Currency Market Insights: Machine Learning for JPY-USD Exchange Rate Prediction

Yu Gu
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Brown University

GitHub repository:
https://github.com/KelvinG991/Final

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Recap

Objectives

The goal

JPY-USD exchange rate prediction
(Regression Problem)

The reasons

- Monetary Policy adjusting
- Economic Stability
- Risk Management
- ...

Resources - Federal Reserve Bank of St. Louis

$$R_{\$} = R_{€} + (E^{e}_{\$/€} - E^{1}_{\$/€})/E^{1}_{\$/€},$$

Spot Exchange Rate for JPY-USD (1971-2023)

Japanese Yen to U.S. Dollar Spot Exchange Rate, Japanese Yen to One U.S. Dollar, Monthly, Not Seasonally Adjusted

https://fred.stlouisfed.org/series/EXJPUS

Spot Interest Rate for JP (1971-2017)

Interest Rates, Discount Rate for Japan, Percent per Annum, Monthly, Not Seasonally Adjusted

https://fred.stlouisfed.org/series/INTDSRJPM193N

Spot Interest Rate for USA (1971-2023)

3-Month Treasury Bill Secondary Market Rate, Discount Basis, Percent, Monthly, Not Seasonally Adjusted

https://fred.stlouisfed.org/series/TB3MS

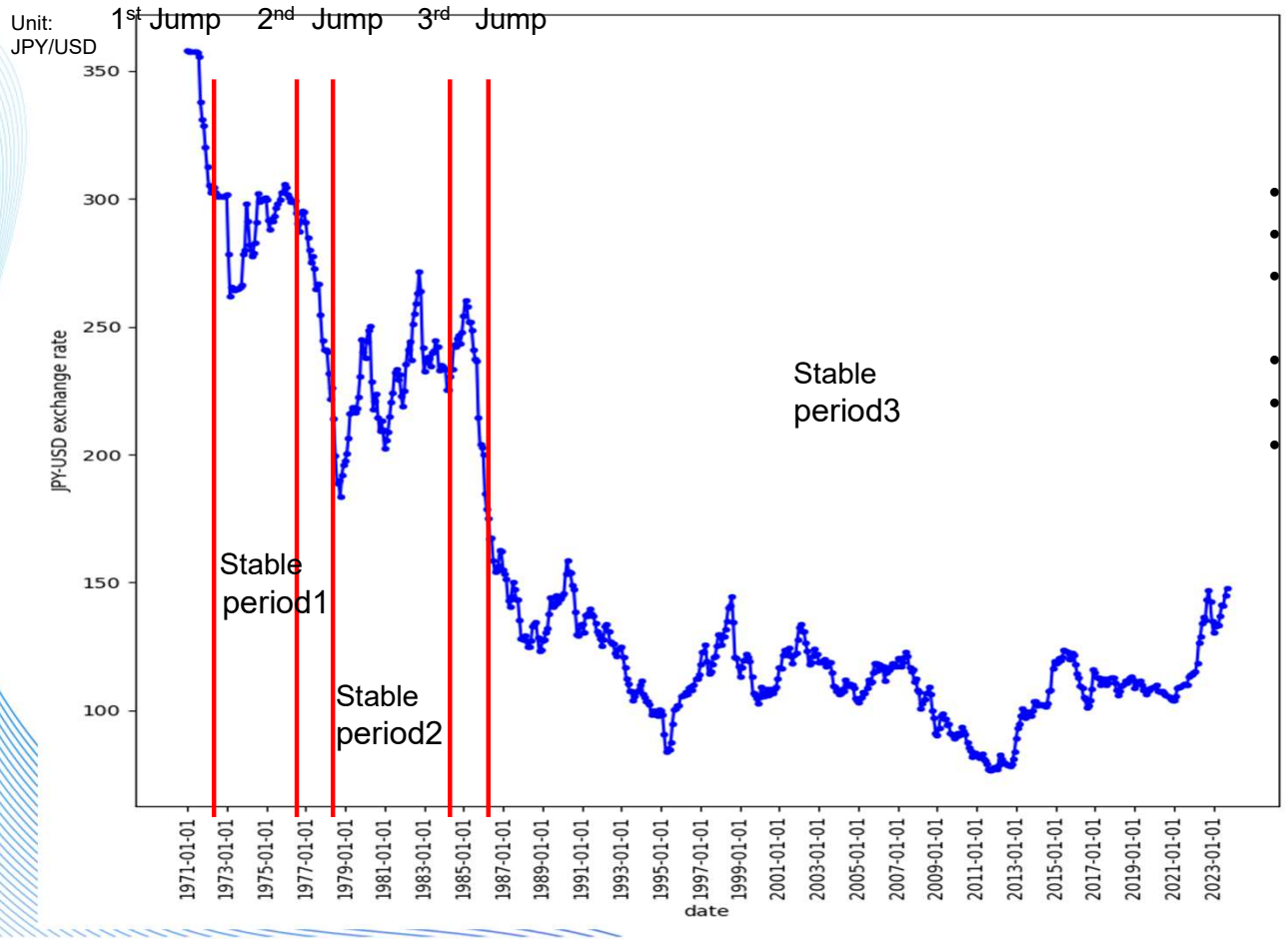
Intro of raw data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
1	date	Ex	ExLag1	ExLag2	ExLag3	ExLag4	ExLag5	ExLag6	ExLag7	ExLag8	ExLag9	ExLag10	R1	R1Lag1	R1Lag2	R1Lag3	R1Lag4	R1Lag5	R1Lag6	R1Lag7	R1Lag8	R1Lag9	R1Lag10	R2	R2Lag1	R2Lag2	R2Lag3	R2Lag4	R2Lag5	R2Lag6	R2Lag7	R2Lag8	R2Lag9	R2Lag10
2	1971/01/01	358.02											4.44											5.75										
3	1971/02/01	357.545											3.7											5.75										
4	1971/03/01	357.5187											3.38											5.75										
5	1971/04/01	357.5032											3.86											5.75										
6	1971/05/01	357.413											4.14											5.5										
7	1971/06/01	357.4118											4.75											5.5										
8	1971/07/01	357.4043											5.4											5.25										
9	1971/08/01	355.78											4.94											5.25										
10	1971/09/01	338.021											4.69											5.25										
11	1971/10/01	331.1105											4.46											5.25										
12	1971/11/01	328.752	331.11	338.02	355.78	357.4	357.41	357.41	357.5	357.52	357.55	358.02	4.22	4.46	4.69	4.94	5.4	4.75	4.14	3.86	3.38	3.7	4.44	5.25	5.25	5.25	5.25	5.25	5.5	5.5	5.75	5.75	5.75	5.75
13	1971/12/01	320.0727	328.75	331.11	338.02	355.78	357.4	357.41	357.41	357.5	357.52	357.55	4.01	4.22	4.46	4.69	4.94	5.4	4.75	4.14	3.86	3.38	3.7	4.75	5.25	5.25	5.25	5.25	5.25	5.25	5.5	5.5	5.75	5.75	5.75
14	1972/01/01	312.72	320.07	328.75	331.11	338.02	355.78	357.4	357.41	357.41	357.5	357.52	3.38	4.01	4.22	4.46	4.69	4.94	5.4	4.75	4.14	3.86	3.38	4.75	4.75	5.25	5.25	5.25	5.25	5.25	5.5	5.5	5.75	5.75
15	1972/02/01	305.187	312.72	320.07	328.75	331.11	338.02	355.78	357.4	357.41	357.41	357.5	3.2	3.38	4.01	4.22	4.46	4.69	4.94	5.4	4.75	4.14	3.86	4.75	4.75	4.75	5.25	5.25	5.25	5.25	5.25	5.5	5.5	5.75
16	1972/03/01	302.5365	305.19	312.72	320.07	328.75	331.11	338.02	355.78	357.4	357.41	357.41	3.73	3.2	3.38	4.01	4.22	4.46	4.69	4.94	5.4	4.75	4.14	4.75	4.75	4.75	4.75	5.25	5.25	5.25	5.25	5.25	5.5	5.5
17	1972/04/01	303.5605	302.54	305.19	312.72	320.07	328.75	331.11	338.02	355.78	357.4	357.41	3.71	3.73	3.2	3.38	4.01	4.22	4.46	4.69	4.94	5.4	4.75	4.75	4.75	4.75	4.75	4.75	5.25	5.25	5.25	5.25	5.25	5.5
18	1972/05/01	304.3795	303.56	302.54	305.19	312.72	320.07	328.75	331.11	338.02	355.78	357.4	3.69	3.71	3.73	3.2	3.38	4.01	4.22	4.46	4.69	4.94	5.4	4.75	4.75	4.75	4.75	4.75	4.75	5.25	5.25	5.25	5.25	5.25
19	1972/06/01	302.4145	304.38	303.56	302.54	305.19	312.72	320.07	328.75	331.11	338.02	355.78	3.91	3.69	3.71	3.73	3.2	3.38	4.01	4.22	4.46	4.69	4.94	4.25	4.75	4.75	4.75	4.75	4.75	4.75	5.25	5.25	5.25	5.25
20	1972/07/01	301.0305	302.41	304.38	303.56	302.54	305.19	312.72	320.07	328.75	331.11	338.02	3.98	3.91	3.69	3.71	3.73	3.2	3.38	4.01	4.22	4.46	4.69	4.25	4.25	4.75	4.75	4.75	4.75	4.75	4.75	5.25	5.25	5.25
21	1972/08/01	301.1609	301.03	302.41	304.38	303.56	302.54	305.19	312.72	320.07	328.75	331.11	4.02	3.98	3.91	3.69	3.71	3.73	3.2	3.38	4.01	4.22	4.46	4.25	4.25	4.25	4.75	4.75	4.75	4.75	4.75	4.75	5.25	5.25
22	1972/09/01	301.119	301.16	301.03	302.41	304.38	303.56	302.54	305.19	312.72	320.07	328.75	4.66	4.02	3.98	3.91	3.69	3.71	3.73	3.2	3.38	4.01	4.22	4.25	4.25	4.25	4.25	4.75	4.75	4.75	4.75	4.75	4.75	5.25
23	1972/10/01	301.011	301.12	301.16	301.03	302.41	304.38	303.56	302.54	305.19	312.72	320.07	4.74	4.66	4.02	3.98	3.91	3.69	3.71	3.73	3.2	3.38	4.01	4.25	4.25	4.25	4.25	4.25	4.75	4.75	4.75	4.75	4.75	4.75
24	1972/11/01	300.9885	301.01	301.12	301.16	301.03	302.41	304.38	303.56	302.54	305.19	312.72	4.78	4.74	4.66	4.02	3.98	3.91	3.69	3.71	3.73	3.2	3.38	4.25	4.25	4.25	4.25	4.25	4.25	4.75	4.75	4.75	4.75	4.75
25	1972/12/01	301.2405	300.99	301.01	301.12	301.16	301.03	302.41	304.38	303.56	302.54	305.19	5.07	4.78	4.74	4.66	4.02	3.98	3.91	3.69	3.71	3.73	3.2	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.75	4.75	4.75	4.75
26	1973/01/01	301.7882	301.24	300.99	301.01	301.12	301.16	301.03	302.41	304.38	303.56	302.54	5.41	5.07	4.78	4.74	4.66	4.02	3.98	3.91	3.69	3.71	3.73	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.75	4.75	4.75
27	1973/02/01	278.4206	301.79	301.24	300.99	301.01	301.12	301.16	301.03	302.41	304.38	303.56	5.6	5.41	5.07	4.78	4.74	4.66	4.02	3.98	3.91	3.69	3.71	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.75	4.75
28	1973/03/01	261.9014	278.42	301.79	301.24	300.99	301.01	301.12	301.16	301.03	302.41	304.38	6.09	5.6	5.41	5.07	4.78	4.74	4.66	4.02	3.98	3.91	3.69	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.75
29	1973/04/01	265.4914	261.9	278.42	301.79	301.24	300.99	301.01	301.12	301.16	301.03	302.41	6.26	6.09	5.6	5.41	5.07	4.78	4.74	4.66	4.02	3.98	3.91	5	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25
30	1973/05/01	264.6505	265.49	261.9	278.42	301.79	301.24	300.99	301.01	301.12	301.16	301.03	6.36	6.26	6.09	5.6	5.41	5.07	4.78	4.74	4.66	4.02	3.98	5.5	5	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25
31	1973/06/01	264.4981	264.65	265.49	261.9	278.42	301.79	301.24	300.99	301.01	301.12	301.16	7.19	6.36	6.26	6.09	5.6	5.41	5.07	4.78	4.74	4.66	4.02	5.5	5.5	5	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25
32	1973/07/01	264.5538	264.5	264.65	265.49	261.9	278.42	301.79	301.24	300.99	301.01	301.12	8.01	7.19	6.36	6.26	6.09	5.6	5.41	5.07	4.78	4.74	4.66	6	5.5	5.5	5	4.25	4.25	4.25	4.25	4.25	4.25	4.25
33	1973/08/01	265.22	264.55	264.5	264.65	265.49	261.9	278.42	301.79	301.24	300.99	301.01	8.67	8.01	7.19	6.36	6.26	6.09	5.6	5.41	5.07	4.78	4.74	7	6	5.5	5.5	5	4.25	4.25	4.25	4.25	4.25	4.25
34	1973/09/01	265.4747	265.22	264.55	264.5	264.65	265.49	261.9	278.42	301.79	301.24	300.99	8.29	8.67	8.01	7.19	6.36	6.26	6.09	5.6	5.41	5.07	4.78	7	7	6	5.5	5.5	5	4.25	4.25	4.25	4.25	4.25
35	1973/10/01	266.3348	265.47	265.22	264.55	264.5	264.65	265.49	261.9	278.42	301.79	301.24	7.22	8.29	8.67	8.01	7.19	6.36	6.26	6.09	5.6	5.41	5.07	7	7	7	6	5.5	5.5	5	4.25	4.25	4.25	4.25
36	1973/11/01	278.2625	266.33	265.47	265.22	264.55	264.5	264.65	265.49	261.9	278.42	301.79	7.83	7.22	8.29	8.67	8.01	7.19	6.36	6.26	6.09	5.6	5.41	7	7	7	7	6	5.5	5.5	5	4.25	4.25	4.25
37	1973/12/01	280.1775	278.26	266.33	265.47	265.22	264.55	264.5	264.65	265.49	261.9	278.42	7.45	7.83	7.22	8.29	8.67	8.01	7.19	6.36	6.26	6.09	5.6	9	7	7	7	7	6	5.5	5.5	5	4.25	4.25
38	1974/01/01	298.1336	280.18	278.26	266.33	265.47	265.22	264.55	264.5	264.65	265.49	261.9	7.77	7.45	7.83	7.22	8.29	8.67	8.01	7.19	6.36	6.26	6.09	9	9	7	7	7	7	6	5.5	5.5	5	4.25
39	1974/02/01	291.0872	298.13	280.18	278.26	266.33	265.47	265.22	264.55	264.5	264.65	265.49	7.12	7.77	7.45	7.83	7.22	8.29	8.67	8.01	7.19	6.36	6.26	9	9	9	7	7	7	7	6	5.5	5.5	5
40	1974/03/01	282.1648	291.09	298.13	280.18	278.26	266.33	265.47	265.22	264.55	264.5	264.65	7.96	7.12	7.77	7.45	7.83	7.22	8.29	8.67	8.01	7.19	6.36	9	9	9	9	7	7	7	7	6	5.5	5.5
41	1974/04/01	277.7741	282.16	291.09	298.13	280.18	278.26	266.33	265.47	265.22	264.55	264.5	8.33	7.96	7.12	7.77	7.45	7.83	7.22	8.29	8.67	8.01	7.19	9	9	9	9	9	7	7	7	7	6	5.5
42	1974/05/01	278.9664	277.77	282.16	291.09	298.13	280.18	278.26	266.33	265.47	265.22	264.55	8.23	8.33	7.96	7.12	7.77	7.45	7.83	7.22	8.29	8.67	8.01	9	9	9	9	9	9	7	7	7	7	6
43	1974/06/01	282.97	278.97	277.77	282.16	291.09	298.13	280.18	278.26	266.33	265.47	265.22	7.9	8.23	8.33	7.96	7.12	7.77	7.45	7.83	7.22	8.29	8.67	9	9	9	9	9	9	9	7	7	7	7
44	1974/07/01	290.98	282.97	278.97	277.77	282.16	291.09	298.13	280.18	278.26	266.33	265.47	7.55	7.9	8.23	8.33	7.96	7.12	7.77	7.45	7.83	7.22	8.29	9	9	9	9	9	9	9	9	7	7	7
45	1974/08/01	302.2836	290.98	282.97	278.97	277.77	282.16	291.09	298.13	280.18	278.26	266.33	8.96	7.55	7.9	8.23	8.33	7.96	7.12	7.77	7.45	7.83	7.22	9	9	9	9	9	9	9	9	9	7	7
46	1974/09/01	299.084	302.28	290.98	282.97	278.97	277.77	282.16	291.09	298.13	280.18	278.26	8.06	8.96	7.55	7.9	8.23	8.33	7.96	7.12	7.77	7.45	7.83	9	9	9	9	9	9	9	9	9	9	7
47	1974/10/01	299.3645	299.08	302.28	290.98	282.97	278.97	277.77	282.16	291.09	298.13	280.18	7.46	8.06	8.96	7.55	7.9	8.23	8.33	7.96	7.12	7.77	7.45	9	9	9	9	9	9	9	9	9	9	9
48	1974/11/01	300.075	299.36	299.08	302.28	290.98	282.97	278.97	277.77	282.16	291.09	298.13	7.47	7.46	8.06	8.96	7.55	7.9	8.23	8.33	7.96	7.12	7.77	9	9	9	9	9	9	9	9	9	9	9
49	1974/12/01	300.4114	300.08	299.36	299.08	302.28	290.98	282.97	278.97	277.77	282.16	291.09	7.15	7.47	7.46	8.06	8.96	7.55	7.9	8.23	8.33	7.96	7.12	9	9	9	9	9	9	9	9	9	9	9
50	1975/01/01	299.6845	300.41	300.08	299.36	299.08	302.28	290.98	282.97	278.97	277.77	282.16	6.26	7.15	7.47	7.46	8.06	8.96	7.55	7.9	8.23	8.33	7.96	9	9	9	9	9	9	9	9	9	9	9
51	1975/02/01	291.6583	299.68	300.41	300.08	299.36	299.08	302.28	290.98	282.97	278.97	277.77	5.5	6.26	7.15	7.47	7.46	8.06	8.96	7.55	7.9	8.23	8.33	9	9	9	9	9	9	9	9	9	9	9
52	1975/03/01	287.9486	291.66	299.68	300.41	300.08	299.36	299.08	302.28	290.98	282.97	278.97	5.49	5.5	6.26	7.15	7.47	7.46	8.06	8.96	7.55	7.9	8.23	9	9	9	9	9	9	9	9	9	9	9
53	1975/04/01	292.1968	287.95	291.66	299.68	300.41	300.08	299.36	299.08	302.28	290.98	282.97	5.61	5.49	5.5	6.26	7.15	7.47	7.46	8.06	8.96	7.55	7.9	8.5	9	9	9	9	9	9	9	9	9	9

Target variable: Ex

Features: ExLag1-10, R1, R1Lag1-10, R2, R2Lag1-10

Features of JPY-USD exchange rate trend



Features:

- 1st Jump: collapse of Bretton Woods System
- 1st stable period: 1973-1977
- 2nd Jump: President Carter's move to halt Dollar decline&2nd Oil Shock
- 2nd stable period: 1979-1985
- 3rd Jump: Plaza Accord&Louvre Accord
- 3rd stable period: 1987-

Intro of raw data

- Non-iid
- Missing continuous data included
- Method: LinearRegression

```
data dimensions of test set: (88, 32)
fraction of missing values in features:
std__R2          0.875
std__R2Lag1      0.875
std__R2Lag2      0.875
std__R2Lag3      0.875
std__R2Lag4      0.875
std__R2Lag5      0.875
std__R2Lag6      0.875
std__R2Lag7      0.875
std__R2Lag8      0.875
std__R2Lag9      0.875
std__R2Lag10     0.875
dtype: float64
fraction of points with missing values: 0.875
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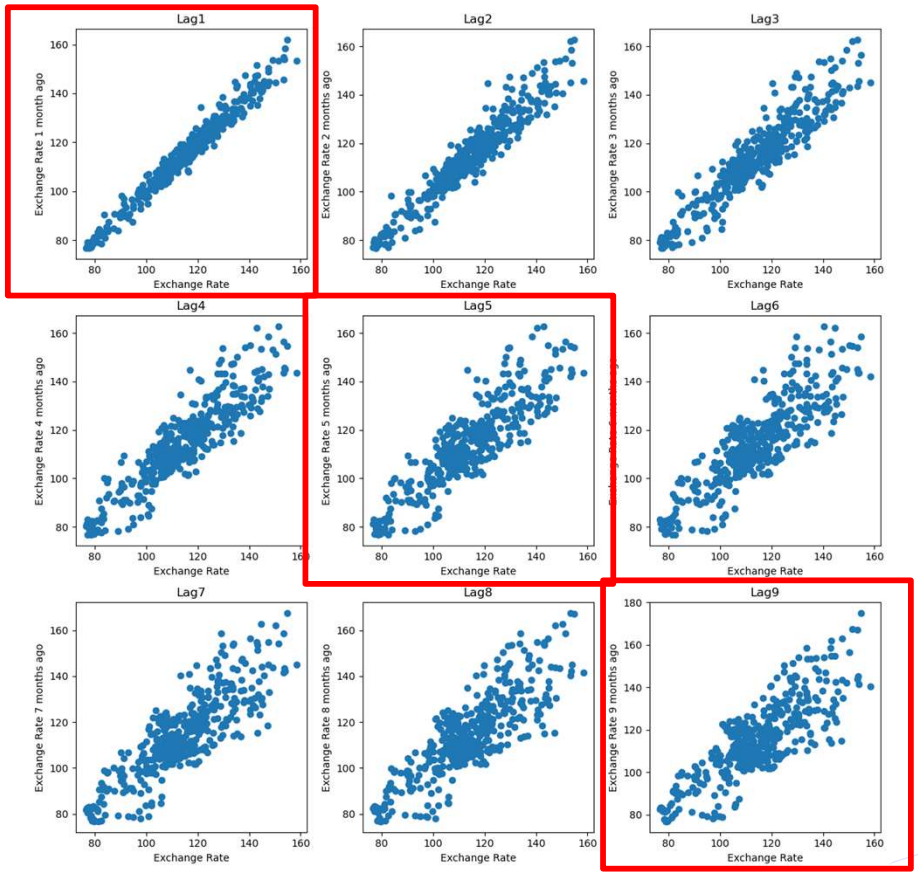
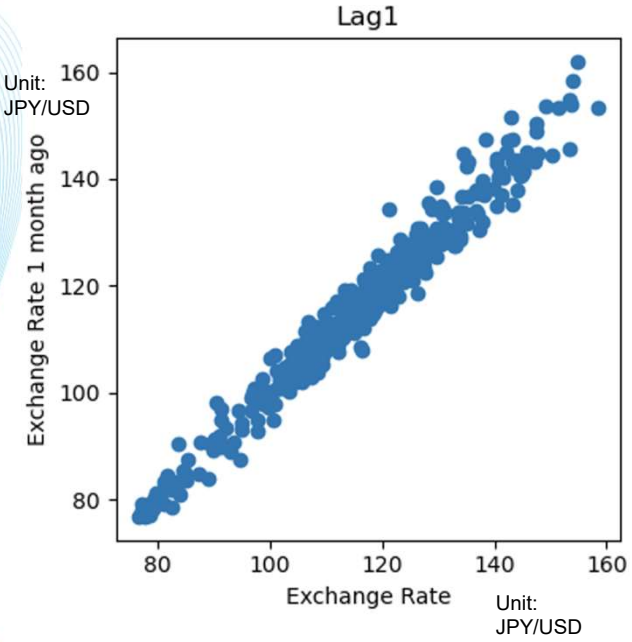
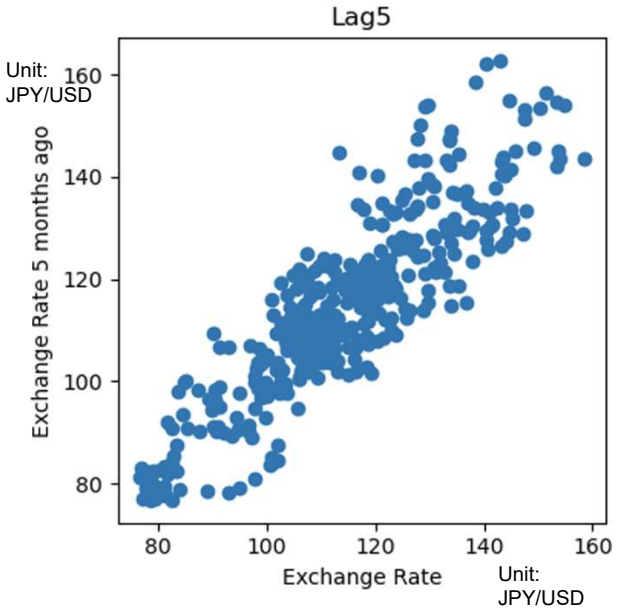
Features of the relationship between the current JPY-USD exchange rate and the former exchange rates

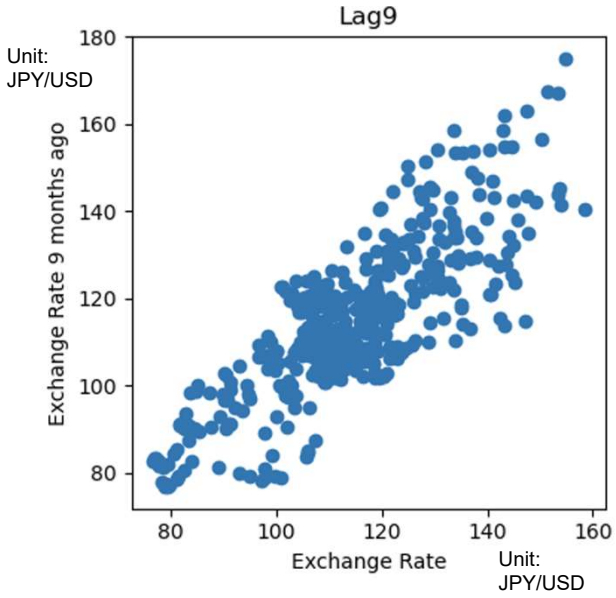


Relationship between exchange rate and former exchange rate

Features of the relationship between the current JPY-USD exchange rate and the former exchange rates





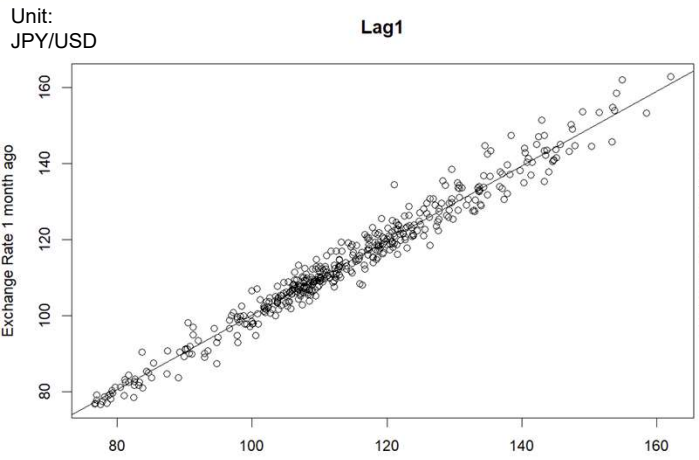


Features:

- Strong linear relationship between current and past exchange rate
- Strong linear relationship holds even between exchange rate 9 months ago

Features of the relationship between the current JPY-USD exchange rate and the former exchange rates

Unit:
JPY/USD



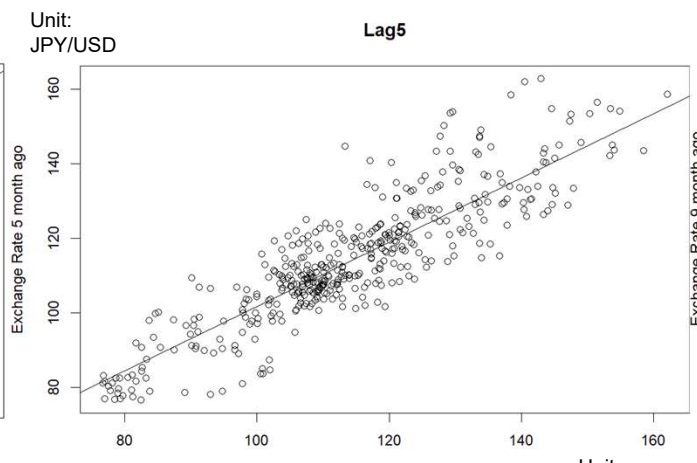
Exchange Rate

Unit:
JPY/USD

(Intercept)	2.31 *
	(0.97)
dataex$ExLag1	0.98 ***
	(0.01)
R^2	0.97
Adj. R^2	0.97
Num. obs.	442
RMSE	2.97

*** p < 0.001; ** p < 0.01; * p < 0.05

Unit:
JPY/USD



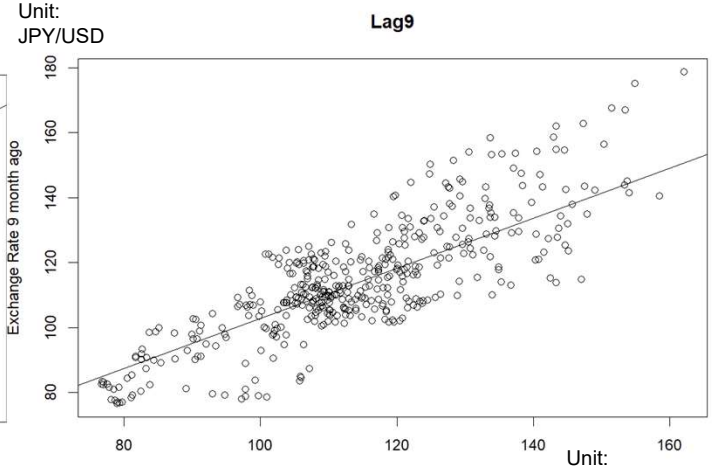
Exchange Rate

Unit:
JPY/USD

(Intercept)	15.61 ***
	(2.56)
dataex$ExLag5	0.86 ***
	(0.02)
R^2	0.77
Adj. R^2	0.77
Num. obs.	442
RMSE	7.97

*** p < 0.001; ** p < 0.01; * p < 0.05

Unit:
JPY/USD



Exchange Rate

Unit:
JPY/USD

(Intercept)	25.89 ***
	(2.95)
dataex$ExLag9	0.77 ***
	(0.03)
R^2	0.68
Adj. R^2	0.67
Num. obs.	442
RMSE	9.57

*** p < 0.001; ** p < 0.01; * p < 0.05

Features:

- The slope goes lower when lag is bigger

02

Splitting

Splitting

Measures to avoid data leakage:

- First 60% of the time series data – train set
- Next 20% of the time series data – validation set
- Last 20% of the time series data – test set

Approach:

- Scikit Learn – TimeSeriesSplit

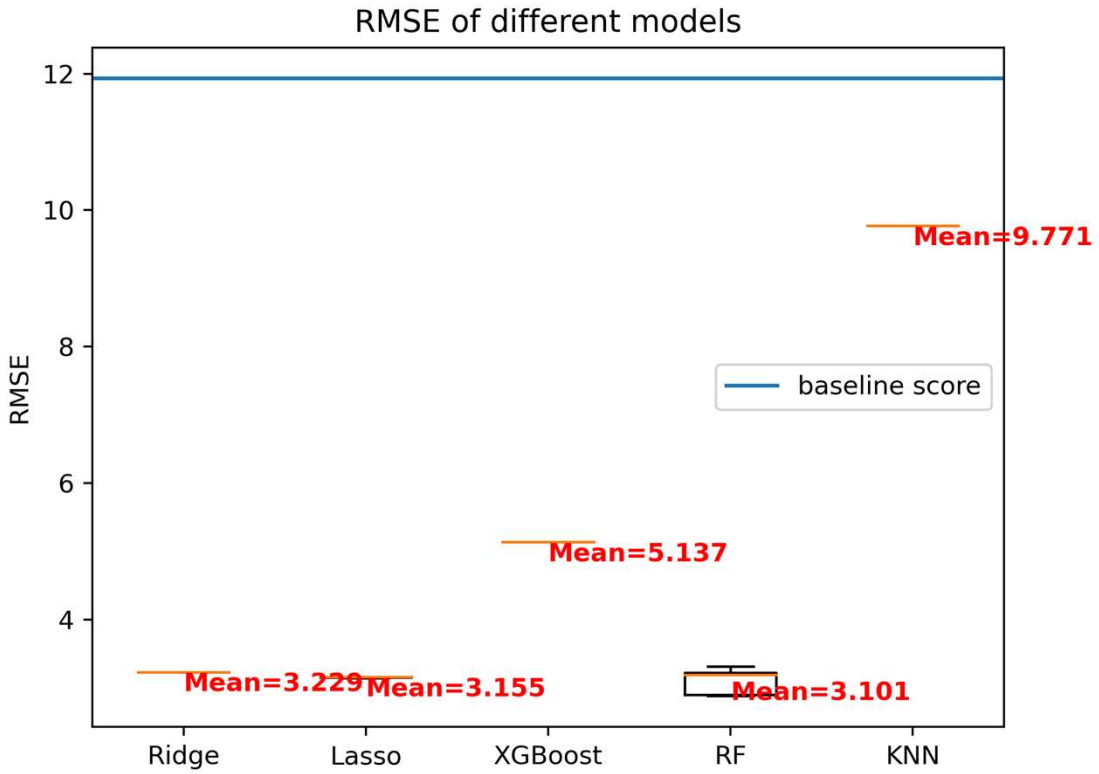
03

Models and Hyper Parameters Tuning

Models and Hyper Parameters Tuning

Model	Hyper parameter(s)	Best Hyper Parameters	Mean RMSE	Baseline RMSE
Ridge	Alpha	0.0001	3.229	11.9320
Lasso	Alpha	0.01	3.115	
XGBoost	Learning Rate Max Depth N_Estimators	0.2 5 50	5.137	
RF	Max Features Max Depth	None 3	3.101	
KNN	N_Neighbors	1	9.771	

Models and Hyper Parameters Tuning

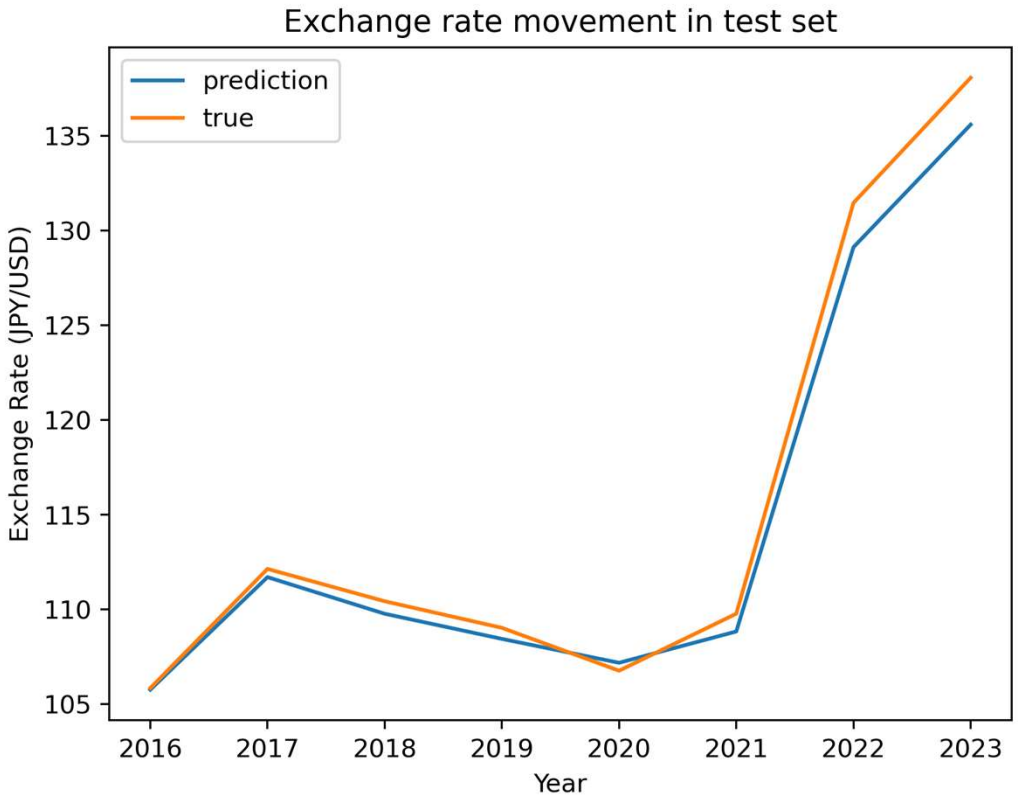


04

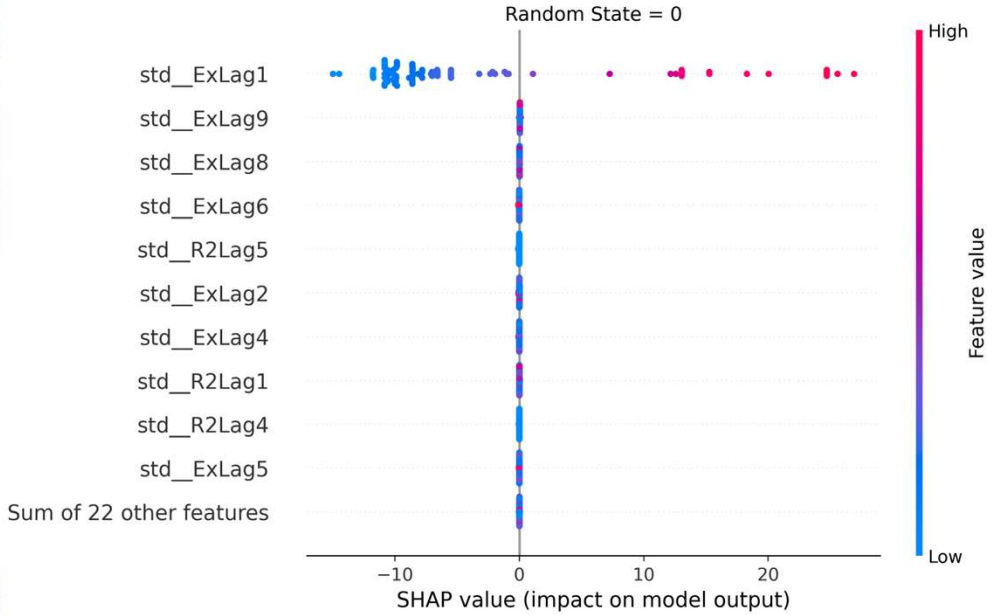
Results

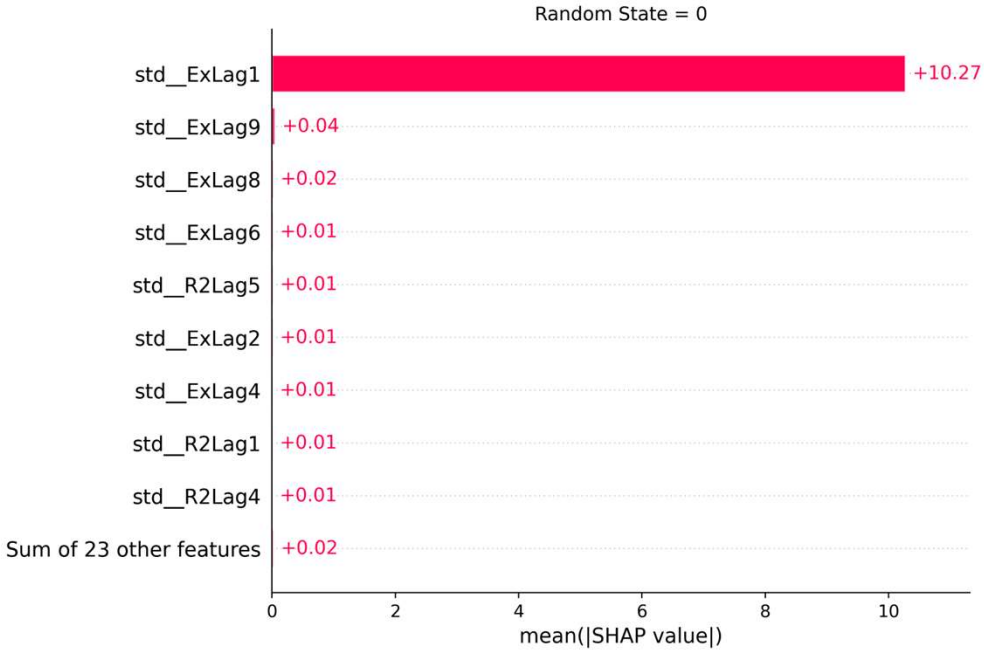
Overall Performance

Best model: RF

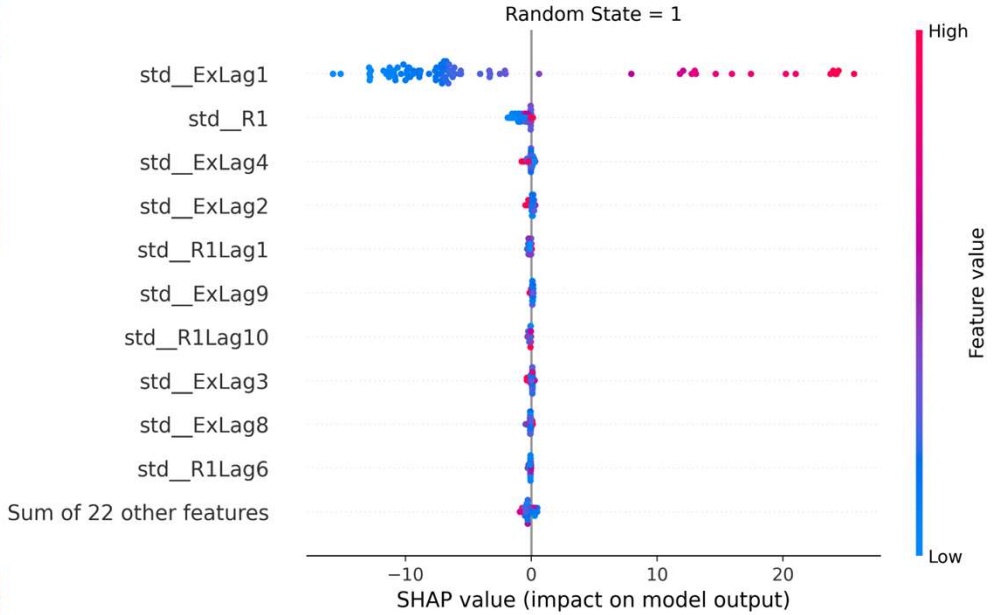


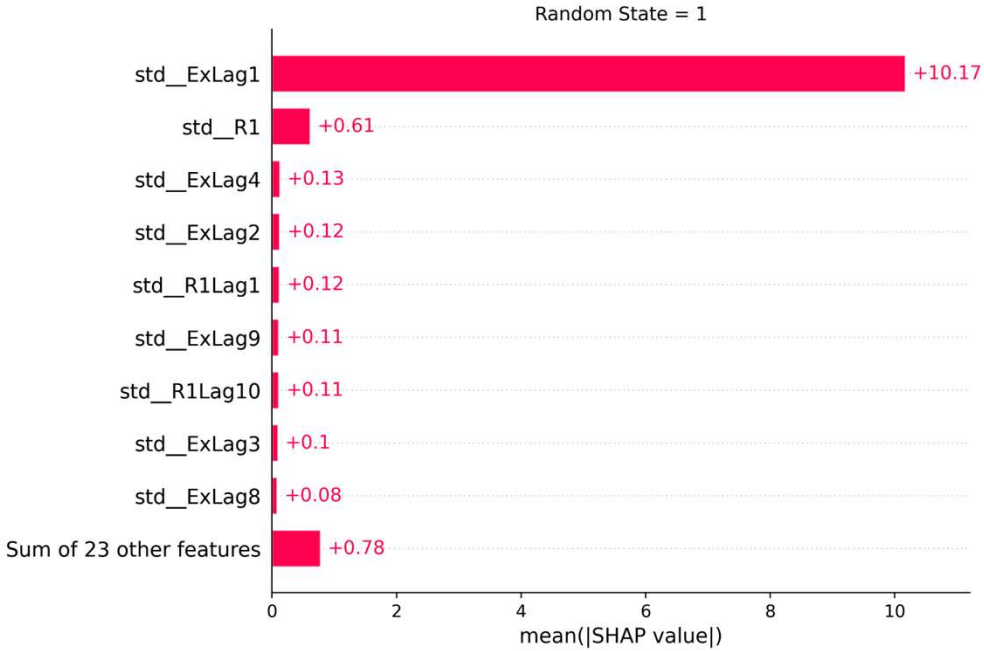
Global Feature Importance



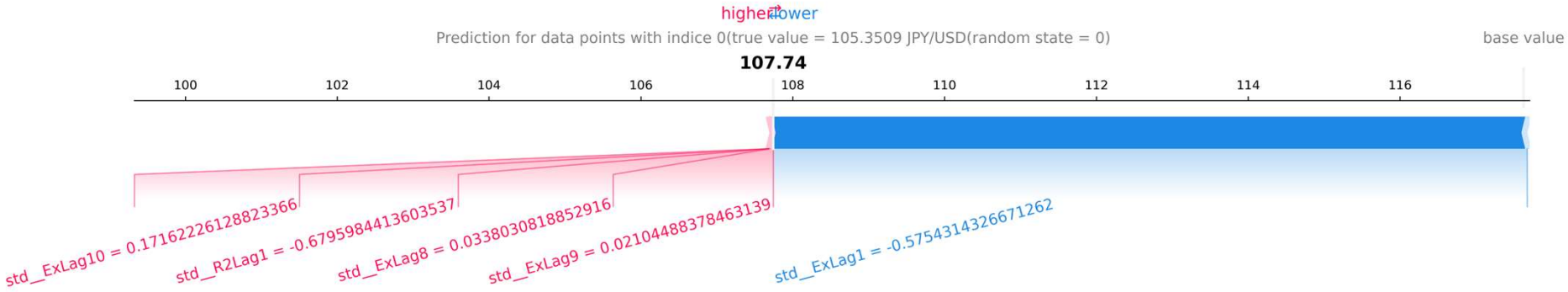


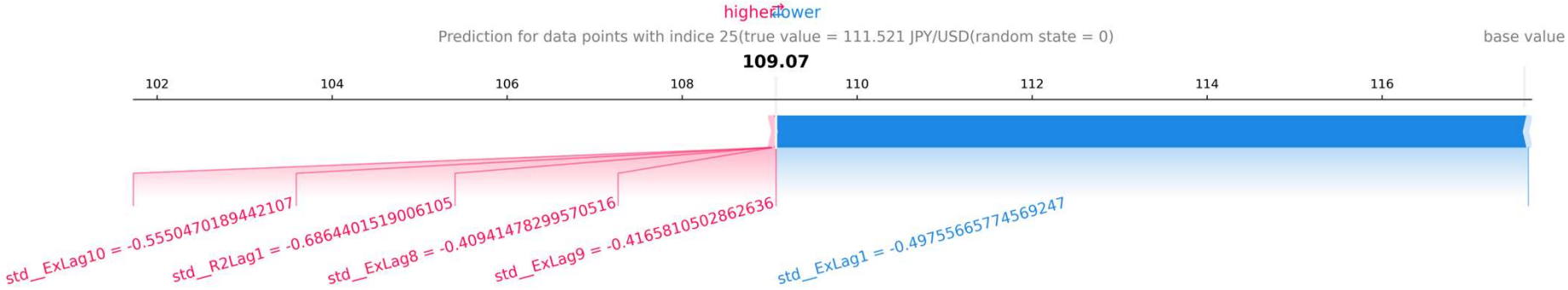
Global Feature Importance



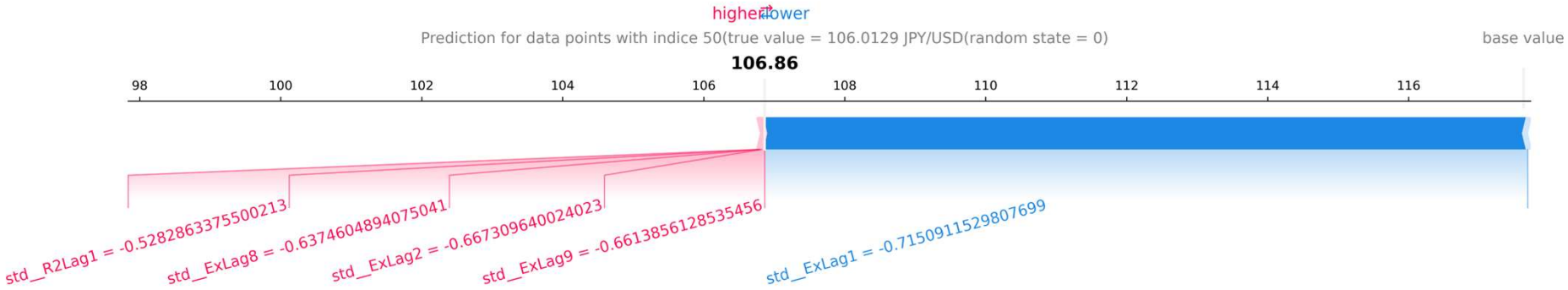


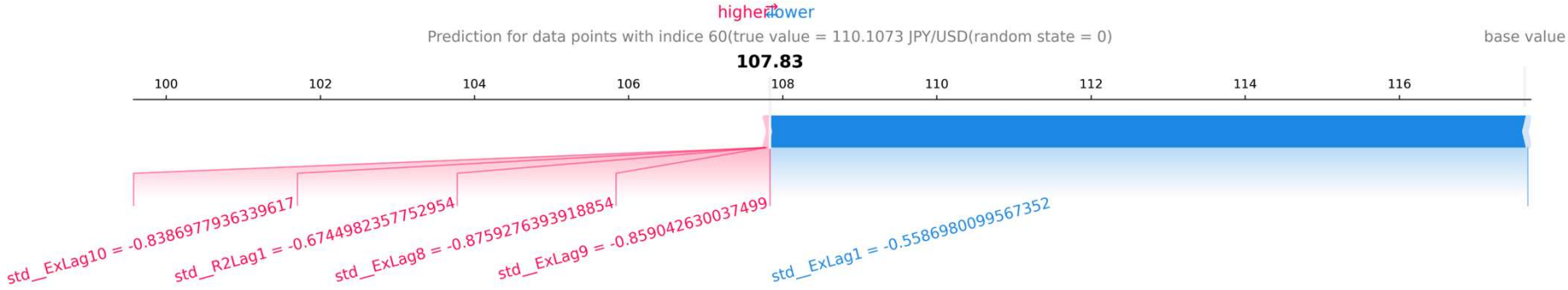
Local Feature Importance





Local Feature Importance





Interpretation of the outcome

- Exchange rate movement follows a trend and is predictable

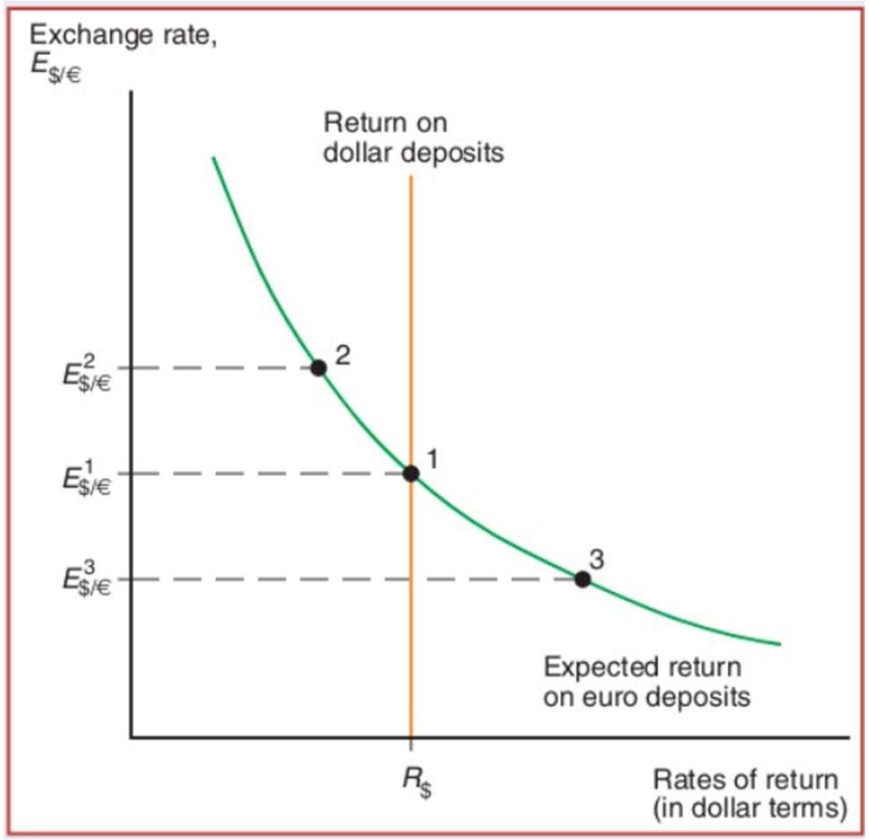
05

Outlooks

Ways to improve predictive power

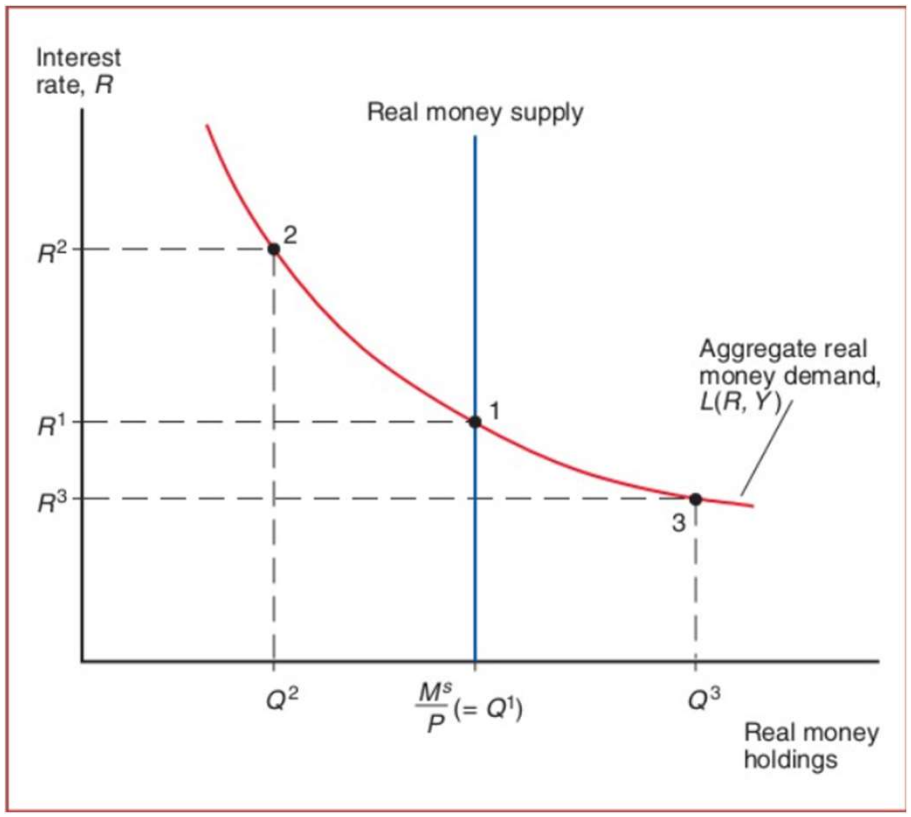
- Increase n_estimators in the Random Forest Regressor
- Improve the original economic model

Original Model



$$R_\$ = R_€ + (E^e_{\$/€} - E^1_{\$/€})/E^1_{\$/€},$$

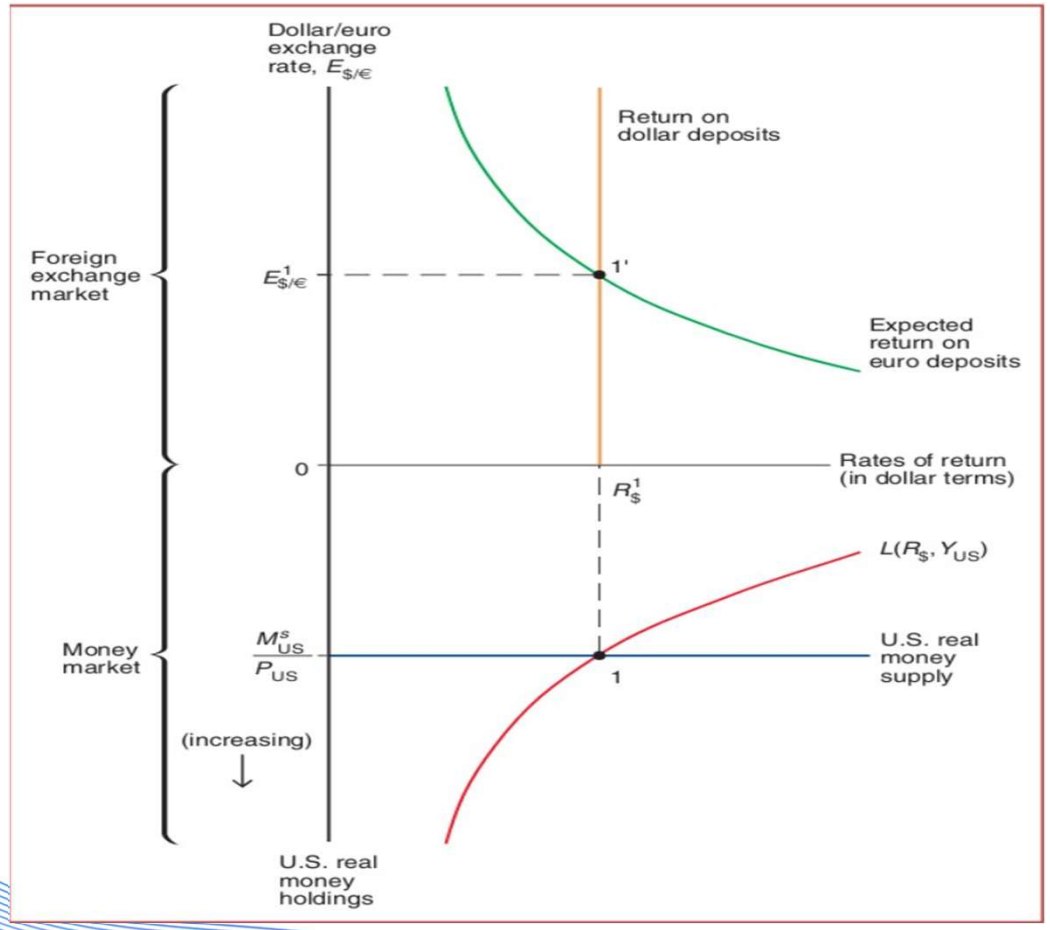
An improved economic model



$$M^d/P = L(R, Y)$$

$$M^s = M^d$$

An improved economic model

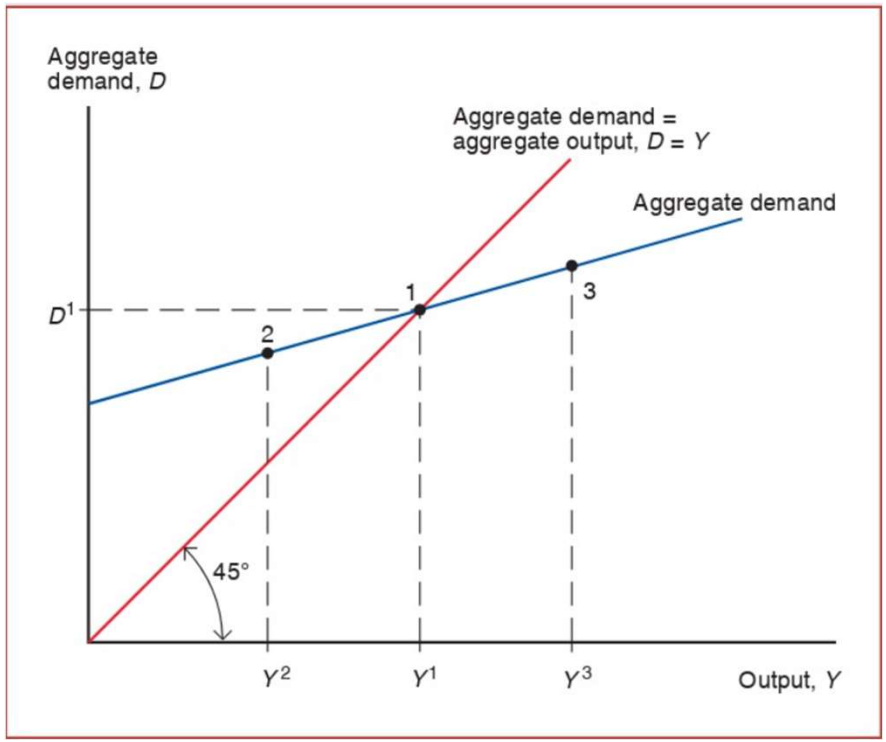


$$R_\$ = R_€ + (E^e_{\$/€} - E^1_{\$/€})/E^1_{\$/€},$$

$$M^d/P = L(R, Y)$$

$$M^s = M^d$$

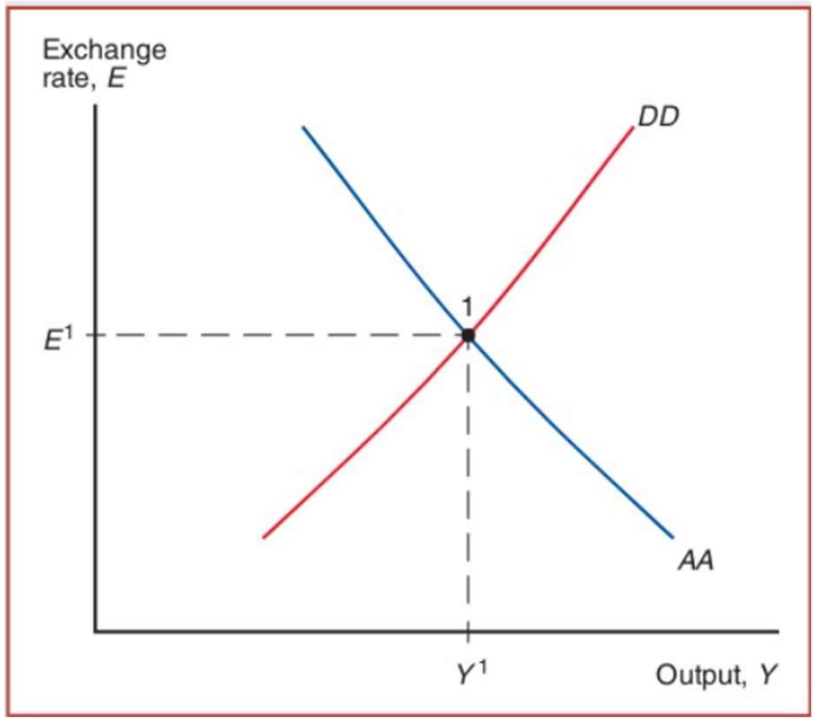
An improved economic model



$$D = C(Y - T) + I + G + CA(EP^*/P, Y - T).$$

$$Y = D(EP^*/P,\ Y - T,\ I,\ G)$$

An improved economic model



$$D = C(Y - T) + I + G + CA(EP^*/P, Y - T).$$

$$Y = D(EP^*/P, Y - T, I, G)$$

$$M^d/P = L(R, Y).$$

$$M^s = M^d.$$

$$R_\$ = R_€ + (E^e_{\$/€} - E^1_{\$/€})/E^1_{\$/€},$$

An improved economic model

Variables we already included in the model:

- Domestic / Foreign Exchange Rate (E/E*)
- Domestic / Foreign Interest Rate (R/R*)
- Expected Exchange Rate (predicted by using lags)

Variables we need to introduce into the new model:

- Consumption (C)
- Investment (I)
- Government Spending (G)
- Tax (T)
- GDP (Y)
- Money Supply (M)
- Price Level (P)
- Export Amount(EX)
- Import Amount(IM)
- Other Dummy Variables (Covid-19, Financial Crisis etc.)
- …

Thank you !

Questions?