Predicting Structural Breaks of Option Price with Implied Volatility

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Abstract

The goal of this research is to examine if implied volatility may be used as a supplemental feature to predict structural breaks or bifurcations in option prices. Structural breaks are large shifts in statistical properties observed in time series data. Recognising such discontinuities is necessary to comprehend the underlying dependencies and features of the data. The study of catastrophes, which looks at how little changes to input variables can have big effects, has been used in both finance and economics.

In this work, we use the Ruptures Python module's offline structural break detecting feature. One of the models Ruptures provides for change point detection is the PELT (Pruned Exact Linear Time) model, which provides accurate and dependable results with linear computing complexity. We investigate the "rbf" (Radial Basis Function), L1-norm (Manhattan norm), and L2-norm (Euclidean norm) PELT model variants. We are mostly interested in these models.

The implied volatility is determined using the bisection method of the Black-Scholes-Merton model. We perform regression analysis in order to determine the relationship between implied volatility and option pricing. However, the findings show that there is no linear relationship between the two variables, indicating that further variables need to be taken into account.

Moreover, we predict structural fractures using the PELT model with the L2 norm. We employ a binary classification approach, where a structural break is represented by 1 when it exists and by 0 when it doesn't. Despite incorporating implied volatility as an additional variable and achieving increased accuracy in the model, the results demonstrate that the inclusion of implied volatility does not significantly improve the predicting of structural breaks in option pricing.

Keywords

Options, volatility, modeling, structural breaks, LSTM, BSM, finance, python

Contents

1 Structural breaks

When we refer to the structural breaks (bifurcations, change points) we connote points of time series data where happens a significant shift in statistical properties. Identification of such breaks is important to obtaining better understanding regarding the nature of data dependencies and properties. The branch of mathematical theories and studies colluded in the theory of catastrophes, which addresses the way dramatic changes occur due to slight changes of input parameters. It found its usage in variety of fields including finance and economics.

1.1 Detection & Dependence IV from option prices' changing points

Ruptures python library is a utility for an offline detection of structural breaks. It presents the following models in change points detection:

The usage in pair with flexibility of bisection method of volatility determination takes it place in Black-Scholes-Merton model. In the following manner the impled volatility for call on SBER (SR190CE3A) might be quantified.

Figure 1.1: Implied Vols

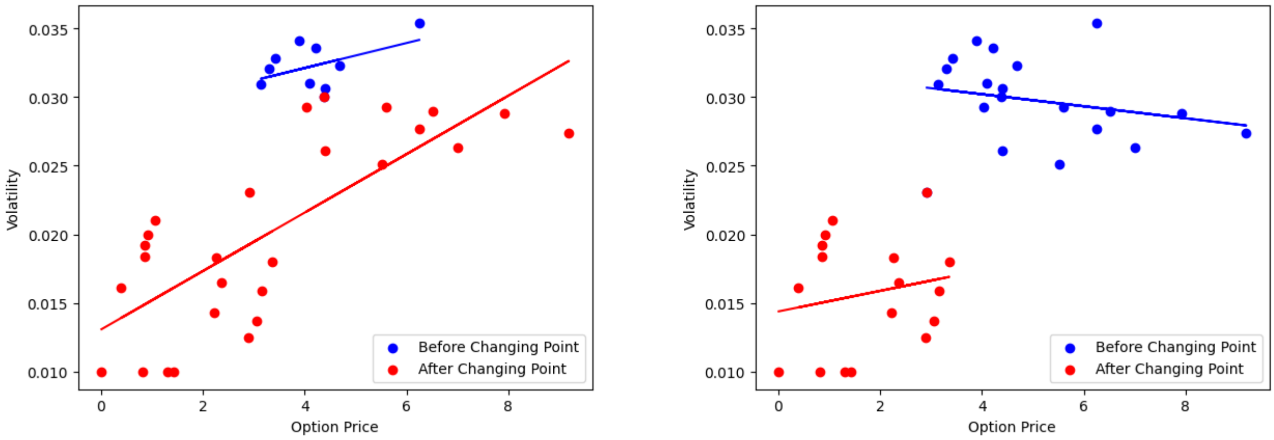
date	price	underlying	daysToExp	bsm_iv	heston_iv
2023-04-11	30.29	218.60	22	0.3130	0.313027
2023-04-12	34.66	219.22	21	0.6288	0.628852
2023-04-13	32.91	219.85	20	0.4905	0.490480
2023-04-14	33.21	221.87	19	0.3269	0.000100
2023-04-17	37.64	228.10	16	0.0914	0.000100
2023-04-18	42.86	232.66	15	0.1042	0.000100
2023-04-19	44.74	232.95	14	0.6105	0.610498
2023-04-20	46.40	236.28	13	0.1199	0.000100
2023-04-21	47.08	235.17	12	0.7151	0.715137
2023-04-24	46.31	235.10	9	0.7225	0.722531

In the following experiments we make our focus on PELT from the ruptures Python library as a model for detecting change points due to its linear complexity of computations, which makes it efficient for analyzing large datasets, it also provides an exact and robust solutions. Additionally, PELT has three models to operate: "rbf", which stands for Radial Basis Function, L1, which stands for L1-norm or Manhattan norm, and L2-norm which is a Euclidean norm.

After structural breaks detection we address a regression analysis of dependence of implied volatility form option price. However for presented in graphs changing point for dates 2022-

10-19 and 2022-11-02 coefficients of before and after the break are 0.00090949, 0.00212789, and -0.00043845, 0.0007493, this pattern continues for every other point tested, which allows us to conclude that there is no linear dependency between two variables or other factors needed to be taken into consideration.

Figure 1.2: Regressions: option price, IV



1.2 Predictions

The goal is to acquire the knowledge of the potential ability to predict the bifurcation of option prices time series by leveraging the implied volatility as helping feature. For such purpose we addressed PELT with L2-norm model, as experimentally obtained it provided maximum of bifurcation detections, which is crucial for large volumes of data. In this binary classification problem 1 - presence of structral break, 0 - absence.

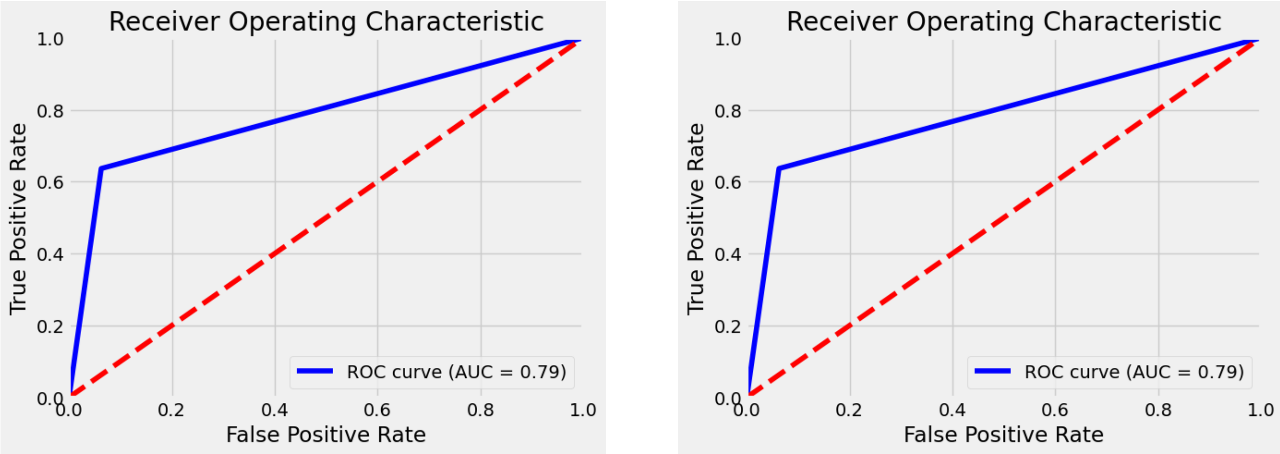
Figure 1.3: Description of data

	price	underlying	daysToExp	bsm_iv	rbf_breaks	l1_breaks	l2_breaks
count	550.000000	550.000000	550.00000	550.000000	550.000000	550.000000	550.000000
mean	21.490073	150.252214	416.80000	0.045253	0.032727	0.109091	0.141818
std	9.125141	14.683202	230.47865	0.054189	0.178084	0.312037	0.349181
min	3.550000	118.310265	17.00000	0.010000	0.000000	0.000000	0.000000
25%	14.912500	140.819153	219.25000	0.010000	0.000000	0.000000	0.000000
50%	20.325000	148.702873	416.50000	0.010000	0.000000	0.000000	0.000000
75%	26.867500	162.408073	616.75000	0.079975	0.000000	0.000000	0.000000
max	44.500000	180.434311	814.00000	0.230700	1.000000	1.000000	1.000000

As a result after several numerical experiments and usage of Long short-term memory (LSTM) machine learning model we are able to conclude that there is no significant increase of predictability power in model coming from leveraging implied volatility to predict change points in option prices.

Despite increasing accuracy of the model from average of 0.75 to 0.86 confusion matrices and AUC ROC stayed the same.

Figure 1.4: AUC ROC without IV and with



2 Conclusion

In conclusion, this study investigates the use of implied volatility as an extra feature to predict structural breaks in option prices. The PELT model and L2-norm are used in the analysis, which makes use of the Ruptures Python module. No linear relationship exists between implied volatility and option prices, according to regression research. As a result, the predictability of structural breaks is not greatly increased by the inclusion of implied volatility.

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