Final Project

Progeamming for Business Intelligence

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Introduction & Background

In this project, we study models of volatility and fractal dimension over time series of 10 currency pairs and develop a conservation law.

Currency Pairs

The quotation of the relative value of a currency unit against the unit of another currency in the foreign exchange market

Volatility

The degree of variation of a trading price series over time

Fractal Dimension

An index for characterizing fractal patterns or sets by quantifying their complexity as a ratio of the change in detail to the change in scale

The “Fractal dimension” here measures the roughness of a surface, has the following simple relation with H:

$$H = 2 - D$$

DATA PROCESSING

Download Data

The data for the currencies exchange rate was gathered from invetsting.com for three year period

Clean Data

A small database for the price time series was extracted from the data.

Calculate Volatility

The volatility was calculated using the moving average and the standard deviation for 100 days run

Calculate Fractal Dimension

The fractal dimension was calculated using the Hurst library in Python.

DATA OVERVIEW

1044

Total Number of Rows

03/11/2016 - 03/11/2020

EUR to USD

Avg Exchange Rate: 1.13
Avg Volatility: 0.014
Avg Fractal Dimension: 1.47

BRL to USD

Avg Exchange Rate: 0.29
Avg Volatility: 0.029
Avg Fractal Dimension: 1.45

NZD to USD

Avg Exchange Rate: 0.69
Avg Volatility: 0.02
Avg Fractal Dimension: 1.45

GBP to USD

Avg Exchange Rate: 1.30
Avg Volatility: 0.02
Avg Fractal Dimension: 1.45

FJD to USD

Avg Exchange Rate: 0.48
Avg Volatility: 0.01
Avg Fractal Dimension: 1.52

USD to KWD

Avg Exchange Rate: 0.30
Avg Volatility: 0.002
Avg Fractal Dimension: 1.50

DATA OVERVIEW

INR to USD

Avg Exchange Rate: 1.14
Avg Volatility: 0.014
Avg Fractal Dimension: 1.47

USD to CAD

Avg Exchange Rate: 1.31
Avg Volatility: 0.013
Avg Fractal Dimension: 1.50

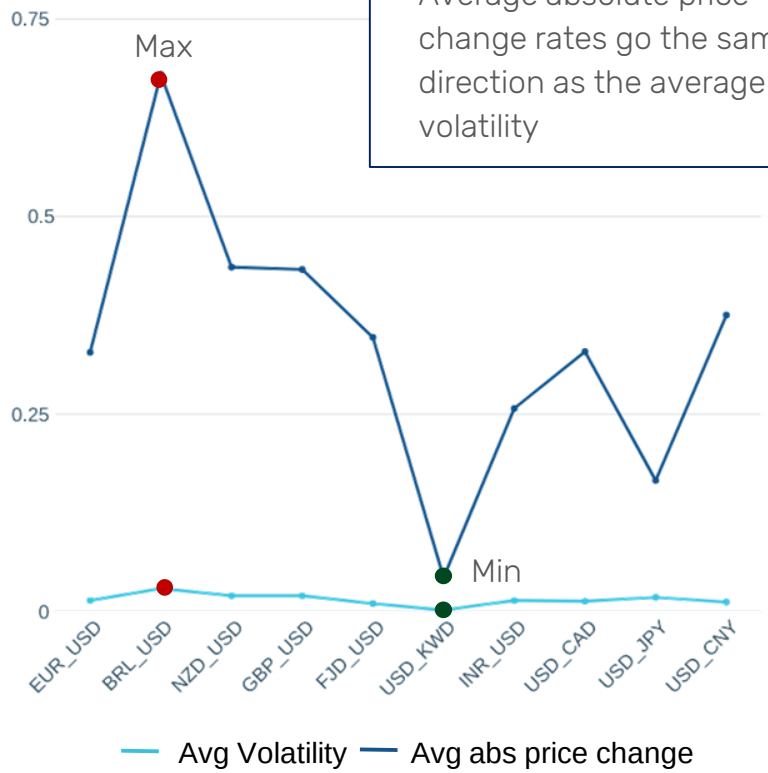
USD to JPY

Avg Exchange Rate: 109.78
Avg Volatility: 0.018
Avg Fractal Dimension: 1.45

USD to CNY

Avg Exchange Rate: 6.77
Avg Volatility: 0.012
Avg Fractal Dimension: 1.34

Average absolute price change rates go the same direction as the average volatility



LAW OF CONSERVATION OF ENERGY

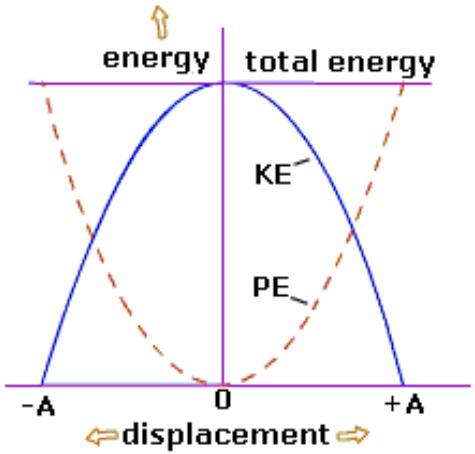
The **law of conservation of energy** states that energy can neither be created nor destroyed - only converted from one form of energy to another.

The total energy in the system is constant, and it can only take different forms.

- Total Energy = Kinetic Energy + Potential Energy
- Total Energy is constant
- Kinetic Energy + Potential Energy = Constant

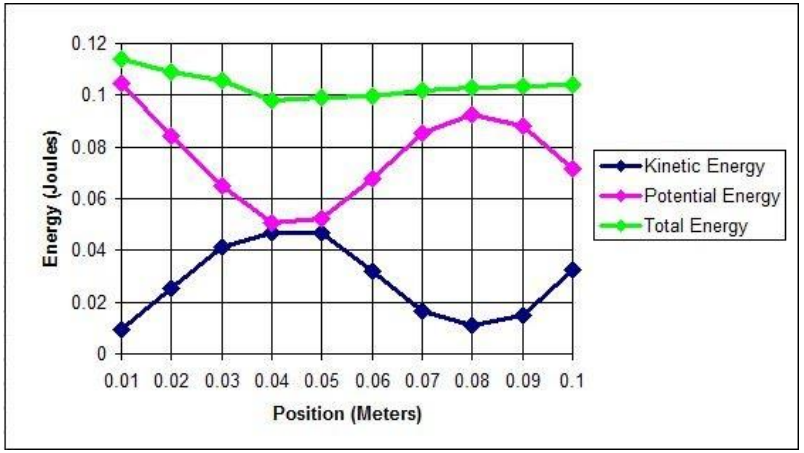
We imitate the same law for our model.

- Volatility + Fractal Dimension = Constant

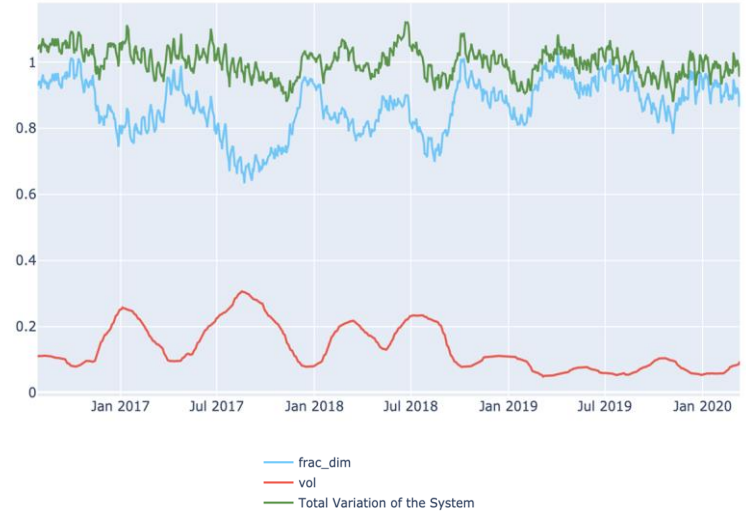


Source: Topper.com

SIMILARITIES BETWEEN THE MODEL & THE ENERGY LAW



Source: [Grace Wu AP Physics]

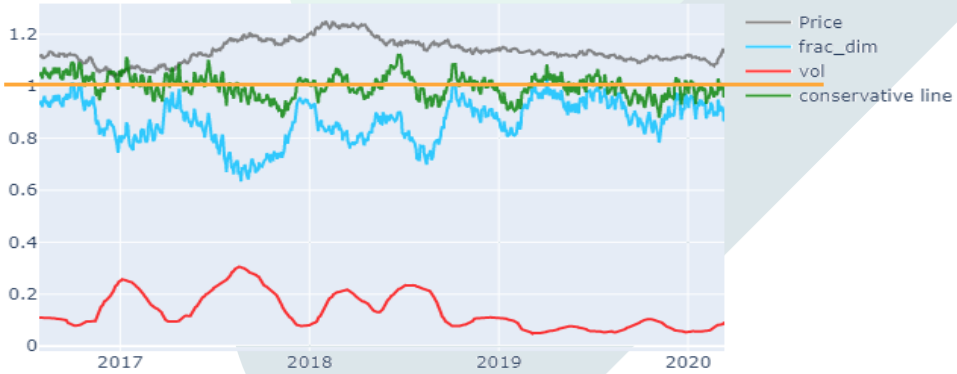


CONSERVATION LAW

The conservation law of price

- based on the changing value of volatility and fractal dimension.
- The price of the currency is determined by both the volatility and fractal dimension.
- If the volatility increases, the fractal dimension would decrease by a specific ratio.

According to our model design, if the volatility and fractal dimension follow the conservation law, the conservative line will be around 1.



MODEL SELECTION

$$a * vol + b * frac.dim = c$$

$$(a/c) * vol + (b/c) * frac.dim = 1$$

Assume:

$$A = a/c$$

$$B = b/c$$

$$A * vol + B * frac.dim = 1$$

Goal: find A and B

Rearrange the equation:

$$B * frac.dim = 1 - A * vol$$

$$frac.dim = -(A/B) * vol + (1/B)$$

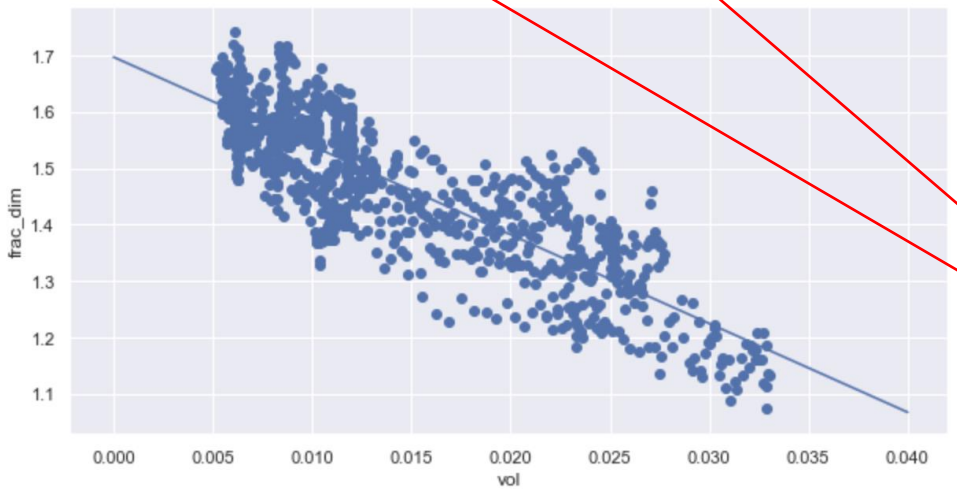
Linear Regression Model:

Vol is the independent variable

Frac.dim is the dependent variable

LINEAR REGRESSION
(Ordinary Least Squares)

$$frac.dim = -(A/B) * vol + (1/B)$$



$$frac.dim = -15.712 * vol + 1.6955$$

Dep. Variable:	y	**R-squared:**	0.716
Model:	OLS	**Adj. R-squared:**	0.716
Method:	Least Squares	**F-statistic:**	2375.
Date:	Wed, 11 Mar 2020	**Prob (F-statistic):**	9.21e-260
Time:	18:41:28	**Log-Likelihood:**	1123.5
No. Observations:	944	**AIC:**	-2243.
Df Residuals:	942	**BIC:**	-2233.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	1.6955	0.005	325.269	0.000	1.685	1.706
x1	-15.7120	0.322	-48.739	0.000	-16.345	-15.079

Omnibus:	8.031	**Durbin-Watson:**	0.151
Prob(Omnibus):	0.018	**Jarque-Bera (JB):**	5.860
Skew:	-0.062	**Prob(JB):**	0.0534
Kurtosis:	2.634	**Cond. No.**	134.

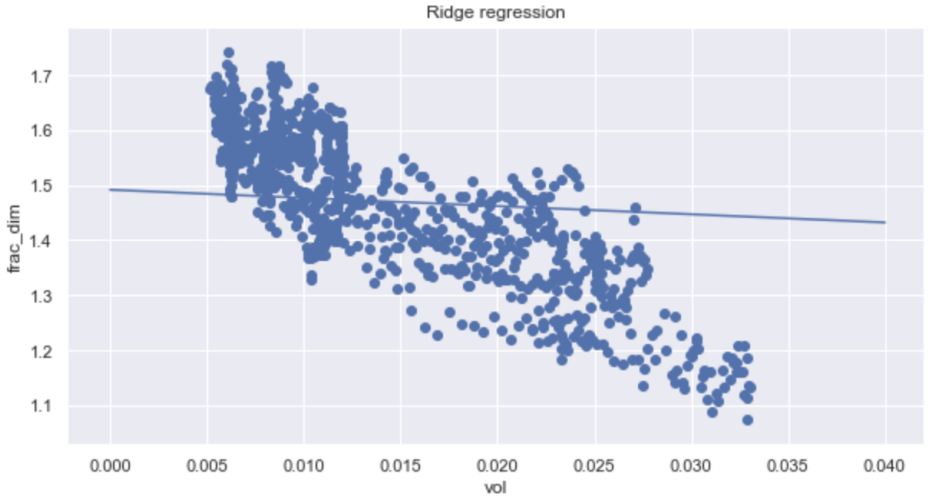
ALTERNATIVE MODEL

Ridge Regression

Coefficient: -1.4861 Intercept: 1.4913

$$frac.dim = -1.4861 * vol + 1.4913$$

R-square: 0.1290 < R-square (Ordinary Least Squares)

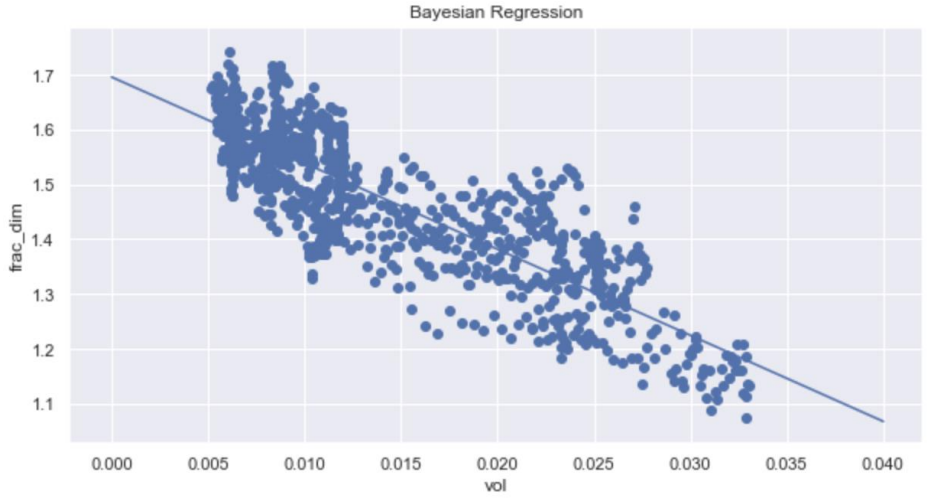


Bayesian Regression

Coefficient: -15.7054 Intercept: 1.6954

$$frac.dim = -15.7054 * vol + 1.6954$$

R-square: 0.7160 = R-square (Ordinary Least Squares)



CORRELATION

Since ordinary least squares linear regression and Bayesian Regression have similar coefficient and r-square, we can use coefficients from either of them to calculate A and B in equation $A * vol + B * frac.dim = 1$

$$frac.dim = -(A/B) * vol + (1/B) \iff frac.dim = -15.712 * vol + 1.6955$$

$$\begin{cases} 1/B = 1.6995 \\ -(A/B) = -15.712 \end{cases} \Rightarrow \begin{cases} A = 9.2668 \\ B = 0.5898 \end{cases}$$

Conservative equation: $9.2668 * vol + 0.5898 * frac.dim \approx 1$

MODEL VALIDATION

R-Squared

R-squared score is 0.716
there is 71.6% points can be described by the model.

Intercept & coefficient

The intercept and coefficient also satisfies the linear regression

p-value

The p-value is less than 0.001
there is more than 99.9% to reject the null hypothesis.

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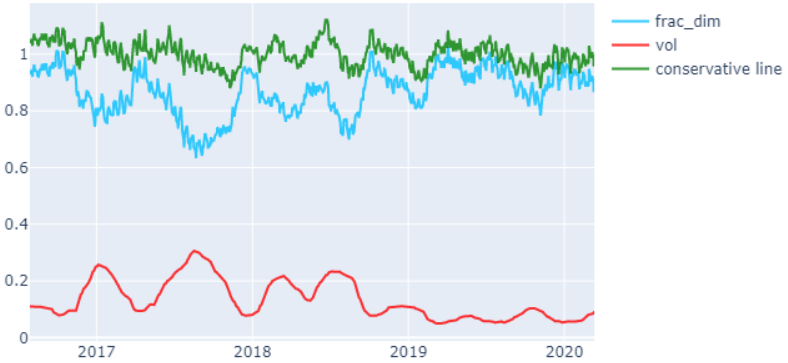
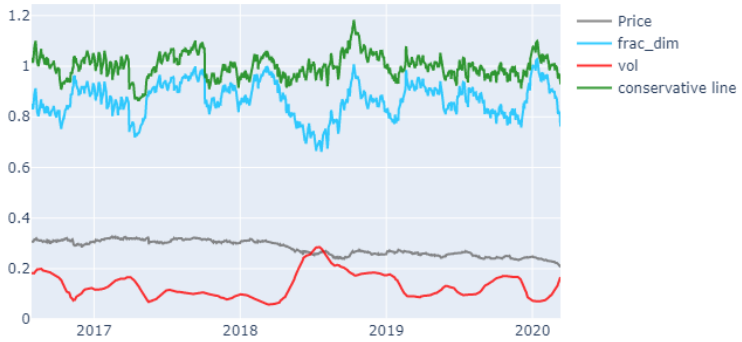
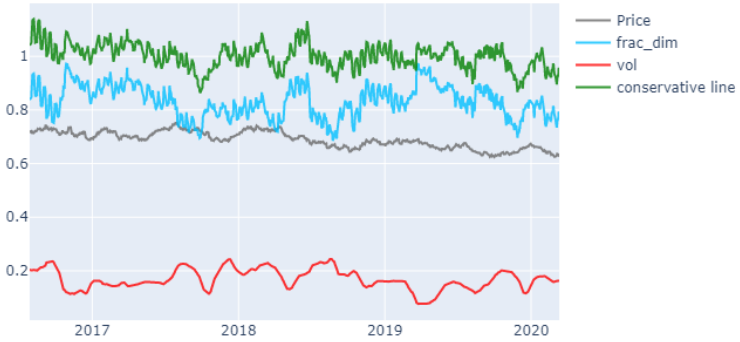
CONSERVATION LAWS OF CURRENCY PAIRS



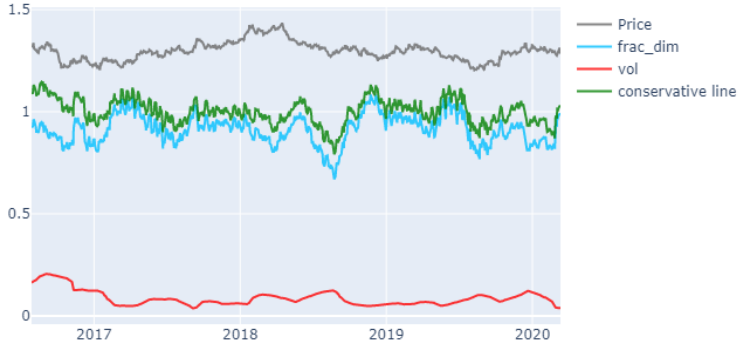
EUR to USD



BRL to USD

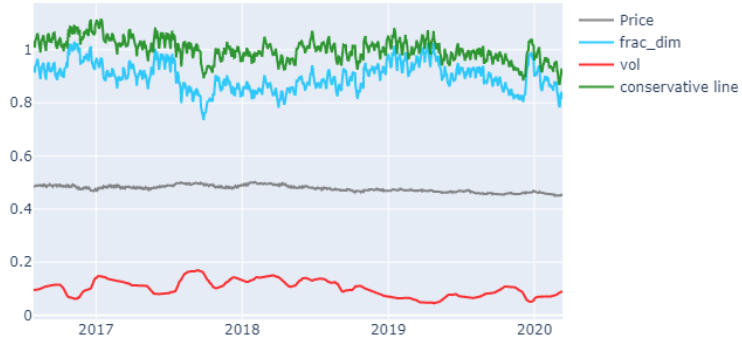


NZD to USD

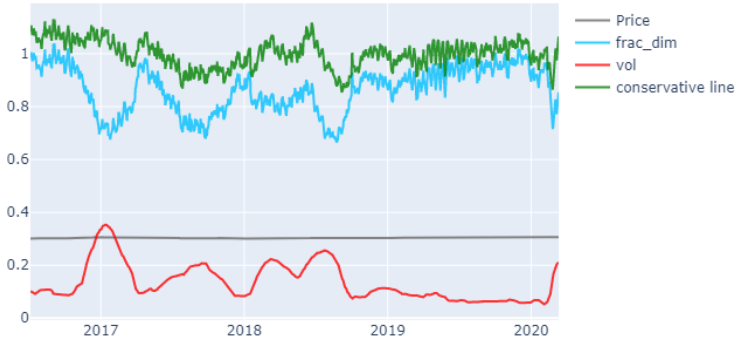


GBP to USD

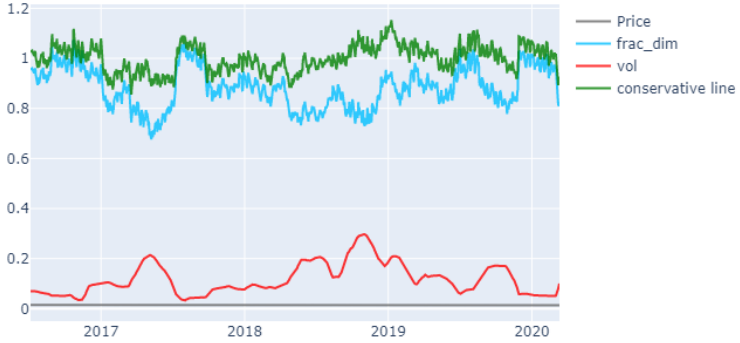
CONSERVATION LAWS OF CURRENCY PAIRS



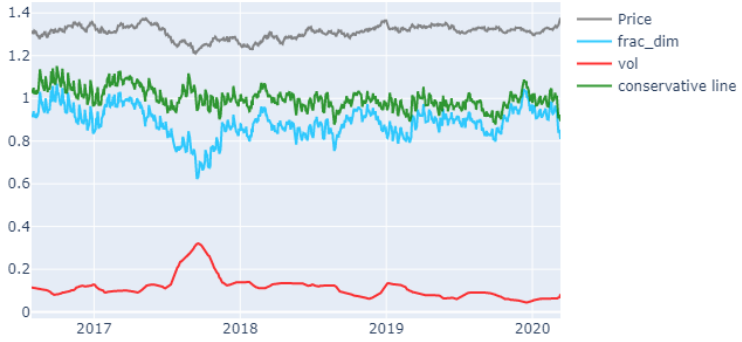
FJD to USD



USD to KWD

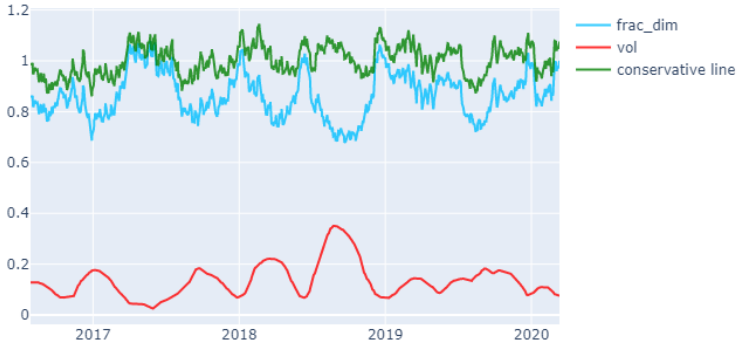


INR to USD

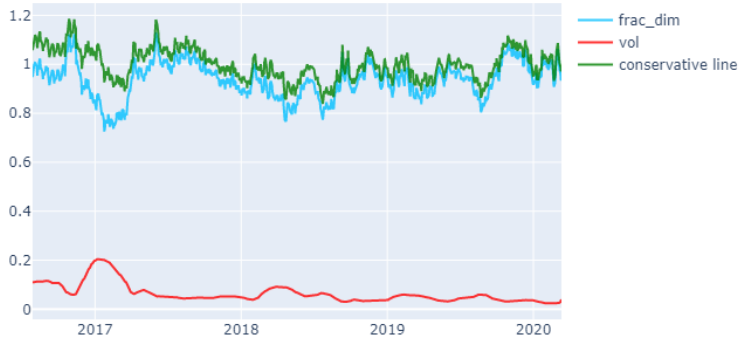


USD to CAD

CONSERVATION LAWS OF CURRENCY PAIRS



USD to CNY



USD to JPY