

Replicate " (Re-)Imag(in)ing Price Trends"

by Jingwen Jiang, Bryan Kelly, and Dacheng Xiu (2021)

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<https://youtu.be/xy2grOVvr2k>

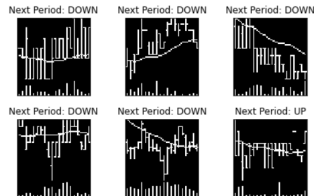
- Main findings of Jiang et al. (2021):
 - Use image as inputs for price trend prediction
 - Apply CNN to detect price pattern
 - Give more accurate return predictions and translate into profitable investment strategies
- Our tasks:
 - Construct a CNN model to learn stock price patterns
 - Evaluate the performance of the trained CNN model
- Our findings:
 - CNN predictions beat random guess and form profitable portfolios
 - Profitable returns cannot be explained by current asset pricing model and driven by **small** firms
 - The portfolio requires high turnover rate, which may dry out the profits

Agenda

- Data preparation
- Model design
- Model training
- Performance evaluation

Data preparation

- Input: 20-day OHLC images from 1993 to 2019 in 64*60 gray scale
- Label: 1 if next 20-day return is positive, and 0 otherwise
- Drop data and labels if no future return available

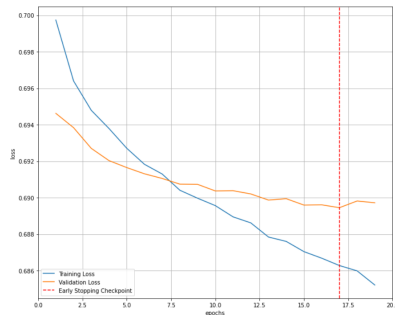


- Follow Jiang et al. (2021)'s architecture
- Make some modifications:
 - Convolution layers: vertical dilation of 4
 - Pool layers: vertical stride of 2
- Characterize with the same number of parameters as Jiang et al. (2021)

Layer (type)	Output Shape	Param #
Conv2d-1	[-1, 64, 48, 60]	1,024
BatchNorm2d-2	[-1, 64, 48, 60]	128
LeakyReLU-3	[-1, 64, 48, 60]	0
MaxPool2d-4	[-1, 64, 24, 60]	0
Conv2d-5	[-1, 128, 20, 60]	123,008
BatchNorm2d-6	[-1, 128, 20, 60]	256
LeakyReLU-7	[-1, 128, 20, 60]	0
MaxPool2d-8	[-1, 128, 10, 60]	0
Conv2d-9	[-1, 256, 6, 60]	491,776
BatchNorm2d-10	[-1, 256, 6, 60]	512
LeakyReLU-11	[-1, 256, 6, 60]	0
MaxPool2d-12	[-1, 256, 3, 60]	0
Linear-13	[-1, 2]	92,162
Dropout-14	[-1, 2]	0
Softmax-15	[-1, 2]	0
Total params: 708,866		
Trainable params: 708,866		
Non-trainable params: 0		
Input size (MB): 0.01		
Forward/backward pass size (MB): 11.48		
Params size (MB): 2.70		
Estimated Total Size (MB): 14.20		

Model training

- Data split: 1993-2000 data, among which we randomly select 70% as training set and use the rest as validation set. We test model with 2001-2019 data.
- Loss function: Cross-entropy loss function
- Optimizer: Adam algorithm with $1e5$ learning rate
- Regularization: Xavier parameter initializer, batch normalization within each block, 50% dropout in FC layer, early stopping of patience 2



Performance evaluation

Accuracy

- The CNN's out-of-sample classification accuracy at the stock level is 51.8% for image sizes 20 days and forecast horizons 20 days. The significant level is over 99.9%.

Out-of-Sample Classification Accuracy (Null: mean = 0.5)

accuracy	estimate	statistic	p.value
Total	0.52	6.38	0.00
Sensitivity	0.53	2.17	0.03
Specificity	0.50	0.29	0.77
Balanced	0.51	13.75	0.00

¹ The Table reports out-of-sample forecast performance for imaged-based CNN models and benchmark signals.

² We calculate classification accuracy each period then report time series averages over each period in the test sample.

³ Total Accuracy = $(TP+TN)/(TP+FP+TN+FN)$

⁴ sensitivity = $TP/(TP+FP)$

⁵ specification = $TN/(TN+FN)$

⁶ Balanced accuracy = $0.5*(sensitivity + specification)$

Performance evaluation

Average return

- Decile 1, which corresponds to stocks having the lowest probability of a positive future return indeed realize lowest return.
- Average return increase monotonically across predicted “up” probability deciles.

Performance of Portfolios: Average Returns in 10 Single-Sorted Portfolios

type	estimate	stat	Lowest	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Highest	H_L
EW	Average ret	param	0.21	0.60	0.74	0.87	0.89	0.95	0.97	1.08	1.17	1.26	1.05***
EW	Average ret	T	(0.45)	(1.39)	(1.69)	(2.04)	(2.19)	(2.32)	(2.42)	(2.72)	(2.95)	(3.40)	(6.83)
VW	Average ret	param	0.57	0.60	0.49	0.69	0.72	0.71	0.58	0.65	0.76	0.75	0.18
VW	Average ret	T	(1.44)	(1.57)	(1.41)	(2.08)	(2.13)	(2.16)	(1.96)	(2.01)	(2.61)	(2.51)	(0.97)
EW_TC	Average ret	param	-0.69	-0.30	-0.17	-0.04	-0.02	0.04	0.06	0.17	0.26	0.35	0.03
EW_TC	Average ret	T	(-1.52)	(-0.70)	(-0.39)	(-0.10)	(-0.06)	(0.09)	(0.15)	(0.44)	(0.66)	(0.95)	(0.21)
VW_TC	Average ret	param	-0.37	-0.34	-0.44	-0.24	-0.2	-0.2	-0.33	-0.24	-0.15	-0.14	-0.84***
VW_TC	Average ret	T	(-0.95)	(-0.91)	(-1.30)	(-0.74)	(-0.61)	(-0.63)	(-1.14)	(-0.75)	(-0.52)	(-0.47)	(-4.37)

¹ Performance of decile portfolios sorted on out-of-sample predicted up probability for next month (20-days).

² Monthly average returns (in percentage) accompanied by , , are significant at the 1%, 5%, and 10% significance level, respectively.

³ EW and VW represents equal-weighted and value-weighted respectively; TC indicates whether we consider the trading cost.

⁴ We assume transaction fees of 0.5% for the total dollar amount traded.

Performance evaluation

Average return

- For the VW portfolio, the slope is relative flatter and the H-L portfolios has no significant average returns.
- Considering the transaction cost, the 0.5% trading cost and monthly re-balancing will shift the average return downward both for EW and VW portfolio.

Performance of Portfolios: Average Returns in 10 Single-Sorted Portfolios

type	estimate	stat	Lowest	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Highest	H_L
EW	Average ret	param	0.21	0.60	0.74	0.87	0.89	0.95	0.97	1.08	1.17	1.26	1.05***
EW	Average ret	T	(0.45)	(1.39)	(1.69)	(2.04)	(2.19)	(2.32)	(2.42)	(2.72)	(2.95)	(3.40)	(6.83)
VW	Average ret	param	0.57	0.60	0.49	0.69	0.72	0.71	0.58	0.65	0.76	0.75	0.18
VW	Average ret	T	(1.44)	(1.57)	(1.41)	(2.08)	(2.13)	(2.16)	(1.96)	(2.01)	(2.61)	(2.51)	(0.97)
EW_TC	Average ret	param	-0.69	-0.30	-0.17	-0.04	-0.02	0.04	0.06	0.17	0.26	0.35	0.03
EW_TC	Average ret	T	(-1.52)	(-0.70)	(-0.39)	(-0.10)	(-0.06)	(0.09)	(0.15)	(0.44)	(0.66)	(0.95)	(0.21)
VW_TC	Average ret	param	-0.37	-0.34	-0.44	-0.24	-0.2	-0.2	-0.33	-0.24	-0.15	-0.14	-0.84***
VW_TC	Average ret	T	(-0.95)	(-0.91)	(-1.30)	(-0.74)	(-0.61)	(-0.63)	(-1.14)	(-0.75)	(-0.52)	(-0.47)	(-4.37)

¹ Performance of decile portfolios sorted on out-of-sample predicted up probability for next month (20-days).

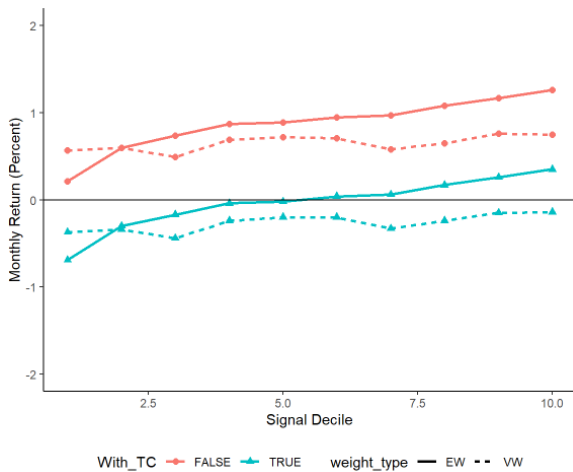
² Monthly average returns (in percentage) accompanied by , , are significant at the 1%, 5%, and 10% significance level, respectively.

³ EW and VW represents equal-weighted and value-weighted respectively; TC indicates whether we consider the trading cost.

⁴ We assume transaction fees of 0.5% for the total dollar amount traded.

Performance evaluation

Average return



Performance evaluation

Sharpe Ratio and Turnover

- Sharpe Ratio has similar pattern as the average returns.
- The turnover rate is quite similar across deciles, on average 180%.
- Under 0.05% trading cost per dollar, **All profits are eaten.**

Out-of-Sample Sharpe Ratio and Turnover

weight_type	statistic	Lowest	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Highest	H-L
EW	SharpeRatio	0.06	0.30	0.38	0.47	0.48	0.53	0.55	0.62	0.67	0.76	1.57
EW	Turnvoer	1.79	1.81	1.82	1.82	1.82	1.83	1.83	1.82	1.82	1.82	2.04
EW	SharpeRatio_tc	-0.49	-0.26	-0.18	-0.10	-0.09	-0.05	-0.04	0.04	0.09	0.15	-0.14
VW	SharpeRatio	0.31	0.35	0.28	0.44	0.47	0.47	0.37	0.42	0.51	0.50	0.08
VW	Turnvoer	1.89	1.88	1.86	1.85	1.84	1.83	1.83	1.80	1.81	1.79	2.05
VW	SharpeRatio_tc	-0.33	-0.33	-0.41	-0.28	-0.25	-0.25	-0.36	-0.28	-0.21	-0.20	-1.11

¹ Performance of decile portfolios sorted on out-of-sample predicted up probability for next month (20-days).

² Each panel reports the annualized sharpe ratio and average turnover rate

³ EW and VW represents equal-weighted and value-weighted respectively; TC indicates whether we consider the trading cost.

⁴ We assume transaction fees of 0.5% for the total dollar amount traded.

Performance evaluation

What can Asset Pricing Theory say?

- Leading asset pricing model can not explain the abnormal return/mis-pricing sorted by the predictors offered by CNN model in equally weighed portfolios. **Something new here**

Alphas in 10 Single-Sorted Portfolios

type	estimate	stat	Lowest	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Highest	H_L
EW													
EW	FF6 Alpha	param	-0.51	-0.14	-0.02	0.11	0.09	0.17	0.20	0.27	0.36	0.47	0.98***
EW	FF6 Alpha	T	(-3.71)	(-1.32)	(-0.18)	(1.04)	(1.06)	(1.84)	(2.32)	(3.21)	(3.84)	(5.25)	(6.15)
EW	Q5_ Alpha	param	-0.36	-0.05	0.06	0.20	0.21	0.25	0.30	0.36	0.44	0.52	0.88***
EW	Q5_ Alpha	T	(-3.04)	(-0.45)	(0.56)	(2.08)	(2.29)	(2.99)	(3.43)	(4.36)	(5.17)	(5.58)	(5.68)
EW	SY4 Alpha	param	-0.41	-0.07	0.06	0.17	0.15	0.21	0.25	0.32	0.42	0.50	0.92***
EW	SY4 Alpha	T	(-2.97)	(-0.68)	(0.51)	(1.49)	(1.61)	(1.92)	(2.76)	(2.95)	(3.62)	(5.06)	(6.04)
EW	BF3 Alpha	param	-0.39	-0.03	0.12	0.22	0.25	0.32	0.31	0.42	0.51	0.58	0.96***
EW	BF3 Alpha	T	(-2.00)	(-0.15)	(0.68)	(1.31)	(1.71)	(1.83)	(1.98)	(2.56)	(2.84)	(3.30)	(5.41)
VW													
VW	FF6 Alpha	param	-0.13	-0.07	-0.20	-0.03	0.03	0.01	-0.08	-0.00	0.14	0.11	0.24
VW	FF6 Alpha	T	(-1.11)	(-0.55)	(-2.37)	(-0.30)	(0.33)	(0.09)	(-0.80)	(-0.03)	(1.49)	(1.28)	(1.42)
VW	Q5_ Alpha	param	-0.09	-0.03	-0.22	0.03	0.10	0.04	-0.05	-0.00	0.11	0.08	0.17
VW	Q5_ Alpha	T	(-0.91)	(-0.25)	(-2.41)	(0.29)	(1.04)	(0.44)	(-0.51)	(-0.01)	(1.38)	(0.90)	(1.19)
VW	SY4 Alpha	param	-0.08	-0.06	-0.22	-0.00	0.06	0.03	-0.08	-0.02	0.12	0.10	0.19
VW	SY4 Alpha	T	(-0.76)	(-0.45)	(-2.52)	(-0.01)	(0.58)	(0.30)	(-0.77)	(-0.20)	(1.40)	(1.21)	(1.18)
VW	BF3 Alpha	param	-0.14	-0.02	-0.23	-0.01	0.06	0.04	-0.09	0.01	0.12	0.09	0.23
VW	BF3 Alpha	T	(-1.15)	(-0.19)	(-2.36)	(-0.16)	(0.64)	(0.44)	(-0.87)	(0.18)	(1.25)	(0.94)	(1.29)

Performance evaluation

What can Asset Pricing Theory say?

- Alpha disappears once we use value weighted approach. **Size matters**
- Considering the trading cost, both EW/VW approach will not generate practical profits.

Alphas in 10 Single-Sorted Portfolios

type	estimate	stat	Lowest	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Highest	H_L
EW_TC													
EW_TC	FF6 Alpha	param	-1.41	-1.04	-0.92	-0.79	-0.81	-0.74	-0.71	-0.63	-0.55	-0.44	-0.15
EW_TC	FF6 Alpha	T	(-10.23)	(-9.66)	(-8.12)	(-7.43)	(-9.17)	(-7.96)	(-8.44)	(-7.55)	(-6.00)	(-5.01)	(-0.96)
EW_TC	Q5_Alpha	param	-1.25	-0.95	-0.85	-0.71	-0.70	-0.66	-0.60	-0.55	-0.46	-0.39	-0.25
EW_TC	Q5_Alpha	T	(-10.63)	(-8.83)	(-8.40)	(-7.57)	(-7.67)	(-8.10)	(-6.89)	(-6.82)	(-5.46)	(-4.22)	(-1.67)
EW_TC	SY4 Alpha	param	-1.30	-0.97	-0.85	-0.74	-0.75	-0.70	-0.65	-0.59	-0.48	-0.40	-0.21
EW_TC	SY4 Alpha	T	(-9.49)	(-9.51)	(-7.32)	(-6.68)	(-8.06)	(-6.40)	(-7.24)	(-5.53)	(-4.21)	(-4.10)	(-1.44)
EW_TC	BF3 Alpha	param	-1.28	-0.93	-0.78	-0.68	-0.65	-0.59	-0.60	-0.49	-0.40	-0.33	-0.17
EW_TC	BF3 Alpha	T	(-6.69)	(-5.48)	(-4.32)	(-4.03)	(-4.44)	(-3.47)	(-3.82)	(-2.99)	(-2.23)	(-1.88)	(-0.96)
VW_TC													
VW_TC	FF6 Alpha	param	-1.07	-1	-1.13	-0.95	-0.88	-0.9	-0.98	-0.9	-0.77	-0.78	-0.89***
VW_TC	FF6 Alpha	T	(-9.17)	(-8.15)	(-13.28)	(-10.79)	(-8.62)	(-10.58)	(-10.43)	(-11.41)	(-8.50)	(-8.68)	(-5.14)
VW_TC	Q5_Alpha	param	-1.03	-0.96	-1.14	-0.9	-0.82	-0.87	-0.95	-0.89	-0.79	-0.81	-0.96***
VW_TC	Q5_Alpha	T	(-10.09)	(-7.58)	(-12.76)	(-10.53)	(-8.85)	(-10.05)	(-10.09)	(-10.49)	(-10.29)	(-9.67)	(-6.82)
VW_TC	SY4 Alpha	param	-1.02	-0.99	-1.15	-0.92	-0.85	-0.89	-0.99	-0.91	-0.78	-0.79	-0.94***
VW_TC	SY4 Alpha	T	(-9.23)	(-8.19)	(-13.03)	(-10.13)	(-8.49)	(-10.51)	(-9.57)	(-11.20)	(-9.48)	(-9.29)	(-5.87)
VW_TC	BF3 Alpha	param	-1.08	-0.96	-1.15	-0.93	-0.85	-0.87	-1	-0.88	-0.78	-0.8	-0.9***
VW_TC	BF3 Alpha	T	(-8.88)	(-8.09)	(-12.20)	(-10.67)	(-8.56)	(-10.38)	(-9.69)	(-10.79)	(-8.01)	(-8.38)	(-5.04)