Current Ability of Stock Market Indices to Track the Technology Sector

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Abstract
This paper investigates the information technology financial sector using the following indices: QTEC, DJUSTC, NDXT, and XTX. These indices stem from popular market indices such as the Dow Jones, NASDAQ, and Standard & Poor's 500 Index and thus, are apt choices to study the sector. From a list of public technology companies with listed stocks, a sample of 40 stocks was selected. The past 100 days (100 business days before May 18th, 2021) of closing prices were used for both the indices as well as the stocks and the natural logarithm of all values was taken such that they could be compared despite different price ranges. These values were used to build simple linear regression models for all the stocks and for the indices themselves and Standard t-tests were run to determine whether there are statistically significant differences between the slopes of the price/value vs. time graphs. Based on the number of statistically insignificant values there are, a relative estimate can be made for how well the indices track the stocks overall and individually using the Chi-square test for homogeneity and index holdings.

Keywords
Stock market, financial indices, tracking market performance, stock price, linear regression.

1. Introduction
From the sheer number of published analyses on the stock market to the prevalence of major stock indices like the Dow Jones and the Standard & Poor's 500, it is clear a majority of consumers and researchers rely heavily on market indices as measures of turbulence and trend in the market. However, the methods used to calculate the values of each index is often either undisclosed or too vague to be useful. As Zatlavi puts it, "Common approaches to index calculation rely on a company's market value generating a weighted average as the index" (Zatlavi, Kenett, Ben-Jacob, 2014). This still doesn't give enough insight into market index. From the description of the NASDAQ index, this index is "divided by an index divisor to arrive at a more appropriate figure for reporting purposes" ("NASDAQ Composite…", 2021). Essentially, these methods are simply unavailable for the public and without them, consumers cannot definitively evaluate how well these indices actually track the movement of either a sector or the market as a whole.

Thus, in order to determine whether or not consumers are justified in relying on these indices, statistics must be introduced as a way of testing the ability of indices to accurately depict market trends.

2. Methods
The main aim of the paper was to determine how well the market indices – QTEC, DJUSTC, NDXT, and XTX – track the technology sector and in doing so, the paper explores whether these indices move in similar ways. The technology sector was used as it was one of the sectors least affected by the COVID-19 pandemic as seen in Smales' paper (2021). The analysis begins with a comparison of how many fail to rejects/rejects occur among the indices with regards to how well the slope of the index matches with the slope of a stock in the sample. This data is then used to conduct a Chi-Square test for homogeneity to determine whether the indices track the stocks in the sample similarly. Finally, using holding counts for each index, the paper establishes a standard by which to evaluate index performance.

2.1 Project Research
The following tests and data analysis/graph creation was all done using the Wolfram Programming Language, a high-level language with a focus on functions. Stocks are investments into companies that often are associated with equity. Market indices factor in multiple stocks as to give an overall picture of the market/sector.

2.2 Hypotheses

In terms of how well the indices compare in tracking the sample stocks, the indices should be relatively similar as they use similar methods of calculation (as stated by Young). Furthermore, given the hitherto reliance on these indices, they should track the sample well.

2.3 Data Collection

To collect a large dataset from which to select a sample of stocks, a web scraper was used to scrape 1,353 public company stocks from https://www.morningstar.com/technology-stocks?page=1. The web scraper selected all capitalized words from the website (as usually stock ticker symbols are capitalized). The scraped list was then fed into another algorithm to ensure the capitalized words were indeed stocks from public technology companies by checking whether the stock was a part of Wolfram's Native Database (and in the process, removed false positives). The sample of 40 stocks was selected using an in-built simple random selection function from Wolfram. As only one sector was being inspected, there was no need to use stratified or cluster sampling, making simple random selection the best option.

```
url = Import["https://www.morningstar.com/technology-stocks?page=1"];
allstocks =
 Flatten[
  Table[
   DeleteDuplicates[
    Select[
     TextWords[
      ToString[Import[StringJoin["https://www.morningstar.com/technology-stocks?page=", ToString[x]]]]],
     UpperCaseQ]], {x, 1, 12}]]
stockstouse = RandomChoice[allstocks, 40]
```

Out[•]= {ESG, DEI, YTD, RETC, TDCH, DPSM, DDD, THDS, DDDX, SIXD, EGHT, ATEN, AAP, AAPJ, AB, ABQQ, ABCO, ABCE, ATHC, ACI,
ACIW, ACM, A, ACMR, ACFN, ACV, ACVA, ADTM, AEY, ADBE, ADTN, AMD, APWL, AVGG, AVOI, ADVC, ADGO, AEHR,
AERS, AKOM, AFFN, AFRM, AIFS, AGYS, AGSO, AIRG, AIS, AIDG, AJIA, AKAM, AKTS, ASPT, ALRM, ALFI, ALF, ALKT,
PTPF, AWRS, ADGL, ALGM, AMOT, ADSV, AXCP, AHAG, ALPE, ALPP, ALTR, ALYI, AYX, ATGN, AHIX, AMSWA, AVOT,
AVCT, AMWK, AMST, AMTA, AMKR, AMPO, APH, AMPG, ASYS, ADI, PLAN, ANDI, ANDR, AGLT, ANSS, AGGG, APPF,
APPN, AGPL, AAPL, AMAT, AAOI, APVS, ALDS, APQT, APP, ASFT, SWRM, APCX, APYP, APT, APTY, ARCS, AWEB,
ARGW, AWSI, ASNT, ANET, ARRY, ARW, ESG, DEI, YTD, AITX, ALIF, A, ASAN, ASTI, AZPN, ALOT, ASUR, ATER,
ATI, ATIW, ATYG, ATLT, ATOM, RTD, AURT, AUUD, AEYE, ADSK, AVLR, AVYA, AVRI, AVNW, AVSR, AVT, AVRN, AWRE,
ACLS, AXT, AXTI, AXTC, B, SCDA, BAND, BRTR, BEEM, BZIC, BELFB, BLLI, BELR, BHE, BNFT, BSY, BEMGQ, BETW,
BHPA, BIGC, BILL, BZRT, BK, BKTI, BKI, BLKB, BLBX, BL, BRTI, BCDS, BLGI, BDR, BCRD, BKSD, BM, BMTX, BOGN,
EPAY, BOX, BOXL, BVTK, BLIN, BCOV, AVGO, BR, BRKS, BSQUARE, BSQR, BTRS, BBLR, BMBL, BZWR, AI, CACI,
CDNS. CAMP. CALX. CBEX. CNCC. CNLK. CSTC. CTLP. CBEV. CXCO. CRSM. CASA. ONOV. CCUR. CCURD. CDK. CDW.

Figure 1: Snippet of Code used to obtain the relevant stocks. The first output is a part of a list of all possible stocks to choose from.

To collect closing prices for stocks, Wolfram's native financial database was used. In addition, to collect closing index values for the market indices, the following links were used: QTEC (Wolfram Native Database), NDXT, DJUSTC, and XTX.

3. Data and Statistical Analyses

Part one describes the categorization of information including the outputs from linear regression and t-tests. The p-values are compared against the alpha value of 0.01 in order to determine whether or not to reject the alternative hypothesis in each case. Part 2 depicts the process of attaining the data organized in Part 1. Part 3 describes the process of using the Chi-square test for homogeneity to evaluate whether the indices are close to one another in terms of fail to reject/reject distributions. Finally, Part 4 describes the process of reaching the stated baseline and comparing the indices to it.

3.1 Data Presentation

As the samples were run against each of the four indices, four tables each with forty columns were created to hold the collated data. The first column states the P-value of the standard t-test when the stock's linear model slope is compared with the listed index's linear model slope. The second column gives a standardized residual plot in order to evaluate

the fit of the linear model onto the past 100 closing prices of the stock (random patterns are expected). Finally, the last column gives the equation of the fitted model on the stock's closing prices.

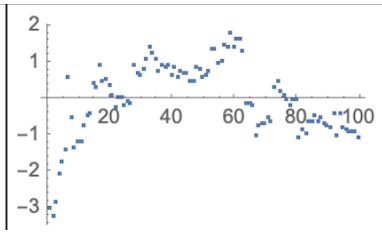
NSYS	5.11072×10^{-15}		FittedModel[2.05098 – 0.00191853 a]

Figure 2: NSYS vs DJUSTC

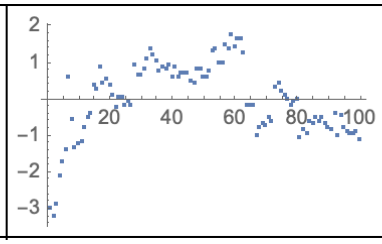
NSYS	0.139291		FittedModel[2.05098 – 0.00191853 a]

Figure 3: NSYS vs NDXT

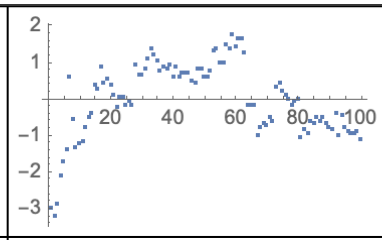
NSYS	3.90336×10^{-7}		FittedModel[2.05098 – 0.00191853 a]

Figure 4: NSYS vs QTEC

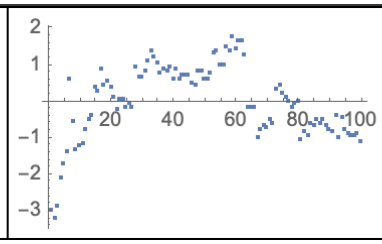
NSYS	2.82038×10^{-16}		FittedModel[2.05098 – 0.00191853 a]

Figure 5: NSYS vs XTX

3.2 First Statistical Tool – Linear Regression Models

The first statistical tool used was linear regression, where standardized residuals, Standard t-tests for slope, and model equation were emphasized. Linear regression was also used as it provides a simple and less computation-heavy way of evaluating stock performance over a certain number of days (and it also has been used before in the same context as seen in Roy, Mittal, and Abraham 2015). The sample of 40 stocks came out to be: {NSYS, SITM, AEY, UBER, EVBG, DSP, FLIR, ADSK, CEVA, SPT, INS, KLIC, ESCO, NTCT, AGYS, U, PCTEL, COHU, DMRC, CSCO, CREX, IIVI, HPQ, TGI, PRCH, NOVA, VRSN, SPT, APH, CTEK, PWFL, KEYS, HLIT, GPRO, PSTG, ESG, MX, YEXT, SPRT, WSTG, IPG, TGI}. Using Wolfram's native database of closing prices, linear

models were fitted to the stocks using day numbers as the independent variable and the natural logarithm of closing prices as the dependent variable. The assumptions for the simple linear regression models are listed in Table 1.

Table 1. Table of Assumptions for the Simple Linear Regression Model.

Assumption	Passed?	Reason
The distribution of e at any particular x value has a mean value 0.	Yes	Stock prices might have fluctuations throughout the day but will end up at the closing price (0).
The standard deviation of e is the same for any particular value of x.	Yes	There would be no reason not to think so. (Unless there is a major fluctuation in price for one of the stocks which is highly unlikely.)
The distribution of e at any particular x value is normal.	Yes	This will be assumed as the fluctuations in the price during the day are likely to be approximately normal.
The random deviations $e_1, e_2, \ldots, e_n$ associated with different observations are independent of one another.	Yes	The standardized residuals plots suggest that this is the case.

One might argue that the standardized residual plots clear patterns that violate the assumptions for simple linear regression. While this may be true, most of the "patterns" are erratic and fluctuate quite a bit leaving graphs that still can be considered randomly distributed. The null hypothesis is: There is no difference in the slope for the last 100 days of closing prices for [Stock Name] and the last 100 days of closing values of [Index Name].

The alternative hypothesis is: There is a statistically significant difference in the slope for the last 100 days of closing prices for [Stock Name] and the last 100 days of closing values of [Index Name].

An alpha value of 0.01 will be used for all tests. In addition, all tests in which the null hypothesis is not rejected will suggest that the index does not deviate in a significant way from the stock in terms of trend.

There were 10 tests in which the null hypothesis was not rejected for QTEC.

There were 11 tests in which the null hypothesis was not rejected for DJUSTC.

There were 9 tests in which the null hypothesis was not rejected for NDXT.

There were 2 tests in the null hypothesis was not rejected for XTX.

3.3 Second Statistical Tool – Chi-Square Test for Homogeneity

By creating two categories of whether the null hypothesis was rejected or not, count data can be gathered and a Chi-square test for homogeneity can be performed to see if there is any statistically significant difference between the roughly distributions for each market index. The null hypothesis will be that the category proportions are the same for all the market indices. The alternative hypothesis will be that the category proportions are not all the same for all the market indices. The assumptions concerning the Chi-square test for homogeneity are listed in Table 2. The observed counts are summarized in Table 3 while the expected counts are summarized in Table 4.

Table 2. Table of Assumptions for the Chi-Square test for Homogeneity.

Assumption	Passed?	Reason
The data are from independently chosen random samples.	Yes	As the stocks are randomly chosen, the tests have also come from a randomly selected sample.
The sample size is large (i.e. all expected counts are greater than 5).	Yes	As seen in the expected counts table, all the expected counts are indeed greater than 5.

Table 3. Table of counts for the results of the Standard t-tests categorized by market index.

	QTEC	DJUSTC	NDXT	XTX	Total
Rejected Null Hypothesis	30	29	31	38	128
Failed to Reject Null Hypothesis	10	11	9	2	32
Total	40	40	40	40	160

Table 4. Table of expected counts for the Chi-Square test for Homogeneity.

	QTEC	DJUSTC	NDXT	XTX	Total
Rejected Null Hypothesis	32	32	32	32	128
Failed to Reject Null Hypothesis	8	8	8	8	32
Total	40	40	40	40	160

The Chi-square test statistic is 7.8125. At (4 - 1) * (2 - 1) = 3 degrees of freedom, the resulting p-value is 0.05005 using a Chi-square distribution. At an alpha level of 0.01, this is not statistically significant, and null hypothesis was not rejected. There is not enough evidence to conclude that the category proportions are not all the same for all the market indices.

3.4 Third Statistical Tool – Establishing Baseline for Index Performance

In an attempt to give a baseline for how well these indices should do, the number of holdings within each index can be used. There is an expectation that an index should track its holdings well, or at least better than stocks not held by the index. Therefore, using list of 1,353 technology stocks, a ratio can be made of the holdings to total stocks for each index (essentially a probability of any given holding for an index to show up in our sample). This ratio can then be applied to the sample to give an approximate number for how many stocks the index should track well in our sample. A table shows this below:

Table 5. Table of expected number of stocks to be tracked by each index within the sample.

Market Index	Total # of Holdings	Ratio	Projected # of stocks expected to be tracked well in sample
QTEC	39	39/1353	1.15
DJUSTC	158	158/1353	4.67
NDXT	39	39/1353	1.15
XTX	196	196/1353	5.79

The Chi-square Goodness of Fit test cannot be used here as the expected counts (the projected number of stocks to be tracked) are not all greater than 5. However, most of our indices do track a larger number of stocks than predicted (QTEC: 10 > 1.15, DJUSTC: 11 > 4.67, NDXT: 9 > 1.15, XTX: 2 < 5.79).

4. Conclusions

To reiterate, the stocks and indices had linear models fitted to them and standard t-tests were run in order to determine whether the difference of the slope of each stock versus a given index was statistically significant. The number of fail to rejects/rejects was counted and a Chi-square test for homogeneity was carried out in which the null hypothesis was not rejected, and the conclusion was that there is not enough evidence to justify there being a difference in category proportions. Finally, using a holdings/set space size ratio, it was found that three of the indices were tracking more stocks than the expected baseline (with the exception of XTX which suggests we should reevaluate any reliance we might have on it). Overall, the market indices do indeed track the technology sector well and do so in a consistent manner.

5. Future Research

This paper used computation-heavy tests and methods to achieve conclusions and thus, the sample size was limited to computation limitations. With resources such as high efficiency computation clusters and large data storage bins offered by Amazon Web Services and others, the sample size could have been increased and more closing prices could have been factored in. There is a potential for selection bias in sample selection as the website might not actually contain all public technology-oriented companies and the web-scraping code may have failed to pick up on certain ticker symbols (unlikely, but possible). Another potential source of error would be the fit of linear models to the sample stocks. Model utility t-tests could have been run to ensure a linear model was appropriate for all the chosen stocks. It is possible Type I and II errors were made in the Standard t-tests and a Type II error in the Chi-square test, but those errors would not significantly skew the results. Further lines of questioning might include similar studies into other market sectors/indices and investigating the reliability of indices that don't seem to be matching the sector very well (like XTX).

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Biography

Tanish Kumar is a junior at Stanford Online High School, intern at Stem-Away, co-founder of Tri-Valley Editing Services, and track and field competitor.