Stats 242: Algorithmic Trading and Quantitative Strategies
Summer 2013

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Class Hour: **11:00am-12:15pm MW**
Room: **Gates B3**

Office: Sequoia Hall
Office Hours: By appointment only

Teaching Assistants: **1. Abhay Subramanian**
Office Hour: TBA
2. Yuming Kuang
Office Hour: TBA

Course Description: This course is an introduction to financial trading strategies based on methods of statistical arbitrage. Topics include methodologies related to high frequency data, momentum strategies, pairs trading, technical analysis, models of order book dynamics and multi-exchange order placement and routing and dynamic trade planning with feedback. Emphasis is on developing, automating and empirically evaluating the models that reflect the market and behavioral patterns. The course will be balanced between theory and practice with a sufficient theory to understand practical applications. Although the methodologies could be applied to various financial markets, the course will mostly focus on stock and equity markets.

Prerequisites: Stats 240 or equivalent.

Optional Texts:

1. Abergel, F., Bouchaud, J-P., Foucault, T., Lehalle, C-A., Rosenbaum, M. (2012); Edited: Market Microstructure: Confronting Many Viewpoints, Wiley (ABFLR)
2. Lai, T.Z. and H. Xing (2008): Statistical Models and Methods for Financial Markets, Springer (LX).
3. Harris, L. (2003): Trading and Exchanges, Oxford University Press (HA).
4. Hasbrouck, J. (2007): Empirical Market Microstructure, Oxford University Press.
5. Acar, E. and S. Satchell (Ed) (2002): Advanced Trading Rules, Butterworth-Heinemann, second edition (AS).
6. Tsay, R.S. (2005): Analysis of Financial Time Series, Wiley, Second Edition.
7. Campbell, J.Y., Lo, A.W. and A.C. MacKinlay (1997): The Econometrics of Financial Markets, Princeton University Press.
8. Edwards, R.D., Magee, J. and W.H.C. Bassetti (2013): Technical Analysis of Stock Trends, 10^{th} edition, CRC Press.
9. Fabozzi, F.J., Focardi, S.M. and P.N. Kolm (2006): Financial Modeling of the Equity Market, Wiley.

Additional research articles are listed at the end; selected papers will be posted on the course site.

Grades: Grades will be based on the following: Assignments (120) and a Final Project (80), with a Total of 200 points.

Homework: There will be three assignments, each consisting of several problems. These assignments will be done individually or in a team of two. Each member of the team should do all the assigned problems and then meet as a group to decide on what to submit. The computer output should be submitted in a standard format and should be clearly annotated. Late assignments will NOT be accepted.

Computer Software: We will use R, which is available for free download (http://www.cran.r-project.org/).

Project: You must complete a class project on a team or an individual basis. You should submit a written report on a project of the team's choosing by Wednesday, August 14, 2013. The report should not exceed ten pages and should be in a formal presentable to a senior finance manager in a quantitative research group. An initial one-page proposal indicating the research questions and the sources of data must be approved by Monday, July 29, 2013.

Tentative Schedule:

Day/Week Of	**Topic**	**Reading**
July 1	Course Overview	ABFLR, Ch. 1
July 3	Stylized Facts of Asset Returns	LX, Ch. 6
July 8	CAPM, Cointegration Review	LX, Ch. 3 & 9
July 10, 15, 17	Trading Algorithms	LX, Ch. 11 & AS, Select Chapters
July 22	Speaker: Daniel Nehren, J.P. Morgan Chase	
July 24, 29	Trading Mechanics, Order Book Dynamics, Execution Algorithms	ABFLR - Part III, Ch. 5
July 31	Market Impact Models	ABFLR - Part III, Ch. 5
Aug 5, 7	Portfolio Rebalancing, Multi-Asset Trading	ABFLR - Part IV

Additional four lectures will be scheduled during this period. Exact dates will be announced later.

Tentative Reading List [Key papers are marked with (*)]

A. Stylized Facts: An Overview

1. Lo, A.W and A. C MacKinlay (1988): Stock market prices do not follow Random Walks: Evidence from a simple specification test, Review of Financial Studies, Vol1, p 41-66.
2. Conrad, J.S , Hameed, A, and Niden, C., 1994, Volume and autocovariances in short-horizon individual security returns, Journal of Finance, Vol. XLIX, p 1305-1329.
3. (*) Cont. R (2001): Empirical properties of asset returns: stylized facts and statistical issues, Quantitative Finance, Vol 1, p223-226
4. Lunde, A and Timmermann, A (2004): Duration dependence in stock prices, Journal of Business and Economic Statistics, Vol 22, p 253-273.
5. Bollerslev, T, Tauchen, G and H. Zhou (2009): Expected stock returns and variance risk premia, RFS p 4463-4491
6. Pollet, J. M and M. Wilson (2010): Average correlation and stock market returns, Journal of Financial Economics, Vol 96, p 364-380.
7. Anatolyev, S. and A. Gerko (2005): A trading approach to testing for predictability, Jr of Business and Econ Stat, Vol 23, No. 4, p 455-461.
8. Anatolyev, S. and N. Gospodinov (2010): Modeling Financial Return Dynamics via Decomposition, Journal of Business & Economic Statistics, Vol 28, No 2, p 232-245.

B. Market Micro Structure

1. (*) Madhavan, A. (2000): Market Microstructure: A Survey, Jounal of Financial Markets, Vol3, p 205-258.
2. Rydberg, T. H. and N. Shephard (2003): Dynamics of Trade-by-Trade Price Movement: Decomposition and Models, Journal of Financial Econometrics, Vol 1, No 1, p 2-25.

3. Rydberg, T. H. and N. Shephard (1999): BIN models for trade-by-trade data. Modeling the number of trades in a fixed interval of time.

4. Engle, R. and A. Lunde (2003): Trades and Quotes: A Bivariate Point Process, J. Financial Econometrics, Vol 1, p 159-188.

C. Algo Trading / Order Book Dynamics

1. (*) Hendershott, T. and R. Riordan (2009): Algorithmic trading and Information. (Unpublished)

2. (*) Cont, R., S. Stoikov and R. Talreja (2010): A Stochastic Model for Order Book Dynamics, Operations Research, Vol 58, No 3, p 549-563.

3. (*) Fama, E.F and M. Blume (1966): Filter rules and stock market trading, The Journal of Business, Vol. 39, p 226-241.

4. Neftci, S.N (1991): Nave trading rules in financial markets and Wiener- Kolmogorov Prediction Theory: A study of Technical Analysis, Journal of Business, Vol.64, p 549-571.

5. Lo, A, MacKinlay, A. C. and Zhang, J. (2002): Econometric Models of Limit-order Execution, Journal of Financial Economics, vol. 65(1), p 31-71.

6. Hall, A. D. and N. Hautsch (2006): Order aggressiveness and order book dynamics, Empirical Economics, vol. 30(4), p 973-1005.

7. Ellul, A., C. W. Holden, P. Jain and R. Jennings (2007): Order Dynamics: Recent Evidence from NYSE, Journal of Empirical Finance, vol 14, p 636-661.

8. Goettler, R. L., Parlour, C. A. and Rajan, U. (2009): Informed Traders and Limit Order Markets, Journal of Financial Economics, vol 93, p 67-87.

9. Kavajecz, K. A. (1999): A Specialist's Quoted Depth and the Limit Order Book, Journal of Finance, Vol. 54, No. 2, p 747-771.

10. (*) Stoikov, S., Avallaneda, M. and Read, J. (2011): Forecasting prices from Level-I quotes in the presence of hidden liquidity, Algorithmic Finance, Vol 1, No. 1, p 35-43.

11. Biais, B. Hillion, P., and Spatt, C. (1995): An empirical analysis of the limit order book and the order flow in the Paris Bourse, Jr of Finance, p 1655-1689

D. Trading Stategies

D.1.: Technical Analysis

1. (*) Brock, W, J. Lakonishok and B. LeBaron (1992): Simple technical trading rules and the stochastic properties of Stock Returns; Journal of Finance, Vol XLVII, p 1731-1763.

2. Gencay, R (1998): Optimization of technical trading strategies and profitability in security markets, Vol 54, p 249-254

3. Sullivan, R, Timmermann, A and H. White (1999): Data-snooping , technical trading rule performance and the Bootstrap, Journal of Finance, Vol LIV, p 1647-169.

4. (*) Lo, A.W, H. Mamaysky and J. Wang (2000): Foundations of technical analysis; Computational algorithms, statistical inference and empirical implementation, Journal of Finance , Vol. LV, P1705- 1765. (Discussion by Jegadeesh: 1765-1775)

5. Ready M. J (2002): Profits from technical trading rules, Financial Management, Autumn, p 43-61.

6. Zhu, Y. and G. Zhou (2009): Technical Analysis: An asset Allocation Perspective on the Use of Moving Averages, Journal of Financial Economics, Vol 92 (3), P 519-544.

7. (*) Han, Y., Yang, K. and Zhou, G. (2011): A New Anomaly: The Cross-Sectional Profitability of Technical Analysis (Unpublished)

8. Osler, C. (2003): Currency Orders and Exchange Rate Dynamics: An Explanation for the Predictive Success of Technical Analysis, Journal of Finance, October p 1791-1805.

D.2: Momentum

1. (*) Jegadeesh, N and S. Titman (1993): Returns to buying winners and selling loosers; Implications for stock market efficiency, Journal of Finance, Vol 48, p 65-91
2. (*) Jegadeesh, N and S. Titman (1993): Cross-sectional and time series determinant of momentum returns, Review of Financial Studies, Vol 15, p 143- 157
3. (*) Chan, L.K.C, N. Jegadeesh and J. Lakonishok (1996), Momentum strategies, Journal of Finance, Vol. LI, p 1681- 1713.
4. Rouwenhorst K. G, (1998), International Momentum Strategies, Journal of Finance, Vol LIII, P 267-283.
5. Moskowitz, T. J and M. Grinblatt (1999): Do industries explain momentum, Journal of Finance, Vol LIV, p 1249-1289.
6. Lee, C.M.C and B Swaminathan (2000): Price Momentum and trading volume; Journal of Finance, Vol. LV, p 2017- 2060.
7. Jegadeesh, N and S. Titman (2001): Profitability of momentum strategies: An evaluation of alternative explanations, Journal of Finance, Vol LVI, p 699-720.
8. Jegadeesh, N and S. Titman (2001): Momentum, Working Paper.
9. (*) Lewellen, J (2002), Momentum and autocorrelation in stock returns, Review of Financial Studies, Vol 15, p 533- 563.
10. Hvidkjaer, S ,(2006), A trade based analysis of momentum, Review of Financial Studies, p 457- 492
11. Liu, L. X. and Zhang, L (2008), Momentum profits, factor pricing, and macroeconomic risks, Review of Financial Studies, Vol 21, p 2417- 2448.
12. Moskowitz, T., Ooi, Y.H., and Pedersen, L.H. (2010): Time Series Momentum, To appear in JFE.

D.3: Statistical Arbitrage

1. Bondarenko , O (2003): Statistical arbitrage and securities prices, Review of Financial Studies, Vol 16, p 875-919.
2. Larsson, E , Larssin, l and J. Aberg (2003), A Market Neutral Statistical Arbitrage Trading Model, Unpublished
3. Hogan, S, R. Jarrow, M. Teo and M. Warachka, (2004): Testing market efficiency using statistical arbitrage with applications to momentum and value strategies, Journal of Financial Economics, Vol 73, p 525-565.
4. (*) Jarrow, R.A, Teo, M, Tse, Y.K and Warachaka, M, (2005), Statistical arbitrage and market efficiency: Enhanced Theory, Robust Tests and Further Applications, unpublished.
5. (*) Avellaneda, M. and J-H. Lee (2010): Statistical arbitrage in the US equities market, Quantitative Finance, vol. 10(7), p 761-782.
6. Popova, I. and E. Popova (2010): Estimation of performance and execution time effect on high frequency statistical arbitrage strategies, Jr of Trading, Spring p 23-30.

D.4: Pairs Trading

1. Froot, K. A and E.M.Dabora (1999): How are stock prices affected by the location of trade; Journal of Financial Economics, Vol 53, p189-216.
2. Elliot, R.J, Van Der Hoek, J and W.P Malcolm (2005): Pairs Trading; Quantitative Finance, Vol 5, P 271-276.
3. (*) Gatev, E, Goetzmann, W.N and R.G. Rouwenhorst (2006): Pairs Trading: Performance of a Relative Value Arbitrage Rule; The Review of Financial Studies, Vol 19, p 797-827.
4. (*) Scruggs, J.T (2007): Noise Trader Risk: Evidence from the Siamese Twins, Journal of Financial Markets, Vol 10, p 76-105.
5. (*) Engelberg, J, Gao, P and R. Jaggannathan (2009): An anatomy of Pairs trading: the role of idiosyncratic news, common information and liquidity; unpublished.

6. Clifton Green, T. and B-H Hwang (2009):Price-Based Return Comovement, Jr Financial Economics, Vol 93, p 37-50.

D.5: Others

1. Fung,W and D. A Hsieh (1997): Empirical characteristics of dynamic trading strategies: The case of hedge funds, Review of Financial Studies, Vol 10, p 275-302.
2. (*) Conrad, J and G. Kaul (1998): An anatomy of trading strategies, Review of Financial Studies, Vol 11, p 489-519.
3. Alexander, G. J, (2000), On back- testing zero investing strategies, Journal of Business, Vol 73, p 255-278
4. Fung,W and D. A Hsieh (2001): The risk in hedge fund strategies: Theory and evidence from trend followers, Vol 14, p 313-341.
5. (*) Creamer, G. and Y. Freund (2007): A Boosting Approach for Automated Trading, Jr of Trading, p 84-94.

E. Execution Strategies

1. Grinold, R. C. and R.N. Kahn (1995): Active Portfolio Management, Probus Publishing.
2. (*) Almgren, R and N. Chriss (2000) : Optimal Execution of portfolio transactions, Journal of Risk, Vol 3, p 5-39
3. Almgren, R (2003): Optimal Execution with nonlinear inpact functions and trading-enhanced risk, Applied Mathematical Finance, Vol 10, p 1-18
4. Almgren, R. and J. Lorenz (2007): Adaptive Arrival Price, Journal of Trading, Vol. 2007, No. 1, p 59-66.
5. Almgren, R. and J. Lorenz (2006): Bayesian Adaptive Trading with a Daily Cycle, Journal of Trading, Vol. 1, No. 4, p 38-46.
6. Garleanu, N. and L.H. Pedersen (2011): Dynamic Trading with Predictable Returns and Transaction Costs, To appear in JFE.
7. Lorenz, J. and R. Almgren (2011): Mean-Variance optimal adaptive execution. (Unpublished)

F. Market Impact Models

1. J. P. Bouchaud, J. D. Farmer and F. Lillo, "How markets slowly digest changes in supply and demand," Handbook of Financial Markets: Dynamics and Evolution, 2008.
2. J. P. Bouchaud, Y. Gefen, M. Potters and M. Wyart, "Fluctuations and response in financial markets: the subtle nature of random price changes," Quantitative Finance, vol. 4, pp. 176-190, 2004.
3. J. P. Bouchaud, J. Kockelkoren and M. Potters, "Random walks, liquidity molasses and critical response in financial markets," Quantitative Finance, vol. 6, pp. 115-123, 2006.
4. (*) J. D. Farmer, P. Patelli and I. I. Zovko, "The predictive power of zero intelligence in financial markets," Proc. Natl. Acad. Sci. U. S. A., vol. 102, pp. 2254-2259, 2005.
5. J. Gatheral, "No-dynamic-arbitrage and market impact," Quantitative Finance, vol. 10, pp. 749-759, 2010.
6. J. Gatheral, "No Arbitrage and Market Impact," 2008.
7. P. Hewlett, "Clustering of order arrivals, price impact and trade path optimisation," in Workshop on Financial Modeling with Jump Processes, Ecole Polytechnique, 2006, pp. 68.
8. F. Lillo and J. D. Farmer, "The long memory of the efficient market," Studies in Nonlinear Dynamics & Econometrics, vol. 8, pp. 1-33, 2004.
9. V. Plerou, P. Gopikrishnan, X. Gabaix and H. E. Stanley, "On the Origin of Power-Law Fluctuations in Stock Prices," 2004.
10. M. Potters and J. P. Bouchaud, "More statistical properties of order books and price impact," Physica A: Statistical Mechanics and its Applications, vol. 324, pp. 133-140, 2003.

11. N. Westray and M. Sarkar, "An Empirical Study into the Temporal Structure of Market Impact," Market Microstructure - Confronting Many Viewpoints, 2010.

12. W. X. Zhou, "Universal price impact functions of individual trades in an order-driven market," 2007.

13. (*) R. Almgren, "Execution costs," Encyclopedia of Quantitative Finance, pp. 1-5, 2008.

14. S. A. Berkowitz, D. E. Logue and E. A. Noser Jr, "The total cost of transactions on the NYSE," Journal of Finance, vol. 43, pp. 97-112, 1988.

15. M. Borkovec and H. G. Heidle, "Building and Evaluating a Transaction Cost Model: A Primer," The Journal of Trading, vol. 5, pp. 57-77, 2010.

16. D. Cushing and A. N. Madhavan, "The Hidden Cost of Trading at the Close," Trading, vol. 2001, pp.12-19, 2001.

17. L. R. Glosten and P. R. Milgrom, "Bid, ask and transaction prices in a specialist market with hetero-geneously informed traders," J. Financ. Econ., vol. 14, pp. 71-100, 1985.

18. (*) G. Huberman and W. Stanzl, "Price manipulation and quasi-arbitrage," Econometrica, vol. 72, pp. 1247-1275, 2004.

19. (*) A. S. Kyle, "Continuous auctions and insider trading," Econometrica: Journal of the Econometric Society, vol. 53, pp. 1315-1335, 1985.

20. (*) A. N. Madhavan, "VWAP strategies," Trading, vol. 2002, pp. 32-39, 2002.

21. A. F. Perold, "The Implementation Shortfall: Paper versus Reality," Journal of Portfolio Management, vol. 14, pp. 4-9, 1988.

22. T. S. Strother, J. W. Wansley and P. Daves, "Electronic communication networks, market makers, and the components of the bid-ask spread," International Journal of Managerial Finance, vol. 5, pp. 81-109, 2009.

23. (*) J. L. Treynor, "What does it take to win the trading game?" Financial Analysts Journal, vol. 37, pp.55-60, 1981.

24. I. M. Werner, "Execution quality for institutional orders routed to Nasdaq dealers before and after decimals," 2003.

25. (*) Almgren,R., C. Thum, E. Hauptmann and H. Li (2005): Equity Market Impack, Risk, July, p57-62.

26. Lillo, J. D. Farmer and R. N. Mantegna (2003): Market Curve for price-impact function, Nature, p129-130.

27. Kissell, R. and R. Malamut (2006): Algorithmic Decision Making Framework, Jr of Trading, Winter p 12-21.

G. Portfolio Approach to Trading

1. Ubukata, M. and Oya, K. (2009): Estimation and Testing for Dependence in Market Microstructure Noise, Journal of Financial Econometrics, Vol 7, p 106-151.

2. (*) Ait-Sahalia, Y., J. Fan, and D. Xiu (2010): High-Frequency Covariance Estimates With Noisy and Asynchronous Financial Data, Journal of the American Statistical Association, Vol. 105, No. 492, p 1504-1517.

3. (*) Fan, J., Li, Y., and Yu, K. (2012): Vast Volatility Matrix Estimation using High Frequency Data for Portfolio Selection, Journal of American Statistical Association, Vol 107, p 412-428.

4. Lo, A. W. and P. N. Patel (2008): 130/30: The New Long-Only, Jr of Portfolio Management, p 12-13.

H. Others

1. Barclay, M. J., T. Hendershott, and D. T. McCormick. 2003. Competition among trading venues: Information and trading on electronic communications networks. The Journal of Finance 58 (6): 2637-66.

2. (*) Foucault, T., O. Kadan, and E. Kandel. 2005. Limit order book as a market for liquidity. Review of Financial Studies 18 (4): 1171-217.

3. Foucault, T., and A. J. Menkveld. 2008. Competition for order flow and smart order routing systems. The Journal of Finance 63 (1): 119-58.

4. Foucault, T., S. Moinas, and E. Theissen. 2007. Does anonymity matter in electronic limit order markets? Review of Financial Studies 20 (5): 1707-47.

5. (*) Glosten, L. R. 1994. Is the electronic open limit order book inevitable? Journal of Finance: 1127-61.

6. Hamilton, J. L. 1979. Marketplace fragmentation, competition, and the efficiency of the stock exchange. The Journal of Finance 34 (1): 171-87.

7. Hendershott, T., and H. Mendelson. 2000. Crossing networks and dealer markets: Competition and performance. The Journal of Finance 55 (5): 2071-115.

8. (*) Kyle, A. S., and A. A. Obizhaeva. 2010. Market Microstructure Invariants. (Unpublished)

9. Mendelson, H., and William E. Simon Graduate School of Business Administration. Managerial Economics Research Center. 1987. Consolidation, fragmentation, and market performance. Cambridge Univ. Press.

10. Stoll, H. R. 2006. Electronic trading in stock markets. The Journal of Economic Perspectives 20 (1): 153-74.

I. New Papers

1. Dumitru, A.M. and G. Urga. 2012. Identifying jumps in financial assets – A comparison between nonparametric jump tests. Journal of Business and Economic Statistics, Vol. 30, No. 2, p 242-255.

2. Harchaoui, G. and C. Levy-Leduc. 2010. Multiple change-point estimators with a total variation penalty. Journal of the American Statistical Association, Vol. 105, p 1480-1493.

3. Hendershott, T., C. M. Jones, and A. J. Menkveld. 2011. Does algorithmic trading improve liquidity? The Journal of Finance, 66 (1): 1-33.

4. O'Hara, M., and M. Ye. 2011. Is market fragmentation harming market quality? Journal of Financial Economics, Vol 100, p 459-474.

5. Maglaras, C., C.C. Moallemi, and H. Zheng. 2012. Optimal order routing in a fragmented market. Working paper (Unpublished).

6. Han, Y., K. Yang, and G. Zhou. 2009. A new anomaly: The cross-sectional profitability of technical analysis. Working paper (Unpublished).

7. Moskowitz, T.J., Y.H. Ooi, and L.H. Pedersen. 2012. Time series momentum. Journal of Financial Economics, Vol. 104, p 228-250.

8. Daniel, K.. 2011. Momentum Crashes. Unpublished.

9. Daniel, K., R. Jagannathan, and S. Kim. 2012. Tail Risk in Momentum Strategy Returns. Working paper (Unpublished).

10. Garleanu, N. and L.H. Pedersen. Dynamic Trading with Predictable Returns and Transaction Costs. Working paper (Unpublished).