Project 4

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1 Introduction

Costco Wholesale Coroporation has existed since 1983 and remains a popular destination for many shoppers around the world. Since its founding, Costco has expanded considerably, and naturally its stock prices have fluctuated with its increasing popularity as well as the state of the economy. From first glance, it would seem obvious that Costco stock prices would have gone up since 1983—so many people love to shop at Costco! But how much has Costco stock price gone up really? When considering changes in stock price, it is important to account for the fact that the value of a dollar has changed considerably since 1983. When looking at Costco stock prices, it is easy to say that they have risen, but how much have they risen when we compare them to how inflation has changed? If the value of a dollar in a certain year was 90% of its value the previous year, then the price of stock would also have changed proportionately from the previous year, assuming that inflation was the only factor causing change in stock price. The goal of this paper, then, is to find whether or not the *value* of Costco stock is increasing over time, or if Costco stock price is increasing at a greater rate than inflation is.

2 Sampling Methods and Data

For this paper, we will be using Costco Wholesale Corporation stock price data from January of 2014 to February 2024, taken from Costco's published stock price data that can be found here: `https://investor.costco.com/stock-info/default.aspx#stock-chart`. We will take the stock price from the last day of each month from January 2014 to February 2024 for our analaysis. We will also be calculating inflation rates using CPI data from the US Bureau of Labor Statistics. We will be taking the CPI (consumer price index for all urban consumers) for every month from January 2014 to February 2024. This data can be found here: `https://data.bls.gov/cgi-bin/surveymost`. Inflation rates for each month are derived from the CPI using the formula

$$I = \frac{C_n - C_{n-1}}{C_{n-1}}$$

where I is the inflation rate for that month, C_n is the CPI for that month, and C_{n-1} is the CPI for the previous month.

3 Solving

To find whether Costco stock prices are truly "increasing", we must compare them to inflation rates. Specifically, we need to compare the percent changes in Costco stock price to the percent changes in inflation over the course of several years. If the percent changes in Costco stock price are the exact same as the percent changes in inflation, it would mean that stock prices are not truly "increasing" at all. As the value of a dollar increases/decreases with inflation, the stock *prices* would also decrease/increase accordingly, but the actual value of the stock would remain consistent. If the percent changes in Costco stock price are greater than that of percent changes in inflation, it would suggest that Costco stock value is increasing and stock prices are increasing for some reason other than inflation. If the percent changes in stock price were less than that

of the percent changes in inflation, it would suggest that Costco stock value is decreasing and prices are also decreasing for some reason other than inflation.

To begin, we can graph the percent change in Costco stock prices for each month from January 2014 to February 2024. For example, a percent change of 0.08 in a certain month would indicate that the stock price increased by 0.08% from the previous month.
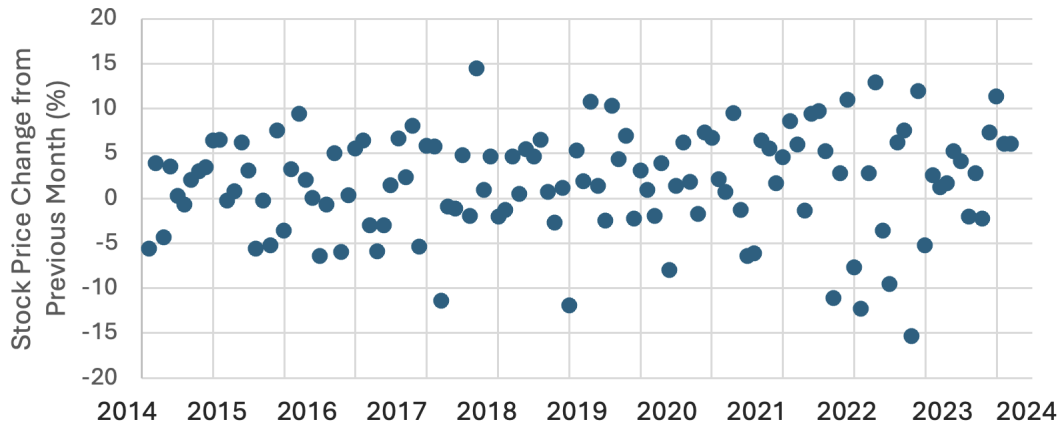
Figure 1: Costco stock price monthly percent increases from 2014 - 2024

Next, we can graph the percent change in each month's inflation rate from the previous month's inflation rate:
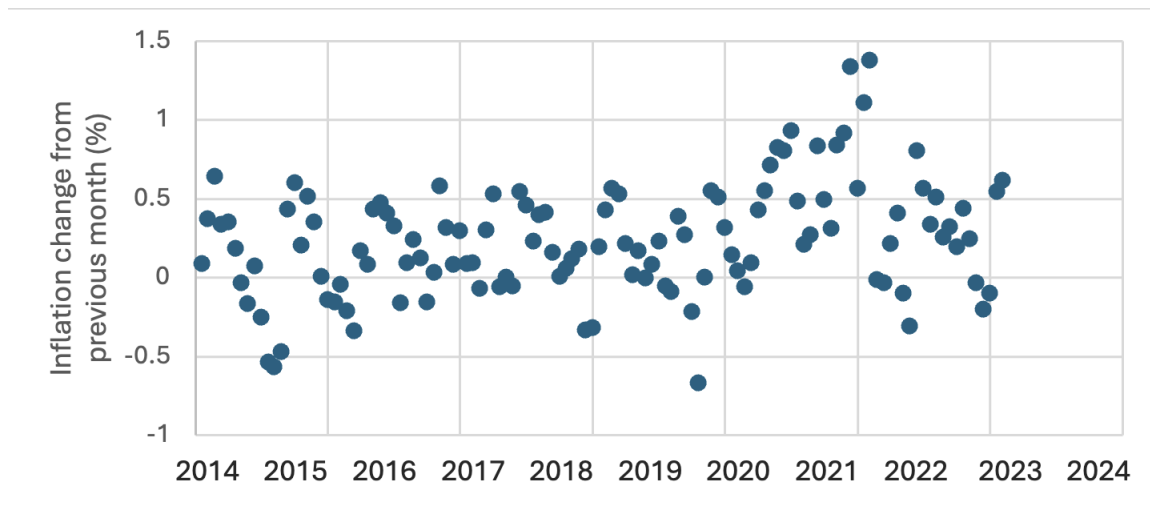
Figure 2: Inflation monthly percent increases from 2014 - 2024

Now, to find whether percent changes in Costco stock price are greater, less than, or equal to percent changes in inflation, we can subtract the percent change in inflation for each month from that month's percent change in stock price. We can then graph the differences of the stock price percent changes and inflation percent changes for each month as such:
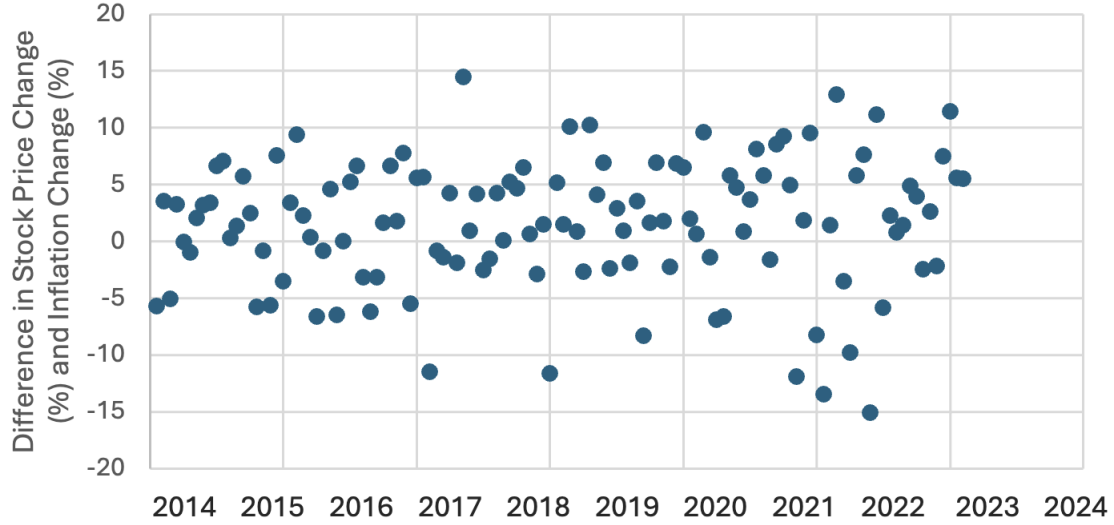
Figure 3: Monthly difference in stock price percent change and inflation percent change 2014 - 2024

As stated above, if these differences as a whole are exactly or are roughly 0, Costco stock prices are not really increasing. If the differences as whole are above 0, stock prices are increasing, and if the differences as a whole are below 0, the stock prices are decreasing. To find whether the data in Figure 3 is above, below, or at 0 "as a whole," we can start by finding a line of best fit for the data. The formula for the slope of a line of best fit of the form $y = mx + b$ is

$$m = \frac{\sum (x_i - \mu_x)(y_i - \mu_y)}{\sum (x_i - \mu_x)^2}$$

where x_i is the ith x-coordinate, μ_x is the average of all the x-coordinates, y_i is the ith y-coordinate, and μ_y is the average of all the y-coordinates. For our purposes, we will let our x-coordinates be the number of months that have passed since the start of 2014 (the difference of stock price percent change and inflation percent change of January 2014 will have an x-coordinate of 1). We will let our y-coordinates be the differences between stock price percent change and inflation percent change for each month. Plugging in the respective values for x_i, μ_x, y_i, and μ_y, we can say that $m \approx 0.010307$.

Next, we can find the y-intercept for the line of best fit. The formula for this is

$$b = \mu_y - m\mu_x$$

Plugging in the respective values for μ_y, m, and μ_x, we can say $b \approx 0.890263$. This means our line of best fit is $y = 0.010307x + 0.890263$ where x is the number of months since the start of 2014 and y is the difference in stock price perentage change and the inflation percentage change. The slope of this line is above zero, meaning that the best fit line suggests that the difference between stock price percentage change and inflation percentage change is getting larger as the months progress. This would mean that Costco stock value is truly increasing, and it is not the price that is changing with respect to inflation while the value of the stock stays the same. However, we need to find whether the positive trend that the best fit line is suggesting is statistically significant. To do this, we first need to calculate the R^2 value of the line of best fit using the following formula:

$$R^2 = 1 - \frac{\sum (y_i - f(x_i))^2}{\sum (y_i - \mu_y)^2}$$

In this formula, y_i is the observed y-coordinates of the data, μ_y is the average of the observed y-coordinates of the data, and $f(x_i)$ is the y-coordinates that the line of best fit model predicts. Plugging in the relevant values into the formula, we get that $R^2 \approx 0.004075$.

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Using this R^2 value, we can now perform an F-test. An F-test is a measure of statistical significance, telling us whether or not the positive trend suggested by the line of best fit is really significant or not. To perform an F-test, we can use the formula

$$F^* = \frac{R^2}{1 - R^2}(N - 2)$$

where R^2 is the R^2 value we just calculated and N is the number of datapoints that we have. We know that our R^2 is 0.004075. Our sample size is 122, as there are 122 months between January 2014 and February 2024, including both January 2014 and February 2024. Plugging these values into the formula, we can say that $F^* \approx 0.491$. An F-test score of 0.491 does not even satisfy the 90% threshold for F-test scores, which is an F-test score between 2.71 and 3.84. This tells us that the positive trend suggested by the line of best fit is not statistically significant, as we cannot conclude that this positive trend exists with even 90% confidence. As a result, we also cannot conclude with any meaningful degree of confidence that the value of Costco stocks is increasing, or that Costco stock prices are increasing disproportionately to the rate that inflation is changing at.

Another method we can use to determine whether or not the value of Costco stock is increasing, decreasing, or staying the same is finding a confidence interval that we believe the true mean of all of the differences of stock price percentage change and inflation percentage change to be within. To do this, we first need to calculate the mean of all the differences of stock price percentage change and inflation percentage change, or all the y-coordinates in Figure 3. Finding the mean simply requires adding all the y-coordinates and dividing by 122, the number of y-coordinates that we have. Doing this, we can say our sample mean is approximately 1.524139.

To find a confidence interval within which we believe the true mean of all the differences of stock price percentage change and inflation percentage change to be within, we can use the following formula:

$$\mu \pm z^* \frac{s}{\sqrt{N}}$$

In this formula, μ is our sample mean, z^* is the t-test value for the confidence level we want to find a confidence interval for, s is the standard deviation of all the values in our dataset, and N is our sample size (122). To start, we can find the confidence interval for a 99% confidence level, which has a t-test value of 2.576 for a sample size of 122. To find the standard deviation of the dataset, we can use the following formula:

$$s = \sqrt{\frac{\sum (x_i - \mu)^2}{N - 1}}$$

Here, x_i is the values in the dataset, μ is the average of the dataset, and N is the sample size (122). Plugging in the respective values for each of these variables, we can say the standard deviation is 5.709274.

Substituting 1.524139 for μ, 2.576 for z^*, 5.709274 for s, and 122 for N into our confidence interval formula, we can say that we can be 99% confident that our true mean is between $[0.19262, 2.85566]$. This confidence interval suggests that we can be 99% confident that the true mean of all the differences of stock price percentage change and inflation percentage change is above 0, as both bounds of our confidence interval are above 0. This suggests that Costco stock value is actually increasing, and that stock price is increasing due to reasons other than inflation because stock price is not increasing at the same rate that inflation is.

4 Analysis

What is interesting about the conclusions we have arrived at so far is that they are different. We first calculated the line of best fit for the differences of stock price percentage change and inflation percentage change for every month from January 2014 to February 2024. When calculating the R^2 value of this line of best fit, we got a very low score of 0.004075 (R^2 is measured on a scale of 0 to 1). Because R^2 measures

how much better a line of best fit is than a line that is simply the mean of the data, having a higher score is better. Us getting a low R^2 score means that our line of best fit is not much better than the mean of the data. When we calculated the F-test score for this line of best fit, we got a very low score as well. It was so low that we found that we could not conclude with 90% confidence or higher that the positive trend suggested by the line of best fit was actually present in the data. This meant we could not conclude that Costco stock prices were increasing at a rate greater than the rate that inflation was increasing at. However, when we calculated a confidence interval, we found that we could conclude with 99% confidence that on average Costco stock prices were increasing at a greater rate than inflation was increasing at. These two different conclusions are confusing, but it seems reasonable to take two opposing conclusions as an inconclusive result. As both conclusions are meaningful, we cannot simply discard one conclusion and take the other as our final conclusion. Therefore we can conclude that we cannot whether Costco stock price percentage change is increasing, decreasing, or staying the same as inflation percentage change. In other words, we cannot conclude whether or not the value of Costco stock prices is going up.

5   Another Discipline

While comparing Costco stock prices/value to inflation rates is inherently economic, we can further contextualize our results by taking a deeper dive into looking at this from an economic angle. For someone looking to buy Costco stock in the near future, the results we have found in this paper do not promise very high yields for this purchaser. When looking to invest in stocks in general, people often look for companies whose stock prices are increasing, as it means they can potentially sell their stocks for a much higher price than they originally bought it at. In our analysis, we found that Costco stock prices were generally increasing (as a large portion of our datapoints signified positive percentage changes in price). However, we were able to say that we cannot conclude that the value of Costco's stock is necessarily increasing, as the difference between the percentage change in stock price and the percentage change in inflation is not significant enough. To a buyer, then, it would appear at first as though Costco stock prices are increasing quite a bit over this almost 10 year period. In fact, Costco stock prices were roughly 100 dollars per share in 2014, but were reaching almost 700 dollars per share in 2024. However, without even a brief analysis of Costco stock prices compared to inflation, a buyer would not realize that the value of Costco stock is not really increasing. Our results were inconclusive, meaning that we cannot confirm that the value of Costco stock was increasing. This means that even though Costco stock prices seem to be skyrocketing, an analysis of stock prices and inflation is necessary for a buyer to make the right decision on buying Costco stock, or any stock in general.

6   Further Inquiry

A direction for further inquiry here would be to find out how Costco's expansion relates to their stock prices. Instead of inflation, we could find data on how many new locations Costco opened from January 2014 to February 2024, and plot that data in a grpah. Then, we could find the Pearson correlation coefficient formula to find the correlation between the increase in Costco locations and their stock prices. A question that we could conside is whether or not stock prices tend to increase as Costco opens new locations. If we are able to get a conclusive result, we could potentially make a claim about whether or not opening new locations is financially beneficial for Costco.