Machine Forecast Disagreement

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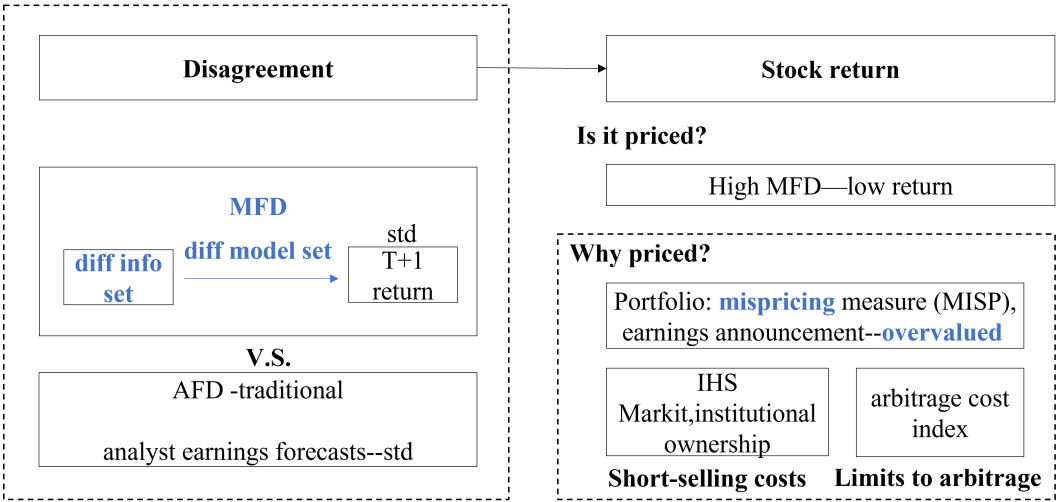

Disagreement
Stock return
Is it priced?
High MFD—low return
MFD
diff info set
diff model set
std
T+1 return
V.S.
AFD -traditional
analyst earnings forecasts--std
Why priced?
Portfolio: mispricing measure (MISP), earnings announcement--overvalued
IHS Markit,institutional ownership
arbitrage cost index
Short-selling costs
Limits to arbitrage

Question

- How to measure disagreement by machine–MFD?
- Is MFD priced in the stock market?
  - Yes, high MFD–low return
  - better than AFD
  - resource: mispricing–overvalued, short selling cost, arbitrage limit

Why interesting?

- Belief disagreement is a primary motivation for trade, drive price dynamics.
  - Theory——Miller (1977): investors disagree about stock value + pessimistic investors face short-sale constraints→ price upward
- However, empirical work on disagreement is limited by belief measure difficult.
  - Beliefs are unobservable, so disagreement is inferred through proxies.
  - A seminal study: analyst earnings forecasts dispersion （AFD）(Diether,2002)
  - Limited coverage (only analyst-covered); focuses on earnings rather than returns/discount rates; subject to analyst bias
- This paper proposes a more objective, comprehensive method:
  - investors share information set but are each assigned a diff information、diff machine learning model to process it

Contribution

- literature on measure of belief disagreement at the asset level.
  - prior: analyst earnings forecasts dispersion (Diether,2002)
  - extend: simulate belief by endowing each investor with a machine learning model
- literature on disagreement pricing
  - prior: AFD is a notably weaker predictor of stock returns.
  - extend:
    - documenting the strong predictive power of MFD for pricing of individual stocks.
    - earnings-based MFD(like AFD) + return-based MFD
- literature on investigating the economic underpinnings of MFD alpha.
  - prior: facus on disagree-return;serveral study short-sale constraints(Barber,2008)
  - extend: systematic： disagree+ short sell cost/arbitrage limit ——mispricing (overvalue)→ low return

Design-MFD construction

- Gu et al.(2020) consider a general risk premium formulation:

$$\mathbb{E}_t\left[r_{i,t+1}\right] = g\left(\mathbf{z}_{i,t}\right), \tag{1}$$

  $\mathbf{z}_{i,t} \in \mathbb{R}^d$ denotes information set available to investors at time t for asset i

- Consider a collection of investors indexed by $k = 1, \ldots, K$. Each investor k differs in her information set $\mathbf{z}_{k,i,t}$. investor k forms beliefs according to

$$\mathbb{E}_{k,t}[r_{i,t+1}] = g_k(\mathbf{z}_{k,i,t}), \tag{2}$$

- We assume that investor k forecasts returns according to

$$g_k(\mathbf{z}_{i,t}) = RF_k(\mathbf{z}_{k,i,t}), \tag{3}$$

  where the investor-specific information set is given by $\mathbf{z}_{k,i,t} = \left[z_{i,t}^{\ell_{k,1}}, \ldots, z_{i,t}^{\ell_{k,d_k}}\right]$.

Design-MFD construction

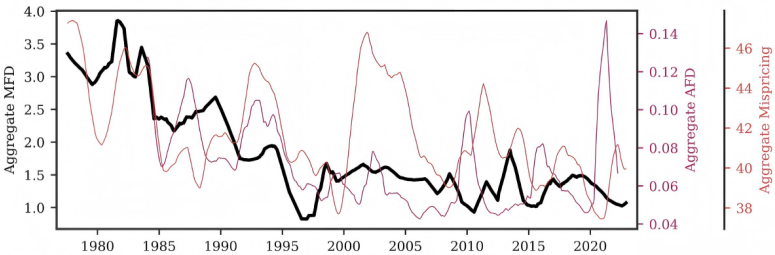
Source of disagreement (Barberis, 2018)	Representation in the model
1.Heterogeneous priors	Randomized structure of random forest models
2.Different information	Investor-specific subsets of the full information set
3.Bounded rationality	Differences in model complexity and feature importance

We measure disagreement, for stock i as the cross-sectional std of investors' expected returns:

$$\mathrm{MFD}_{i,t} = \sqrt{\frac{1}{K}\sum_{k=1}^{K}\left(\mathbb{E}_{k,t}[r_{i,t+1}] - \overline{\mathbb{E}_t[r_{i,t+1}]}\right)^2}, \tag{4}$$

Design-MFD construction

- data:1966.7 to 2022.12.
  - Jensen et al.(2023), publicly available stock returns and characteristics
  - 153 stock characteristics,map these ranks into the [1, 1]
- set the number of investors, K, to 100, dk = 76(50%)
- 10-year rolling window to estimate the random forest regressor



- correlation of agg MFD to agg AFD is 36%, 48% to an agg mispricing score

Design-Pricing MFD

1. MFD——stock return
   - Univariate portfolio-level analysis
   - Bivariate portfolio-level analysis
   - Fama-MacBeth cross-sectional regressions
2. MFD v.s. AFD
   - corr of return-based MFD,earnings-based MFD & AFD
   - portfolio-level analysis
3. decompose MFD: model and information set
   - 4 model * 25 information set

Design-Sources of return predictability

1. Mispricing versus risk
   - compare MFD to the mispricing measure (MISP) of Stambaugh et al. (2015).
   - stock price reactions around earnings announcements.
2. Short-selling costs
   - the indicative borrowing fee provided by IHS Markit
   - institutional ownership
3. Limits to arbitrage
   - idiosyncratic risk
   - monthly illiquidity
   - market capitalization (size)

Result1-MFD and stock return

Panel A: Equal-Weighted Portfolios											
	Excess Return	t-stat	CAPM	t-stat	FF6	t-stat	HXZ	t-stat	SY	t-stat	DHS	t-stat
Low	1.14***	(5.09)	0.50***	(3.72)	0.24***	(2.86)	0.27***	(2.72)	0.30***	(2.87)	0.51***	(3.81)
2	1.06***	(4.85)	0.42***	(3.30)	0.20***	(3.22)	0.24***	(3.03)	0.20***	(2.66)	0.45***	(3.67)
3	1.06***	(4.62)	0.38***	(2.97)	0.19***	(3.09)	0.25***	(3.15)	0.20***	(2.61)	0.46***	(3.56)
4	1.00***	(4.28)	0.29**	(2.43)	0.13***	(2.67)	0.21***	(3.45)	0.16**	(2.43)	0.40***	(3.39)
5	0.97***	(4.02)	0.23**	(1.96)	0.12**	(2.42)	0.21***	(3.22)	0.14**	(2.39)	0.41***	(3.47)
6	0.87***	(3.44)	0.11	(0.92)	0.09*	(1.90)	0.18***	(3.56)	0.05	(0.90)	0.35***	(3.00)
7	0.77***	(2.87)	-0.03	(-0.22)	0.03	(0.51)	0.16***	(2.73)	0.02	(0.32)	0.32**	(2.48)
8	0.61**	(2.08)	-0.22	(-1.51)	-0.05	(-0.89)	0.07	(1.04)	-0.02	(-0.26)	0.27*	(1.87)
9	0.44	(1.44)	-0.42***	(-2.63)	-0.14**	(-2.20)	0.02	(0.27)	-0.11	(-1.14)	0.21	(1.44)
High	-0.18	(-0.52)	-1.12***	(-5.68)	-0.64***	(-7.79)	-0.46***	(-3.71)	-0.70***	(-4.97)	-0.27	(-1.52)
H-L	-1.32***	(-5.61)	-1.62***	(-7.15)	-0.88***	(-6.69)	-0.74***	(-4.15)	-1.00***	(-4.77)	-0.78***	(-4.59)
Panel B: Value-Weighted Portfolios												
	Excess Return	t-stat	CAPM	t-stat	FF6	t-stat	HXZ	t-stat	SY	t-stat	DHS	t-stat
Low	0.93***	(4.85)	0.35***	(3.36)	0.08	(0.82)	0.08	(0.79)	0.15	(1.33)	0.12	(1.10)
2	0.89***	(4.34)	0.26***	(3.09)	0.10	(1.31)	0.05	(0.56)	0.05	(0.57)	0.08	(1.00)
3	0.90***	(4.54)	0.25**	(2.48)	0.18*	(1.83)	0.22**	(2.07)	0.22*	(1.90)	0.23**	(2.16)
4	0.86***	(4.08)	0.16**	(2.47)	0.18***	(2.66)	0.17**	(2.36)	0.19***	(2.72)	0.20***	(2.88)
5	0.80***	(3.69)	0.09	(1.12)	0.04	(0.43)	0.06	(0.64)	0.06	(0.63)	0.12	(1.52)
6	0.72***	(3.28)	0.01	(0.07)	0.01	(0.10)	0.01	(0.14)	0.00	(0.00)	0.08	(1.05)
7	0.65***	(2.62)	-0.12	(-1.22)	-0.09	(-0.93)	-0.08	(-0.68)	-0.17	(-1.49)	-0.01	(-0.14)
8	0.54**	(2.13)	-0.23*	(-1.76)	-0.01	(-0.06)	0.05	(0.38)	0.11	(0.97)	0.10	(0.91)
9	0.44	(1.51)	-0.40***	(-2.89)	-0.17	(-1.40)	-0.04	(-0.26)	-0.10	(-0.78)	0.04	(0.36)
High	-0.21	(-0.64)	-1.12***	(-5.62)	-0.55***	(-4.28)	-0.40**	(-2.43)	-0.42***	(-2.86)	-0.48***	(-3.37)
H-L	-1.14***	(-4.33)	-1.47***	(-5.73)	-0.63***	(-3.51)	-0.48**	(-2.36)	-0.57***	(-2.75)	-0.59***	(-3.17)

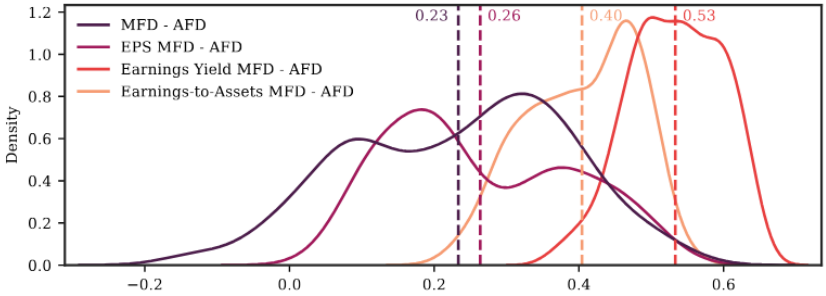
- high MFD–low return

Result1-MFD and stock return

	Excess Return	Excess Return	Excess Return	Industry-adj. Return	DGTW-adj. Return
Const	0.86***	0.82***	0.84***	0.08	0.03
	(3.64)	(3.44)	(3.57)	(0.79)	(0.75)
MFD	-0.34***	-0.31***	-0.23***	-0.21***	-0.18***
	(-7.05)	(-7.38)	(-5.36)	(-5.91)	(-4.76)
BETA	0.02	0.04	0.07	0.09**	0.06
	(0.29)	(0.56)	(1.28)	(2.43)	(1.38)
SIZE	-0.04**	-0.05**	-0.06***	-0.04***	-0.04***
	(-1.96)	(-2.14)	(-2.72)	(-2.83)	(-3.09)
BM	0.13**	0.14**	0.08	0.09**	-0.03
	(2.39)	(2.56)	(1.48)	(2.23)	(-0.82)
MOM	0.38***	0.38***	0.37***	0.31***	0.23***
	(6.54)	(6.72)	(5.87)	(5.92)	(4.79)
AG		-0.26***	-0.24***	-0.19***	-0.19***
		(-5.01)	(-4.12)	(-4.18)	(-4.00)
OP		0.16***	0.14***	0.14***	0.15***
		(3.63)	(3.33)	(3.27)	(3.33)
SUE			0.07***	0.06***	0.05***
			(3.03)	(3.42)	(2.60)
ILLIQ			0.02	0.09	0.03
			(0.75)	(1.40)	(0.62)
IVOL			0.00	-0.04	0.02
			(0.07)	(-0.64)	(0.39)
MAX			-0.16***	-0.12**	-0.14**
			(-2.93)	(-2.43)	(-2.49)
TURN			-0.15***	-0.13***	-0.13***
			(-3.54)	(-3.03)	(-2.90)
STR			-0.28***	-0.36***	-0.33***
			(-4.88)	(-6.60)	(-5.57)
Observations	1,167,280	1,102,119	978,110	934,973	934,973

- high MFD–low return(control other characteristic)

Result1-MFD v.s. AFD



- correlations between AFD and our earnings-based measures of MFD are higher

Result1-MFD v.s. AFD

Table I.1: Univariate Portfolio Sorts on AFD

Panel A: Equal-Weighted Portfolios												
	Excess Return	t-stat	CAPM	t-stat	FF6	t-stat	HXZ	t-stat	SY	t-stat	DHS	t-stat
Low	1.11***	(5.14)	0.37***	(3.29)	0.26***	(4.14)	0.26***	(3.48)	0.32***	(4.38)	0.40***	(3.92)
2	0.73***	(3.38)	-0.03	(-0.31)	-0.12*	(-1.70)	-0.08	(-0.87)	-0.08	(-0.92)	0.10	(1.01)
3	0.74***	(3.18)	-0.06	(-0.58)	-0.05	(-0.80)	-0.03	(-0.32)	-0.01	(-0.18)	0.13	(1.23)
4	0.69***	(2.70)	-0.16	(-1.48)	-0.08	(-1.28)	-0.03	(-0.31)	-0.06	(-0.79)	0.15	(1.30)
5	0.73***	(2.74)	-0.16	(-1.34)	-0.07	(-1.17)	-0.06	(-1.01)	-0.07	(-1.01)	0.20*	(1.70)
6	0.72***	(2.61)	-0.18	(-1.39)	-0.03	(-0.44)	-0.01	(-0.14)	-0.06	(-0.77)	0.24*	(1.77)
7	0.61**	(2.05)	-0.34**	(-2.54)	-0.11*	(-1.65)	-0.02	(-0.26)	-0.10	(-1.21)	0.21	(1.48)
8	0.63*	(1.93)	-0.34**	(-2.19)	-0.04	(-0.54)	0.05	(0.68)	-0.12	(-1.14)	0.28*	(1.73)
9	0.41	(1.21)	-0.59***	(-3.25)	-0.29***	(-3.48)	-0.11	(-1.26)	-0.33***	(-2.71)	0.08	(0.40)
High	0.31	(0.88)	-0.71***	(-3.70)	-0.34***	(-3.31)	-0.19*	(-1.95)	-0.35**	(-2.55)	-0.01	(-0.03)
H-L	-0.79***	(-3.75)	-1.08***	(-5.88)	-0.60***	(-4.73)	-0.45***	(-3.80)	-0.67***	(-4.02)	-0.40**	(-2.23)
Panel B: Value-Weighted Portfolios												
	Excess Return	t-stat	CAPM	t-stat	FF6	t-stat	HXZ	t-stat	SY	t-stat	DHS	t-stat
Low	0.88***	(5.27)	0.29***	(3.51)	0.01	(0.26)	-0.03	(-0.41)	0.04	(0.63)	0.02	(0.32)
2	0.73***	(3.91)	0.08	(1.16)	-0.07	(-0.96)	-0.04	(-0.43)	0.02	(0.20)	-0.00	(-0.00)
3	0.68***	(3.06)	-0.04	(-0.42)	0.01	(0.15)	-0.04	(-0.47)	-0.03	(-0.29)	-0.06	(-0.79)
4	0.61**	(2.46)	-0.17	(-1.47)	-0.05	(-0.65)	-0.08	(-1.03)	-0.05	(-0.55)	-0.10	(-1.17)
5	0.74***	(2.91)	-0.04	(-0.31)	0.15	(1.31)	0.05	(0.50)	0.04	(0.39)	0.16	(1.47)
6	0.74***	(3.17)	-0.06	(-0.53)	0.10	(0.87)	0.07	(0.51)	0.08	(0.56)	0.10	(0.81)
7	0.74***	(2.99)	-0.05	(-0.45)	0.07	(0.60)	0.05	(0.40)	0.12	(1.02)	0.08	(0.65)
8	0.67**	(2.25)	-0.22	(-1.53)	0.06	(0.43)	0.15	(1.10)	0.08	(0.56)	0.21	(1.31)
9	0.73**	(2.32)	-0.19	(-1.16)	0.04	(0.26)	0.37**	(2.18)	0.05	(0.28)	0.24	(1.42)
High	0.46	(1.35)	-0.55***	(-2.91)	-0.12	(-0.74)	0.12	(0.66)	-0.06	(-0.33)	0.05	(0.25)
H-L	-0.42	(-1.58)	-0.83***	(-3.66)	-0.14	(-0.75)	0.15	(0.70)	-0.10	(-0.47)	0.03	(0.11)

- AFD has weak predictive ability.

Result1-MFD v.s. AFD

Table 7: Analyst Forecast Dispersion and MFD

Panel A: Average AFD in MFD Decile Portfolio												
	Low	2	3	4	5	6	7	8	9	High	H-L	t-stat
AFD	0.08	0.10	0.11	0.13	0.14	0.16	0.18	0.20	0.22	0.26	0.18***	18.48

Panel B: Bivariate Portfolio Sort on AFD														
	Low	2	3	4	5	6	7	8	9	High	H-L	t-stat	FF6	t-stat
AFD Low	1.18	0.98	1.09	1.01	1.08	0.97	0.89	0.86	0.75	0.66	-0.51**	-2.23	-0.29*	-1.72
AFD 2	0.92	1.00	0.83	0.86	0.97	0.71	0.74	0.65	0.41	0.07	-0.85***	-3.22	-0.50***	-2.67
AFD 3	0.96	0.89	0.94	0.86	0.87	0.82	0.64	0.72	0.61	-0.02	-0.98***	-3.43	-0.60***	-3.14
AFD 4	0.87	0.88	0.91	0.84	0.69	0.78	0.54	0.55	0.21	-0.09	-0.96***	-2.79	-0.38	-1.57
AFD High	0.61	0.70	0.71	0.45	0.39	0.30	0.53	0.18	0.35	-0.59	-1.20***	-3.41	-0.80***	-2.99
AFD H-L	-0.57	-0.28	-0.38	-0.57	-0.68	-0.67	-0.36	-0.69	-0.40	-1.25	-0.68**	-2.34	-0.51*	-1.69

- enven control AFD, MFD can predict return

Result1-MFD decompose

Value-Weighted					
Total		Model		Information Set	
H-L	FF6	H-L	FF6	H-L	FF6
-0.92***	-0.64***	-0.73***	-0.56***	-0.68***	-0.43**
(-4.18)	(-3.32)	(-3.66)	(-3.28)	(-3.38)	(-2.43)

- how to interpret information, might be a more powerful predictor than disagreement about what information to use.

Result2-sources

Panel A: Average MISP in MFD Decile Portfolio									
	Low	2	3	4	High	H-L	t-stat		
MISP	43.92	46.52	48.83	51.36	55.73	11.81***	18.38		
Panel B: Bivariate Portfolio Sort on MISP									
	Low	2	3	4	High	H-L	t-stat	FF6	t-stat
MISP Low	1.28	1.30	1.25	1.18	0.91	-0.36***	-2.65	-0.29***	-2.78
MISP 2	1.06	1.17	1.08	1.02	0.63	-0.44***	-2.81	-0.33***	-3.21
MISP High	0.73	0.56	0.29	0.22	-0.32	-1.05***	-5.01	-0.67***	-5.21
MISP H-L	-0.54	-0.74	-0.96	-0.96	-1.23	-0.69***	-4.31	-0.38***	-2.60

- high MFD stocks indeed have a higher average mispricing score
- high MISP group have higher MFD H-L portfolio return

Result2-sources

	Panel A: One-day Window		Panel B: Three-day Window	
Dep. variable	Ret_t^d	Ret_t^d	Ret_t^d	Ret_t^d
MFD	-0.26***	-0.32***	-0.25***	-0.31***
	(-6.31)	(-6.84)	(-6.16)	(-6.67)
MFD × EDAY	-0.50***	-0.50***	-0.36***	-0.36***
	(-3.43)	(-3.42)	(-5.18)	(-5.13)
EDAY	0.25***	0.26***	0.15***	0.15***
	(9.28)	(9.44)	(11.60)	(11.78)
Lagged Controls?	No	Yes	No	Yes
Day Fixed Effects?	Yes	Yes	Yes	Yes

- MFD-related mispricing is mainly corrected around earnings announcements, with high-MFD stocks showing stronger negative returns

Result2-sources

Panel A: Average BORROWFEE in MFD Quintile Portfolio									
	Low	2	3	4	High	H-L	t-stat		
BORROWFEE	0.67	0.68	0.88	1.27	3.82	3.15***	8.85		
Panel B: Bivariate Portfolio Sort on BORROWFEE									
	Low	2	3	4	High	H-L	t-stat	FF6	t-stat
BORROWFEE Low	0.92	1.00	0.97	0.89	0.83	-0.09	-0.45	-0.11	-0.78
BORROWFEE 2	1.00	0.98	0.80	0.66	0.28	-0.72**	-2.38	-0.67**	-2.32
BORROWFEE High	0.76	0.33	-0.38	-1.08	-1.94	-2.69***	-5.45	-2.42***	-5.91
BORROWFEE H-L	-0.16	-0.67	-1.35	-1.97	-2.76	-2.60***	-5.89	-2.31***	-5.42
Panel C: Average INST in MFD Quintile Portfolio									
	Low	2	3	4	High	H-L	t-stat		
INST	0.52	0.52	0.51	0.49	0.42	-0.10***	-9.63		
Panel D: Bivariate Portfolio Sort on INST									
	Low	2	3	4	High	H-L	t-stat	FF6	t-stat
INST Low	1.16	0.98	0.81	0.40	-0.30	-1.46***	-5.75	-1.07***	-6.69
INST 2	1.11	1.06	0.96	0.77	0.34	-0.77***	-3.50	-0.43***	-3.53
INST High	1.09	1.02	0.92	0.74	0.56	-0.53***	-2.89	-0.34***	-2.78
INST H-L	-0.07	0.04	0.10	0.34	0.86	0.93***	5.54	0.72***	4.20

- high Short-Sale Contraints group have higher MFD H-L portfolio return

Result2-sources

Panel A: Average ARB in MFD Decile Portfolio									
	Low	2	3	4	High	H-L	t-stat		
ARB	13.38	14.59	15.77	16.83	18.52	5.14***	8.68		
Panel B: Bivariate Portfolio Sort on ARB									
	Low	2	3	4	High	H-L	t-stat	FF6	t-stat
ARB Low	1.00	0.93	0.89	0.81	0.59	-0.41***	-4.03	-0.38***	-4.45
ARB 2	1.14	1.06	1.01	0.86	0.41	-0.73***	-4.07	-0.50***	-4.39
ARB High	1.06	0.76	0.49	0.34	-0.41	-1.48***	-6.30	-0.97***	-5.47
ARB H-L	0.06	-0.17	-0.40	-0.47	-1.01	-1.07***	-5.01	-0.60***	-3.14

- high Limits-to-Arbitrage group have higher MFD H-L portfolio return

Thanks!

Question & idea?

Idea

- 机器模拟人:
  - 模拟散户、机构：使用几个特征，使用 50% 特征
  - earnings 预测-分析师预测, 作为分析师偏差的代理
  - 机器模拟投资者阅读文本/新闻——文本信息的分歧
  - 模拟真实股市：依据股吧等的数据，模拟出不同风格的投资者：情绪、风险偏好等特征来设置模型
- 其他?
  - 在债市中，分歧也十分重要，也存在“分歧指数”，因此该文章的机器学习模拟分歧也可以迁移到债市

Appendix-Q1

Table 1: Descriptive Statistics

	Mean	Sd	10^{th}	Q1	Q2	Q3	90^{th}
RET_{t+1}	0.77	12.94	-12.77	-6.08	0.11	6.71	14.66
MFD	1.93	0.53	1.31	1.52	1.91	2.27	2.64
SUE	-0.08	1.77	-1.89	-0.76	0.01	0.77	1.77
AG	0.29	0.74	-0.07	0.01	0.10	0.26	0.70
MOM	0.23	0.53	-0.27	-0.09	0.12	0.40	0.82
ILLIQ	0.91	2.60	0.00	0.02	0.10	0.55	2.19
OP	0.22	0.39	-0.07	0.11	0.23	0.34	0.50
IVOL	0.03	0.01	0.01	0.02	0.03	0.03	0.04
BETA	1.20	0.62	0.48	0.77	1.12	1.54	2.04
SIZE ($\times 10^{-9}$)	3.74	17.09	0.07	0.17	0.51	1.73	6.12
BM	0.62	0.46	0.16	0.29	0.51	0.83	1.22
MAX	0.04	0.02	0.02	0.02	0.03	0.05	0.06
TURN ($\times 10^{3}$)	6.25	9.82	1.24	2.51	4.44	7.41	12.00
STR	0.02	0.12	-0.11	-0.05	0.01	0.08	0.16
AFD	0.16	0.42	0.01	0.02	0.05	0.11	0.31