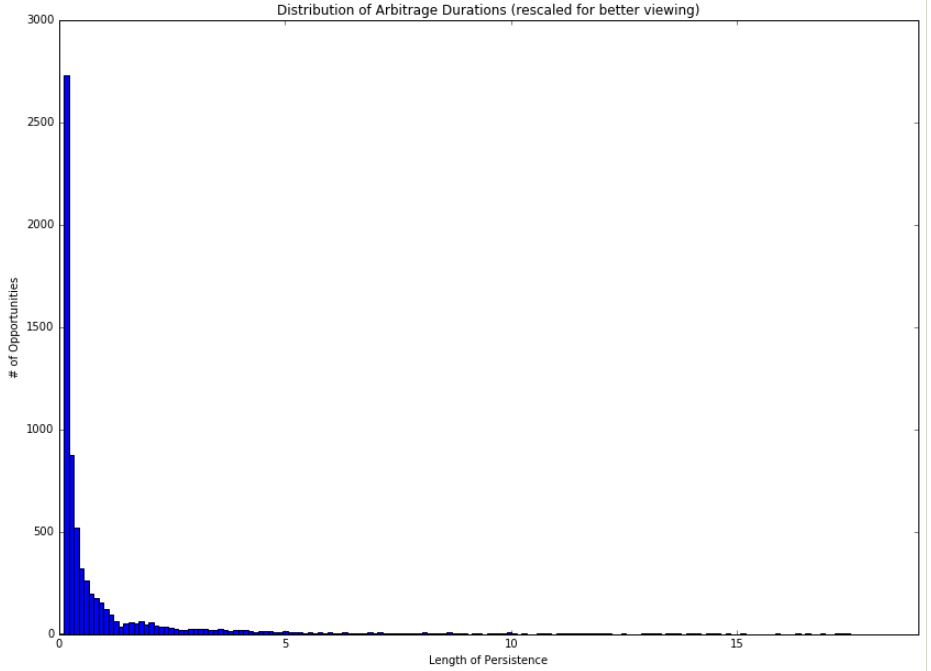
- 3 main goals:
  - 1) Identify important trends in incidences, magnitude, and persistence of arbitrage
    - Distribution of arbitrage across time
    - Distribution of magnitude and persistence
  - 2) Find correlation in magnitude and arbitrage if it exists
    - Graph correlation between magnitude and duration
    - Find ways to predict duration of arbitrage i.e. regression, Bayesian probabilities, clustering
  - 3) Observe clusters of arbitrage points and attempt to group points according to stock price movements and the time of day
    - Look at corresponding stock data of each country
    - Forex opening/closing hours

DATASET COLLECTION

- TrueFX: Free to use web API for tick by tick Forex data
- Bloomberg Terminal: restricted tick data for stock prices available at Questrom
- Restrictions due to trading hours and availability of the Bloomberg Terminal

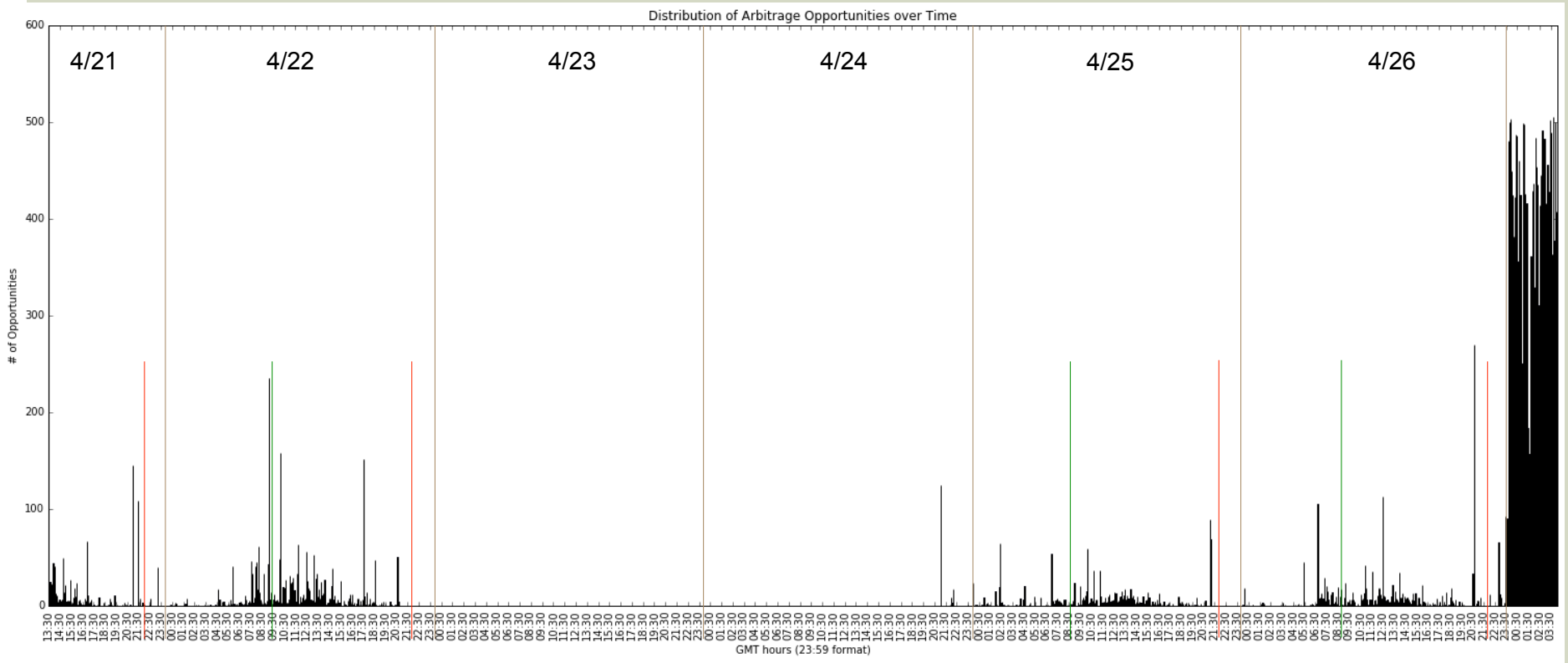
1) DISTRIBUTION OF ARBITRAGE





- 6889 instances across 72 hours, ~174 mins total
- On average ~0.03% profit, about 1.523 seconds, max of 8% return and 2.5 minutes
- Exponential distribution of both magnitude and duration

1) DISTRIBUTION OF ARBITRAGE



- Spikes of arbitrage instances around ½ to 1 hour before closing hours of New York and Tokyo
- Forex closed during 4/23-4/24 weekend, thus no activity until Sunday night at 8PM
- 4/27 is not a glitch: why was there a huge spike in arbitrage?

Markets

Bank of Japan rates announcement catches investors off guard

BY LEIKA KIHARA AND STANLEY WHITE APRIL 28 2016, 09:53

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Bloomberg Markets Tech Pursuits Politics Opinion Businessweek

Bank of Japan Stuns Market by Holding Off on More Stimulus

by Toru Fujioka and Masahiro Hidaka

April 27, 2016 – 11:09 PM EDT *Updated on* April 28, 2016 – 5:25 AM EDT

Bank of Japan Stuns Markets by Holding Its Fire

Japanese yen gains as much as 3.2% against the U.S. dollar following the BOJ's decision

Mixed Results

Interest rates have fallen across the board since the Bank of Japan announced its negative-rate policy, but the yen has risen contrary to the BOJ's expectations and prices are falling.

JPY: BANK OF JAPAN KEEPS NEGATIVE RATES

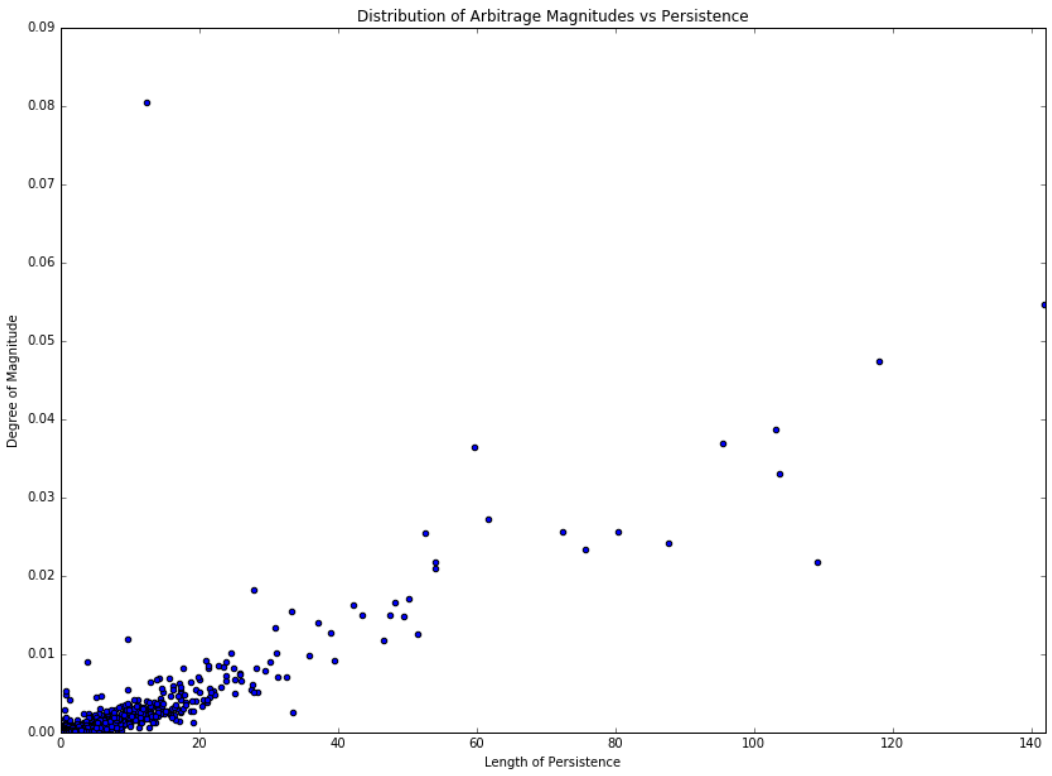
Investors were surprised when the BoJ defied expectations, leading to widespread buyout of the Yen

Massive jump by the Yen led to huge discrepancies in the market = more arbitrage cycles of greater magnitude and duration

4/27:
00:00 GMT is Tokyo opening hour

2) CORRELATION AND REGRESSION

- A clear positive linear relationship
  - Pearson Correlation Coefficient = 0.8430109
- Higher magnitude takes longer to adjust for in the market
- Regression: clear that magnitude is a strong indicator for duration of arbitrage
- Adj. R Square of 0.828
- F-statistic: 1.258e+04

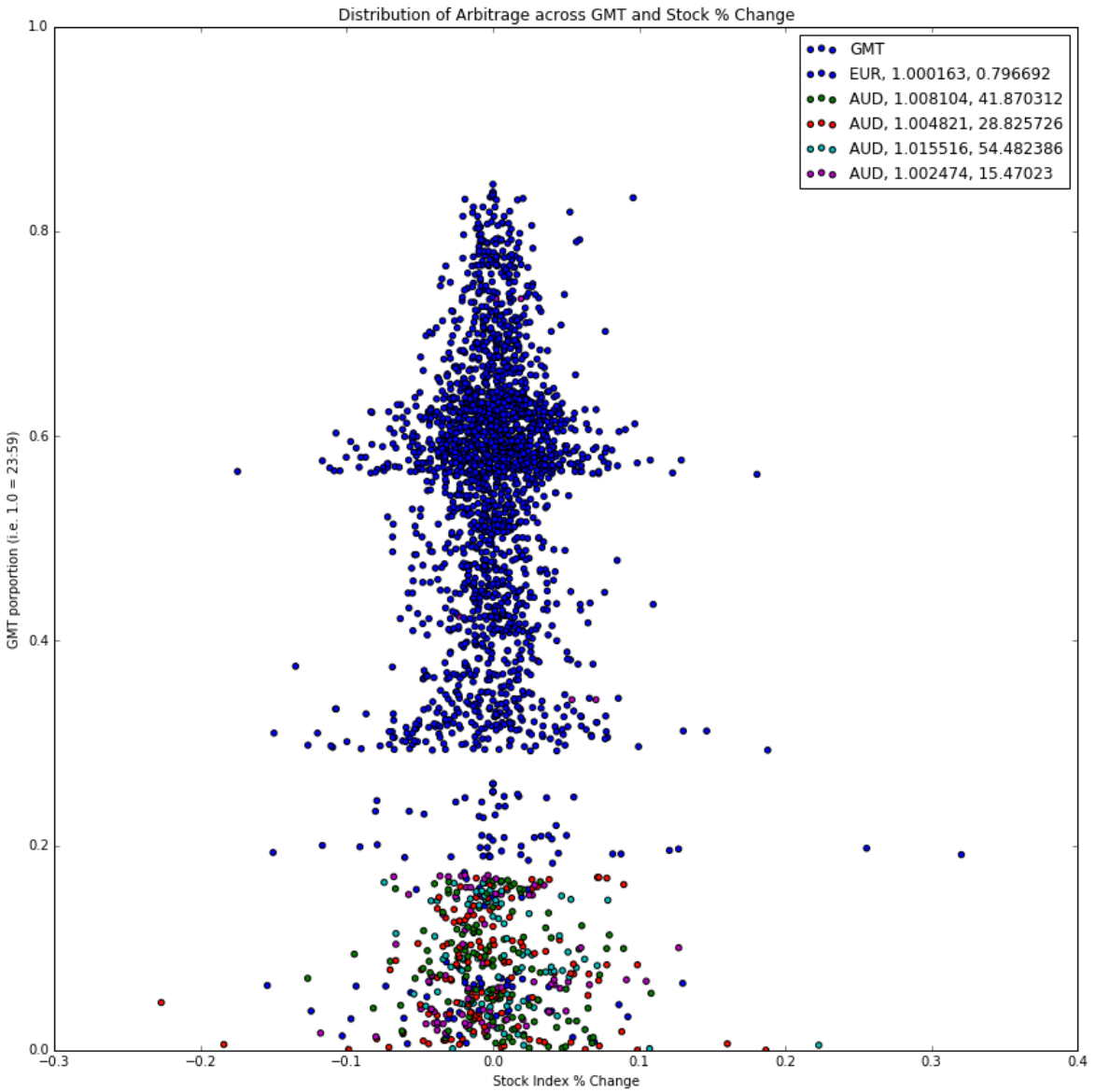


	coef	std err	t	P>|t|	[95.0% Conf. Int.]
Intercept	-3569.6672	31.878	-111.980	0.000	-3632.175 -3507.159
Magnitude	3571.2150	31.834	112.182	0.000	3508.792 3633.638

Omnibus:	859.914	Durbin-Watson:	0.644
Prob(Omnibus):	0.000	Jarque-Bera (JB):	47097.544
Skew:	-0.745	Prob(JB):	0.00
Kurtosis:	23.709	Cond. No.	563.

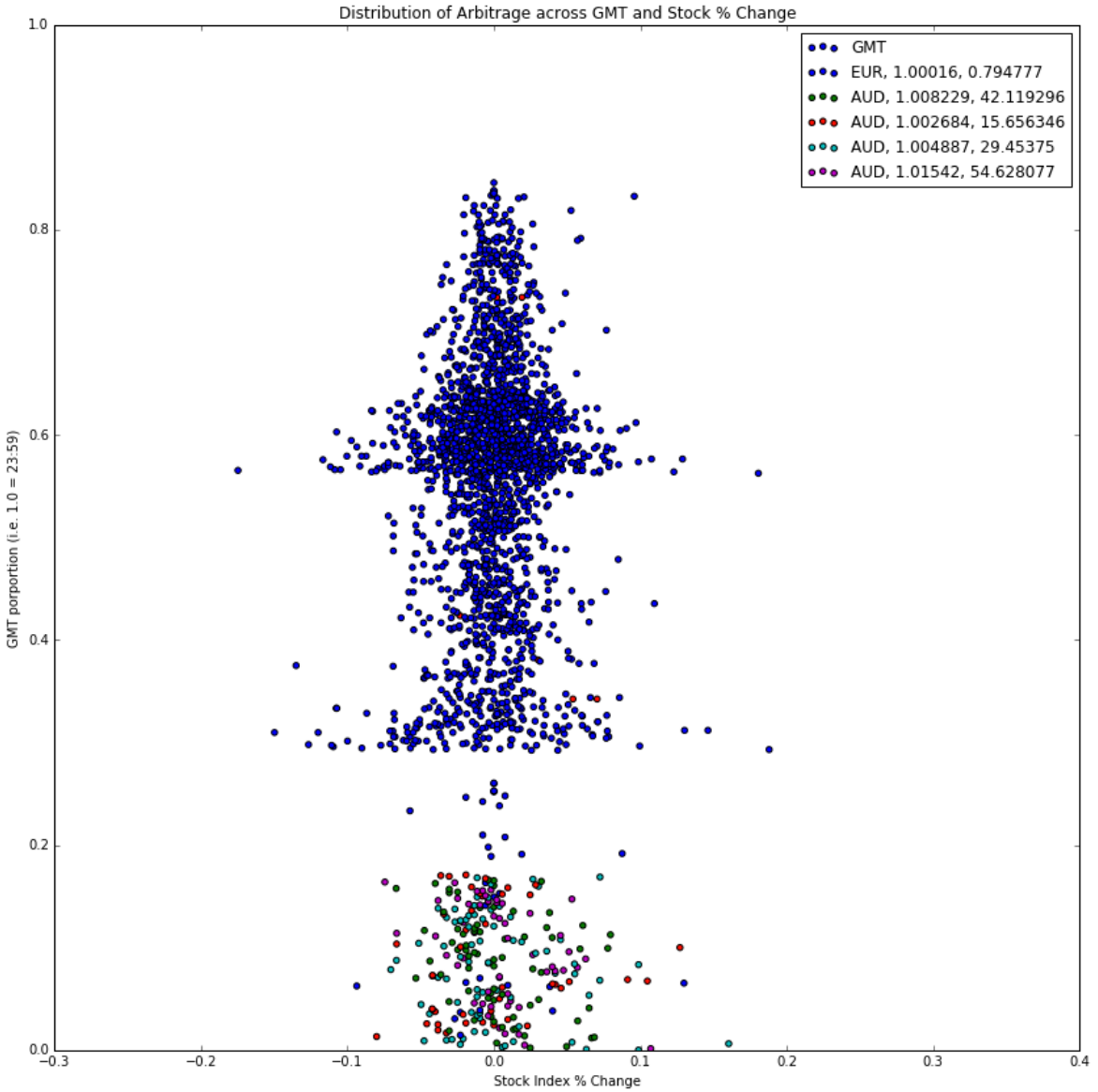
3) CLUSTERING

- Used K-Means ++ to generate clusters, elbow plot to determine K
- Graphed as stock price % change vs. time of day
- Weighed the “value” of the arbitrage the most heavily i.e. magnitude and persistence
- Gap between 0.9 to 1.0 due to lack of stock data



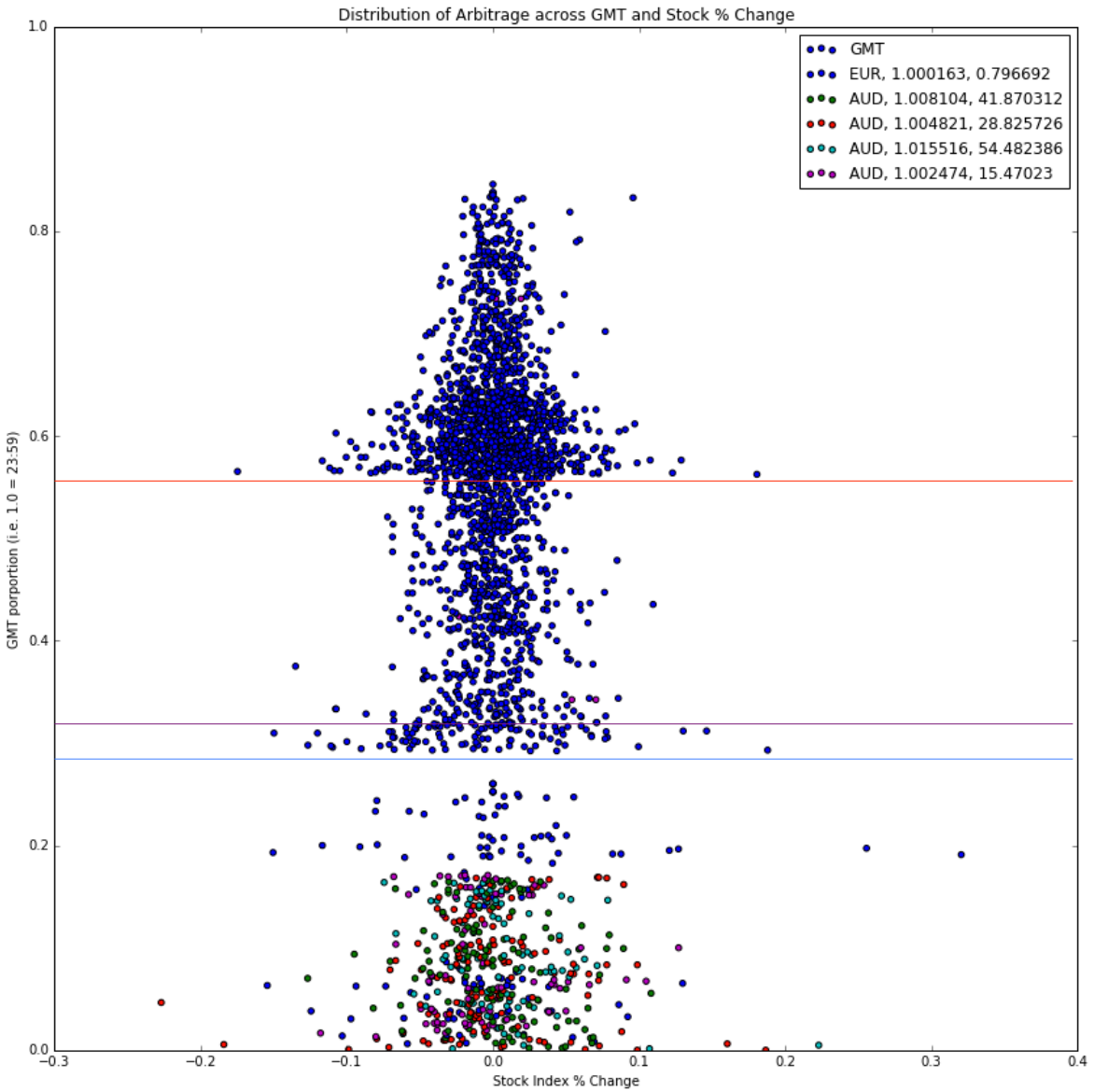
3) CLUSTERING

- Removed the outlier day; market shocks are not good when trying to infer an overall pattern
- Shows that there is a clear divide between blue cluster and every other cluster around 0.29 GMT = 7:00 AM Sydney closing hour
- However no clear relationship between price % change and arbitrage



3) CLUSTERING

- Blue: Low value
  - Nearly all but JPY and most AUD: ('EUR', 683), ('USD', 574), ('CHF', 498), ('CAD', 323), ('AUD', 32)
- Purple, Red, Green then Cyan of high value clusters in ascending order
  - Heavily comprised of AUD, JPY always 2nd: [('AUD', 74), ('JPY', 54)]
  - [('AUD', 71), ('JPY', 53)]
  - [('AUD', 52), ('JPY', 36)]
  - [('AUD', 41), ('JPY', 37), ('EUR', 4), ('CHF', 3), ('USD', 1), ('CAD', 1)]
- Cosine Similarity very high for all clusters, 0.8686 to 0.99997



CONCLUSION

- Direct linear relationship: high correlation between magnitude and duration, very useful for traders and analysts
- Intraday seasonality: Opening hours of bigger markets and closing hours of smaller markets are riper grounds for arbitrage compared to regular trading hours
- No stock market to Forex relationship: in the timespan that we have observed there isn't enough conclusive evidence in the clustering or regressions that market forces influence each other
- Market shocks are important driving forces: When prices rapidly move, discrepancies are harder to fix in supply and demand markets

FUTURE IMPROVEMENTS

- Collect much more data, confirm linear relationship of magnitude and duration
- Observe more market shocks and get a better understanding of their effects
- Look at other potential factors that may influence currencies prices i.e. commodities prices like Oil, Natural Gas, manufactured goods that involve hard currencies or government bonds that determine interest rates
- Design a recommendation system: using our current dataset as training, build a model that can accurately predict the duration of arbitrage opportunities based off of Bayesian probabilities

THANK YOU

- References:
  - Aiba, Yukihiro; Hatano, Naomichi; Takayasu, Hideki; Marumo, Kouhei; Shimizu, Tokiko (2002). "Triangular arbitrage as an interaction among foreign exchange rates". Physica A: Statistical Mechanics and its Applications
  - Fenn, Daniel J.; Howison, Sam D.; McDonald, Mark; Williams, Stacy; Johnson, Neil F. (2009). "The Mirage of Triangular Arbitrage in the Spot Foreign Exchange Market". International Journal of Theoretical and Applied Finance