

Investigating the Impact of the MACD Technical Indicator on Linear Regression Models for Predicting Financial Time Series

How does the inclusion of the MACD technical indicator impact the computational efficiency and predictive accuracy of linear regression models for predicting financial time series?

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1. Introduction

In the world of finance, investors use different strategies developed through code, math, and data just to gain the slightest edge in forecasting a trend. Minor improvements can translate to gains of millions; however, these improvements sometimes come with computational costs like a longer runtime or higher memory usage. The computational efficiency of a predictive model is important since these models are typically applied to enormous datasets in the real world. If a certain model is more accurate but is also slower or takes up more memory, it might not be practical.

With a good understanding of Python, I wanted to figure out if incorporating the MACD technical indicator, combined with closing prices, in a linear regression model would make an improvement in stock price predictions compared to a model that just uses closing prices.

The aim of this investigation is to analyze the trade-offs between adding the MACD indicator as a feature to a linear regression model and the impact it has on the runtime performance and memory usage of the model.

2. Background Information

2.1 Financial Time Series

“A time series consists of the values of a function sampled at different points in time” (Skiena 2). Financial time series are closely analyzed to help forecast future values. Analyzing this data helps “in developing/evaluating any investment strategy, risk modeling, and arbitrage” (Skiena 4). In this investigation, financial time series will be used to demonstrate the tradeoffs that are involved with adding an extra feature to a linear regression model.

2.2 Linear Regression

2.2.1 Machine Learning

“Machine learning is a branch of computer science that broadly aims to enable computers to ‘learn’ without being directly programmed” (Bi et al). “Computers ‘learn’ in machine learning by improving their performance at tasks through ‘experience’” (Bi et al). The two main types of machine learning models are supervised and unsupervised. Supervised learning uses labeled data, which means that the outcome is known for each observation (Bi et al). Unsupervised learning does not use labeled data as it aims to find patterns or grouping within a given dataset (Bi et al). Some common unsupervised learning techniques include clustering methods such as k-means and Gaussian mixture models (Bi et al).

2.2.2 Mathematical Foundation

We are going to be exploring linear regression in this investigation, which is a supervised machine learning algorithm. Assuming that there is a linear relationship between X and Y , linear regression is able to predict “a quantitative response Y on the basis of a single predictor variable X ” (James et al, 70). “The linear relationship is written as

$$Y = \beta_0 + \beta_1 X$$

where:

- Y is the dependent variable
- X is the independent variable
- β_0 is the intercept (value of Y when $X = 0$)

- β_1 is the slope (change in Y for a change of one unit in X)” (James et al, 71).

Linear regression models are able to determine the best-fitting line by using the least squares method. “The least squares approach chooses β_0 and β_1 to minimize the residual sum of squares (RSS)”, which finds the total squared difference between the actual and predicted values (James et al, 71). “RSS is calculated by taking the squared differences between the observed response values and the fitted values, and then summing these squared differences across all observations” (James et al, 71). The smaller the RSS value is, the better the models fit the data because “RSS is a measure of the lack of fit of the model to the data” (James et al, 71). Minimizing the RSS will ensure that the regression line fits the data more accurately, making our model more reliable. “The least squares line balances the residuals, resulting in a line that is as close as possible to the observed data points” (James et al, 71).

2.2.3 Implementing Linear Regression with Python

When making a linear regression model in Python, there are 5 general steps to follow:

1. “Import the packages and classes you need” (Stojiljkovic, 7).
2. “Provide data to work with and eventually do appropriate transformations” (Stojiljkovic, 7). To provide your data, you need to have it stored in comma-separated values (CSV) files. “Importing CSV data into scikit-learn is crucial for enabling the transformation and optimization of data, thus facilitating effective predictive analysis in various machine learning projects.” (Creates).
3. “Create a regression model and fit it with existing data” (Stojiljkovic, 7). You need to create an instance of the Linear Regression class that will represent your model (Stokiljkovic, 7).

4. “Once you have your model fitted, you can get the results to check whether the model works satisfactorily and interpret it.” (Stojiljkovic 8)
5. “Once there is a satisfactory model, you can use it for predictions with either existing or new data.” (Stojiljkovic, 9).

2.3 Computational Efficiency in Machine Learning

2.3.1 Time Complexity

“Time complexity is a fundamental concept in computer science that quantifies the amount of time taken by an algorithm to run, relative to the size of its input” (Panday). “One of the effective methods for studying the efficiency of algorithms is Big-O notations” (Devi et al, 844). “BigO specifically describes the worst-case scenario, and can be used to describe the execution time required or the space used (e.g. in memory or on disk) by an algorithm” (Devi et al, 845). “Because bigO notation discards multiplicative constants on the running time, and ignores efficiency for low input sizes, it does not always reveal the fastest algorithm in practice or for practically-sized data sets, but the approach is still very effective for comparing the scalability of various algorithms as input sizes become large” (Devi et al, 844).

2.3.2 Space Complexity

Space complexity “measures how much memory is used for everything, including the data, extra memory requirements, and so on” (Wyss-Gallifent, 11). It is a “theoretical measure of the execution of an algorithm, usually the time or memory needed, given the problem size n , which is usually the number of items” (Devi et al, 844). “It will often be the case that one algorithm may be slower but in-place, while another may be faster and not in-place”

(Wyss-Gallifent, 11). “In-place (or nearly in-place) algorithms can solve larger problem instances in main memory; in addition, they can be used to handle larger base cases within external-memory divide-and-conquer algorithms” (Brönnimann, 1). By adding an extra feature to a linear regression model (MACD values in my case), the model has to store an extra column of values. With an extra column, more memory will be taken up leading to a higher space complexity. This is a downside to adding an extra feature and could pose a potential trade-off.

2.4 MACD

The moving average convergence divergence (MACD) is an indicator that helps traders identify short-term momentum swings in a stock’s price (Dodds).

“To perform the MACD calculation, traders take the 26-day moving average of a stock and subtract it from that stock’s 12-day moving average” (Dodds). “The calculation creates the MACD line” (Dolan). “A nine-day EMA of the MACD line is called the signal line, plotted on top of the MACD line, which can function as a trigger for buy or sell signals” (Dolan). “If a stock’s MACD is positive, that means its short-term average is higher than its long-term average, which could be a bullish indicator that the stock is on an upswing” (Dodds). On the other hand, a negative MACD shows that there is a downward trend (Dodds).

An important aspect of MACD is the “zero line”. When both of the MACD lines converge, it creates a “zero line”, which helps a trader know when to buy or sell (Dodds).

3. Methodology

3.1 Experiment Overview

This experiment involves crafting two linear regression models. Model A uses 1 feature: Close_{t-1}. Model B uses 2 features: Close_{t-1} and MACD_{t-1}. Both of these models are made to predict the closing price on that day, which is Close_t. Everything will be constant in both models except for the features. The goal of this is to see whether adding a feature with MACD would improve the accuracy of the models' predictions.

The accuracy of each model will be compared through the MAE, RMSE, and R² metrics. The computational efficiency (runtime and peak memory) for each model will be recorded by using Python profiling tools. This is necessary to see whether adding the extra MACD feature is actually worth it.

3.2 Data Selection

All stocks tested in this experiment should have unique attributes to them so the model's efficiency can be analyzed for different stock behaviors. Here is a list of stocks that will bring a variety to this experiment:

- **AAPL** - Apple is a very stable and popular company that has a high valuation. AAPL will show if MACD allows our model to make better predictions than historical data on stable stocks.
- **TSLA** - Tesla is a very volatile stock that has a lot of random price swings. TSLA should be used in the model to show whether MACD is able to help make a better prediction compared to historical data for unstable stocks.
- **SPY** - The S&P 500 is an index fund that reflects a broad sense of the market as it represents the performance of 500 top companies on the stock exchange. This will help to

see if MACD allows our model to make better predictions with stocks that have a large-scale momentum.

- **BABA** - Alibaba is an international company that will make our experiment not just limited to America. BABA will give an insight into whether MACD will allow our model to make better predictions on stocks from other countries.

3.3 Programming Language and Tools

The linear regression model is going to be programmed in Python. “We’re living in the era of large amounts of data, powerful computers, and artificial intelligence” (Stojiljkovic, 1). “Python is one of the main programming languages for machine learning” (Stojiljkovic, 1). Many Python libraries will need to be used to make this model, which are collections of pre-written code. Some libraries that will be used include:

- **NumPy** - “NumPy is a fundamental Python scientific package that allows many high-performance operations on single- and multi-dimensional arrays. It also offers many mathematical routines” (Stojiljkovic, 6).
- **Scikit-learn** - “Scikit-learn is a widely used Python library for machine learning, built on top of NumPy and some other packages. It provides the means for preprocessing data, reducing dimensionality, implementing regression, classification, clustering, and more. Like NumPy, scikit-learn is also open source” (Stojiljkovic, 6).
- **Yfinance** - “Y-finance intends to ... provide a secure, threaded, and pythonic means to download historical market data” (Namratha 12).
- **Pandas** - “Pandas is a Python library used for working with data sets”(W3Schools). “It has functions for analyzing, cleaning, exploring, and manipulating data”(W3Schools). We

use Pandas because it “can clean messy data sets, and make them readable and relevant”(W3Schools).

- **Time** - “Return the value (in fractional seconds) of a performance counter, i.e. a clock with the highest available resolution to measure a short duration” (Python Software Foundation).
- **Tracemalloc** - “The tracemalloc module is a debug tool to trace memory blocks allocated by Python” (Python Software Foundation).

3.4 Evaluation Metrics

In order to figure out which model gives a more accurate prediction, evaluation metrics are needed to find the differences. To have a variety and be more certain when one model outperforms the other, we are going to use 3 evaluation metrics: MAE (Mean Absolute Error), RMSE (Root Mean Squared Error), and R^2 (Coefficient of Determination). The Mean Absolute Error (MAE) “provides us the average of the absolute difference between the observed value and the predicted values” (Tatachar, 2). “The MAE gives the same weight to all errors” (Chai & Draxler, 1). Therefore, it is preferred when “the model errors are likely to have a uniform distribution” (Chai & Draxler, 1). However, the MAE can’t capture the impact of large errors as it treats all the errors as if they have the same magnitude (Chai & Draxler, 1). “The Root Mean Squared error which is also called the Root Mean Squared Deviation is the square root of the mean of squares of all the errors” (Tatachar, 2). “The RMSE penalizes variance as it gives errors with larger absolute values more weight than errors with smaller absolute values” (Chai & Draxler, 1). The coefficient of determination provides an idea about how accurately a model fits. The closer the R^2 value is to 1 or -1, the more accurate the model is. Additionally, we will need

to output the runtime (seconds) and memory (MB) used for each model to measure and compare the computational cost between the two models.

3.5 Measuring Computational Efficiency

The computational efficiency will be measured by timing each model's training and getting the peak memory during that same time. This will be done through starting a timer with `time.perf_counter()` and memory tracing through `tracemalloc.start()` (Python Software Foundation). Then we will run `fit()` and `predict()` to capture the entire computational cost (Python Software Foundation). Finally, we will figure out the peak memory through `tracemalloc.get_traced_memory()` and stop tracing (Python Software Foundation).

3.6 Experimental Design

Step 1:

Import the necessary Python libraries (see Appendix A for code).

Step 2:

Downloading one year of historical stock data (see Appendix B for code).

Step 3:

Calculating MACD values for a stock using Python's pandas library. We are only calculating the MACD lines, the difference between the 12-period and 26-period exponential moving averages (see Appendix C for code) (Dolan).

Step 4:

We need to restructure our dataset so that the input values (yesterday's values) can be used to predict the target (today's closing price) (see Appendix D for code). We are shifting the

‘Close’ and ‘MACD’ columns one day backward so it would become ‘Close_t-1’ and ‘MACD_t-1’. The ‘target’ column represents today's closing price.

Step 5:

Prepare the dataset by setting up the input (features) and output (target) (see Appendix E for code).

Step 6:

Split the data into training and testing sets (see Appendix F for code).

Step 7:

Train the two linear regression models: Model A and Model B (see Appendix G for code).

Step 8:

Make predictions on the test data (see Appendix H for code).

Step 9:

Save the results to a CSV file for the analysis (see Appendix I for code).

Step 10:

Evaluate both of the models' performance using MAE, RMSE, and R^2 metrics (see Appendix J for code).

Step 11:

Measure the runtime and peak memory for each model to compare the computational efficiency (see Appendix K for code).

4. Analysis

My analysis will evaluate the predictive accuracy and computational efficiency of the two linear regression models I created. This analysis will do more than just cover the difference in the two models' performance; it will examine the memory and runtime performance so that people can understand the trade-off that comes with adding extra features to predictive models.

Three evaluation techniques were used to compare Model A to Model B. With MAE, the lower the value, the more precise the model. With RMSE, the lower the value, the less sensitive the model is to large errors. For R^2 , the closer the value is to 1 or -1, the better fit the model is for the data.

After evaluating this data, I believe Model B has outperformed Model A. Even though Model B's performance is modest compared to Model A, it remains much more consistent when looking for long-term predictions. However, there are still a lot of computational costs with Model B, potentially making Model A more practical in some situations.

When looking at the MAE metric, Model B outperformed Model A in AAPL, TSLA, and BABA. Regarding the MAE metric, Model B performed better on BABA (Figure 8, Appendix O). This is most likely because the MACD feature was able to identify momentum shifts from global events and regulations since BABA is an international company. TSLA is known to be very volatile and sentiment-driven. Model B was able to have a lower MAE value than Model A for TSLA, which is surprising considering the random momentum shifts that are typical for TSLA (Figure 4, Appendix M). A potential reason for this could be that Model B was able to capture a short-term momentum trend with TSLA that Model A was not able to capture. SPY and AAPL are slow-moving stocks that have very little short-term trend to be detected. The MAE values were very close, but Model A slightly outperformed Model B for SPY (Figure 6,

Appendix N). This makes sense considering that the MACD feature relies on detecting momentum shifts that are fairly rare in such a stable stock. The opposite occurred for AAPL (Figure 2, Appendix L). This tells me that the data I provided for AAPL probably had a lot more minor fluctuations that the MACD feature was able to pick up.

Regarding the RMSE metric, Model B outperformed Model A in AAPL and BABA. The RMSE metric is different from the MAE metric as it is impacted more by extreme points. The RMSE values for AAPL were almost identical, meaning that the MACD feature was not useful in enhancing the performance according to this metric (Figure 2, Appendix L). For BABA, Model B outperformed Model A regarding RMSE, which means that the MACD feature was able to smooth out large fluctuations in the given data (Figure 8, Appendix O). Model A was able to outperform Model B in SPY, most likely because the MACD feature overreacted to slight changes in momentum, because SPY is a very stable stock and does not typically fluctuate (Figure 6, Appendix N). In TSLA, the large spikes and volatility were likely why Model A outperformed Model B in the RMSE metric (Figure 4, Appendix M). Model B might have overcommitted to momentum trends. Since the price of TSLA is very random, it might have made larger errors when committing to these momentum shifts.

The R^2 metric doesn't tell us how big the errors are, like MAE and RMSE, but it tells us how well each model fits. Based on the R^2 metric, Model B fits the data better than Model A for AAPL and BABA (Appendix L, Figure 2 and Appendix O, Figure 8). Model A, however, fit the data better for TSLA and SPY because Model A's R^2 value was closer to 1 (Appendix M, Figure 4 and Appendix N, Figure 6).

These differences that we discovered in Model A and Model B represent the bias-variance trade-off. Model A has a higher bias because it assumes that there is a linear

relationship between yesterday's and today's prices. Model B reduces bias by adding the MACD feature, which allows it to detect momentum shifts. According to our results, increasing the model's complexity (through adding the MACD feature) slightly improved its accuracy. However, we need to explore the computational efficiency of both these models to really show us which model would be more practical in the real world.

With regard to time complexity, Model B always took slightly longer to run and required more memory compared to Model A. The differences were minuscule, with only fractions of a millisecond in increased runtime (see Appendices L-O, Figures 2L, 4M, 6N, 8O). However, these small costs are still able to show the trade-offs of adding an additional feature to my model. As we have explored earlier, time complexity is able to quantify how much time it takes for an algorithm to run relative to the size of its input. Both models scale linearly with the number of data points, or $O(n)$, because each additional data point needs a constant number of calculations. Devi et al. explained that Big-O notation describes the worst-case execution time or memory usage. Even though both of my models are $O(n)$ since they process every data point once to figure out predictions and errors, Model B needs extra preprocessing to compute EMA12, EMA26, and then subtract them to form MACD values. This is why Model B has to carry a high constant factor, meaning that it will always take slightly longer for the same input size.

Two passes through the dataset and one subtraction explain the consistent 0.0001 extra seconds Model B takes to process. High-frequency trading involves using extremely large datasets. If our models run for 6.5 trading hours a day, and collect 100,000 data points for 1,000 stocks per day, our 0.0001s would turn into many extra hours that our model has to run for. With our experiment, this extra runtime is negligible, but when it comes to high-frequency trading, tiny increases in runtime can affect profits and reactions to events.

With regard to space complexity, Model B uses more memory because it has to store MACD values along with the closing price values (see Appendices L-O, Figures 2L, 4M, 6N, 8O). The additional 0.02 MB of memory comes from storing an extra column in the dataset (the MACD feature). Let's assume that each number in the extra column in the Pandas DataFrame takes up around 8 bytes. With 250 rows, it would end up using 2000 bytes of extra memory, which is 0.02 MB. In my dataset, this only added on average 0.02 MB, but at real financial institutions where they run thousands of models with extremely large datasets, this additional storage can come with a significant amount of costs. Let's say a financial institution has 100,000 models, meaning that they would have $100000 * 0.02 = 2000$ MB of extra memory. This means that they would be spending a lot more money on RAM storage to keep this model with an extra feature running, which might not be worth it with Model B's results not being that much better than Model A's.

5. Conclusion

In this investigation, I used a linear regression model. This model assumes that there is a linear relationship between the features and the target. However, a lot of nonlinear factors affect stock prices, such as news events and unpredictable earnings. Fully linear models, like the ones I made, are not able to fully grasp the complex factors that influence price swings. Could nonlinear models use MACD more effectively to make predictions? The features for Model A were just the closing prices. Model B had MACD values and closing prices for its features. However, there are a lot of other features that can benefit a linear regression model. These include trading volume, inflation data, unemployment rates, etc. There are a lot of other technical indicators, too, that could all be implemented in a model like RSI. Using an additional amount of

features could have expanded the scope of this paper and made it more accurate to real-life situations since stocks are affected by so many different factors.

It is clear that adding the MACD feature didn't change the results radically. However, it almost always made steadier predictions. In the world of finance, small margins are extremely important when looking at big, long-term investments. It is clear that MACD helps with more structured behaviors like AAPL and BABA. TSLA is volatile, while SPY is flatline and does not have a structure showing why Model B didn't perform as well on those. The computational efficiency results showed me that even when the accuracy of your model has slight improvements, computational costs still exist, which could become important at larger scales. Even though a company would love to have a model that performs slightly better, buying extra RAM or having to wait longer for results can motivate them to stick to a model with fewer features. Overall, regarding adding the MACD technical indicator as an additional feature, it would most likely not make sense for a large financial institution to add the MACD feature to its prediction model because the computational costs will most likely negate the minimal profits.

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Appendix A - Importing Python Libraries

Python

```
import yfinance as yf #Importing yfinance library to get
data.
import pandas as pd #This imports the Pandas library which
can be used to create DataFrames, load CSV files, and slice
datasets.
from sklearn.linear_model import LinearRegression # This
imports the linear regression model into our code from the
Scikit-learn library.
from sklearn.metrics import mean_absolute_error,
mean_squared_error, r2_score #This imports the three
evaluation metrics that we will use for this experiment
import numpy as np #This imports NumPy, which is used for
fast operations with numbers
import time, tracemalloc # "The tracemalloc module is a
debug tool to trace memory blocks allocated by
Python"(Python Documentation). The time module is able to
provide various time-related functions.
```

Appendix B - Downloading Historical Data

Python

```
data = yf.download('SYMBOL', start='2019-01-01',  
end='2024-01-01') #Downloads the historical data of  
whatever stock from January 1, 2019 to January 1, 2024.  
data = data[['Close']] #This is a pandas library feature  
that means it will only keep data from the closed column.
```

Appendix C - Calculating MACD Values

Python

```
data['EMA12'] = data['Close'].ewm(span=12,
adjust=False).mean() #Calculates the 12-period Exponential
Moving Average
data['EMA26'] = data['Close'].ewm(span=26,
adjust=False).mean() #Calculates the 26-period Exponential
Moving Average
data['MACD'] = data['EMA12'] - data['EMA26'] #Calculates
the MACD line by subtracting the 26-period EMA from the
12-period EMA
data.drop(columns=['EMA12', 'EMA26'], inplace=True)
#Standard pandas syntax to remove one of more columns from
a DataFrame. The .drop() method with the columns as the
parameter determines which columns to remove, and
inplace=True makes the change to the DataFrame.
```

Appendix D - Creating Lagged Features

Python

```
data['Close_t-1'] = data['Close'].shift(1) #This creates a new column called Close_t-1, which contains the previous day's closing price. shift(1) moves the values down by a single row.
```

```
data['MACD_t-1'] = data['MACD'].shift(1)#This creates a new column called MACD_t-1, which contains the previous day's closing price. shift(1) moves the values down by a single row.
```

```
data['Target'] = data['Close'] #This sets up the target column that holds the values we are trying to predict.
```

```
data.dropna(inplace=True) #This removes all the rows that have missing data. inplace=True means that it will update the DataFrame directly without having to make a copy
```

Appendix E - Preparing Feature Sets

Python

```
X_close_only = data[['Close_t-1']] #This is Model A which  
is using the previous day's closing price  
X_close_macd = data[['Close_t-1', 'MACD_t-1']] #This is  
Model B which is using the MACD value from the previous day  
y = data['Close'] #The model needs to know the real prices  
so it can get trained accurately
```

Appendix F - Splitting Training and Testing Data

Python

```
train_mask = data.index < '2023-01-01' #For each row, if
the data is before Jan 1, 2023, it is marked as True. This
is used to select our training data.
test_mask = data.index >= '2023-01-01' #For each row, if
the data is after Jan 1, 2023, it is marked as True. This
is used to select our training data.
X_train_close = X_close_only[train_mask] #Gets the closing
prices from yesterday for training
X_test_close = X_close_only[test_mask] #Gets the closing
prices from yesterday for testing
X_train_macd = X_close_macd[train_mask] #Gets the closing +
MACD values from yesterday for training
X_test_macd = X_close_macd[test_mask] #Gets the closing +
MACD values from yesterday for testing
y_train = y[train_mask] #Gets the actual closing prices for
training
y_test = y[test_mask] #Gets the actual closing prices for
testing
```

Appendix G - Training Linear Regression Models

Python

```
model_a = LinearRegression().fit(X_train_close, y_train)
#This trains Model A by using just the closing price
(Close_t-1) to predict today's price.
model_b = LinearRegression().fit(X_train_macd, y_train)
#This trains Model B by using the closing price + MACD to
predict today's price.
```

Appendix H - Making Predictions

Python

```
preds_a = model_a.predict(X_test_close) #This uses Model A  
to predict the prices for 2023 only using the closing  
prices.  
preds_b = model_b.predict(X_test_macd) #This uses Model B  
to predict the prices for 2023 by using the closing prices  
+ MACD.
```

Appendix I - Exporting Results to a CSV File

Python

```
results = pd.DataFrame({ #This creates a new dataframe
called results
    'Date': y_test.index.strftime('%Y-%m-%d').to_numpy(),
#This takes the 2023 dates. The strftime('%Y-%m-%d')
formats each date to become a readable string. .to_numpy()
converts the result to a NumPy array so it can fit properly
in the DataFrame.
    'Actual Closing Price': y_test.to_numpy().flatten(),
#Converts y_test to a NumPy array. .flatten() makes sure it
becomes a 1D array.
    'Predicted Closing Price (Model A: Close Only)':
preds_a.flatten(), #Flattens Model A's predictions
    'Predicted Closing Price (Model B: Close + MACD)':
preds_b.flatten() #Flattens Model B's prediction
})
results.to_csv('SYMBOL_predictions_with_MACD.csv',
index=False) #to_csv() saves results as a CSV file. The
filename is "SYMBOL_predictions_with_MACD.csv". index=False
tells Pandas not to include row indexes in teh CSV.
```

Appendix J - Evaluating Model Performance

Python

```
print('Training Days:', len(y_train)) #Prints how many days
in training set
print('Testing Days:', len(y_test)) #Prints how many days
in testing set
print('Total Days:', len(data)) #Prints total number of
usable rows in dataset
print('Test set percentage: {:.2f}%'.format(100 *
len(y_test) / len(data))) #Calculates the percentage of the
dataset being used for testing
print()
print('Model A (Close Only)') #Labels the Model A output
print('MAE:', mean_absolute_error(y_test, preds_a)) #Prints
MAE for Model A
print('RMSE:', np.sqrt(mean_squared_error(y_test,
preds_a))) #Prints RMSE for Model A
print('R²:', r2_score(y_test, preds_a)) #Prints R^2 for
Model A
print('-'*40) #Sets up a divider for organization
print('Model B (Close + MACD)') #Labels the Model B output
print('MAE:', mean_absolute_error(y_test, preds_b)) #Prints
MAE for Model B
print('RMSE:', np.sqrt(mean_squared_error(y_test,
preds_b))) #Prints RMSE for Model B
print('R²:', r2_score(y_test, preds_b)) #Prints R^2 for
Model B
```

Appendix K - Measuring Runtime and Memory Usage

Python

```

start = time.perf_counter()#Starts a time for Model A
tracemalloc.start()#Starts tracing memory allocations
model_a_prof = LinearRegression().fit(X_train_close,
y_train)#Trains new linear regression model using Close_t-1
as the feature
preds_a_prof = model_a_prof.predict(X_test_close)#Uses
trained model to make predictions on the test set
_, peak = tracemalloc.get_traced_memory()#Gets current and
peak memory usage
tracemalloc.stop()#Stops tracing memory allocations
runtime_a = time.perf_counter() - start#Calculates the
runtime
mem_a_mb = peak / 10**6 #Converts memory from bytes to
megabytes

#repeats same steps for Model B
start = time.perf_counter()
tracemalloc.start()
model_b_prof = LinearRegression().fit(X_train_macd,
y_train)
preds_b_prof = model_b_prof.predict(X_test_macd)
_, peak = tracemalloc.get_traced_memory()
tracemalloc.stop()
runtime_b = time.perf_counter() - start
mem_b_mb = peak / 10**6

#Prints the results for both models
print(f"Model A = runtime: {runtime_a:.4f}s, peak memory:
{mem_a_mb:.2f} MB")
print(f"Model B = runtime: {runtime_b:.4f}s, peak memory:
{mem_b_mb:.2f} MB")

```

Appendix L - AAPL Model Predictions and Results

Date	Actual Closing Price	Predicted Closing Price (Model A: Close Only)	Predicted Closing Price (Model B: Close + MACD)
2023-01-03	123.47061157226600	128.30233558541300	128.39117723000100
2023-01-04	124.74411010742200	123.51790833389700	123.61187729449100
2023-01-05	123.42124938964800	124.78783960196200	124.88325056878800
2023-01-06	127.96244049072300	123.46868442241600	123.56606951590600
2023-01-09	128.48562622070300	127.99715494225500	128.08893283900400
2023-01-10	129.05824279785200	128.51887514778800	128.60455654541500
2023-01-11	131.78294372558600	129.08988773701300	129.16916930445500
2023-01-12	131.70396423339800	131.80695635447400	131.8767271380280
2023-01-13	133.03668212890600	131.72819809610500	131.78992532435300
2023-01-17	134.20162963867200	133.05718284190000	133.11023005045900
2023-01-18	133.48094177246100	134.2188671528480	134.2630371751440
2023-01-19	133.5402069091800	133.50019804522800	133.5380219205850
2023-01-20	136.10691833496100	133.5592971710990	133.5917991783850
2023-01-23	139.30548095703100	136.11881883972800	136.14341519094500
2023-01-24	140.70733642578100	139.30842179135800	139.3222654801880
2023-01-25	140.0458984375	140.70635044532100	140.70978112869100
2023-01-26	142.1190643310550	140.0467652475240	140.04302691687900
2023-01-27	144.06385803222700	142.1141238815790	142.10213702259600
2023-01-30	141.1713409423830	144.05346991369000	144.03260591156900
2023-01-31	142.44485473632800	141.16905521324000	141.1455463225480
2023-02-01	143.57025146484400	142.4390016973520	142.41215222452700
2023-02-02	148.89132690429700	143.56124601492800	143.53067111879100
2023-02-03	152.52427673339800	148.86741629604800	148.82711772677600
2023-02-06	149.78968811035200	152.49018966871000	152.43780919218700
2023-02-07	152.67234802246100	149.76326105290500	149.70583744309000
2023-02-08	149.97726440429700	152.63784618710500	152.57338654167600
2023-02-09	148.940673828125	149.95031191653300	149.8848606593580
2023-02-10	149.3065185546880	148.91662499148200	148.85276679129200
2023-02-13	152.11447143554700	149.28144493017200	149.21923471320300
2023-02-14	151.4718017578130	152.08153229911400	152.0176248032180
2023-02-15	153.57778930664100	151.4406628389140	151.37713249716300
2023-02-16	151.97607421875	153.54075118969000	153.4755238928840
2023-02-17	150.8291473388670	151.94352275440600	151.88001454686200
2023-02-21	146.8050537109380	150.79980859475900	150.74012540545300

2023-02-22	147.23023986816400	146.78698707777000	146.73666391636800
2023-02-23	147.71469116210900	147.2109822225650	147.16821424807500
2023-02-24	145.05503845214800	147.69407649323100	147.65719613161400
2023-02-27	146.25135803222700	145.04187388338800	145.01380967707100
2023-02-28	145.7471466064450	146.23484238660900	146.21257118593400
2023-03-01	143.67079162597700	145.73204333530400	145.7153834091350
2023-03-02	144.26405334472700	143.6615045474620	143.65243416361900
2023-03-03	149.32626342773400	144.25310444804200	144.24946324292700
2023-03-06	152.0947265625	149.30113449476500	149.2949999166080
2023-03-07	149.889892578125	152.0618427345220	152.05009000630000
2023-03-08	151.14553833007800	149.8631848324090	149.85028180126800
2023-03-09	148.8912353515630	151.11531332568800	151.10013337895300
2023-03-10	146.82485961914100	148.86732499976700	148.85374840869800
2023-03-13	148.77259826660200	146.80673750654900	146.79759644095900
2023-03-14	150.86868286132800	148.74902023569800	148.7409849604690
2023-03-15	151.26419067382800	150.83923337208500	150.82940205701400
2023-03-16	154.0919189453130	151.2336333058040	151.22207809790900
2023-03-17	153.2515106201170	154.0534406714320	154.03694204779600
2023-03-20	155.6244354248050	153.2153864604180	153.19645225751200
2023-03-21	157.48321533203100	155.58166433436200	155.55796025218000
2023-03-22	156.04959106445300	157.43523751051700	157.40563096721200
2023-03-23	157.1371612548830	156.00562904706400	155.9738165958890
2023-03-24	158.4422607421880	157.0901527845590	157.0556686630280
2023-03-27	156.4945068359380	158.39159648560000	158.35375983628000
2023-03-28	155.87161254882800	156.44929854040500	156.41206227152700
2023-03-29	158.95643615722700	155.8281490768900	155.79285273512700
2023-03-30	160.52847290039100	158.90433161548300	158.8669021403750
2023-03-31	163.0398406982420	160.47196483969100	160.43123470573800
2023-04-03	164.29547119140600	162.9762979064830	162.93013422326800
2023-04-04	163.7615966796880	164.22841118371600	164.17690592201700
2023-04-05	161.91268920898400	163.6960321373820	163.64179216947300
2023-04-06	162.8025360107420	161.85230374352300	161.79923707878700
2023-04-10	160.2021942138670	162.7396579462520	162.68708969130800
2023-04-11	158.986083984375	160.1466001104190	160.09871969256200
2023-04-12	158.29397583007800	158.9338963944650	158.892105253772
2023-04-13	163.6923828125	158.2437269425490	158.20830927396200
2023-04-14	163.34632873535200	163.62701214898100	163.58977186411900

2023-04-17	163.36610412597700	163.28192742302300	163.2442091813210
2023-04-18	164.59210205078100	163.30164741970900	163.26412098211000
2023-04-19	165.73904418945300	164.52421113400600	164.48574106699400
2023-04-20	164.77008056640600	165.66794050969900	165.6277330953230
2023-04-21	163.15847778320300	164.70169110418000	164.6620420619940
2023-04-24	163.4649658203130	163.09460267055300	163.05822465210100
2023-04-25	161.9225616455080	163.40023218709200	163.3666000596540
2023-04-26	161.91268920898400	161.86214852581900	161.83331286700000
2023-04-27	166.51025390625	161.85230374352300	161.82775446308200
2023-04-28	167.76588439941400	166.4369899483590	166.40994284437100
2023-05-01	167.67691040039100	167.6891032255920	167.65875721384700
2023-05-02	166.6387481689450	167.60037845655100	167.56804906122300
2023-05-03	165.56106567382800	166.56512427867800	166.53318997919800
2023-05-04	163.91981506347700	165.49046053952500	165.46085254944100
2023-05-05	171.61203002929700	163.85380732691600	163.82878398141400
2023-05-08	171.5428009033200	171.5244752045010	171.49298990956300
2023-05-09	169.83233642578100	171.45544000005300	171.41935516217700
2023-05-10	171.6021270751950	169.74976679904300	169.71299100715700
2023-05-11	171.7899627685550	171.5145999901110	171.47547157605100
2023-05-12	170.85931396484400	171.70190952653400	171.6612514471750
2023-05-15	170.36427307128900	170.7738676145940	170.73390365945500
2023-05-16	170.36427307128900	170.28021340743100	170.24210322484900
2023-05-17	170.97813415527300	170.28021340743100	170.24415829177100
2023-05-18	173.31472778320300	170.89235497122500	170.8576394386650
2023-05-19	173.42364501953100	173.2224034376770	173.18608210056900
2023-05-22	172.47314453125	173.33101557991800	173.29381518577200
2023-05-23	169.8593292236330	172.38317759105700	172.34717081771500
2023-05-24	170.1365509033200	169.77668398587800	169.74577791996600
2023-05-25	171.275146484375	170.05312912460500	170.0264015220680
2023-05-26	173.69094848632800	171.18853532268500	171.16398101254400
2023-05-30	175.5424346923830	173.597570288209	173.5718290494320
2023-05-31	175.49290466308600	175.44387019398100	175.41507111908600
2023-06-01	178.30474853515600	175.3944789059850	175.36380432976500
2023-06-02	179.15623474121100	178.19844636686800	178.16296470956000
2023-06-05	177.79983520507800	179.04754742787700	179.00764488768100
2023-06-06	177.4335174560550	177.69494737740900	177.6540370422640
2023-06-07	176.05726623535200	177.32965574126600	177.28911060706500

2023-06-08	178.77999877929700	175.95725961387700	175.91951412906300
2023-06-09	179.16615295410200	178.67236536129800	178.63370413730300
2023-06-12	181.96810913085900	179.0574378583140	179.01807949679200
2023-06-13	181.4928436279300	181.85154532085300	181.80840816517300
2023-06-14	182.12648010253900	181.37761111037600	181.3327630285540
2023-06-15	184.1660614013670	182.00947267085600	181.9630991242640
2023-06-16	183.08688354492200	184.043340785848	183.99365886376300
2023-06-20	183.1759796142580	182.96718587410700	182.91707814338500
2023-06-21	182.13636779785200	183.0560323715220	183.00622343713700
2023-06-22	185.14625549316400	182.01933266919900	181.97190896460000
2023-06-23	184.8294219970700	185.02078920183100	184.97183752860900
2023-06-26	183.4334259033200	184.70484320554400	184.6557903576140
2023-06-27	186.19573974609400	183.31275751356300	183.26626402720100
2023-06-28	187.3739471435550	186.06733368645000	186.01978418868900
2023-06-29	187.71058654785200	187.24224074208900	187.19290278617200
2023-06-30	192.04718017578100	187.5779371671560	187.52744019252700
2023-07-03	190.55215454101600	191.90238332313400	191.8457756227840
2023-07-05	189.43333435058600	190.41154548725400	190.3529220825540
2023-07-06	189.9085693359380	189.29585928586000	189.23804947140800
2023-07-07	188.78977966308600	189.76976306424400	189.71278493523000
2023-07-10	186.74032592773400	188.65410729494400	188.60011636899700
2023-07-11	186.215576171875	186.61039439765600	186.562349825232
2023-07-12	187.88880920410200	186.0871145473230	186.04519771124000
2023-07-13	188.6511688232420	187.75566059407900	187.71690575013900
2023-07-14	188.7996826171880	188.51588472558000	188.4791366855400
2023-07-17	192.0669708251950	188.66398250933300	188.62917138776800
2023-07-18	191.80955505371100	191.9221185358670	191.88491098396900
2023-07-19	193.1659698486330	191.66542382591900	191.62721647800400
2023-07-20	191.21551513671900	193.01803909243400	192.97779721271100
2023-07-21	190.0373077392580	191.07304790695100	191.0344789469030
2023-07-24	190.83926391601600	189.8981408513120	189.86313720307400
2023-07-25	191.7006378173830	190.69785062432500	190.6651288290580
2023-07-26	192.57191467285200	191.55681168367700	191.52522061608600
2023-07-27	191.30459594726600	192.42564795742000	192.39425838844400
2023-07-28	193.88873291015600	191.16187918831900	191.1328878209560
2023-07-31	194.50257873535200	193.73877758242300	193.70864806932200
2023-08-01	193.6708984375	194.35090393017000	194.3195011349250

2023-08-02	190.67092895507800	193.52155329794000	193.4908027130040
2023-08-03	189.27493286132800	190.52998719574500	190.504385425361
2023-08-04	180.18594360351600	189.13790150376400	189.1187588597260
2023-08-07	177.0770721435550	180.0743719158100	180.07313879508700
2023-08-08	178.0176239013670	176.97420888742	176.99161453344900
2023-08-09	176.42359924316400	177.91212601375000	177.94287009848300
2023-08-10	176.2057647705080	176.32256646606700	176.36573483652500
2023-08-11	176.26524353027300	176.10534218158400	176.15824230773500
2023-08-14	177.92095947265600	176.1646543321100	176.22465943998600
2023-08-15	175.9281768798830	177.81573235711000	177.87851341520400
2023-08-16	175.0557403564450	175.82853185773300	175.89562849083800
2023-08-17	172.50779724121100	174.95853916443200	175.02964541094200
2023-08-18	172.9936065673830	172.41773323339800	172.49483484589000
2023-08-21	174.3319854736330	172.9021817322320	172.9826458813550
2023-08-22	175.71006774902300	174.23681163140000	174.31731157880700
2023-08-23	179.5667266845700	175.61103368440700	175.6888920793570
2023-08-24	174.86737060546900	179.45688951958000	179.52664615720300
2023-08-25	177.07826232910200	174.77069706637000	174.83982940651200
2023-08-28	178.64471435546900	176.97539573907200	177.0404765265310
2023-08-29	182.54095458984400	178.53745989014200	178.59659851689900
2023-08-30	186.0406951904300	182.42278615078000	182.47139340150100
2023-08-31	186.25880432128900	185.91272343465500	185.94782229411600
2023-09-01	187.83518981933600	186.13022160798	186.15413367209200
2023-09-05	188.07313537597700	187.70219140553400	187.7150678895100
2023-09-06	181.3413543701170	187.93947043973200	187.94336148423300
2023-09-07	176.0372314453130	181.22654619749200	181.23272557211700
2023-09-08	176.65191650390600	175.9372809443950	175.95273483651300
2023-09-11	177.82180786132800	176.5502441747180	176.57221043225500
2023-09-12	174.78805541992200	177.71685848483700	177.7422241273140
2023-09-13	172.71600341796900	174.69160405497000	174.72363423086200
2023-09-14	174.23284912109400	172.62535619233400	172.6652976968230
2023-09-15	173.5091094970700	174.13795297517400	174.18176129688800
2023-09-18	176.44374084472700	173.4162406581880	173.46370022511400
2023-09-19	177.5343017578130	176.34265164787600	176.38858827284400
2023-09-20	173.9849853515630	177.4301577305490	177.47298855333800
2023-09-21	172.43836975097700	173.89078351053800	173.93569025966000
2023-09-22	173.29098510742200	172.3485002203420	172.39686714768400

2023-09-25	174.5699462890630	173.19872726881600	173.24827643712300
2023-09-26	170.4852752685550	174.4741058816450	174.52240922684500
2023-09-27	168.96836853027300	170.40087665875800	170.45337902573800
2023-09-28	169.22616577148400	168.8882190117300	168.94572714130300
2023-09-29	169.74171447753900	169.14529412284900	169.20590378410000
2023-10-02	172.25990295410200	169.65939869694600	169.7211954531000
2023-10-03	170.92147827148400	172.1705333366690	172.22925798428100
2023-10-04	172.17068481445300	170.83585778936100	170.8934484897880
2023-10-05	173.4099884033200	172.0815651108800	172.136086287279
2023-10-06	175.9678497314450	173.3173972180090	173.36733101155400
2023-10-09	177.45497131347700	175.8680935794790	175.91049897010800
2023-10-10	176.86012268066400	177.35104950310300	177.3851486351030
2023-10-11	178.2580108642580	176.75786713365400	176.78601592889200
2023-10-12	179.16021728515600	178.15183961544100	178.17326462335400
2023-10-13	177.316162109375	179.05151881609900	179.06633077608400
2023-10-16	177.18728637695300	177.21262912513000	177.22475869718700
2023-10-17	175.63075256347700	177.08411439364100	177.09437708353500
2023-10-18	174.3319854736330	175.53194067300800	175.54291728299800
2023-10-19	173.95526123046900	174.23681163140000	174.2501905254150
2023-10-20	171.39736938476600	173.86114265132200	173.87695192320000
2023-10-23	171.51634216308600	171.3104158577580	171.33161704320300
2023-10-24	171.9525909423830	171.42905537485800	171.45428529626600
2023-10-25	169.6326446533200	171.86408215360200	171.89174067720000
2023-10-26	165.458740234375	169.55063439423600	169.5832063845080
2023-10-27	166.77732849121100	165.38842172951300	165.43038831776000
2023-10-30	168.82955932617200	166.7033164159480	166.75059897347200
2023-10-31	169.30548095703100	168.7497986337580	168.79803065173700
2023-11-01	172.47802734375	169.22438713424800	169.27228047120800
2023-11-02	176.0471649169920	172.38804672604100	172.4309360536490
2023-11-03	175.13502502441400	175.9471865908790	175.98087948228900
2023-11-06	177.6929168701170	175.03760174373800	175.0650449100950
2023-11-07	180.26071166992200	177.5883285373020	177.60723943963800
2023-11-08	181.32151794433600	180.1489305452550	180.15753786253900
2023-11-09	180.8456573486330	181.20676533661800	181.2058617640170
2023-11-10	185.04489135742200	180.73223770031500	180.72468540489800
2023-11-13	183.45652770996100	184.9197090027690	184.90145737374000
2023-11-14	186.07733154296900	183.3357946084570	183.3116235419030

2023-11-15	186.6431884765630	185.94925716308300	185.9173301850280
2023-11-16	188.33084106445300	186.5135290435640	186.47522716821100
2023-11-17	188.31097412109400	188.19645425457000	188.15143686366500
2023-11-20	190.05816650390600	188.1766429616030	188.1270353882900
2023-11-21	189.2540740966800	189.9189411873220	189.8640755802110
2023-11-22	189.91917419433600	189.1171011677530	189.05997216643000
2023-11-24	188.58892822265600	189.78033821678800	189.72135637731800
2023-11-27	188.4102325439450	188.45381847057800	188.3960291320700
2023-11-28	189.01580810546900	188.27562334620300	188.2198611934260
2023-11-29	187.9932861328130	188.87950259657100	188.82530267475000
2023-11-30	188.569091796875	187.8598448666940	187.80903831176300
2023-12-01	189.84971618652300	188.43403760970500	188.3858642005270
2023-12-04	188.0528564453130	189.71107477163800	189.66391335383700
2023-12-05	192.01385498046900	187.91924831350100	187.8760158662380
2023-12-06	190.921875	191.8691514768670	191.82426743197500
2023-12-07	192.857666015625	190.7802303018390	190.73614622995300
2023-12-08	194.28721618652300	192.71059886632300	192.6651803117510
2023-12-11	191.7755889892580	194.13614464527300	194.08836911297500
2023-12-12	193.29449462890600	191.6315529056850	191.58605045896600
2023-12-13	196.52085876464800	193.14620385484600	193.10113562430700
2023-12-14	196.66976928710900	196.36353044379300	196.31503600103800
2023-12-15	196.13369750976600	196.51202384476400	196.4612973602270
2023-12-18	194.4658966064450	195.97745368768700	195.92645352330000
2023-12-19	195.50828552246100	194.31432455360100	194.26615024576300
2023-12-20	193.41360473632800	195.35379357644600	195.30715356504700
2023-12-21	193.26467895507800	193.26498031636700	193.22308638456900
2023-12-22	192.19256591796900	193.1164716993490	193.07918342093500
2023-12-26	191.6465606689450	192.0473618172880	192.01574235849000
2023-12-27	191.7458038330080	191.5028860137270	191.4770013150480
2023-12-28	192.17269897460900	191.6018511822810	191.58079406375000
2023-12-29	191.1303253173830	192.02755052432100	192.01009427188500

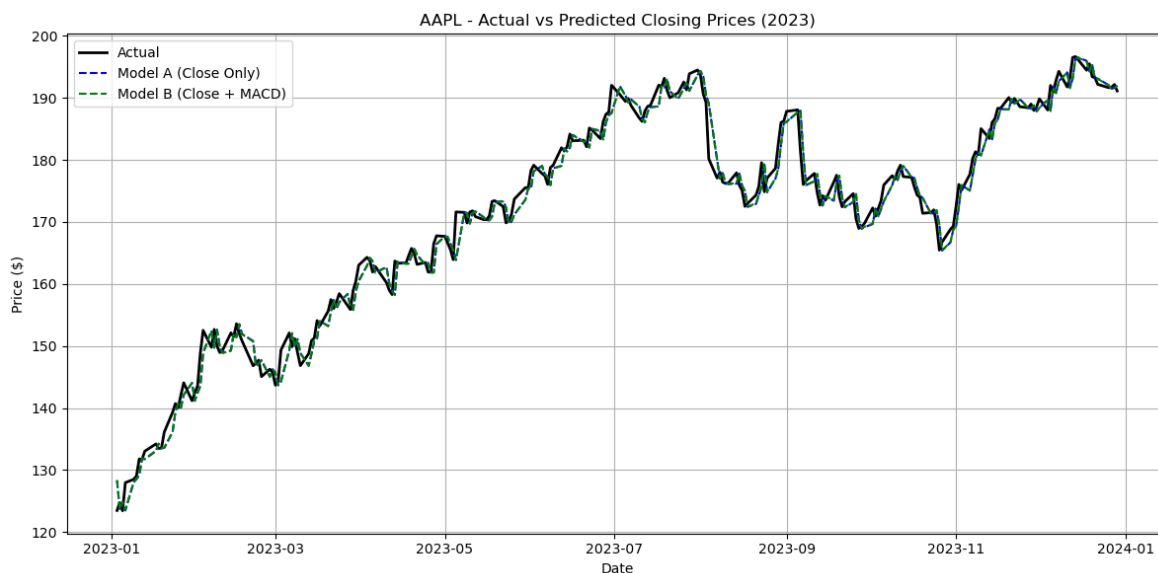


Figure 1: AAPL - Actual vs Predicted Closing Prices (2023)

Metric	Model A	Model B	Difference
MAE	1.6532587316356757	1.6502948975525942	0.00296383408
RMSE	2.138101735737432	2.138007498755096	0.0000942369823361
R ²	0.9847996241300145	0.9848009640157281	0.0000013398857136
Runtime (seconds)	0.0027 seconds	0.0028 seconds	0.0001 seconds
Peak Memory (MB)	0.04 MB	0.06 MB	0.02 MB

Figure 2: AAPL - Evaluation Metrics

Appendix M - TSLA Model Predictions and Results

Date	Actual Closing Price	Predicted Closing Price (Model A: Close Only)	Predicted Closing Price (Model B: Close + MACD)
2023-01-03	108.0999984741210	123.38643228942400	123.11741020685400
2023-01-04	113.63999938964800	108.3500339084450	108.07539454045600
2023-01-05	110.33999633789100	113.87401604917100	113.60141979465300
2023-01-06	113.05999755859400	110.58355487412700	110.3131632870910
2023-01-09	119.76999664306600	113.2956912789790	113.03217373037700
2023-01-10	118.8499984741210	119.98628856805600	119.73763139107000
2023-01-11	123.22000122070300	119.06895055092500	118.83460524927300
2023-01-12	123.55999755859400	123.42631754329900	123.20971804349600
2023-01-13	122.4000015258790	123.76533079023900	123.56583035023500
2023-01-17	131.49000549316400	122.6086885718900	122.42372077511400
2023-01-18	128.77999877929700	131.6724093041800	131.50914942846800
2023-01-19	127.16999816894500	128.9702385072950	128.8242769322390
2023-01-20	133.4199981689450	127.36489317364900	127.23222671846900
2023-01-23	143.75	133.59682145416100	133.4815978929710
2023-01-24	143.88999938964800	143.89695434195100	143.80692340652100
2023-01-25	144.42999267578100	144.03654892684700	143.9684842854400
2023-01-26	160.27000427246100	144.57498083582900	144.52528602993900
2023-01-27	177.89999389648400	160.36919143310600	160.34910387175100
2023-01-30	166.66000366210900	177.94820438079900	177.96961401649400
2023-01-31	173.22000122070300	166.74071429851500	166.78581317171500
2023-02-01	181.41000366210900	173.28174378739300	173.34949982264500
2023-02-02	188.27000427246100	181.4480650405230	181.54099355999900
2023-02-03	189.97999572753900	188.28823012979900	188.40695537855400
2023-02-06	194.75999450683600	189.9932771871330	190.13304127746200
2023-02-07	196.80999755859400	194.7594547188950	194.91853897924500
2023-02-08	201.2899932861330	196.80353023783600	196.9781812620380
2023-02-09	207.32000732421900	201.27057216920000	201.45960785264700
2023-02-10	196.88999938964800	207.28315057173300	207.48719744420900
2023-02-13	194.63999938964800	196.88330074558700	197.08755263896700
2023-02-14	209.25	194.63980656460300	194.83835847395900
2023-02-15	214.24000549316400	209.2075627217140	209.41248059143600
2023-02-16	202.0399932861330	214.1831397381550	214.39680817927400
2023-02-17	208.30999755859400	202.01840356286100	202.22548423180900
2023-02-21	197.3699951171880	208.27027827397800	208.47400716597900

2023-02-22	200.86000061035200	197.36190857742300	197.55101156556200
2023-02-23	202.07000732421900	200.8418228065410	201.01905274597500
2023-02-24	196.8800048828130	202.0483308161030	202.21553997911700
2023-02-27	207.6300048828130	196.87333513761900	197.02587295274600
2023-02-28	205.7100067138670	207.59225178009900	207.74071678629400
2023-03-01	202.77000427246100	205.67780523808600	205.82061601356600
2023-03-02	190.89999389648400	202.74630374058600	202.87986161201200
2023-03-03	197.7899932861330	190.91061520426400	191.02379314798600
2023-03-06	193.80999755859400	197.7806923321130	197.88141642720100
2023-03-07	187.7100067138670	193.81220466319000	193.8989038219430
2023-03-08	182.0	187.72985179021200	187.7982222598800
2023-03-09	172.9199981689450	182.03635541868200	182.0833594227010
2023-03-10	173.44000244140600	172.98260818699500	173.00303260600100
2023-03-13	174.47999572753900	173.50110888004100	173.49971571007500
2023-03-14	183.25999450683600	174.5380950514640	174.52046716240600
2023-03-15	180.4499969482420	183.29270668275300	183.2706550669060
2023-03-16	184.1300048828130	180.49083416218200	180.46378084827700
2023-03-17	180.1300048828130	184.1602014453750	184.1324333693960
2023-03-20	183.25	180.1717673458470	180.14026570830000
2023-03-21	197.5800018310550	183.28274107478500	183.25091007770900
2023-03-22	191.14999389648400	197.57130806210200	197.5530624036760
2023-03-23	192.22000122070300	191.15989233548400	191.14797084421700
2023-03-24	190.41000366210900	192.22680576014900	192.22000419072400
2023-03-27	191.80999755859400	190.4220417644600	190.41755575362000
2023-03-28	189.19000244140600	191.81798761342700	191.8162435322740
2023-03-29	193.8800048828130	189.20556814693000	189.2035053665070
2023-03-30	195.27999877929700	193.8820095629730	193.8835621998900
2023-03-31	207.4600067138670	195.27795541194000	195.28395266717100
2023-04-03	194.77000427246100	207.42274515662900	207.4434176376440
2023-04-04	192.5800018310550	194.76943554153100	194.79075717361500
2023-04-05	185.52000427246100	192.58576543769300	192.60361518964300
2023-04-06	185.05999755859400	185.54618168637400	185.5540743655930
2023-04-10	184.50999450683600	185.087505070474	185.08605003011200
2023-04-11	186.7899932861330	184.53909233885500	184.5295613310270
2023-04-12	180.5399932861330	186.81249855841200	186.7986004229180
2023-04-13	185.89999389648400	180.58057027790100	180.55766000208400
2023-04-14	185.0	185.9250725798540	185.89941766943000

2023-04-17	187.0399932861330	185.02768099332800	184.99975216201900
2023-04-18	184.30999755859400	187.0617756896330	187.03397041225800
2023-04-19	180.58999633789100	184.3396736768130	184.3097758663740
2023-04-20	162.99000549316400	180.6304287470790	180.5952536175210
2023-04-21	165.0800018310550	163.08132783795900	163.02543201279200
2023-04-24	162.5500030517580	165.1652810034410	165.0935086725920
2023-04-25	160.6699981689450	162.64259765266400	162.556927177357
2023-04-26	153.75	160.76802875719200	160.67023740528000
2023-04-27	160.19000244140600	153.8680395907690	153.75505323421500
2023-04-28	164.30999755859400	160.28942092535600	160.17084325825900
2023-05-01	161.8300018310550	164.39750317917500	164.28031521967300
2023-05-02	160.30999755859400	161.92467829757500	161.8079222260870
2023-05-03	160.61000061035200	160.4090690796480	160.29211523623800
2023-05-04	161.1999969482420	160.7082046800460	160.59236805260900
2023-05-05	170.05999755859400	161.29649505820600	161.1832746830910
2023-05-08	171.7899932861330	170.13087719724600	170.0291361058890
2023-05-09	169.14999389648400	171.85587068518400	171.76674655523900
2023-05-10	168.5399932861330	169.22350478808300	169.14284853702600
2023-05-11	172.0800018310550	168.61526797931800	168.54111314058800
2023-05-12	167.97999572753900	172.14504067761400	172.079867267008
2023-05-15	166.35000610351600	168.05688963973100	167.99591684993800
2023-05-16	166.52000427246100	166.43161309014900	166.3724577096960
2023-05-17	173.86000061035200	166.6011197136180	166.54385780468200
2023-05-18	176.88999938964800	173.9198926347310	173.87143536789900
2023-05-19	180.13999938964800	176.9411302479490	176.90361138710900
2023-05-22	188.8699951171880	180.18173295381500	180.1563956345790
2023-05-23	185.77000427246100	188.88648611592700	188.87927835413900
2023-05-24	182.89999389648400	185.79545881759400	185.80046528383000
2023-05-25	184.47000122070300	182.93374700520900	182.94503161874800
2023-05-26	193.1699981689450	184.49921469231400	184.5162130833970
2023-05-30	201.16000366210900	193.17405581585300	193.20340256765000
2023-05-31	203.92999267578100	201.1409584069400	201.18786879625800
2023-06-01	207.52000427246100	203.90293806630100	203.96635041045200
2023-06-02	213.97000122070300	207.4825692337750	207.56161150707200
2023-06-05	217.61000061035200	213.91391617633000	214.01047456173000
2023-06-06	221.30999755859400	217.54339059831300	217.6564548569600
2023-06-07	224.57000732421900	221.23268909744200	221.36100108818300

2023-06-08	234.86000061035200	224.48327262594500	224.6252646924730
2023-06-09	244.39999389648400	234.74351265252500	234.90427690710000
2023-06-12	249.8300018310550	244.25592128544400	244.43933975127700
2023-06-13	258.7099914550780	249.67022848718000	249.87516117366100
2023-06-14	256.7900085449220	258.52454184215700	258.7525674381100
2023-06-15	255.89999389648400	256.6101105148130	256.85255378996200
2023-06-16	260.5400085449220	255.72266932158600	255.97226848674100
2023-06-20	274.45001220703100	260.34926748312000	260.6055125310290
2023-06-21	259.4599914550780	274.219050715747	274.4907190195670
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2023-06-23	256.6000061035160	264.4074760530920	264.67224245312200
2023-06-26	241.0500030517580	256.42065746073800	256.6726962596900
2023-06-27	250.2100067138670	240.91561685589100	241.1390998270210
2023-06-28	256.239990234375	250.04913459533000	250.25409575253300
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2023-06-30	261.7699890136720	257.31804904726400	257.5036384275640
2023-07-03	279.82000732421900	261.5756914939480	261.75599427001100
2023-07-05	282.4800109863280	279.5735186256690	279.76456340805900
2023-07-06	276.5400085449220	282.22583095337500	282.4273294247840
2023-07-07	274.42999267578100	276.30300388123000	276.50481723828800
2023-07-10	269.6099853515630	274.1990890704730	274.39583540764700
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2023-07-13	277.8999938964840	271.7661418354150	271.930457096426
2023-07-14	281.3800048828130	277.659056868987	277.8195067902440
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2023-07-19	291.260009765625	293.05441492751000	293.22505458689600
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2023-07-24	269.05999755859400	259.8307515754050	259.94353368401800
2023-07-25	265.2799987792970	268.8446211605520	268.94019989311000
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2023-07-31	267.42999267578100	266.2322016940550	266.2634998624640
2023-08-01	261.07000732421900	267.2193293963000	267.24510774487400

2023-08-02	254.11000061035200	260.8777337841340	260.89275492632300
2023-08-03	259.32000732421900	253.9378517565010	253.93672986212700
2023-08-04	253.86000061035200	259.1327938655900	259.1227448979940
2023-08-07	251.4499969482420	253.68857462528100	253.66685014907200
2023-08-08	249.6999969482420	251.28553942879500	251.25171697119700
2023-08-09	242.19000244140600	249.54059951025200	249.49545953666600
2023-08-10	245.33999633789100	242.05231996567000	241.9913300547230
2023-08-11	242.64999389648400	245.1932057331800	245.12224224335000
2023-08-14	239.75999450683600	242.51098136690100	242.43057407646800
2023-08-15	232.9600067138670	239.62933833857900	239.5391467204860
2023-08-16	225.60000610351600	232.84901254111700	232.74522920541200
2023-08-17	219.22000122070300	225.51029318940000	225.3891245838410
2023-08-18	215.49000549316400	219.1487359319590	219.00826586726200
2023-08-21	231.27999877929700	215.42952539425700	215.27106053190500
2023-08-22	233.19000244140600	231.17386230768800	231.0170876533280
2023-08-23	236.86000061035200	233.07834324173300	232.92801571570200
2023-08-24	230.0399932861330	236.737729702289	236.59751439288700
2023-08-25	238.58999633789100	229.93744225955400	229.80054608117100
2023-08-28	238.82000732421900	238.46272319022700	238.33685653436800
2023-08-29	257.17999267578100	238.69206910551200	238.57719540290800
2023-08-30	256.8999938964840	256.9989670162610	256.9108090936530
2023-08-31	258.0799865722660	256.71977784646800	256.6551129019080
2023-09-01	245.00999450683600	257.89635860278700	257.851574655536
2023-09-05	256.489990234375	244.86415809420900	244.8231242791060
2023-09-06	251.9199981689450	256.3109596997460	256.28216833233100
2023-09-07	251.49000549316400	251.7541816526630	251.73207822533400
2023-09-08	248.5	251.32543229000500	251.30756981239100
2023-09-11	273.5799865722660	248.3440723233270	248.32659037107000
2023-09-12	267.4800109863280	273.3515407384560	273.35720274328200
2023-09-13	271.29998779296900	267.2692030801470	267.2898386245910
2023-09-14	276.0400085449220	271.0781345188990	271.11276005122900
2023-09-15	274.3900146484380	275.8044496187890	275.85414198375300
2023-09-18	265.2799987792970	274.159226638601	274.218818792019
2023-09-19	266.5	265.07555215367200	265.1332068873630
2023-09-20	262.5899963378910	266.2920257712010	266.3472353310680
2023-09-21	255.6999969482420	262.39332778739300	262.44215892160000
2023-09-22	244.8800048828130	255.5232506595430	255.5593326838210

2023-09-25	246.99000549316400	244.73454433194900	244.7490427497600
2023-09-26	244.1199951171880	246.83844392803600	246.83625874766400
2023-09-27	240.5	243.97673211565100	243.9587706724470
2023-09-28	246.3800048828130	240.3672041242720	240.3330834693530
2023-09-29	250.22000122070300	246.2302071192720	246.1885585407570
2023-10-02	251.60000610351600	250.05910020329800	250.01597536976900
2023-10-03	246.52999877929700	251.4351148363290	251.39274104425600
2023-10-04	261.1600036621090	246.37976731213700	246.33359728145200
2023-10-05	260.04998779296900	260.9674698998520	260.93154739423700
2023-10-06	260.5299987792970	259.8606636139780	259.8335226743100
2023-10-09	259.6700134277340	260.3392866604830	260.31932027864800
2023-10-10	263.6199951171880	259.48178793516600	259.46659485350700
2023-10-11	262.989990234375	263.42034835084700	263.4123078638830
2023-10-12	258.8699951171880	262.79216511147800	262.78935846899200
2023-10-13	251.1199951171880	258.6840828576580	258.68117005759
2023-10-16	253.9199981689450	250.95649178982400	250.94551630169500
2023-10-17	254.85000610351600	253.74839870242700	253.73261234424600
2023-10-18	242.67999267578100	254.6757175421950	254.65721217003700
2023-10-19	220.11000061035200	242.54089340547400	242.5089448020410
2023-10-20	211.99000549316400	220.03616191051800	219.97134715174200
2023-10-23	212.0800018310550	211.93964555717100	211.8393745004180
2023-10-24	216.52000427246100	212.02938167289000	211.90135990688900
2023-10-25	212.4199981689450	216.45654595771200	216.3121279546370
2023-10-26	205.75999450683600	212.36839491982900	212.2092274353250
2023-10-27	207.3000030517580	205.72764849259500	205.55182049887600
2023-10-30	197.36000061035200	207.2632041411280	207.07674112619400
2023-10-31	200.83999633789100	197.35194296945500	197.1499731664030
2023-11-01	205.66000366210900	200.82187637593700	200.61190752515000
2023-11-02	218.50999450683600	205.62794676890800	205.41875858109700
2023-11-03	219.9600067138670	218.4407821848390	218.2468552083560
2023-11-06	219.27000427246100	219.88660171765300	219.7094287197700
2023-11-07	222.17999267578100	219.19859440113700	219.03583161617600
2023-11-08	222.11000061035200	222.10016864539500	221.95291242196000
2023-11-09	209.97999572753900	222.0303789602810	221.89695759612300
2023-11-10	214.64999389648400	209.93544768477000	209.8028382522220
2023-11-13	223.7100067138670	214.59194267020800	214.46415782383100
2023-11-14	237.41000366210900	223.62575868596000	223.5119207840730

2023-11-15	242.83999633789100	237.28614243390800	237.1980489650290
2023-11-16	233.58999633789100	242.7004344209750	242.6398680522390
2023-11-17	234.3000030517580	233.47718056581800	233.43060688670400
2023-11-20	235.60000610351600	234.18513431293800	234.14934763002400
2023-11-21	241.1999969482420	235.48137843821900	235.45545434080200
2023-11-22	234.2100067138670	241.06517704875600	241.05234166322400
2023-11-24	235.4499969482420	234.09539819721900	234.08682235192300
2023-11-27	236.0800018310550	235.33180303068500	235.32671084169700
2023-11-28	246.72000122070300	235.95998627005500	235.95812216710500
2023-11-29	244.13999938964800	246.56922036621100	246.57957757768000
2023-11-30	240.0800018310550	243.99667854625600	244.01502886109300
2023-12-01	238.8300018310550	239.94842036958200	239.96844531040300
2023-12-04	235.5800018310550	238.7020347134800	238.7212103050350
2023-12-05	238.72000122070300	235.4614320076140	235.47626204449800
2023-12-06	239.3699951171880	238.59235216715600	238.6058573542480
2023-12-07	242.63999938964800	239.2404666224620	239.2534554939290
2023-12-08	243.83999633789100	242.50101575893300	242.51627065221800
2023-12-11	239.74000549316400	243.6975429458570	243.7155945992870
2023-12-12	237.00999450683600	239.60940712264300	239.6254703215090
2023-12-13	239.2899932861330	236.88728989515400	236.8982994531480
2023-12-14	251.0500030517580	239.16069611471100	239.16912866127100
2023-12-15	253.5	250.88670210471000	250.90391854034400
2023-12-18	252.0800018310550	253.3296149477370	253.35685111365900
2023-12-19	257.2200012207030	251.91372266816500	251.94714487390100
2023-12-20	247.13999938964800	257.0388598774710	257.08104091861000
2023-12-21	254.5	246.98800412090100	247.0274728325510
2023-12-22	252.5399932861330	254.32672347261900	254.36897074153200
2023-12-26	256.6099853515630	252.37238406939600	252.41504281588600
2023-12-27	261.44000244140600	256.4306078540380	256.4763377242990
2023-12-28	253.17999267578100	261.24665906964600	261.2989123415180
2023-12-29	248.47999572753900	253.01053291673400	253.05985566969900



Figure 3: TSLA - Actual vs Predicted Closing Prices (2023)

MAE	5.385706515751588	5.385590212872197	0.0001163028793911
RMSE	7.106295914473116	7.109191919449343	0.0028960049762270
R²	0.9711430120210763	0.9711194872452187	0.0000235247758576
Runtime (seconds)	0.0027 seconds	0.0029 seconds	0.0002 seconds
Peak Memory (MB)	0.04 MB	0.06 MB	0.02 MB

Figure 4: TSLA - Evaluation Metrics

Appendix N - SPY Model Predictions and Results

Date	Actual Closing Price	Predicted Closing Price (Model A: Close Only)	Predicted Closing Price (Model B: Close + MACD)
2023-01-03	368.1686706542970	369.7505066330980	369.83905786052800
2023-01-04	371.0110168457030	368.19998074446600	368.2898983825120
2023-01-05	366.7764892578130	371.0313837759020	371.11676352599300
2023-01-06	375.1875	366.81315930862800	366.90156931712100
2023-01-09	374.9747619628910	375.1917872832480	375.26736938805200
2023-01-10	377.6043701171880	374.9798682970970	375.04461470253400
2023-01-11	382.38031005859400	377.5993523423820	377.650571461201
2023-01-12	383.7724609375	382.35690470139500	382.3886584900140
2023-01-13	385.2613220214840	383.74369573714900	383.7573600091460
2023-01-17	384.55560302734400	385.22682463936600	385.2237613624750
2023-01-18	378.4841613769530	384.5238226949180	384.50914801229000
2023-01-19	375.7288513183590	378.47575636644600	378.46321746396500
2023-01-20	382.72833251953100	375.7310543748180	375.72594366376600
2023-01-23	387.3205261230470	382.70358726029100	382.6925469614200
2023-01-24	386.90484619140600	387.27810071303300	387.2542675626710
2023-01-25	387.04986572265600	386.8640211677220	386.83116131418800
2023-01-26	391.3037109375	387.00848236729000	386.969026827809
2023-01-27	392.2027282714840	391.2459500877900	391.19460368197800
2023-01-30	387.2818298339840	392.1415061648270	392.07986743192500
2023-01-31	392.9762268066410	387.23955340641400	387.17948451576300
2023-02-01	397.1526794433590	392.9120266960250	392.8445325994540
2023-02-02	402.93402099609400	397.0723998032880	396.9924224198850
2023-02-03	398.6511535644530	402.8314829324550	402.73249106439400
2023-02-06	396.2149353027340	398.56510473199100	398.45980685150600
2023-02-07	401.3968200683590	396.13826601954800	396.0341686466110
2023-02-08	397.0076599121090	401.3002002970480	401.18962078801200
2023-02-09	393.56591796875	396.92793860371900	396.8212331468050
2023-02-10	394.4844055175780	393.4994475207850	393.4037108425550
2023-02-13	399.1152648925780	394.41439885146800	394.32731487431100
2023-02-14	398.93157958984400	399.0274292107440	398.94023158111600
2023-02-15	400.22705078125	398.8444511046410	398.75848394372900
2023-02-16	394.7164306640630	400.1349346740160	400.0489835650630
2023-02-17	393.7303466796880	394.64553069076	394.57052076084700

2023-02-21	385.83172607421900	393.6632431738310	393.60013348538700
2023-02-22	385.29998779296900	385.79503261098400	385.75627869363400
2023-02-23	387.34954833984400	385.26534154590100	385.2479494330060
2023-02-24	383.2117919921880	387.307011192997	387.30330928540400
2023-02-27	384.5169372558590	383.1851853923540	383.199714932411
2023-02-28	383.0957336425780	384.4853057883840	384.51228054914900
2023-03-01	381.6261901855470	383.0695738725810	383.1087234053140
2023-03-02	384.59423828125	381.60568822359000	381.6569442664400
2023-03-03	390.76226806640600	384.5623092013690	384.6176691633500
2023-03-06	391.03302001953100	390.70659179596700	390.7537845963230
2023-03-07	385.0389709472660	390.9763013419630	391.0159623273300
2023-03-08	385.6673583984380	385.0053296267280	385.0495028583850
2023-03-09	378.5518798828130	385.63129775810700	385.6781585456810
2023-03-10	373.08953857421900	378.54321415302900	378.6044544643170
2023-03-13	372.55780029296900	373.1019031027950	373.184165855906
2023-03-14	378.71624755859400	372.572212037711	372.671654771655
2023-03-15	376.34765625	378.70694900590700	378.8082262532250
2023-03-16	382.95068359375	376.34747687979400	376.4530769573250
2023-03-17	378.4729919433590	382.9250822729290	383.0217286099680
2023-03-20	382.1122131347660	378.4646299356720	378.56088503667700
2023-03-21	387.12957763671900	382.0898399627150	382.1789287511570
2023-03-22	380.5303649902340	387.08788738691800	387.1615690563760
2023-03-23	381.55908203125	380.5140820042940	380.5864334009400
2023-03-24	384.0628356933590	381.5388384386890	381.6083132935190
2023-03-27	384.781005859375	384.0329525372100	384.0952200867790
2023-03-28	383.91729736328100	384.7483577159640	384.8031459749860
2023-03-29	389.49749755859400	383.8879745362130	383.9380717447990
2023-03-30	391.7781066894530	389.44669071118100	389.48310370010700
2023-03-31	397.30010986328100	391.71851939487900	391.739703765765
2023-04-03	398.8139953613280	397.21926260949800	397.2187178826000
2023-04-04	396.6013488769530	398.72731958066400	398.7070268993970
2023-04-05	395.56292724609400	396.52319188422200	396.4917834703610
2023-04-06	397.1059875488280	395.48876822308800	395.4513358149530
2023-04-10	397.5135498046880	397.0258876746390	396.981857342085
2023-04-11	397.62030029296900	397.4318807975830	397.3826907304440
2023-04-12	395.9996643066410	397.53822029171000	397.4856689233990
2023-04-13	401.25958251953100	395.92382382641700	395.87242188363500

2023-04-14	400.2794189453130	401.1634911189220	401.1047694204330
2023-04-17	401.7157287597660	400.18710121830500	400.12499841145600
2023-04-18	401.97772216796900	401.6178811757290	401.55172093175500
2023-04-19	401.9097900390630	401.87886589759200	401.81005749118100
2023-04-20	399.716552734375	401.8111953104200	401.7415398340890
2023-04-21	400.027099609375	399.6264020674550	399.5610862176710
2023-04-24	400.44439697265600	399.93575332309600	399.87453559584600
2023-04-25	394.0877990722660	400.3514440728640	400.29371838841100
2023-04-26	392.4185791015630	394.0193193587090	393.9764902888320
2023-04-27	400.2308654785160	392.3565259595540	392.32959316961800
2023-04-28	403.6469421386720	400.13873468452700	400.11126297219500
2023-05-01	403.23931884765600	403.5416592967460	403.50783549039500
2023-05-02	398.7072448730470	403.13560537363300	403.09800377044500
2023-05-03	395.97052001953100	398.62098008653800	398.5892007521350
2023-05-04	393.1658935546880	395.894791746117	395.87342463524700
2023-05-05	400.44439697265600	393.10096321860900	393.09347154874700
2023-05-08	400.5511474609380	400.3514440728640	400.34263203482900
2023-05-09	398.7945251464840	400.45778356699100	400.447660300765
2023-05-10	400.65789794921900	398.70792432701900	398.7003156920550
2023-05-11	399.9591064453130	400.56412306111700	400.55575826176800
2023-05-12	399.43505859375	399.86802193575700	399.8605961659470
2023-05-15	400.81317138671900	399.34599169186200	399.3407007865970
2023-05-16	398.1346740722660	400.7187986889380	400.713192864814
2023-05-17	402.9676208496090	398.0506137089500	398.04978231911200
2023-05-18	406.8495178222660	402.86495342503100	402.85989722607400
2023-05-19	406.25750732421900	406.7319049207130	406.7167533399030
2023-05-22	406.4225158691410	406.1421736895630	406.1203928264580
2023-05-23	401.8612976074220	406.3065469442060	406.27992064450200
2023-05-24	398.9498596191410	401.76288957681000	401.7411369416110
2023-05-25	402.40472412109400	398.8626607550070	398.8507759512360
2023-05-26	407.61614990234400	402.304223874098	402.2946749671470
2023-05-30	407.7713928222660	407.4955854329920	407.4788915177380
2023-05-31	405.51025390625	407.6502306607290	407.6278248048910
2023-06-01	409.36297607421900	405.3977972306770	405.37549053282200
2023-06-02	415.2828674316410	409.2356862459730	409.20743974597400
2023-06-05	414.4870910644530	415.13278575688300	415.0898545192020
2023-06-06	415.3896179199220	414.3400731643030	414.28745269569000

2023-06-07	413.9533386230470	415.23912525100900	415.17833845943500
2023-06-08	416.4571533203130	413.80837569367000	413.74470379640500
2023-06-09	417.20440673828100	416.30255059236000	416.2333959820910
2023-06-12	420.9892272949220	417.04692705124600	416.97312515771800
2023-06-13	423.7647399902340	420.81717587945500	420.7342149232220
2023-06-14	424.26934814453100	423.58200272674700	423.4880118219260
2023-06-15	429.5293273925780	424.08466811708000	423.98238199664600
2023-06-16	428.0662841796880	429.32439620975200	429.20784548967700
2023-06-20	425.8453674316410	427.8669857786700	427.74315201685600
2023-06-21	423.6634826660160	425.65461965944100	425.53087869745300
2023-06-22	425.1927490234380	423.4811352477560	423.3632489978880
2023-06-23	421.9783020019530	425.0045138613	424.8903906707870
2023-06-26	420.2541809082030	421.8024426046250	421.698483971757
2023-06-27	424.861572265625	420.0849594542030	419.9937834380360
2023-06-28	425.0758972167970	424.67461214881800	424.58686611280900
2023-06-29	426.75128173828100	424.88811193934100	424.8037072234670
2023-06-30	431.7872314453130	426.55704615548100	426.4736232944360
2023-07-03	432.2840270996090	431.5736072308910	431.4832848797840
2023-07-05	431.6411437988280	432.0684901996980	431.9729244021950
2023-07-06	428.2610778808590	431.4280820283800	431.3309680624040
2023-07-07	427.1798400878910	428.06102951538000	427.97018185302900
2023-07-10	428.2610778808590	426.9839545362760	426.9015727258450
2023-07-11	430.98846435546900	428.06102951538000	427.98476423253900
2023-07-12	434.4561462402340	430.7779154300710	430.7028015044980
2023-07-13	437.9043884277340	434.2322465844770	434.1529602699370
2023-07-14	437.6317138671880	437.6672128853210	437.57961463582800
2023-07-17	439.15118408203100	437.3955881340290	437.3030857981040
2023-07-18	442.41436767578100	438.9092083205820	438.81164337689600
2023-07-19	443.3981628417970	442.15982851154000	442.053935314032
2023-07-20	440.45648193359400	443.1398360221630	443.02704049536000
2023-07-21	440.45648193359400	440.20948071703300	440.098057369076
2023-07-24	442.42413330078100	440.20948071703300	440.1010005481730
2023-07-25	443.6319274902340	442.16955653844700	442.061538007071
2023-07-26	443.7001647949220	443.3727006662480	443.26439076902700
2023-07-27	440.7583923339840	443.4406752542600	443.3335504084140
2023-07-28	445.0736083984380	440.51022874887800	440.4108149573360
2023-07-31	445.92108154296900	444.80883103847100	444.70959259994500

2023-08-01	444.6450500488280	445.65304137349000	445.5536532751920
2023-08-02	438.45965576171900	444.38192265767600	444.28612446467300
2023-08-03	437.20306396484400	438.22034241523400	438.1398202802760
2023-08-04	435.2257385253910	436.9685885529820	436.9039976063040
2023-08-07	439.0245361328130	434.99887590491300	434.9514561682850
2023-08-08	437.1154479980470	438.7830479716330	438.7434559239600
2023-08-09	434.19317626953100	436.881309911576	436.8517685079120
2023-08-10	434.3490295410160	433.9702890599230	433.9546233889760
2023-08-11	434.09576416015600	434.1255422893410	434.12124231122700
2023-08-14	436.4920349121090	433.87325199152600	433.8787176974050
2023-08-15	431.4073181152340	436.2602969939040	436.269528140694
2023-08-16	428.2416076660160	431.19515658412700	431.2163900965000
2023-08-17	424.9784851074220	428.04163426173400	428.0783480869330
2023-08-18	425.1830139160160	424.7910748709450	424.84584572721700
2023-08-21	427.94940185546900	424.99481623447700	425.06335541131100
2023-08-22	426.7901916503910	427.7505534566280	427.82458077719700
2023-08-23	431.5436706542970	426.59580626268900	426.6754996840300
2023-08-24	425.56292724609400	431.3309841598150	431.4062932474740
2023-08-25	428.5630187988280	425.3732668812420	425.4548406569720
2023-08-28	431.28070068359400	428.36180794730900	428.442882286624
2023-08-29	437.51483154296900	431.06902663526100	431.14415334968800
2023-08-30	439.3168029785160	437.27915581198600	437.3379663420080
2023-08-31	438.67388916015600	439.07418957690700	439.11630013054900
2023-09-01	439.49212646484400	438.433751005505	438.46368087133700
2023-09-05	437.59271240234400	439.24883805997100	439.26787177221200
2023-09-06	434.6510314941410	437.35673682656900	437.37068417146900
2023-09-07	433.3165588378910	434.42638152143900	434.4418834928210
2023-09-08	433.9691162109380	433.0970466446040	433.1165316980500
2023-09-11	436.82318115234400	433.74709164257700	433.76879993864700
2023-09-12	434.4269714355470	436.5901683063010	436.60867542565600
2023-09-13	434.9334716796880	434.2031841040920	434.22336311997200
2023-09-14	438.6836242675780	434.7077342996380	434.72865363464800
2023-09-15	433.39825439453100	438.44344863232800	438.4584479085640
2023-09-18	433.6524353027340	433.1784276696970	433.1980321232450
2023-09-19	432.75311279296900	433.43162997003500	433.4549332425960
2023-09-20	428.7746276855470	432.5357698921570	432.56364705411700
2023-09-21	421.6877136230470	428.57260213034900	428.6111911703850

2023-09-22	420.7395324707030	421.5129730039750	421.5726539874400
2023-09-25	422.5088195800780	420.5684423914780	420.6465183454010
2023-09-26	416.3016357421880	422.33091766634500	422.419832838937
2023-09-27	416.4677734375	416.14763176386600	416.25519052592700
2023-09-28	418.88226318359400	416.3131298216210	416.4345879209770
2023-09-29	417.86566162109400	418.7183236741960	418.84538263250500
2023-10-02	417.699462890625	417.7056360731830	417.837610047172
2023-10-03	412.10809326171900	417.5400772152600	417.6751246490240
2023-10-04	415.1091003417970	411.97023460951700	412.1163673924160
2023-10-05	414.95269775390600	414.9596876781070	415.10831791242900
2023-10-06	419.87933349609400	414.8038872471760	414.95319394202200
2023-10-09	422.5675048828130	419.7115552213960	419.8513844711770
2023-10-10	424.7668762207030	422.38937702803900	422.51545732046900
2023-10-11	426.5068664550780	424.58028068790500	424.6904487422700
2023-10-12	423.90667724609400	426.31357188205100	426.40716094141100
2023-10-13	421.7951965332030	423.7233935178230	423.80774706522400
2023-10-16	426.2331237792970	421.62004210011900	421.7004720435220
2023-10-17	426.2135314941410	426.04088312781500	426.1100267532530
2023-10-18	420.53424072265600	426.0213662738330	426.08095909911800
2023-10-19	416.83929443359400	420.3639410258440	420.4257414197760
2023-10-20	411.7170715332030	416.68322044526200	416.7533284897960
2023-10-23	411.0035095214840	411.58071833214600	411.66618298458300
2023-10-24	414.1022644042970	410.86990356608900	410.9684089634460
2023-10-25	408.1589660644530	413.95672810400100	414.05927682327600
2023-10-26	403.27142333984400	408.03631172859800	408.1514537931190
2023-10-27	401.4434814453130	403.1675862620900	403.3006709858860
2023-10-30	406.2430419921880	401.3466820256130	401.49622690704900
2023-10-31	408.7944030761720	406.1277640497070	406.2805261932550
2023-11-01	413.1540222167970	408.6693022794000	408.8183497587560
2023-11-02	421.0718688964840	413.0121366913360	413.14906372115300
2023-11-03	424.9134521484380	420.8994993071550	421.0114662276010
2023-11-06	425.8909606933590	424.7262922917610	424.810449896039
2023-11-07	427.1031188964840	425.7000373850630	425.7598142387930
2023-11-08	427.4159240722660	426.90752872488800	426.9456855768730
2023-11-09	424.0826416015630	427.2191295867510	427.2396434353930
2023-11-10	430.7002868652340	423.8986804026520	423.91135362698700
2023-11-13	430.289794921875	430.4908474360640	430.4861913595090

2023-11-14	438.63775634765600	430.0819359050470	430.0643695842570
2023-11-15	439.5663146972660	438.39775730594900	438.3559813555810
2023-11-16	440.1039733886720	439.32274066438000	439.2606115650370
2023-11-17	440.6513671875	439.8583293457760	439.78033065285400
2023-11-20	444.0433654785160	440.4036156539940	440.3134529037270
2023-11-21	443.0755615234380	443.78255459987200	443.67826108877800
2023-11-22	444.7862243652340	442.8184767333090	442.70614498628600
2023-11-24	445.0599365234380	444.5225534466500	444.4026493643040
2023-11-27	444.2583923339840	444.79521180080100	444.67052322339500
2023-11-28	444.6982421875	443.99675359232900	443.8715174684250
2023-11-29	444.3854675292970	444.43491000423500	444.3103439852940
2023-11-30	446.1352233886720	444.12333954245600	444.0016250721520
2023-12-01	448.7745056152340	445.86635876350900	445.74559556943500
2023-12-04	446.418701171875	448.4954796354490	448.37245338542000
2023-12-05	446.33074951171900	446.14874514456700	446.02969589471200
2023-12-06	444.5321350097660	446.06113210223600	445.947272212546
2023-12-07	447.924072265625	444.26944234656400	444.164509002104
2023-12-08	449.8497619628910	447.64832049227300	447.5461239516540
2023-12-11	451.5994873046880	449.5665961980720	449.4644625013930
2023-12-12	453.6620788574220	451.3095850190410	451.2058372227720
2023-12-13	459.9180908203130	453.3642355020410	453.2570419879170
2023-12-14	461.3941650390630	459.5961615390540	459.4767227172110
2023-12-15	460.6344299316410	461.06655280604000	460.93623073087500
2023-12-18	463.2255859375	460.30974271276300	460.17401511096300
2023-12-19	466.0423583984380	462.8909226521020	462.74840519629700
2023-12-20	459.58428955078100	465.69685041307600	465.54589710431400
2023-12-21	463.9420166015630	459.2636454193410	459.1193792134060
2023-12-22	464.8744201660160	463.60459502606300	463.4604145484520
2023-12-26	466.83734130859400	464.5334087950890	464.38938797481400
2023-12-27	467.681396484375	466.48877260347000	466.3434038646370
2023-12-28	467.85809326171900	467.32957812907100	467.1835925808760
2023-12-29	466.503662109375	467.505594615919	467.36082955588900

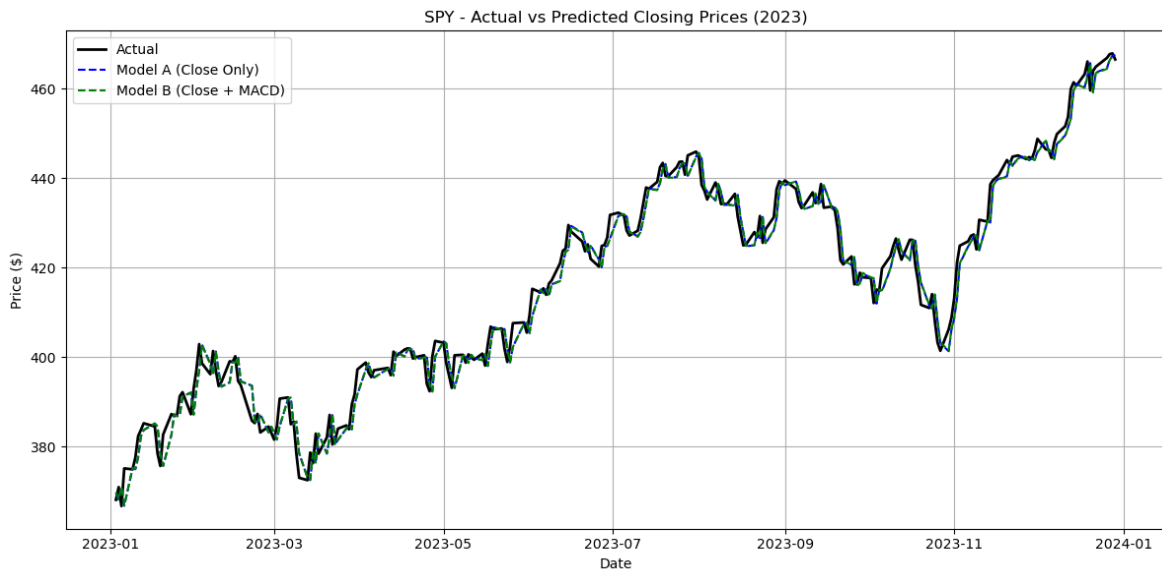


Figure 5: SPY - Actual vs Predicted Closing Prices (2023)

MAE	2.6847235474315667	2.6902350350210513	0.0055114875894846
RMSE	3.3830958498717236	3.3845688881417053	0.0014730382699817
R²	0.9798644882509153	0.9798469499735851	0.0000175382773302
Runtime (seconds)	0.0029 seconds	0.0029 seconds	0 seconds
Peak Memory (MB)	0.04 MB	0.06 MB	0.02 MB

Figure 6: SPY - Evaluation Metrics

Appendix O - BABA Model Predictions and Results

Date	Actual Closing Price	Predicted Closing Price (Model A: Close Only)	Predicted Closing Price (Model B: Close + MACD)
2023-01-03	88.82937622070310	85.23632255961740	85.12754555987020
2023-01-04	100.36038208007800	88.98395494353670	88.87297484192620
2023-01-05	100.9977798461910	100.48694557321300	100.35685266788700
2023-01-06	103.72119140625	101.12279474547100	100.97221510570300
2023-01-09	107.03369903564500	103.83958962339900	103.66995710884000
2023-01-10	110.9449691772460	107.14404932850600	106.95490096437200
2023-01-11	111.08016967773400	111.04581681849400	110.83591382229800
2023-01-12	109.27423095703100	111.1806888417340	110.95433761918700
2023-01-13	113.00201416015600	109.37913775110400	109.14442712800900
2023-01-17	111.24435424804700	113.09786409449100	112.85437508353500
2023-01-18	109.34182739257800	111.34447451636400	111.09706130460900
2023-01-19	112.58674621582000	109.44656995729500	109.2018898321930
2023-01-20	115.75439453125	112.68360506706900	112.43967505536500
2023-01-23	115.4356918334960	115.84355740209300	115.59648930828500
2023-01-24	115.3487777709960	115.5256290105350	115.27736368288400
2023-01-25	116.13102722168000	115.43892611065600	115.19233443094100
2023-01-26	116.44007110595700	116.21927504213900	115.97525623454700
2023-01-27	114.32508087158200	116.5275680868530	116.28705197530600
2023-01-30	107.39102172851600	114.41771634065000	114.18502125268500
2023-01-31	106.4252700805660	107.50050388572200	107.28682913165700
2023-02-01	108.95553588867200	106.53709858592200	106.34487838081200
2023-02-02	105.98103332519500	109.06121697040400	108.88435235968400

2023-02-03	102.68783569335900	106.09394112882600	105.93355260317400
2023-02-06	101.83798217773400	102.80874450654900	102.66857632589100
2023-02-07	101.88626861572300	101.9609557580170	101.84041145466700
2023-02-08	101.50962829589800	102.00912488137800	101.90508094420100
2023-02-09	104.74488067627000	101.63339963047400	101.54338877147300
2023-02-10	100.09963989257800	104.86079178254600	104.77785253820400
2023-02-13	101.20059204101600	100.22683687357800	100.15479190600400
2023-02-14	100.65011596679700	101.32511419661800	101.26249978479400
2023-02-15	99.54916381835940	100.7759755350980	100.72111977105000
2023-02-16	99.57814025878910	99.6776982120573	99.63075972601940
2023-02-17	96.5843276977539	99.70660425258910	99.66628654578470
2023-02-21	91.84249877929690	96.72006532818150	96.68898001864630
2023-02-22	91.53346252441410	91.98975695077370	91.97372008285910
2023-02-23	90.93470764160160	91.68147151691820	91.67944908461210
2023-02-24	85.95144653320310	91.08417134289520	91.0934820655761
2023-02-27	86.19288635253910	86.113017348681	86.13771841822460
2023-02-28	84.78289794921880	86.35387057634580	86.39169154419380
2023-03-01	86.86890411376950	84.9473078194498	84.99614563567740
2023-03-02	86.6757583618164	87.02824591426190	87.08219976853230
2023-03-03	86.62747192382810	86.83556942081690	86.89150204158590
2023-03-06	86.55021667480470	86.78740029745560	86.84371442601190
2023-03-07	85.69070434570310	86.710332744421	86.76574379239200
2023-03-08	83.97167205810550	85.85290864904530	85.90753152383650
2023-03-09	80.51429748535160	84.13805284743530	84.19356017541620

2023-03-10	80.11833953857420	80.68907816138610	80.74960813663870
2023-03-13	80.06039428710940	80.29408221679350	80.35932933227900
2023-03-14	80.97785186767580	80.23627774658830	80.30401050552900
2023-03-15	78.71800994873050	81.15150631216930	81.21841750366380
2023-03-16	79.4036865234375	78.8971548067415	78.96466227514690
2023-03-17	78.87252807617190	79.58116549150160	79.64774065218410
2023-03-20	78.22547912597660	79.05129752366920	79.11605981202660
2023-03-21	80.83299255371090	78.40582061542650	78.46884056033190
2023-03-22	80.78470611572270	81.00699894208550	81.06383524110870
2023-03-23	83.556396484375	80.95882981872420	81.00826488618190
2023-03-24	83.92338562011720	83.72378620915490	83.76226041164970
2023-03-27	83.17010498046880	84.08988372407410	84.11678088618260
2023-03-28	95.02946472167970	83.33843322226480	83.35612500161960
2023-03-29	96.49740600585940	95.1689799794848	95.16225916128910
2023-03-30	99.83888244628910	96.63335481744450	96.59922978097090
2023-03-31	98.67999267578130	99.96671295222490	99.90549320561660
2023-04-03	95.01980590820310	98.81063876983760	98.72832001318730
2023-04-04	97.2699966430664	95.15934463264090	95.0665150419639
2023-04-05	95.17433166503910	97.40406840208310	97.30201761738430
2023-04-06	99.2208023071289	95.31349496042710	95.20663161473700
2023-04-10	98.0619125366211	99.35013447365540	99.23540782799610
2023-04-11	96.34288787841800	98.1940602912682	98.07357094276980
2023-04-12	90.62565612792970	96.47921210051680	96.35793414407590
2023-04-13	92.8758544921875	90.77587068732270	90.66357644720450

2023-04-14	91.31134033203130	93.02060206762350	92.91553331979180
2023-04-17	93.1172866821289	91.45988898294130	91.36215175311510
2023-04-18	92.21914672851560	93.26144768442980	93.16812159936790
2023-04-19	90.28765106201170	92.36548981253680	92.276435035229
2023-04-20	87.63184356689450	90.4386868237939	90.3564797541177
2023-04-21	86.07699584960940	87.78933176291510	87.7174091989384
2023-04-24	83.91372680664060	86.23826163593540	86.1779813008172
2023-04-25	80.0797119140625	84.08024837723010	84.03285884799290
2023-04-26	79.9831314086914	80.25554844027620	80.22450105385570
2023-04-27	81.57661437988280	80.1592025826952	80.1425411393226
2023-04-28	81.7890853881836	81.74881409705080	81.74068565519580
2023-05-01	81.27723693847660	81.96076889504220	81.95763295171890
2023-05-02	78.73731994628910	81.45016401003930	81.45086690088580
2023-05-03	78.68903350830080	78.91641788957090	78.92320023998460
2023-05-04	79.66443634033200	78.86824876620970	78.8802505904657
2023-05-05	80.36943054199220	79.84128180199580	79.85514361087840
2023-05-08	80.45634460449220	80.54456318044380	80.55752931325540
2023-05-09	79.4036865234375	80.63126608032240	80.6421890915074
2023-05-10	80.10868072509770	79.58116549150160	79.59106449814400
2023-05-11	84.87947082519530	80.28444686994960	80.29220205750560
2023-05-12	82.41680908203130	85.04364606617230	85.04186476940370
2023-05-15	85.31404876708980	82.5869674987386	82.57820979612750
2023-05-16	85.71967315673830	85.47716817642370	85.45943319893110
2023-05-17	87.57390594482420	85.88180707871860	85.8545877733467

2023-05-18	82.83208465576170	87.7315349035684	87.69370133231070
2023-05-19	81.10340118408200	83.00123413701900	82.96059987137620
2023-05-22	83.1507797241211	81.27675059942360	81.23835639417540
2023-05-23	80.04107666015630	83.31915491771840	83.28017522881520
2023-05-24	78.42828369140630	80.21700705290040	80.18068372790910
2023-05-25	76.0815200805664	78.60813245571540	78.5773144759553
2023-05-26	78.19650268554690	76.26707043955060	76.2442314713869
2023-05-30	75.97528839111330	78.3769145748946	78.3579744718552
2023-05-31	76.82514190673830	76.16109684598420	76.14678460080580
2023-06-01	80.15696716308590	77.00888559451590	76.997464230476
2023-06-02	81.38346862792970	80.33261599331080	80.31774865421080
2023-06-05	81.50901794433590	81.55613760360570	81.53469168765500
2023-06-06	83.73023223876950	81.6813818908601	81.6535364922873
2023-06-07	82.35887145996090	83.89719961977060	83.86075344639090
2023-06-08	83.18941497802730	82.52917063939190	82.48655374215800
2023-06-09	82.57133483886720	83.35769630509420	83.30949818505050
2023-06-12	82.91900634765630	82.74111782652480	82.68885159503310
2023-06-13	84.51248931884770	83.08794464775610	83.0321740503137
2023-06-14	86.29911804199220	84.67755616211160	84.61655596186990
2023-06-15	89.04183197021480	86.45984416991230	86.39146764125950
2023-06-16	88.94525909423830	89.19589451981110	89.11712231945780
2023-06-20	84.91809844970700	89.0995562730886	89.01168843764460
2023-06-21	83.79783630371090	85.08217984268960	84.9932090943989
2023-06-22	83.91372680664060	83.96463943681970	83.87860930194800

2023-06-23	82.01119995117190	84.08024837723010	83.99716330198820
2023-06-26	82.54236602783200	82.1823438181606	82.10441699838940
2023-06-27	84.14550018310550	82.71221939685150	82.63866097896070
2023-06-28	81.69249725341800	84.31145864719250	84.23893771440520
2023-06-29	80.6881332397461	81.8644154266027	81.79550203556760
2023-06-30	80.49497985839840	80.86249157200170	80.79904432488180
2023-07-03	81.19031524658200	80.66980746769820	80.61138339804210
2023-07-05	81.41244506835940	81.3634534993022	81.30801291053480
2023-07-06	80.96820068359380	81.58504364413760	81.53119927977960
2023-07-07	87.4483642578125	81.14187857618380	81.0896879247071
2023-07-10	87.45801544189450	87.60629822717250	87.54638521292660
2023-07-11	88.64588165283200	87.61592596315800	87.54685276015570
2023-07-12	90.78018188476560	88.80090618607710	88.72308585207440
2023-07-13	93.30078125	90.93002101510900	90.84199454591100
2023-07-14	91.32099914550780	93.4444964418894	93.34425800745470
2023-07-17	90.21039581298830	91.46952432978530	91.36179023100740
2023-07-18	88.07608795166020	90.36161927075930	90.25108468326480
2023-07-19	88.93560028076170	88.23249683086890	88.12388623469950
2023-07-20	88.75212097167970	89.08992092624460	88.98318639987500
2023-07-21	89.01286315917970	88.90688739050200	88.80201061958440
2023-07-24	93.0496826171875	89.16699609013780	89.06381473475030
2023-07-25	91.72662353515630	93.19400786738070	93.08686608886540
2023-07-26	93.8126220703125	91.87416323208020	91.76442226878140
2023-07-27	92.17086029052730	93.95509371603390	93.84161485092100

2023-07-28	97.10582733154300	92.31732068917550	92.20287291481690
2023-07-31	98.66067504882810	97.24029794916990	97.11960034532010
2023-08-01	96.67123413085940	98.79136807614970	98.66199286217480
2023-08-02	91.81352996826170	96.80676061720160	96.67350260813850
2023-08-03	94.23755645751950	91.9608585211003	91.83322168339770
2023-08-04	93.58084869384770	94.37899570115820	94.25547876237640
2023-08-07	93.25248718261720	93.7238834460715	93.60412762929750
2023-08-08	90.99264526367190	93.39631970766970	93.2810062284018
2023-08-09	91.60106658935550	91.1419682022419	91.03413165773070
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2023-08-11	92.4412612915039	95.9493365218259	95.84765735576230
2023-08-14	90.25867462158200	92.58706473565520	92.48825016396630
2023-08-15	88.45272827148440	90.40978078326210	90.31835702177080
2023-08-16	86.06734466552730	88.60822208177360	88.52654037812020
2023-08-17	87.54493713378910	86.2286338999499	86.15904620551270
2023-08-18	85.01467895507810	87.70263647389500	87.64168663122300
2023-08-21	85.53617858886720	85.17852570027060	85.12719817934030
2023-08-22	85.0629653930664	85.69875832125910	85.65532761367810
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2023-08-24	86.05767822265630	86.92227232069550	86.88781200112240
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2023-08-29	90.80915069580080	89.2344359071869	89.19889214894620
2023-08-30	90.44217681884770	90.95891944478230	90.91681158294290

2023-08-31	89.71786499023440	90.59283715158010	90.5450935231569
2023-09-01	91.7555923461914	89.87028507944420	89.81919646451150
2023-09-05	91.40792083740230	91.90306166175360	91.84675042195390
2023-09-06	91.21475982666020	91.55623484052230	91.49533268128530
2023-09-07	86.88822937011720	91.3635431253603	91.29951665593470
2023-09-08	86.96549224853520	87.04752421880830	86.98728350539090
2023-09-11	85.67138671875	87.12459938270140	87.06927807487790
2023-09-12	85.27542877197270	85.83363795535740	85.78389116620040
2023-09-13	84.63803100585940	85.43864201076490	85.39430467911890
2023-09-14	84.98570251464840	84.80279283850750	84.76358136081180
2023-09-15	84.08755493164060	85.14961965973880	85.11398186285130
2023-09-18	84.03926086425780	84.25365417698730	84.22161376277420
2023-09-19	84.12619018554690	84.20547744276750	84.17640778024520
2023-09-20	82.80310821533200	84.29219556436310	84.26497609382900
2023-09-21	81.22895050048830	82.97232809648720	82.94797457785770
2023-09-22	85.27542877197270	81.401994886678	81.38228667288550
2023-09-25	84.232421875	85.43864201076490	85.4171415247549
2023-09-26	82.96729278564450	84.39816915792950	84.37434061847880
2023-09-27	83.23770904541020	83.13611377111730	83.11229774271220
2023-09-28	82.60997009277340	83.40587303931400	83.38184551133130
2023-09-29	83.76885986328130	82.77965921390060	82.75577642647970
2023-10-02	83.56605529785160	83.93573339628790	83.91018992015880
2023-10-03	81.64421844482420	83.73342155599890	83.70588796404400
2023-10-04	81.1999740600586	81.81625391409990	81.78955572728640

2023-10-05	80.80401611328130	81.37308884614620	81.34816390729480
2023-10-06	83.11215209960940	80.97809290155360	80.95487964258340
2023-10-09	81.943603515625	83.28062114120110	83.25523127202940
2023-10-10	84.18412780761720	82.11491161196990	82.08792780404090
2023-10-11	84.77323913574220	84.34999242370980	84.31875667286610
2023-10-12	81.61524200439450	84.93767247260590	84.90085655972540
2023-10-13	81.14202880859380	81.78734787356810	81.75002556041070
2023-10-16	81.4220962524414	81.31528437594090	81.27943561253550
2023-10-17	81.03579711914060	81.59467138012300	81.55948871355490
2023-10-18	80.16663360595700	81.20931078237450	81.17473152271640
2023-10-19	78.81458282470700	80.34225895101330	80.3092201171724
2023-10-20	77.20178985595700	78.99349305346400	78.96361332330340
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2023-10-25	78.25444793701170	80.20737931691500	80.18461541998430
2023-10-26	79.68376159667970	78.43471904509980	78.4118746720532
2023-10-27	79.9831314086914	79.86056010654220	79.83600558354240
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2023-10-31	79.71273040771480	80.46749562740920	80.43676341399990
2023-11-01	79.65478515625	79.88945853621550	79.85644032361380
2023-11-02	80.55292510986330	79.83165406601030	79.79683930619660
2023-11-03	82.3878402709961	80.72761193790340	80.68981354364350
2023-11-06	82.4361343383789	82.55806906906520	82.51462625142640
2023-11-07	82.48442077636720	82.60624580328500	82.55721104414620

2023-11-08	81.89531707763670	82.65441492664620	82.6007462138966
2023-11-09	79.8962173461914	82.06674248860870	82.01013800183340
2023-11-10	79.91552734375	80.07249968281660	80.0166022090415
2023-11-13	79.44232177734380	80.09176276564610	80.03724492434210
2023-11-14	80.9971694946289	79.61970687887740	79.56680779099590
2023-11-15	84.08755493164060	81.17077700585720	81.11705133593650
2023-11-16	76.40021514892580	84.25365417698730	84.19408336595960
2023-11-17	74.94194030761720	76.58499122025000	76.53012322405330
2023-11-20	75.77247619628910	75.13025933999280	75.08465426775830
2023-11-21	76.23603820800780	75.95877739483670	75.91970704427970
2023-11-22	76.2553482055664	76.42121315647840	76.38589382585560
2023-11-24	75.80145263671880	76.44047623930780	76.40748603742070
2023-11-27	74.87433624267580	75.98768343536850	75.95675805436010
2023-11-28	74.11139678955080	75.06281952294360	75.03461516175760
2023-11-29	72.11229705810550	74.30173367429040	74.27672248786330
2023-11-30	72.31510162353520	72.30749086849840	72.28765747347320
2023-12-01	71.4555892944336	72.50980270878740	72.4941291588906
2023-12-04	70.52847290039060	71.65237861341170	71.64046113856340
2023-12-05	69.90074157714840	70.72751470098680	70.71959012619850
2023-12-06	69.04122161865230	70.10130848643190	70.09712254991610
2023-12-07	69.85245513916020	69.24387678019770	69.24336568344480
2023-12-08	69.66896057128910	70.05313936307060	70.05397128718650
2023-12-11	68.92533874511720	69.87009060561110	69.87102739945470
2023-12-12	68.94464874267580	69.12827545064580	69.1296054377548

2023-12-13	69.01225280761720	69.14753853347520	69.14867467819720
2023-12-14	70.02629089355470	69.21497835052430	69.21503112904600
2023-12-15	71.95777893066410	70.22655277368630	70.22348686527790
2023-12-18	71.31072998046880	72.15334815157070	72.14387226717660
2023-12-19	72.8076400756836	71.50787124332790	71.49267382558350
2023-12-20	71.78975677490230	73.00114451096090	72.97904775432390
2023-12-21	74.63786315917970	71.98573421512180	71.9584100886601
2023-12-22	73.67870330810550	74.82692096415360	74.7915070133207
2023-12-26	74.23657989501950	73.87009144608530	73.82795451126840
2023-12-27	74.49105072021480	74.42661264033750	74.37858195454220
2023-12-28	75.59701538085940	74.68046521429720	74.62696316146990
2023-12-29	75.86127471923830	75.7837428713634	75.72411438960640

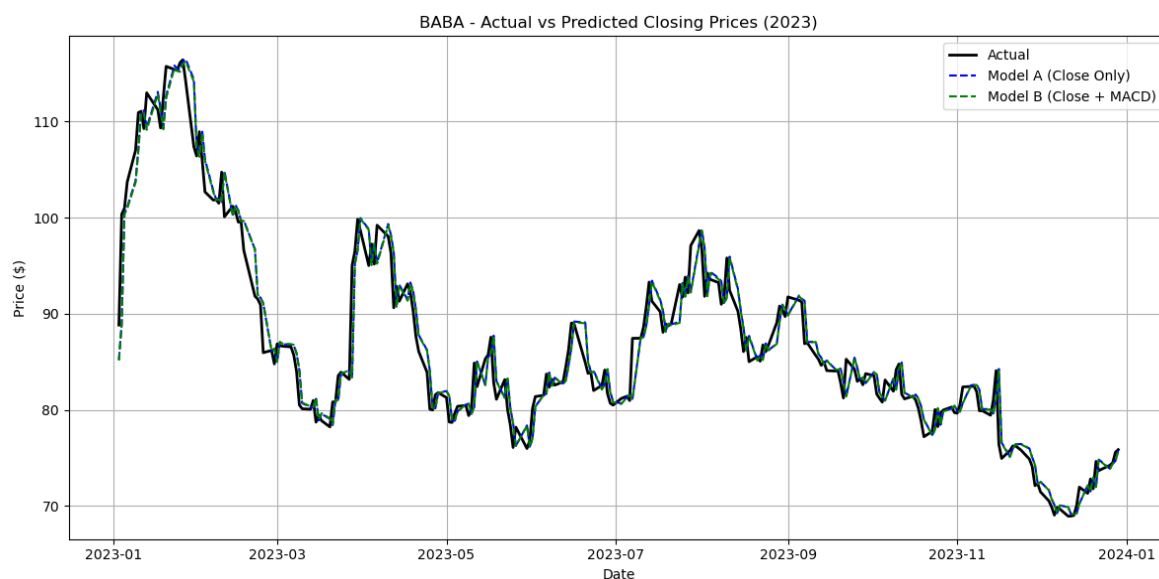


Figure 7: BABA - Actual vs Predicted Closing Prices (2023)

MAE	21.633596449513537	1.6266108604592255	0.0069855890543118
RMSE	2.305264334614707	2.301196576316434	0.0040677582982730
R²	0.9490839319675397	0.9492634615106208	0.0001795295430811
Runtime (seconds)	0.0023 seconds	0.0024 seconds	0.0001 seconds
Peak Memory (MB)	0.04 MB	0.06 MB	0.02 MB

Figure 8: BABA - Evaluation Metrics