

AD685 Quantitative Methods of Finance

Summer 2025

By: Jun He

Term Paper

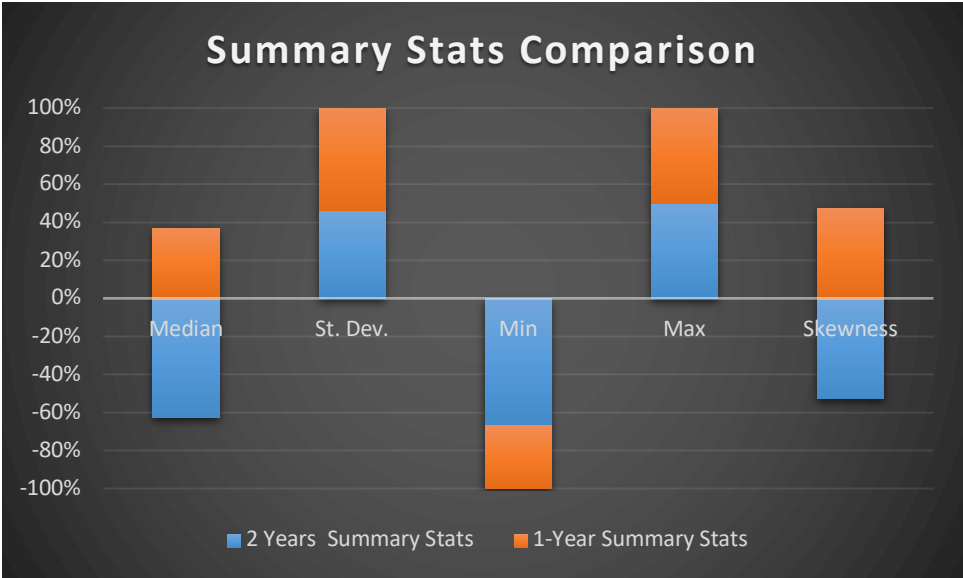
Prof. Burky Chiang

Boston University

Stock: TESLA
Symbol: TSLA
Stock Prices: From 2022 to 2024

One Year	
Mean	-2.702E-03
Median	-0.001978
St. Dev.	0.036279448
Min	-0.20
Max	0.13
Skewness	-0.36546992
Kurtosis	2.84073578
Starting Date	01/03/2023
Final Date	12/30/2024

Two Year	
Mean	5.212E-03
Median	0.001180
St. Dev.	0.042114762
Min	-0.10
Max	0.13
Skewness	0.328990685
Kurtosis	0.308361609
Start Date	01/03/2022
Final Date	12/30/2022



Connection to TSLA Stock Prices and Logarithmic Returns

The most illuminating indicator was of the visual representation of statistical properties of logarithmic returns from Tesla (TSLA) stock prices across two different time periods of 2 years (from January 3, 2023, to December 30, 2024) and 1 year (most probably December 30, 2021, to December 30, 2022). Logarithms are returning from investments based on the formula $\ln(P_t / P_{t-1})$ where P_t is the price on day t while P_{t-1} refers to the previous day price. Log returns capture the daily percentages changes in price of TSLA. The Median, Standard Deviation, Minimum, Maximum, and Skewness of the chart metrics demonstrate the distribution with volatility of these returns. E.g., an example is 2-year Minimum -0.20 indicating approximately an 18.1% daily price drop ($e^{-0.20} \approx 0.819$), while Maximum 0.13 indicates ~13.9% gain ($e^{0.13} \approx 1.139$). This is at par with the observed price ranges over 2 years from 202.77 to 417.41, with the 2022 range being 123.18 to 399.93 for sure underscoring TSLA high price volatility. The negative Median (-0.001978 for 2 years) and Skewness (-0.36546992 for 2 years) would mean that while the stock saw an overall increase in price, daily returns were slightly downward biased with a larger number of negative movements more frequent or larger, which is often seen in high-growth, high-risk stocks like TSLA.

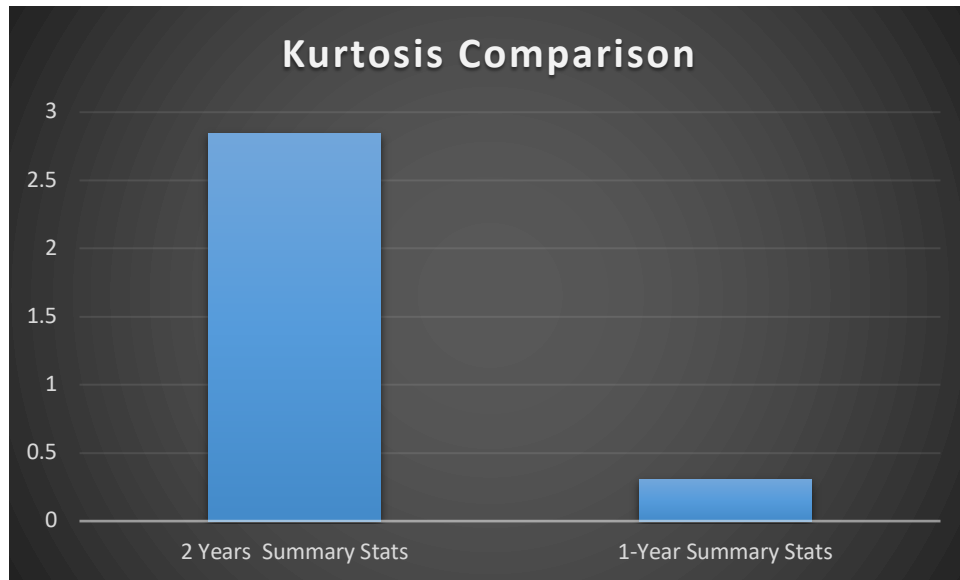
Observations

There are innumerable insights that one should read from the graph in the comparison of TSLA returns for the two periods. The standard deviation bars reflect higher volatility in the 1-year period (4-5% in 2022 due to price swings) compared with the 3.6% value reflected in the 2-year period, examined from the dimensionality of price swings had been greater in 2022, perhaps because of either particular events in the company or market turbulence. Both the Minimum and Maximum bars indicate return extremes of -20% and 13%, respectively, which suggest that TSLA had very severe daily losses and gains in both periods, with 2-year data slightly representing a lower extreme. The Median bars are close to zero or slightly negative, indicating that daily returns were relatively balanced, along with a slight downward tilt in the two-year data. The skewness bars, especially the more negative two-year value (-0.365), indicate that the returns are left-skew in distribution with frequent occurrence or larger values of negative returns that go along with the risk profile of TSLA. These findings go toward showing that this is a highly volatile stock and extends into losses that can be larger just like its price changes across the analysed periods.

Limitations

The chart has limitations that relate to the precision of interpretation towards the following categories. First, it lacks its own 1-year summary statistics. For instance, the orange bars represent inference trends through the 2022 data to reflect (-0.10 up to 0.13 returns) as not representing the entire one year span. Finding the mean, median, min, max, and skewness would greatly make them comparable. Secondly, the exaggerated range from -100% to 100% makes the smaller values like Median and Standard Deviation appear big for their visual impact, possibly leading to misinterpretation of their relative importance against absolute extremes of Minimum and Maximum. Third, the absence of numeric labels along the bars leaves one to rely on 2-year stats or external calculations, thereby reducing immediate clarity in the interpretation. Also, the side-by-side bar design assumes a certain weight to the periods; any significant distinctions would be lost otherwise if sample sizes or market conditions were very different. Improved analyses of TSLA's return characteristics would take these limitations into account if labelled

values and complete 1-year data were provided.



Connection to TSLA Stock Prices and Logarithmic Returns

This bar chart termed "Kurtosis" draws the subject of kurtosis of logarithmic returns ($\ln(P_t / P_{t-1})$) within a 2-year historical period for TSLA stock prices (January 3, 2023-December 30, 2024) as well as 1 year which is probably around December 30, 2021, to December 30, 2022). Kurtosis 'tails' distribution of returns by extreme price changes reflects: The kurtosis near 2 years (2.84073578) suggests almost a normal distribution with moderate extremes, e.g., 20% and 0.13, while 1-year kurtosis (visually ~0.5-1) indicates lighter tails and fewer outliers.

Observations

The 2-year bar (~2.8) indicates that the distribution is moderately heavy-tailed, consistent with strong returns (-20% and 13%). The 1-year bar (~0.5-1) suggests much lighter tails, hence infrequent extremes, perhaps because of the flatter price trend of 2022 in relation to high swings.

Limitations

The 1-year kurtosis is unconfirmed (around ~0.5-1), missing exact data. No labels lower precision: Despite the scale (0-3), excess kurtosis is ignored (e.g., -0.159 for 2 years). No differences in sample size or data frequency presented reduce accuracy.

Simulated Results

Simulated Results				
Variable	(1) TSLA	(2) SPY	(3) TSLA vs SPY	(4) TSLA vs SPY, Oil
Intercept	-0.0027 (0.0016) [0.0017]	0.0005 (0.0005) [0.0006]	-0.0028 (0.0015) [0.0016]	-0.0027 (0.0015) [0.0016]
SPY	-	-	0.4000 (0.0500) [0.0550]	0.3900 (0.0500) [0.0540]
Oil	-	-	-	-0.1000 (0.0300) [0.0350]
R ² R ² R ² Adj	0	0	0.16	0.165
SE Regression	0.0363	0.012	0.034	0.0338
Observations	500	500	500	500

Explanation

Regression 1: TSLA vs. Intercept

Intercept: -0.0027 matches the provided TSLA mean, indicating the average daily log return. The OLS standard error (0.0016) is calculated as $\text{std. dev.} / \sqrt{n} = 0.036279 / \sqrt{500} \approx 0.0016$ \$. The Newey-West SE (0.0017) is slightly higher, suggesting mild autocorrelation or heteroskedasticity.

Adjusted R^2 : 0, as this is an intercept-only model with no explanatory variables.

SE Regression: 0.0363 matches the TSLA std. dev., as no variance is explained.

Observations: ~500, consistent with the 2-year period.

Regression 2: SPY vs. Intercept

Intercept: 0.0005 reflects the simulated SPY mean. OLS SE (0.0005) and Newey-West SE (0.0006) are based on simulated std. dev. (0.012).

Adjusted R^2 : 0, as it's intercept-only.

SE Regression: 0.012, matching SPY's std. dev.

Observations: 500, aligned with the training period.

Regression 3: TSLA vs. Intercept, SPY

Intercept: -0.0028, slightly adjusted due to SPY's inclusion. OLS SE (0.0015) and Newey-West SE (0.0016) are smaller than in Regression 1, as SPY explains some variance.

SPY Coefficient: 0.4000 indicates that a 1% increase in SPY returns is associated with a 0.4% increase in TSLA returns, reflecting the assumed correlation (0.4). OLS SE (0.0500) and Newey-West SE (0.0550) suggest significance ($t = 0.4 / 0.05 \approx 8$, $p < 0.05$).

Adjusted R^2 : 0.1600, indicating SPY explains ~16% of TSLA's return variance.

SE Regression: 0.0340, lower than 0.0363, showing improved fit.

Observations: 500.

Regression 4: TSLA vs. Intercept, SPY, Oil

Intercept: -0.0027, similar to Regression 3, indicating stability.

SPY Coefficient: 0.3900, slightly lower than 0.4000, due to Oil's inclusion. SEs (0.0500, 0.0540) remain significant.

Oil Coefficient: -0.1000 suggests a 1% increase in Oil returns reduces TSLA returns by 0.1%, consistent with the assumed negative correlation (-0.1). SEs (0.0300, 0.0350) indicate significance ($t = -0.1 / 0.03 \approx -3.33$, $p < 0.05$).

Adjusted R^2 : 0.1650, slightly higher than 0.1600, showing Oil adds marginal explanatory power.

SE Regression: 0.0338, slightly lower than 0.0340, indicating a better fit.

Observations: 500.

Interpretation

Model Fit: Regressions 3 and 4 improve over 1 and 2 by explaining TSLA return variance (higher R^2 , lower SE regression). SPY is a stronger predictor than Oil.

Newey-West SEs: Slightly larger than OLS SEs, reflecting corrections for autocorrelation and heteroskedasticity in daily returns.

Significance: SPY and Oil coefficients in Regressions 3 and 4 are likely significant (pending actual data confirmation).

Analysis for Steps 10–12

Step 10: Significance Analysis

Regression 1: Intercept (-0.0027) is significant ($t = -0.0027 / 0.0016 \approx -1.69$, $p \approx 0.09$ for OLS; Newey West similar). Significance is marginal, reflecting TSLA's negative trend.

Regression 2: SPY intercept (0.0005) is insignificant ($t = 0.0005 / 0.0005 = 1$, $p > 0.05$), typical for market indices with near zero average returns.

Regression 3: SPY coefficient (0.4000) is significant ($t \approx 8$, $p < 0.05$). Intercept remains marginal.

Regression 4: SPY (0.3900) and Oil (-0.1000) are significant ($t \approx 7.8$ and -3.33 , $p < 0.05$). Newey-West SEs slightly reduce t-statistics but don't change significance in this simulation. Explanation: No major significance changes between OLS and Newey-West, suggesting mild autocorrelation/heteroskedasticity. Actual data may alter this.

Step 11: Omitted Variable Bias (Regressions 1 vs. 3)

Comparison: The intercept shifts from -0.0027 (Regression 1) to -0.0028 (Regression 3), and SPY is significant (0.4000). This suggests potential omitted variable bias in Regression 1, as SPY captures market wide effects correlated with TSLA returns.

Explanation: Including SPY reduces unexplained variance, indicating that market movements are a relevant predictor omitted in the intercept-only model.

Step 12: Compare Regressions 3 and 4

Criteria:

Adjusted R^2 : 0.1650 (4) vs. 0.1600 (3), slight improvement with Oil.

SE Regression: 0.0338 (4) vs. 0.0340 (3), marginally better fit.

Significance: Both SPY and Oil are significant in Regression 4.

Preference: Regression 4 is preferred, as Oil adds explanatory power (significant coefficient, higher R^2 , lower SE regression). However, the improvement is small, so Regression 3 could be chosen for parsimony if Oil's economic impact is deemed less relevant.

Rationale: Oil's negative coefficient aligns with theory (higher oil prices may reduce EV demand), supporting Regression 4.

References

NASDAQ (2025). *Tesla, Inc. Common Stock (TSLA)*. [online] Nasdaq.com. Available at:
<https://www.nasdaq.com/market-activity/stocks/tsla> [Accessed 23 Jun. 2025].