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Connecting Markets East & West

Equity Research

Factor forecasting with machine learning

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See Appendix A-1 for analyst certification, important disclosures, and the status of non-U.S. analysts.

Machine learning

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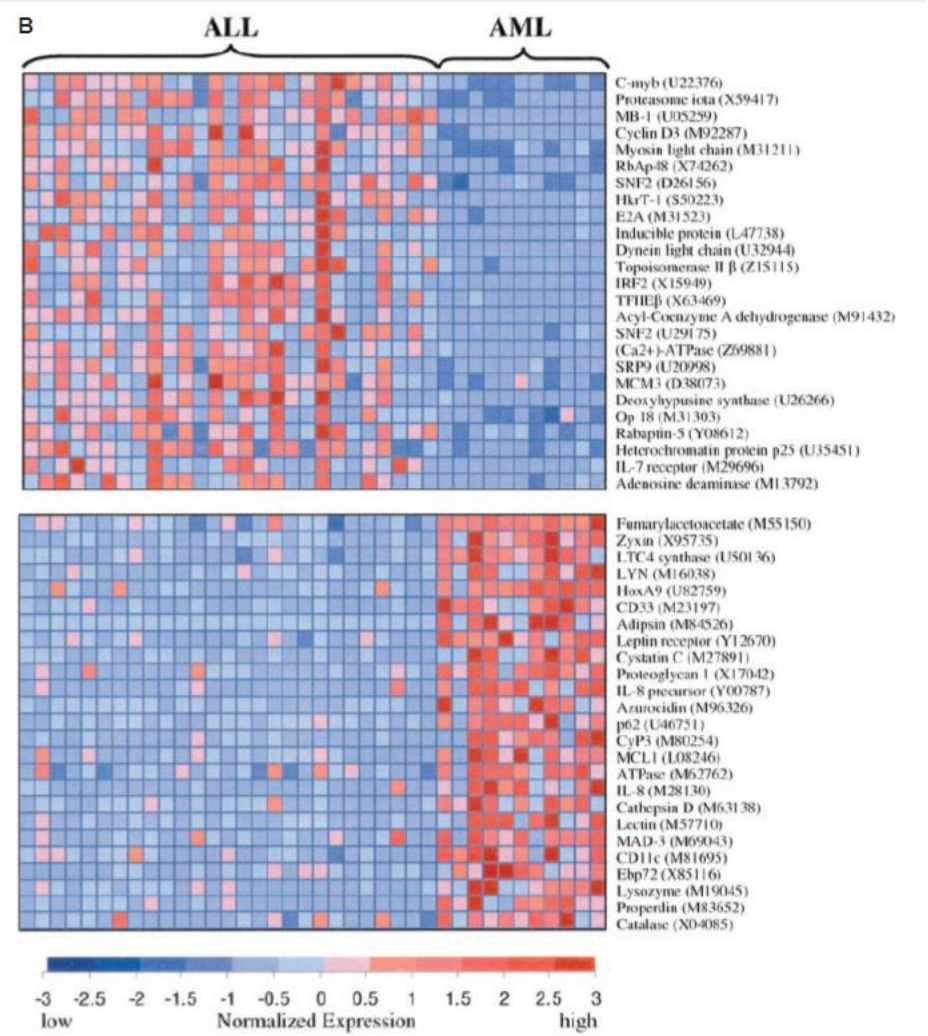
almost everywhere



Source: .R. Golub et al, Molecular Classification of Cancer: Class Discovery and Class Prediction by Gene Expression Monitoring, SCIENCE, Vol 286, 15 October 1999

Machine Learning for Classification

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Examples of Classification Problems

- Spam Filtering
- Cancer characterization
- Credit Card Fraud Detection
- Facial recognition
- Etc .

Machine Learning Techniques for Classification Problems

Supervised vs. Unsupervised Learning

Parametric or Algorithmic

- Logistic Regression with regularization
- Support Vector Machines
- Classification and Regression Trees (CART)
- Random Forest
- Neural Networks
- Etc.

Framing the problem

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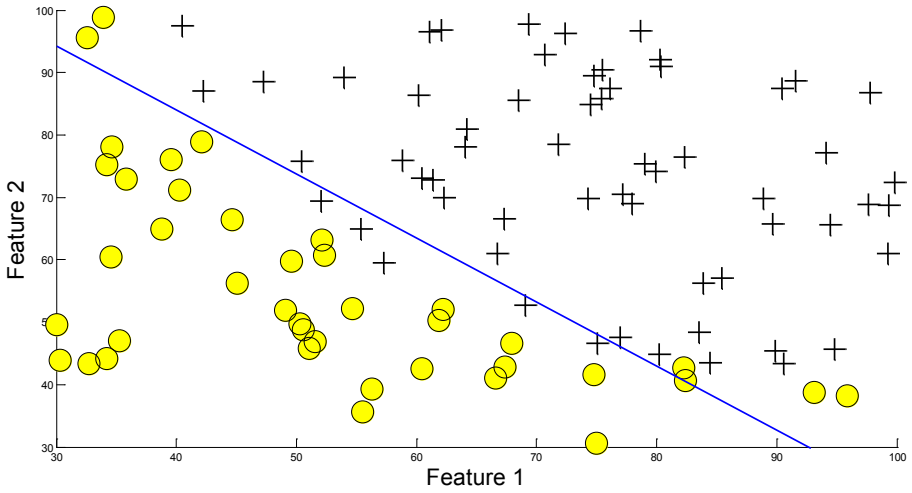
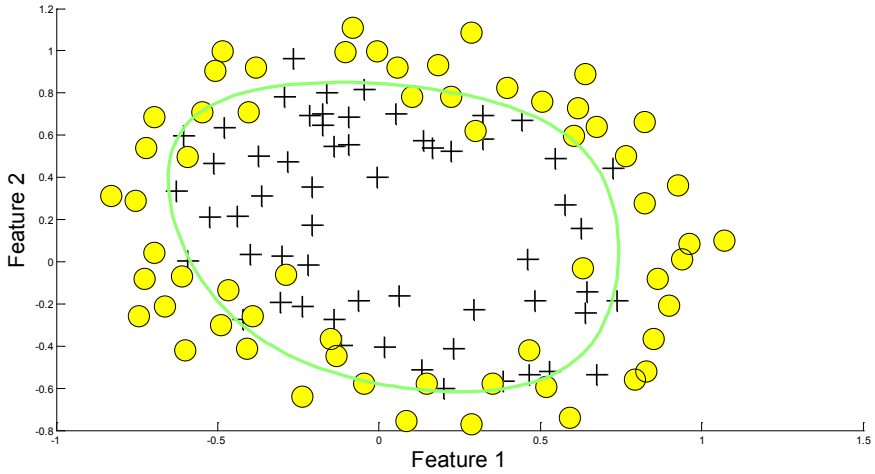
- Pattern recognition means classification
- The relevant problem is digital (classification) rather than analogue (linear regression, CAPM)





- Focus here on forecasting factor returns using two techniques
- Two machines can be better than one – ensemble approach/wisdom of crowds

Fitting vs. training

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- What is the ***future*** beta of a stock?

  Adjusted beta = blend of estimated beta and beta of 1

  Shrink the beta towards 1 for out-of-sample accuracy

- Bias – variance tradeoff

  relax the tightness of the training fit to improve test data performance

Fitting vs. training

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Training involves shrinkage/regularization

- Ridge regression shrinks regression coefficients through penalty on squared magnitude

$$\hat{\beta}^{ridge} = \underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{N} (y_i - \beta_0 - \sum_{j=1}^{p} x_{ij}\beta_j)^2 + \lambda \sum_{j=1}^{p} \beta_j^2 \right\}$$

- The Lasso shrinks regression coefficients through penalty on absolute magnitude

$$\hat{\beta}^{Lasso} = \underset{\beta}{\text{minimize}} \left\{ \sum_{i=1}^{N} (y_i - \beta_0 - \sum_{j=1}^{p} x_{ij}\beta_j)^2 + \lambda \sum_{j=1}^{p} |\beta_j| \right\}$$

- The general form is

$$\hat{\beta} = \underset{\beta}{\text{minimize}} \{ Loss + Penalty \}$$

Model fit vs. model performance

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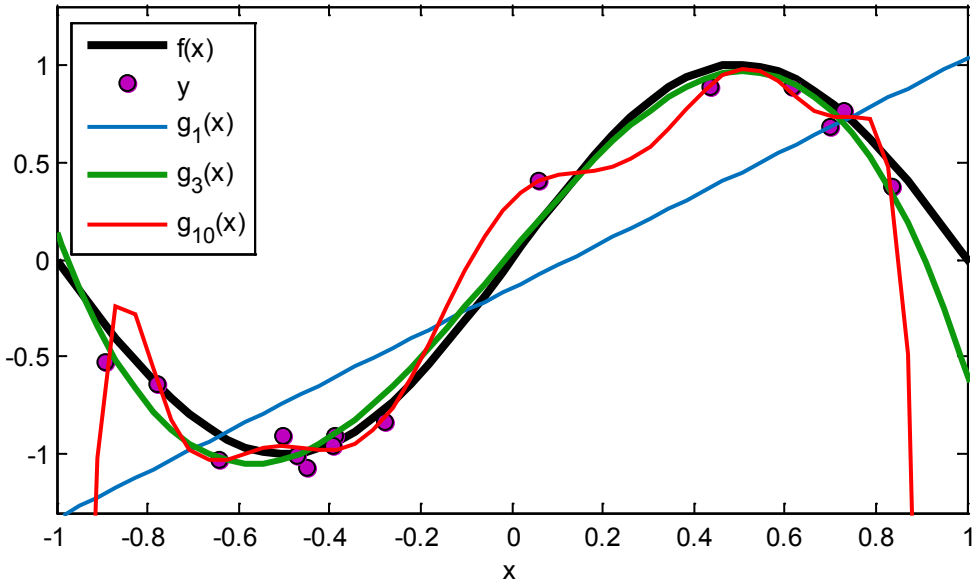
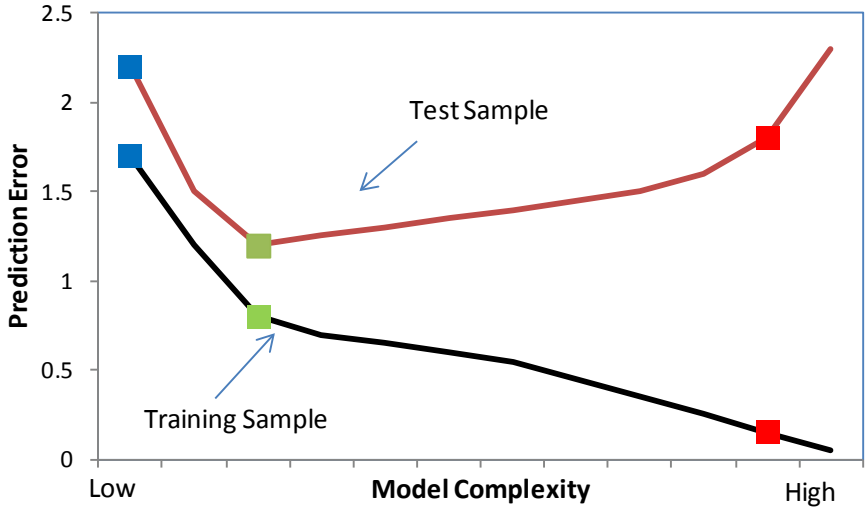
- Prediction Error for *training* data may be very different than for *test* data
- Relax *training* fit (increase bias) to improve *test performance (decrease variance)*





Y =sin px

Logistic Regression with shrinkage for classification

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- Classification is based on probability of category (y=0 or y=1); linear regression not appropriate
- p(X) = Probability(y=1|X)

$$p(X) = \frac{e^{\beta_0 + \beta_1 X}}{1 + e^{\beta_0 + \beta_1 X}}$$

rearrange

$$\log\left(\frac{p(X)}{1 - p(X)}\right) = \beta_0 + \beta_1 X$$

- Classic logistic regression inadequate for predictions
- Shrinkage or regularization of betas makes prediction practical

Logistic Regression with shrinkage for Factor Return Prediction – Book/Price

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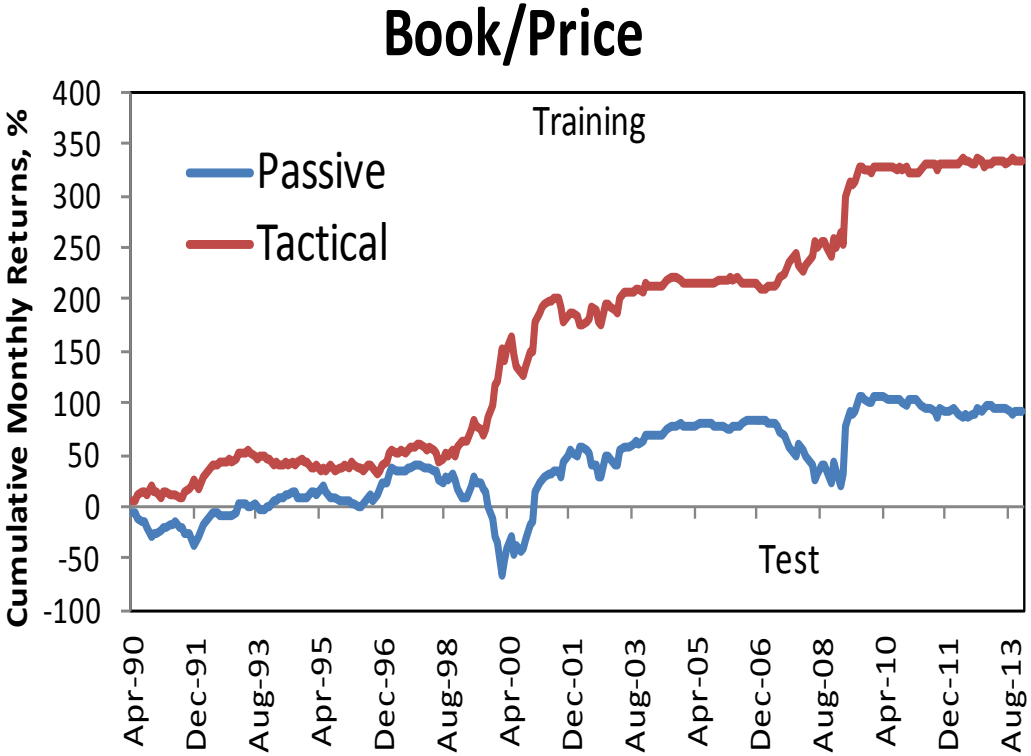

Book/Price	Passive	Tactical w/ Shrinkage
since 1990 ret	**4.03**	**14.04**
since 1990 vol	22.03	21.69
since 1990 IR	0.18	0.65
since 2006 (Test) ret	**2.30**	**14.48**
since 2006 (Test) vol	23.69	23.32
since 2006 (Test) IR	0.10	0.62
2013 ret	**-4.11**	**5.59**
2013 vol	7.03	6.94
2013 IR	-0.59	0.81

Note: The chart shows cumulative monthly returns of Book/Price without modeling (Passive, blue line) and with modeling (Tactical, red line). Independent variables used for modeling are VIX, the one-month change of VIX, dispersion of Book/Price, the change of dispersion of Book/Price and the lagged one-month B/P returns. Analysis is from April 1990 to Dec. 2013.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Book/Price
The Power of Prediction

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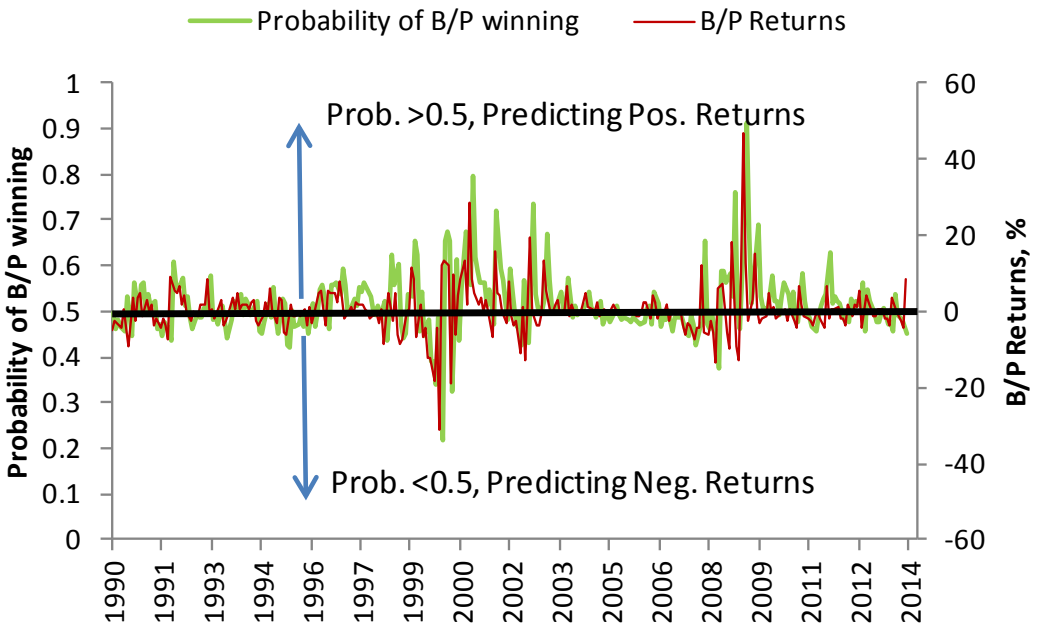

Note: The chart shows prediction probability for B/P returns (blue line) and the next month B/P returns (red line). Analysis is from April 1990 to Dec. 2013.
Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Factor Return Prediction – Book/Price

Book/Price	Passive	Tactical w/ Shrinkage	w/o Shrinkage
since 1990 ret	**4.03**	**14.04**	**6.07**
since 1990 vol	22.03	21.69	21.99
since 1990 IR	0.18	0.65	0.28
since 2006 (Test) ret	**2.30**	**14.48**	**4.76**
since 2006 (Test) vol	23.69	23.32	23.65
since 2006 (Test) IR	0.10	0.62	0.20
2013 ret	**-4.11**	**5.59**	**-11.69**
2013 vol	7.03	6.94	9.65
2013 IR	-0.17	0.81	-1.21
2014 ret (Jan. - Apr.)	**6.21**	**3.35**	**-10.47**

Note: The chart shows cumulative monthly returns of Book/Price without modeling (passive, blue line) , with modeling using shrinkage method (tactical, red line) and with modeling but not using shrinkage method (Tactical w/o Shrinkage, green line). Independent variables used for modeling are VIX, the one-month change of VIX, dispersion of Book/Price, the change of dispersion of Book/Price and the lagged one-month B/P returns. Analysis is from April 1990 through April 2014.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Factor Return Prediction – Book/Price

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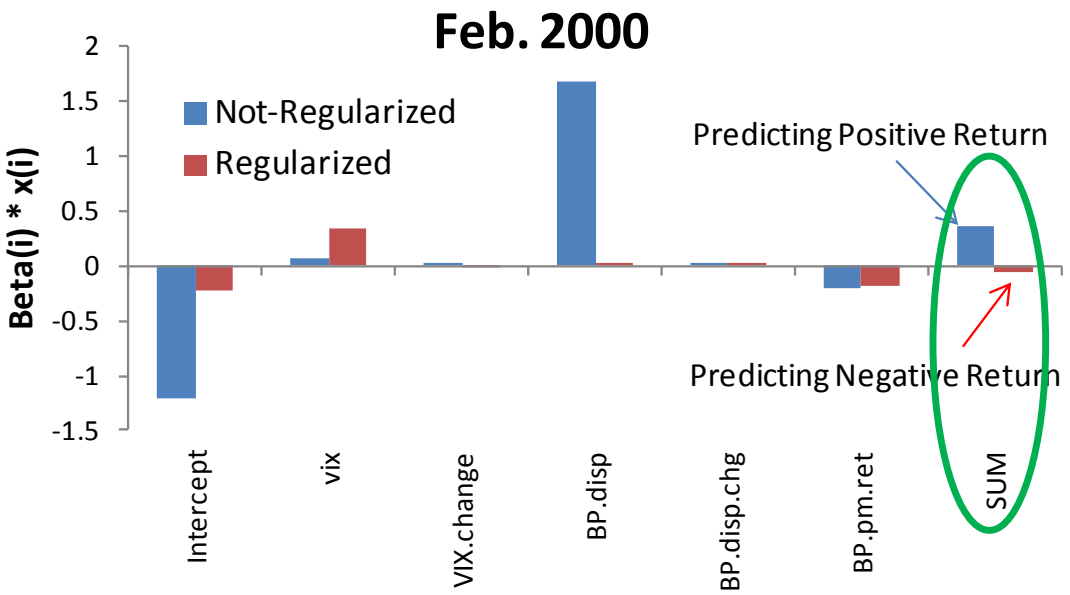
- **February 2000** Tech bubble endgame, passive Book/Price lost 31%.
- LR w/shrinkage made correct prediction, but non-regularized LR failed
- Correct prediction reinforced by CART model



Forward looking Book/Price Returns w.r.t. VIX			
1990 to 2005	Next Mon. Ret	# months	Ann ret
VIX > 15	0.48	131	5.76
VIX < 15	0.26	58	3.12
2006 to 2013			
VIX > 15	0.25	73	2.99
VIX < 15	-0.23	23	-2.75
2006 to 2013			
VIX > 30	3.95	13	47.34
VIX < 30	-0.46	83	-5.54

Note: The left chart shows beta coefficients multiply their respective independent variables at Feb. 2000. SUM is the sum of all products. If SUM is positive, it indicates positive returns for B/P of the next month and vice versa The right table shows the next month return statistics under different VIX scenarios. Analysis is from April 1990 through Dec. 2013.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Factor Return Prediction – Book/Price

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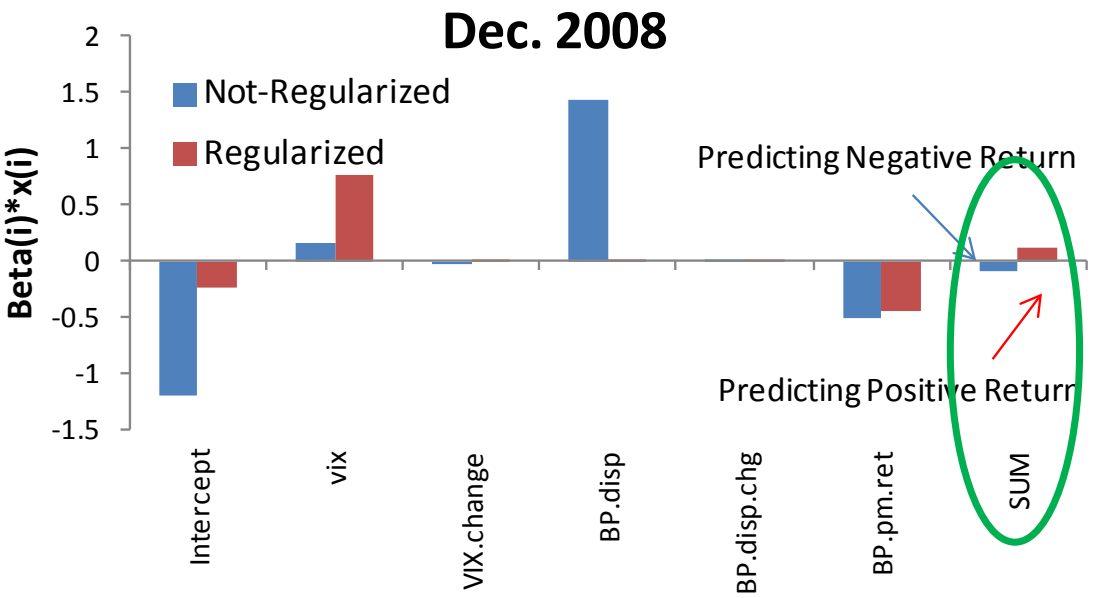
- **December 2008:** Book/Price gained 18% following 10% loss in Nov, 23% loss Jan - Nov
- Regularized LR forecast gain, non-regularized forecast loss.
- Correct prediction reinforced by CART model



Forward looking Book/Price Returns w.r.t. VIX			
1990 to 2005	Next Mon. Ret	# months	Ann ret
VIX > 15	0.48	131	5.76
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VIX < 15	-0.23	23	-2.75
2006 to 2013			
VIX > 30	3.95	13	47.34
VIX < 30	-0.46	83	-5.54

Note: The chart shows beta coefficients multiply their respective independent variables at Dec. 2008. SUM is the sum of all products. If SUM is positive, it indicates positive returns for B/P of the next month and vice versa The right table shows the next month return statistics under different VIX scenarios. Analysis is from April 1990 through Dec. 2013.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Factor Return Prediction – Book/Price

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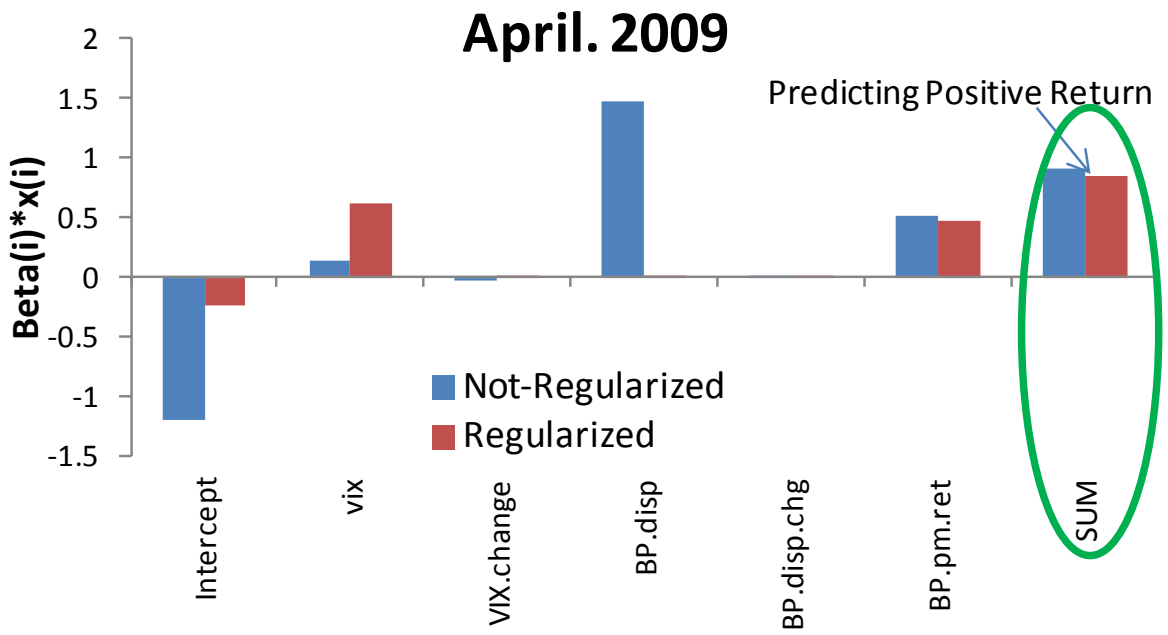
- **April 2009**: passive Book/Price gained 47% following 11% loss from Jan. to March 2009.
- Regularized and non-regularized LR both correctly forecast the B/P recovery



Note: The chart shows beta coefficients multiply their respective independent variables at Apr. 2009. SUM is the sum of all products. If SUM is positive, it indicates positive returns for B/P of the next month and vice versa.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Factor Return Prediction – Book/Price

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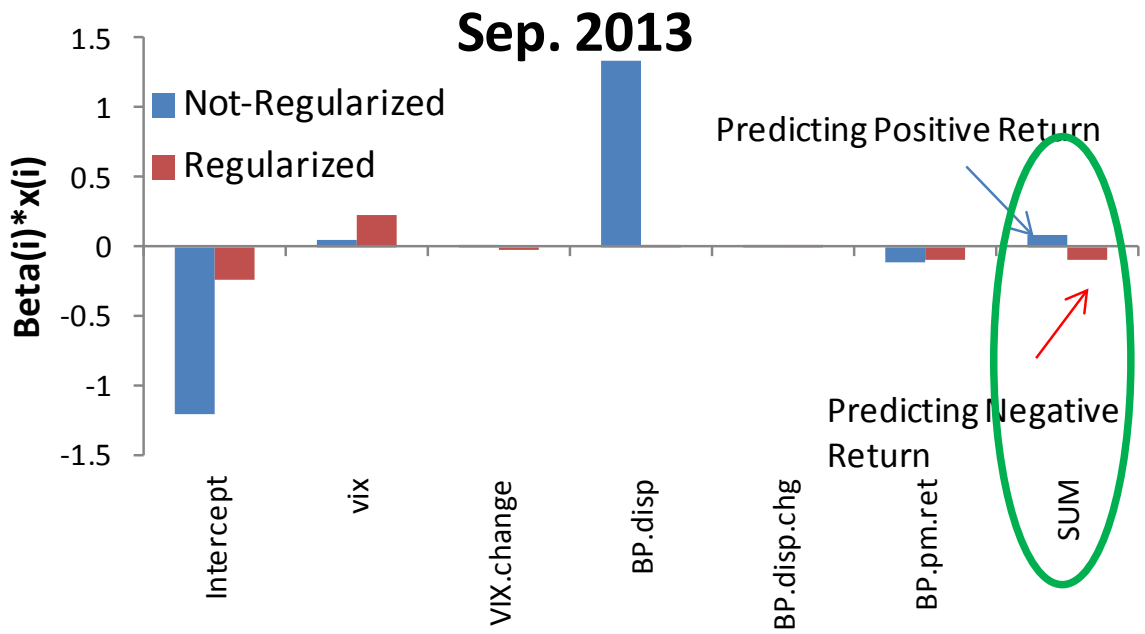
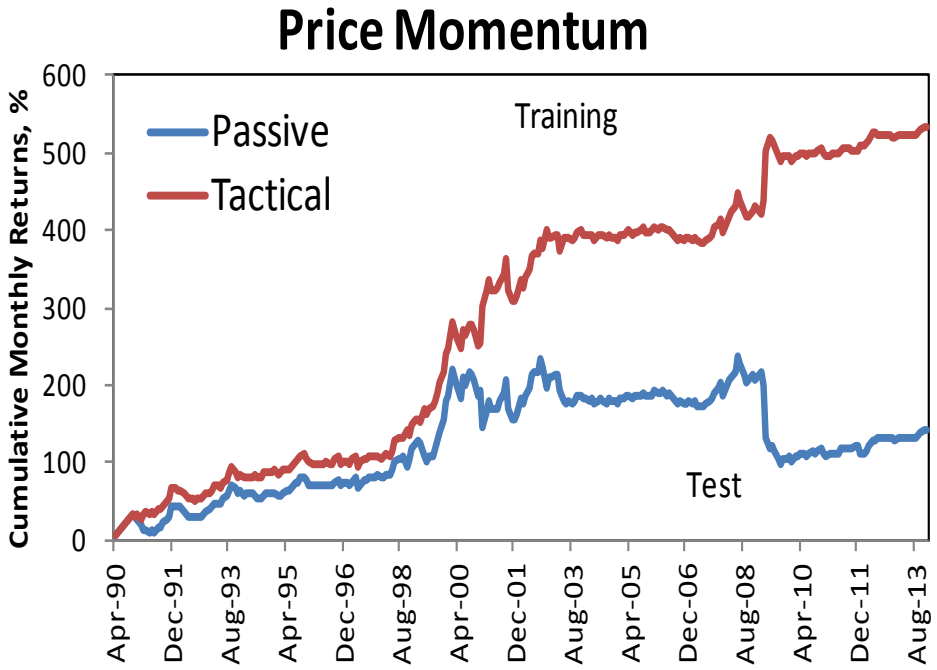
- **Sep. 2013:** passive Book/Price lost 4%.
  - Regularized LR made correct prediction, non-regularized LR failed.
  - 2013 bad for BP and non-regularized LR, good for regularized LR
- Correct prediction reinforced by CART model



Note: The chart shows beta coefficients multiply their respective independent variables at Sep 2013. SUM is the sum of all products. If SUM is positive, it indicates positive returns for B/P of the next month and vice versa.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Logistic Regression with shrinkage for Factor Return Prediction – Price Momentum



1-Year Price Momentum	Passive	Tactical
since 1990 ret	**5.95**	**22.39**
since 1990 vol	31.27	30.64
since 1990 IR	0.19	0.73
since 2006 (test) ret	**-5.74**	**16.62**
since 2006 (test) vol	30.79	30.45
since 2006 (test) IR	-0.19	0.55
2013 ret	**11.09**	**11.09**
2013 vol	7.14	7.14
2013 IR	1.55	1.55

Note: The chart shows cumulative monthly returns of 1-year price momentum without modeling (Passive, blue line) and with modeling (Tactical, red line). Independent variables used for modeling are VIX, the one-month change of VIX, dispersion of Book/Price, the change of dispersion of Book/Price. Analysis is from April 1990 through Dec. 2013.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Tactical Allocation B/P + Price Momentum

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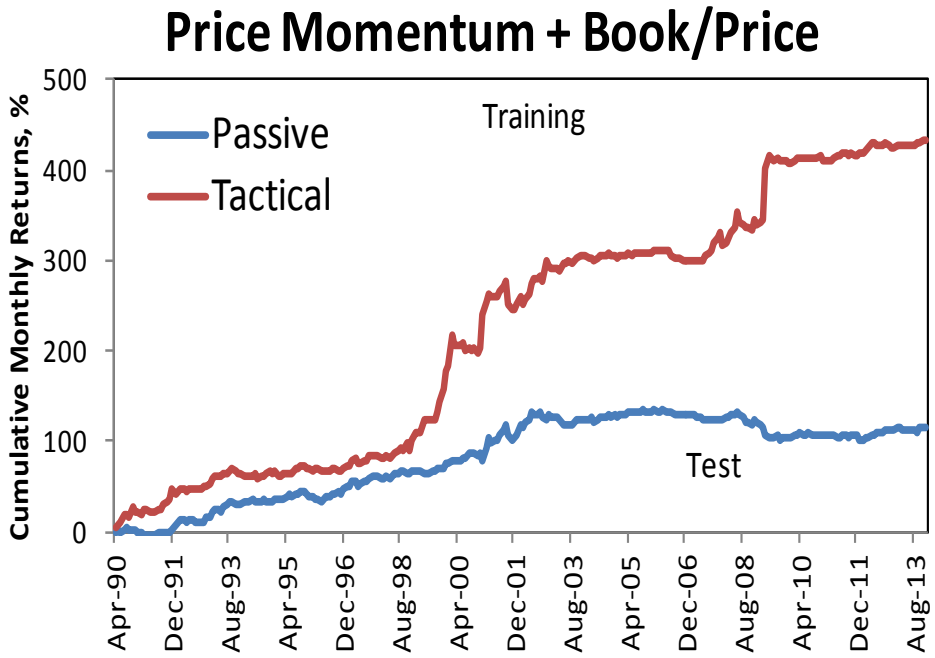
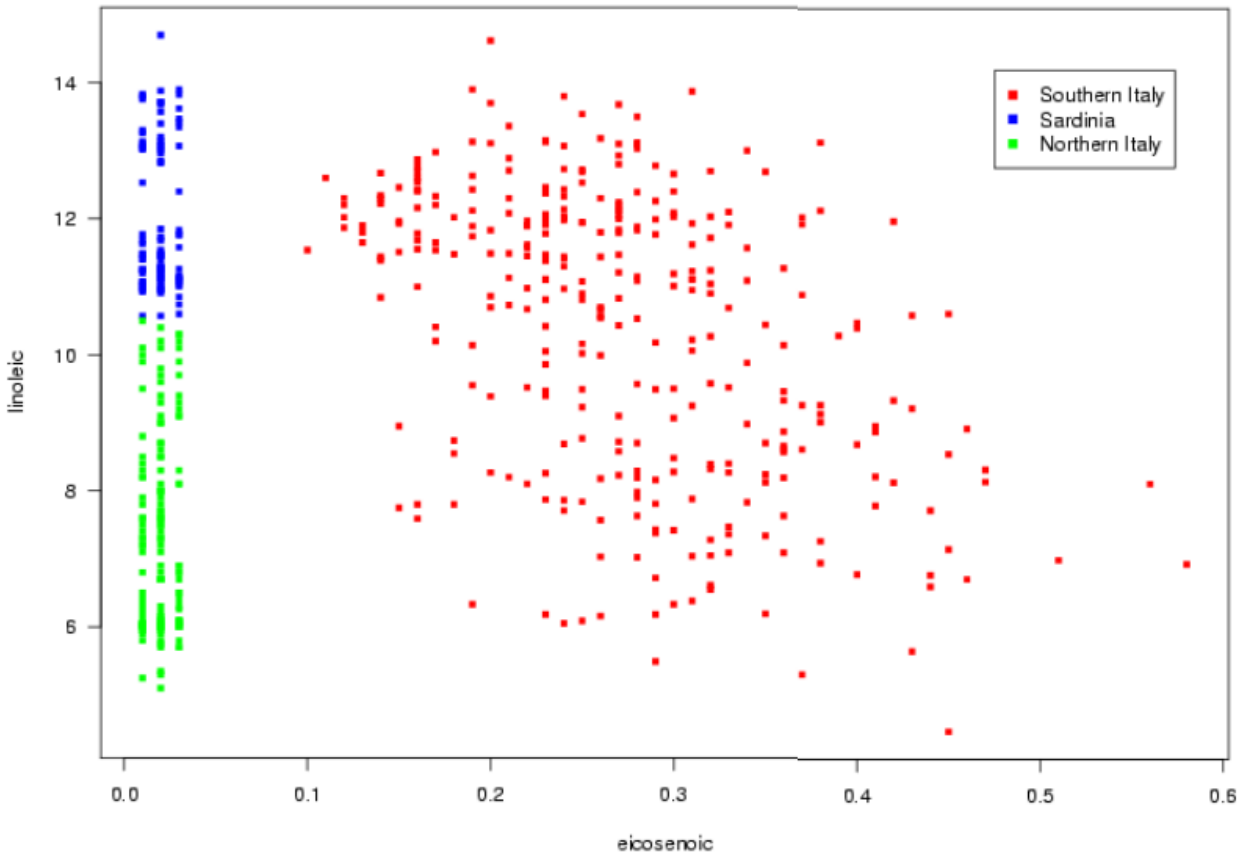


BP+Price Momentum	Passive	Tactical
since 1990 ret	**4.89**	**18.24**
since 1990 vol	9.13	22.10
since 1990 IR	0.54	0.83
since 2006 (test) ret	**-2.06**	**15.64**
since 2006 (test) vol	7.25	24.05
since 2006 (test) IR	-0.28	0.65
2013 ret	**3.49**	**8.34**
2013 vol	4.19	6.04
2013 IR	0.83	1.38

Note: The chart shows cumulative monthly returns of Book/Price plus 1-year price momentum without modeling (Passive, blue line) and with modeling (Tactical, red line). Analysis is from April 1990 through Dec. 2013.

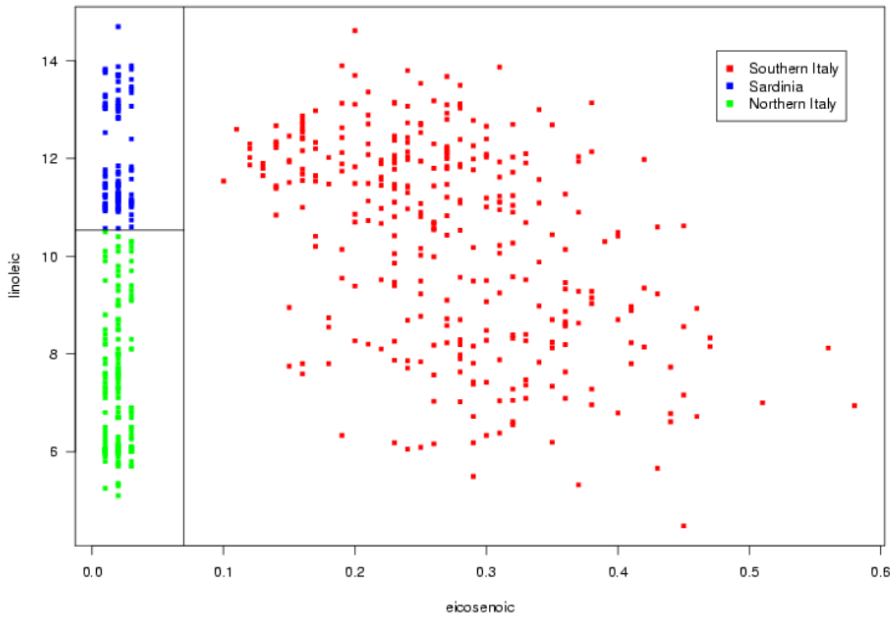
Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

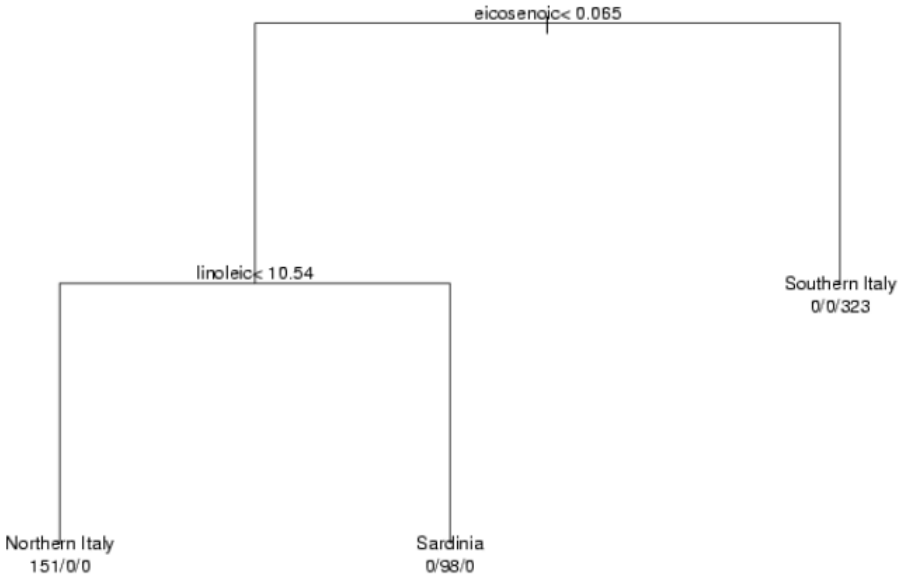
Classification - find the three groups



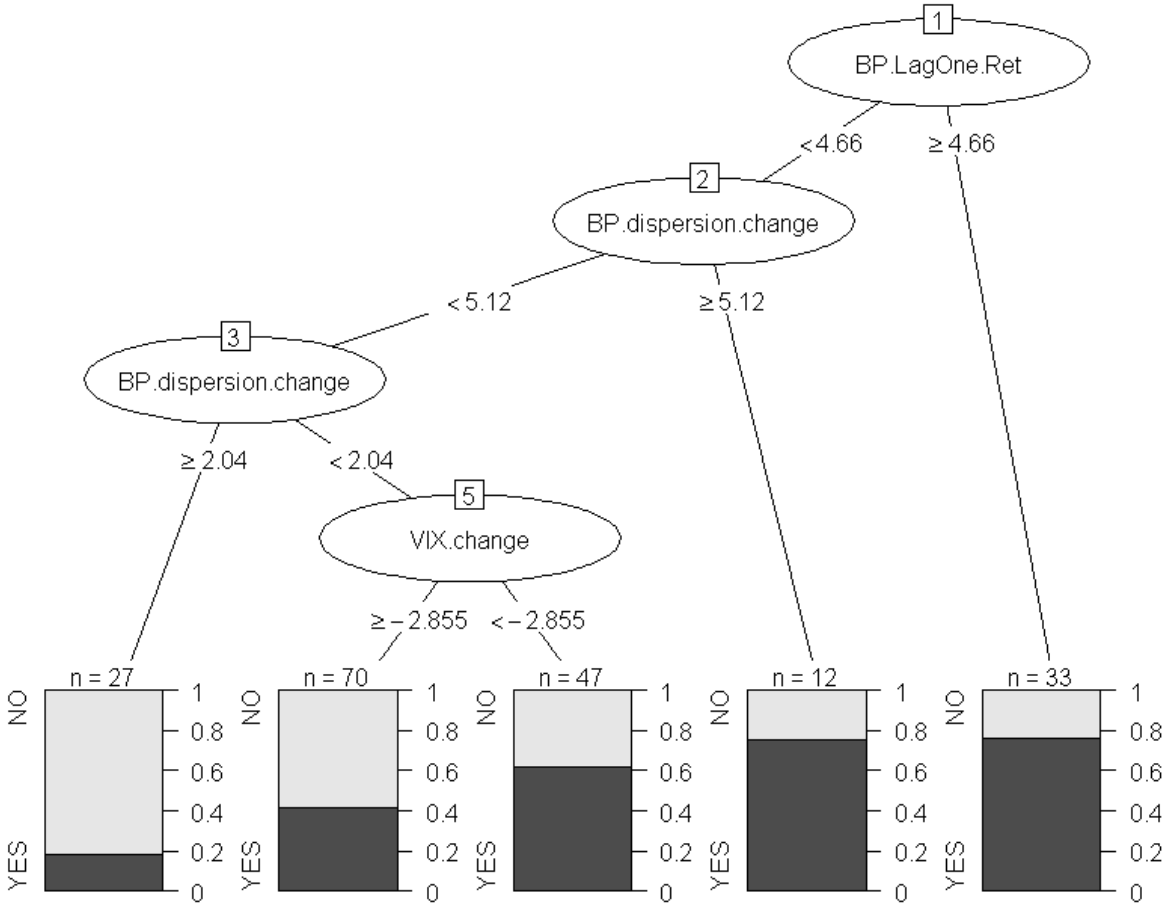
Olive data: 572 olive oils were analyzed for their content of eight fatty acids (palmitic, palmitoleic, stearic, oleic, linoleic, arachidic, linolenic, and eicosenoic).; There were 9 collection areas, 4 from Southern Italy (North and South Apulia, Calabria, Sicily), two from Sardinia (Inland and Coastal) and 3 from Northern Italy (Umbria, East and West Liguria).
See Forina M, Armanino C, Lanteri S, and Tiscornia E (1983). Classification of olive oils from their fatty acid composition. In Martens H and Russwurm Jr H, editors, Food Research and Data Analysis, pp 189-214. Applied Science Publishers, London.
Example based on Rafael Irizarry'ts course notes on statistical learning at Harvard School of Public Health

Partition the data for classification





Decision tree:
CART for Factor Return Prediction – Book/Price



Note: The chart shows the categorical decision tree for Book/Price returns using the CART methodology. Positive returns are categorized as "YES" and negative returns are categorized as "NO". The input features include VIX, the one-month change of VIX, dispersion of Book/Price, the change of dispersion of Book/Price and the lagged one-month B/P returns. Analysis is from April 1990 through Dec. 2005. This model was used for predictions after 2005 .

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Comparison between Logistic Regression w/shrinkage & CART – Book/Price

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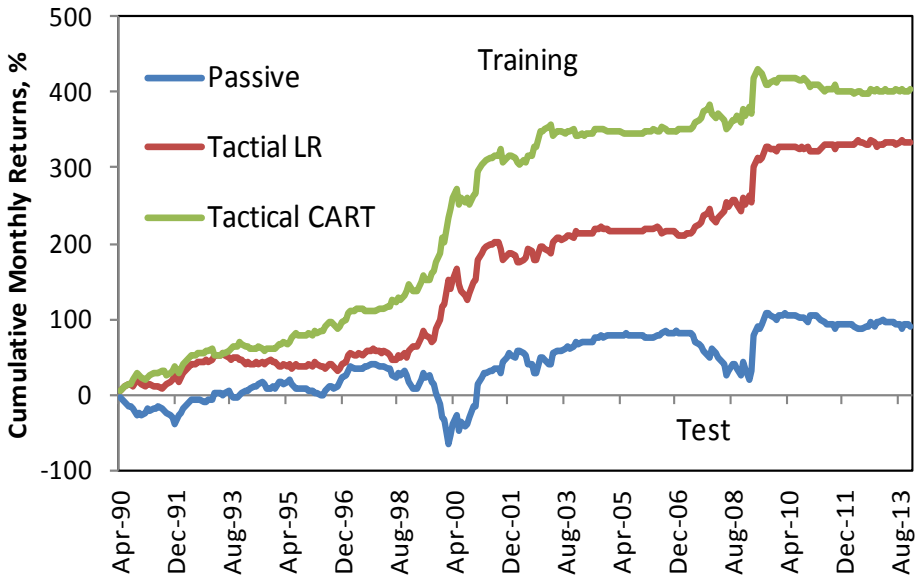

Book/Price	Passive	Tactical LR w/ Shrinkage	Tactical CART
since 1990 ret	**4.03**	**14.04**	**17.57**
since 1990 vol	22.03	21.69	21.47
since 1990 IR	0.18	0.65	0.82
since 2006 (Test) ret	**2.30**	**14.48**	**9.25**
since 2006 (Test) vol	23.69	23.32	23.54
since 2006 (Test) IR	0.10	0.62	0.39
2013 ret	**-4.11**	**5.59**	**-1.21**
2013 vol	7.03	6.94	9.91
2013 IR	-0.17	0.81	-0.12
2014 ret (Jan. - Apr.)	**6.21**	**3.35**	**20.03**

Note: The chart shows cumulative monthly returns of Book/Price without modeling (passive, blue line) , with modeling using logistic regression plus shrinkage method (Tactical LR, red line) and with CART modeling (Tactical CART green line). Independent variables used for modeling are VIX, the one-month change of VIX, dispersion of Book/Price, the change of dispersion of Book/Price and the lagged one-month B/P returns. Analysis is from April 1990 through April 2014.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Advantage When Both Models Agree – Book/Price

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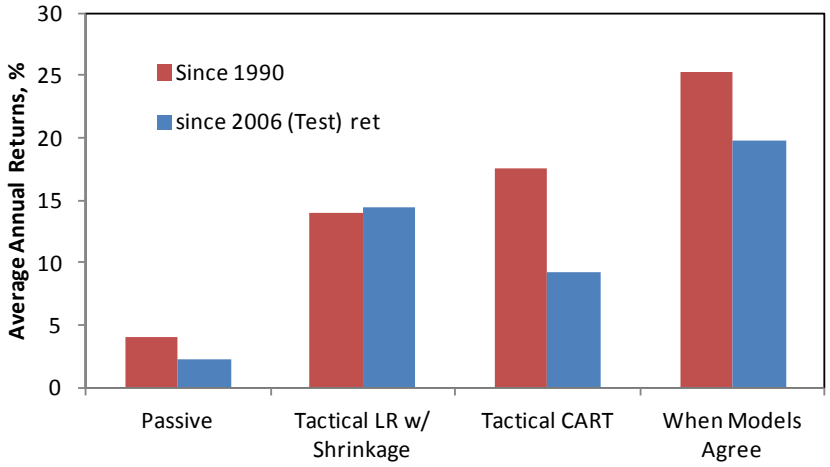
- The two models agree 62% of the time.
- When the models agree forecast accuracy is enhanced.



Book/Price	Passive	Tactical LR w/ Shrinkage	Tactical CART	When Models Agree
since 1990 ret	**4.03**	**14.04**	**17.57**	**25.23**
since 1990 vol	22.03	21.69	21.47	24.07
since 1990 IR	0.18	0.65	0.82	1.05
since 2006 (Test) ret	**2.30**	**14.48**	**9.25**	**19.78**
since 2006 (Test) vol	23.69	23.32	23.54	27.27
since 2006 (Test) IR	0.10	0.62	0.39	0.73
2013 ret	**-4.11**	**5.59**	**-1.21**	**2.19**
2013 vol	7.03	6.94	9.91	10.59
2013 IR	-0.17	0.81	-0.12	0.21
2014 ret (Jan. - Apr.)	**6.21**	**3.35**	**20.03**	**11.69**

Note: The left chart shows average annual returns of Book/Price without modeling (passive) , with modeling using logistic regression plus shrinkage method (Tactical LR), with CART modeling (Tactical CART green) and when the two models (LR and CART) agree with each other (When Models Agree) since 1990 (red bars) or since 2006 (blue bars). The right table summarizes their return statistics in different periods. Analysis is from April 1990 through April 2014.

Source: Nomura Securities International Inc. Compustat, I/B/E/S, Russell and IDC.

Conclusion

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- Machine learning ***almost*** everywhere
- Time for finance to catch up

Appendix A-1

Any Authors named on this report are Research Analysts unless otherwise indicated

Analyst Certification

I, Joseph Mezrich, hereby certify (1) that the views expressed in this Research report accurately reflect my personal views about any or all of the subject securities or issuers referred to in this Research report, (2) no part of my compensation was, is or will be directly or indirectly related to the specific recommendations or views expressed in this Research report and (3) no part of my compensation is tied to any specific investment banking transactions performed by Nomura Securities International, Inc., Nomura International plc or any other Nomura Group company.

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The rating system is a relative system, indicating expected performance against a specific benchmark identified for each individual stock, subject to limited management discretion. An analyst's target price is an assessment of the current intrinsic fair value of the stock based on an appropriate valuation methodology determined by the analyst. Valuation methodologies include, but are not limited to, discounted cash flow analysis, expected return on equity and multiple analysis. Analysts may also indicate expected absolute upside/downside relative to the stated target price, defined as (target price - current price)/current price.

STOCKS

A rating of **'Buy'**, indicates that the analyst expects the stock to outperform the Benchmark over the next 12 months. A rating of **'Neutral'**, indicates that the analyst expects the stock to perform in line with the Benchmark over the next 12 months. A rating of **'Reduce'**, indicates that the analyst expects the stock to underperform the Benchmark over the next 12 months. A rating of **'Suspended'**, indicates that the rating, target price and estimates have been suspended temporarily to comply with applicable regulations and/or firm policies. Securities and/or companies that are labelled as **'Not rated'** or shown as **'No rating'** are not in regular research coverage. Investors should not expect continuing or additional information from Nomura relating to such securities and/or companies. Benchmarks are as follows: **United States/Europe/Asia ex-Japan**: please see valuation methodologies for explanations of relevant benchmarks for stocks, which can be accessed at: http://go.nomuranow.com/research/globalresearchportal/pages/disclosures/disclosures.aspx; **Global Emerging Markets (ex-Asia)**: MSCI Emerging Markets ex-Asia, unless otherwise stated in the valuation methodology; **Japan:** Russell/Nomura Large Cap.

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Explanation of Nomura's equity research rating system in Japan and Asia ex-Japan prior to 21 October 2013

STOCKS

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