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Innovation and Research of Sector-based VIX Derived from VIX

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Abstract: VIX, also known as the Chicago Board Options Exchange Volatility Index, is designed to measure the market's expectation of 30-day volatility. People could use VIX for risk management, hedging, or portfolio diversification because it is seen as a signal of risk, uncertainty, and people's fear in financial markets. However, considering previous studies have not focused on the sector–based VIX, this paper aims to monitor the market risks better and assess market expectations, in terms of portfolio management or risk hedging, by creating sector–based VIX. First, we figure out 11 sectors in the current market based on the Global Industry Classification Standard (GICS). Second, we select a few of the 11 sectors to compute the respective VIX for each sector over a fixed period. Third, we do the correlation between different sectors. Findings from the above calculations suggest that healthcare with utilities and consumer staples have a positive correlation, as well as consumer staples and utilities. In contrast, a negative correlation is observed between information technology and utilities and consumer staples; moreover, consumer discretionary exhibits a negative correlation with utilities. These results show potential diversification opportunities for investors to consider when managing investment. Besides, by exploring correlations across several sectors, this study provides investors with a unique perspective on the volatile market environment with greater flexibility.

Keywords: VIX, Sector-Based VIX, Correlation, Portfolio Management, Risk Hedging

1. Introduction

1.1. Background

CBOE Volatility Index, a tool that helps people to analyze and predict, is prominent among the other means for the complexity and dynamics of today's financial markets. Because of market uncertainty and psychological factors, VIX also refers to the "fear index" because investors may be more cautious and do some initiatives that result in higher VIX during the high volatility period.

In order to better learn the changing patterns of the VIX, it is necessary to look at its history. The development of VIX is divided into the following main phases: At the beginning, it was introduced

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by the Chicago Board Options Exchange in 1993, which was initially designed to calculate based on the price of S&P 100 (OEX) options. However, from 1993 to 2003, it shifted to use options on the broader S&P 500 index. Then, it gained popularity and recognition for the period of 2003 to 2008 and is well known as the "fear index". It is worth paying attention to VIX fluctuations when facing some significant events. Figure 1 shows VIX from 1986 to 2022 [1]. On October 19, 1987, Black Monday, the DJIA fell 508 points and coexisted with futures and options markets crashed. VIX reached its all-time peak during the stock market crash, and this was the only time the VIX index level exceeded 100. Although VIX had fallen slightly at the end of the week, it remained extremely high in the next few weeks [2]. During the 2008 Financial crisis, also known as the Subprime crisis, because of the real estate bubble economy, the VIX intraday value was over 89. Moreover, the most recent fluctuation was in 2020 during the Covid – 19, and its VIX also exceeded 80.

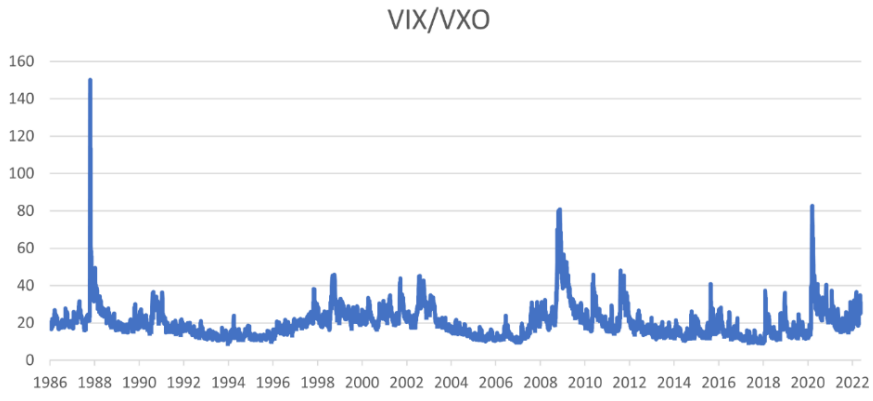

Figure 1: Dr. Peter Niculescu, "Capital Market Risk Advisors", Using the VIX to Distinguish between Transitory and Persistent Risk

Here is another index called the S&P 500, which tracks the prices of 500 of the largest U.S. companies by market capitalization and negatively correlates with VIX overall. Figure 2 shows the relationships between S&P 500 and VIX from 1990 to 2018 [3]. The reason for this relationship is mainly in response to investor behavior. For example, if the stock market experiences periods of uncertainty or faces some geopolitical events, investors will seek to protect their investments by buying option contracts. The increased demand for options drives up the prices of these contracts and results in higher VIX, whereas the stock prices represented by the S&P 500 will decline as investors sell off their holdings. However, an interesting phenomenon shows that the S&P 500 and VIX sometimes fluctuate in the same direction, for instance, in July 1997 or January 1999 [2]. This seems reasonable when occurring government intervention, and it may lead to stock prices and market volatility moving in the same patterns.

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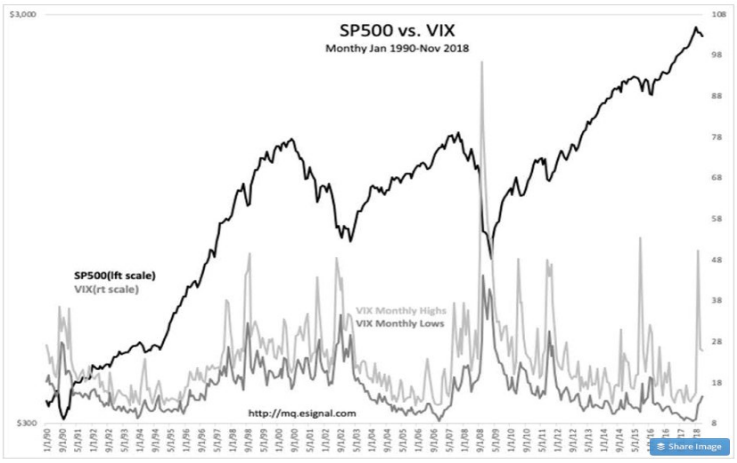

Figure 2: Todd Sullivan, "The VIX And Investment Timing"

It is worth mentioning that there are other types of VIX–like indexes, such as OVX and GVZ. OVX measured the market's expectation of future volatility in crude oil prices, and GVZ is the gold volatility index, which represented implied volatility in the gold market. Figure 3 is a comparison diagram for VIX, OVX, and GVZ [4]. Although they move independently from each other, they are aligned in the macroeconomic trends, especially when something important happens. In the diagram, some of the crucial points are marked. For example, the start of the

Iraq War 1991, the European debt crisis began in 2009, Brexit around 2016 to 2020, and even Covid-19 in recent years. Therefore, during political or economic instability periods, VIX, OVX, and GVZ will tend to increase, and a more obvious example that can explain the connection between VIX and OVX is the supply chain issues caused by the war between Russia and Ukraine. Russia is one of the world's largest oil producers. Based on the data in Figure 4, the cost of the EU trade with Russia by product group in 2011 and 2021 shows that energy was the EU's most extensive imported product from Russia, which can be calculated at around 76.64% in 2011 and 62.46% in 2021 [5]. Because of the provision of weapons support by the EU for Ukraine during the war between Russia and Ukraine, Russia sanctions EU energy imports, thus increasing the cost of energy imports since the EU needs to import from other countries at higher prices, and then oil price hikes. Moreover, due to rising energy prices, the cost of living is increasing and bringing out social unrest, which causes higher VIX. As well as oil, gold prices will increase during market uncertainty because investors seek the safe haven of gold after receiving extreme adverse shocks from the market [6]. Gold has stored value especially remains relatively stable prices in the face of crisis, for example, for periods of currency devaluation and inflation. Also, there is evidence that investors will transmit the uncertainty and volatility of the stock market to the gold market [7]. When the stock market situation is not optimistic, investors will feel panic and fear so in order to hedge risk on the gold market to produce higher demand, which results in higher gold prices.

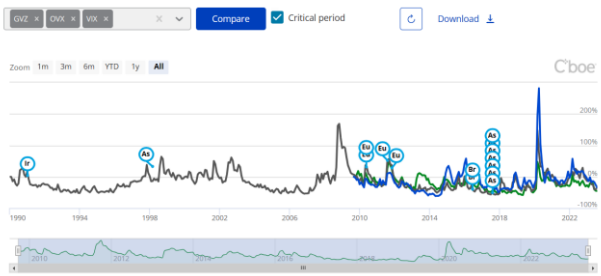

Figure 3: Cboe, "Cboe Volatility Index"

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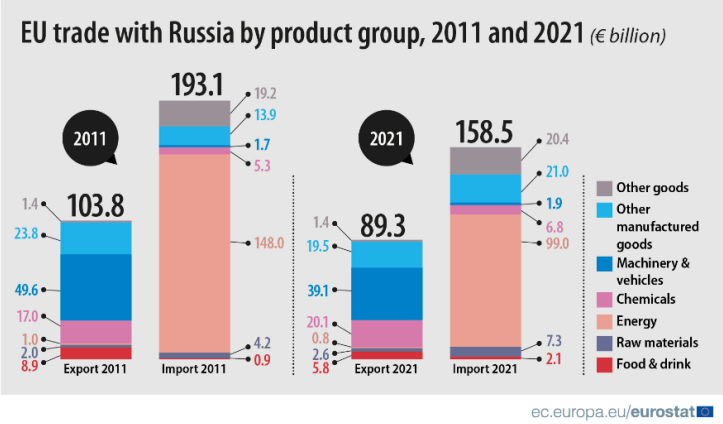

Figure 4: Eurostat, "Energy represented 62% of EU imports from Russia"

1.2. Motivation

We first find a positive correlation between OVX, GVZ, and VIX, then consider whether there is a similar relationship with VIX for a sector or between different sectors. This paper aims to create sector-based VIX, which uses them to assess the market's risks and realize portfolio diversification in practice. Besides, the sector-based VIX does not preclude future trading possibilities.

We select the healthcare sector as an example among 11 sectors. One of the reasons we chose the healthcare sector as an example is that VIX is a kind of volatility index, especially the degree of fluctuations is pronounced when it comes to high–endomential events. The essential recent event with a clear sectoral direction was COVID-19, which connected well with the medical board. In addition, we will pick the top 10 companies in the sector based on market capitalization to compute the overall VIX. However, during COVID-19, other sectors may be more variable, while healthcare is smoother and relatively stable, which helps us to select the top 10 companies. After calculating the VIX for the healthcare sector, we compute other sectors that will be highlighted and explained later in the data parts. Moreover, aside from the computational dimension, people's demand for healthcare has proliferated over the past decades. On the one hand, education is becoming more and more accessible, and with that comes a growth in health awareness, which increases the demand for healthcare to prevent disease or adopt a healthy lifestyle. On the other hand, some problems are exposed when facing global health threats, illustrating people's higher need for healthcare, such as COVID-19. Insufficient access to healthcare could affect the distribution of the pandemic burden. In the United States, acute and critical care might be unavailable in many rural areas because of the lack of resources, and residents in such areas must go to a place where these medical resources are sufficient. As a result, these cases flood hospitals in more densely populated areas [8]. This places a more significant burden on densely populated areas and can also exacerbate the spread of the local pandemic. In particular, more and more technological products have been applied to the medical field in recent years, which is worth drawing our attention to.

1.3. Organization of the paper

This paper is divided into four sections. Section 1 provides an overview of the background and motivation of the research. Then, the methodology of this paper will be discussed in the second section. Section 3 analyzes the data and gives an explanation of the findings. Last, the conclusions are drawn.

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2. Methodology

The sector-based VIX indices will allow a comparative analysis of the original VIX methodology published by CBOE (Chicago Board Options Exchange). Thorough evaluation of the new indices could provide insights into relative volatility across sectors. If successful, this approach may spur further research into sector-focused trading strategies and tools for risk management.

By studying the white paper published by CBOE, we learn that VIX is calculated from the wide range of put and call options based on the S&P 500 index [9]. The generalized formula used in the VIX calculation given by CBOE is:

$$VIX = 100 \times \sqrt{\left\{T_1\sigma_1^2\left[\frac{N_{T_2}-N_{30}}{N_{T_2}-N_{T_1}}\right]+T_2\sigma_2^2\left[\frac{N_{30}-N_{T_1}}{N_{T_2}-N_{T_1}}\right]\right\}\times\frac{N_{365}}{N_{30}}}$$

Here, N_{T_1} is the number of minutes to settlement of the near-term options while N_{T_2} is the number of minutes to settlement of the next-term options. N_{30} is the number of minutes in 30 days which equals to 43200 minutes and N_{365} is the number of minutes in a 365-day year which equals 525600 minutes. T is the time to expiration. And VIX needs the option with the expiration of more than 23 days and less than 37 days. To be specific, CBOE uses minutes as the unit in the calculation:

$$T = \frac{\{M_{current\ day} + M_{settlement\ day} + M_{other\ days}\}}{Minutes\ in\ a\ year}$$

σ_1^2 and σ_2^2 is the volatility for near-term and next-term options with time to expiration of T_1 and T_2 respectively, resulting VIX always reflect an interpolation of σ_1^2 and σ_2^2. σ^2 can be computed by:

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2}e^{RT}Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0}-1\right]^2$$

K_0 denoted as the first strike below the forward index level F, which is the forward index level derived from index option prices. K_i stands for the strike price of ith out-of-the-money option. Further, more ΔK_i is the interval between strike prices, which is:

$$\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$$

And, Q (K_i) is the average value of the bid and ask for each option with strike K_i. R is the risk-free rate to expiration.

To construct sector-based volatility indices, we first require an underlying sector index. We identify potential candidates such as the Dow Jones Industrials (INDU) and NASDAQ Health Care Index (IXHC). However, the methodology depends on options data rather than direct index levels or stock prices. We therefore focus on collecting robust options data for suitable companies within each sector.

Besides, the VIX methodology requires options expiring within 23 to 37 days. This constraint significantly limits the pool of companies with adequate options data. Reviewing CBOE's company-specific indices (e.g., VXAPL for Apple Inc.), we initially decided to build single-company volatility indices that can be aggregated to the sector level [10].

Following the Global Industry Classification Standard, we categorize the overall market into 11 sectors. At this stage, we exclude real estate due to unique volatility drivers (housing bubbles, political reasons…) in that industry. The remaining 10 sectors are energy, materials, industrials, consumer discretionary, consumer staples, healthcare, financials, information technology, communication services, and utilities. Furthermore, considering the great attention paid to the healthcare sector these

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years, we chose healthcare as the place to start. Company-level volatility indices will be constructed based on the VIX methodology. The sector-level index will aggregate the company indices using market capitalization weights.

This sector-focused approach aims to leverage the robust options data available for major companies. By replicating VIX methods at the company and sector levels, we can research the characteristics and potential applications of the resulting volatility indices. Therefore, we identify the largest 20 healthcare companies by market capitalization that also meet our options data requirements. And by collecting the option chain for all of them, we follow the calculation of VIX to get the company-based VIX for every one of them.

For piloting, we chose the 20 biggest companies within the healthcare sector. By collecting the option chain for all of them, we follow the calculation of VIX to get the company-based VIX for every one of them. However, for piloting purposes, we tend to use days instead of minutes as the unit. Therefore, we will cancel the constant in the equation, which is $\frac{N_{365}}{N_{30}}$. Here is the company-based equation for VIX that uses days as the unit to compute:

$$VIX_{company-based} = 100 \times \sqrt{\left\{T_1\sigma_1^2\left[\frac{D_{T_2} - D_{30}}{D_{T_2} - D_{T_1}}\right] + T_2\sigma_2^2\left[\frac{D_{30} - D_{T_1}}{D_{T_2} - D_{T_1}}\right]\right\}}$$

Since we use different time units, which might cause some errors, we want to check the accuracy. We do the same calculation on Apple and compare our result with CBOE's, and if the error is below 20 percent, we will ignore that.

Another question here should be how to weigh company-based VIXs. The most straightforward and intuitive way might be to weight by market capitalization. However, some companies have higher volatility than others and will distribute more on a sector-based index. Also, since VIX is extremely volatile in rare and profound events, such as Brexit and market meltdowns, we want this index to be a sensitive signal to let people know that something is happening within a single sector and might be an opportunity to hedge or arbitrage. This question can be a research topic by itself, but to continue our project, we move on with market capitalization weighting. By weighting each company-based VIX, we will get the sector-based VIX in the end:

$$VIX_{sector-based} = \omega_1 VIX_1 + \omega_2 VIX_2 + \cdots + \omega_n VIX_n$$

Where ω stands for the weight of each company according to their market capitalization, and VIX_n is the company-based VIX for each company we chose.

The proposed sector-based VIX indices will allow a comparative analysis of the original VIX methodology published by CBOE. Through evaluation of the new indices could provide insights into relative volatility across sectors. If successful, this approach may spur further research into sector-focused trading strategies and tools for risk management. For example, the CBOE applies the VIX methodology to create tradable VIX futures and options contracts. Similar products based on sector-level volatility indices could be envisioned. However, extensive historical data will be required to thoroughly research the characteristics of the new indices and product possibilities.

There are some implementation challenges to address. Options contract expiration means ongoing data collection is needed. Robust processes must be in place to incorporate new options data as it becomes available. Some sampling and filtering of the options data may also be required, given variations in contract terms across companies.

In summary, this project aims to demonstrate a novel application of the VIX methodology to sector-level volatility indices. There is potential for meaningful insights and innovations in sector-based index. However, realizing this potential will require methodical research and product

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development informed by substantial empirical analysis. We look to build a foundation for such efforts by creating sector-based VIX indices.

3. Data and Findings

Our initial objective was to develop a CBOE Volatility Index (VIX) metric for a specific economic sector. We hoped to identify the most representative public companies within the target sector, similar to the S&P 500 methodology, and obtain their historical stock prices from public financial databases. The following steps would involve calculating the individual VIX for each company using the methods outlined in the CBOE's white paper, followed by devising an appropriate weighting scheme to combine the individual components into an overall sector-level VIX. An equitable weighting methodology poses the primary challenge from our perspective, as an unreasonable equal-weight approach would likely yield an inaccurate aggregate figure. We want to study the S & P 500's weighting techniques for guidance.

An example of the company's weekly stock prices over the past decade is shown below. We used this data to compute a ten-year historical VIX for this company and compared it to the S&P 500 VIX and gold VIX benchmarks, seeking any correlations. Table 1 shows part of the historical data that we used [11].

Table 1: Yahoo Finance, "JNJ historical price (05/01/2023-07/21/2023)"

Date	Open	High	Low	Close	Adj Close	Volume
5/1/2023	163.60	166.18	161.25	162.68	160.30	28694000
5/8/2023	161.99	162.57	159.39	160.78	158.43	27043800
5/15/2023	160.80	161.03	157.56	158.91	156.58	29241400
5/22/2023	158.00	159.14	153.72	154.35	152.09	30215500
5/29/2023	153.97	157.31	153.15	156.97	155.84	32476200
6/5/2023	156.75	160.73	156.75	160.01	158.86	30091200
6/12/2023	160.00	164.99	158.73	164.23	163.05	39839900
6/19/2023	164.26	166.27	162.69	165.48	164.29	30109900
6/26/2023	164.98	165.94	161.33	165.52	164.33	30814200
7/3/2023	164.34	164.39	159.20	159.25	158.10	24612500
7/10/2023	159.43	160.30	157.41	159.87	158.72	31050000
7/17/2023	159.75	170.82	157.33	170.19	168.96	53311300
7/24/2023	171.50	175.36	169.75	174.48	173.22	69818900
7/31/2023	169.69	172.68	166.06	169.04	167.82	93877700

Unfortunately, our initial efforts were unsuccessful due to the team's unfamiliarity with the VIX calculation. We had overlooked that the VIX derives from options pricing rather than direct stock prices since options provide insight into expected future volatility. So, we started focusing on options trading and discovered that obtaining historical options data needed to be revised. Current month contracts were readily accessible, but the historical data was scarce. With limited progress on the historical options data front, we focused on estimating the current month's VIX for individual companies and sectors to compare versus the S&P 500 VIX, hoping meaningful relationships would emerge. Figure 5 below exemplifies August options pricing for Johnson & Johnson, courtesy of Barchart.com [12].

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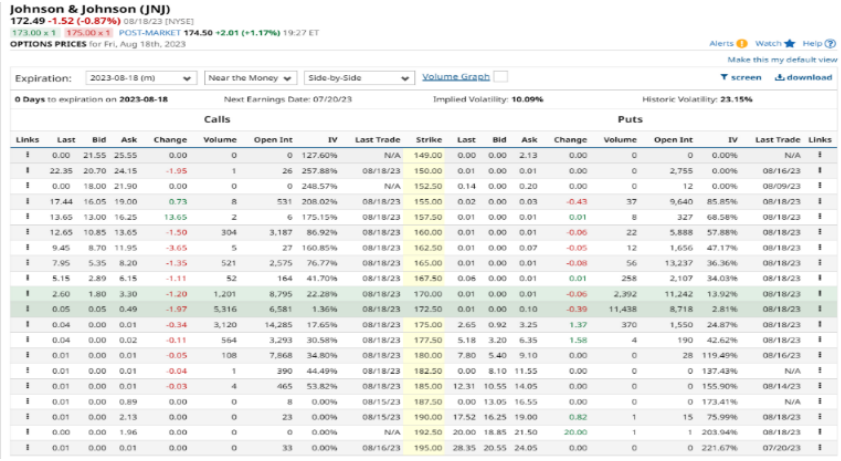

Figure 5: Barchart, "Johnson and Johnson option price"

The actual VIX calculations follow the methodology delineated in the CBOE white paper. Given its presumed stability, we selected the healthcare sector first and chose the top 10 companies by market capitalization to represent it. The individual company VIX calculations could then be aggregated to produce an overall sector VIX, initially employing market capitalization to weight each constituent. However, identifying an optimal weighting scheme remains an area for improvement. Table 2 shows the calculation for healthcare sector with 49.87 as the result.

Table 2: Initial Calculation for Healthcare Sector

Full Name	Company (By Rank)	Near term (sigma 1^2)	Next term (sigma 2^2)	vix^2	vix	market cap (billion)	Weight	VIX*Weight	VIX_Healthcare
UnitedHealth	UNH	0.000613	0.000491	0.208785	45.69303	468.05	0.578325	26.42542	49.86794
Elevance Health	ELV	0.000779	0.000616	0.264572	51.43656	109.14	0.134854	6.936424	
CVS Health	CVS	0.000936	0.000778	0.322389	56.77932	93.44	0.115455	6.555454	
McKesson	MCK	0.000633	0.00052	0.217316	46.61712	57.15	0.070615	3.29186	
Centene	CNC	0.000827	0.000643	0.279409	52.85915	36.10	0.044605	2.357801	
Cardinal Health	CAH	0.00071	0.000588	0.244251	49.42175	23.23	0.028703	1.418558	
Baxter BAX	BAX	0.003248	0.002572	1.103208	105.0337	22.21	0.027443	2.882418	

This sector VIX results were surprisingly elevated compared to the S&P 500 VIX of approximately 17% on August 1st. While the small sample size for our sector analysis likely contributed to inflated volatility, it did not fully explain the discrepancy. It may also be because healthcare companies tend

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to have high stock volatility. However, the number was still too big, so we reconsidered our calculation. Upon re-examining the white paper, an issue with our unit conversions became evident. The CBOE employs minute-level data, necessitating a large multiplier when annualizing to obtain the final VIX value. Removing this adjustment made our values more accurate.

To improve the diversification, we expanded our database and added the top 10 pharmacy firms. The result is a healthcare sector VIX of 16.2%, which logically confirms the relatively lower volatility of healthcare versus other sectors like technology compared with the S&P 500 VIX Index. Due to time constraints, we repeated the analysis for the technology, consumer discretionary, financial, and utility sectors, yielding sensible comparative results. Financials exhibited the highest volatility, as expected. Graphs below are the results for this for industries. Specifically, Table 3 shows the sector-based VIX for the finance sector, Table 4 for the technology sector, Table 5 for the consumer discretionary sector, and Table 6 for the energy sector.

Table 3: Calculate Process and the VIX Index for Financial sector

Company (By Rank)	**Near term (sigma 1^2)**	**Next term (sigma 2^2)**	**vix^2**	**vix**	**market cap(billion)**	**Weight**	**VIX*Weight**	**VIX_FIN**
AXP	0.005984639	0.004839311	0.16808588	40.9982786	121.88	0.071750674	2.941654125	24.78503998
BAC	0.007163374	0.005752394	0.20079142	44.8097556	248.11	0.14606219	6.54501104	
GS	0.001105566	0.000900747	0.03111879	17.64052	116.98	0.068866047	1.214832884	
JPM	0.000392683	0.000431501	0.01216868	11.0311746	453.14	0.266763213	2.94271159	
MA	0.000866189	0.000718172	0.0245055	15.6542311	368.06	0.216676675	3.391906735	
MS	0.000724229	0.00061076	0.02059217	14.3499729	147.59	0.086886134	1.246813666	
SCHW	0.001183976	0.000990509	0.0335846	18.3261014	119.51	0.070355457	1.289341236	
SPGI	0.000856455	0.000703212	0.02416123	15.543884	123.39	0.072639961	1.129101671	
V	0.002485783	0.002020357	0.06991924	26.4422458	495.34	0.291606325	7.710726134	
WFC	0.017907655	0.002479085	0.38294395	61.882465	164.86	0.097052971	6.00587709	

Table 4: Calculate Process and the VIX Index for Technology Sector

Company (By Rank)	**Near term (sigma 1^2)**	**Next term (sigma 2^2)**	**vix^2**	**vix**	**Market cap(billion)**	**Weight**	**VIX*Weight**	**VIX_Tech**
APPL	0.00468915	0.00380254	0.1318084	36.3054266	2802	0.249891419	9.072414583	21.12727744

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Table 4: (continued).

MSFT	0.001263	0.0010475	0.035735	18.9037033	2395	0.213593844	4.037714653	
GOOG	0.0003969	0.00035128	0.0114508	10.7008411	1650	0.147152335	1.57465375	
AMZN	0.0004279	0.0003857	0.012415	11.1422619	1414	0.126105092	1.405095958	
NVDA	0.001377764	0.001150491	0.03906019	19.763651	1051	0.093731578	1.852478195	
META	0.001438822	0.001214291	0.04091935	20.2285318	782.17	0.06975645	1.411070559	
TSLA	0.002594194	0.002169241	0.07357629	27.1249498	767.62	0.068458833	1.856942419	
AVGO	0.000393502	0.00033628	0.01123284	10.5985093	351.08	0.03131045	0.331844091	
ORCL	0.000475433	0.000410647	0.01361513	11.6683889	306.98	0.027377469	0.319450955	
ADBE	0.000651114	0.00056343	0.01865658	13.6589092	234.18	0.02088493	0.285265356	

Table 5: Calculate Process and the VIX Index for Consumer Discretionary Sector

Company (By Rank)	**Near term (sigma 1^2)**	**Next term (sigma 2^2)**	**vix^2**	**vix**	**market cap(billion)**	**Weight**	**VIX*Weight**	**VIX_CD**
AMZN	0.000427893	0.000378674	0.0123446	11.1106234	1,414.40	0.418321685	4.647814715	17.09283803
TSLA	0.002594195	0.002169241	0.07357631	27.1249525	767.62	0.227030608	6.158194471	
HD	0.001274578	0.00103003	0.0357918	18.91874	329.98	0.097594591	1.846366697	
BABA	0.000984845	0.000838656	0.02808346	16.7581208	243.05	0.071884252	1.204644975	
MCD	0.001538844	0.001241187	0.04318876	20.7819062	210.43	0.062236659	1.293394966	
NKE	0.000515335	0.000432402	0.01463073	12.0957536	168.59	0.049862028	0.603118809	
LKW	0.003179589	0.002583781	0.0894296	29.9047821	128.7	0.038064197	1.138301532	

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Table 5: (continued).

BKNG	0.000203074	0.000181107	0.00587254	7.66325253	118.36	0.035006048	0.268260188	
SBUX	0.000548737	0.00046132	0.01558795	12.4851713	114.55	0.033879206	0.42298769	
PDD	0.001377008	0.001166912	0.03920928	19.8013323	110.91	0.032802643	0.649536033	

Table 6: Calculate Process and the VIX Index for Energy Sector

Company (By Rank)	**Near term (sigma 1^2)**	**Next term (sigma 2^2)**	**vix^2**	**vix**	**market cap(billion)**	**Weight**	**VIX*Weight**	**VIX_Energy**
XOM	0.000442264	0.000375562	0.012600 9	11.2253712	442.94	0.336437382	3.776634496	21.77581792
CVX	0.006597564	0.005307761	0.185028 9	43.0149852	298.85	0.226993073	9.764103 68	
COP	0.000429492	0.000374 64	0.012336 23	11.1068577	140.89	0.107013733	1.188586299	
NEE	0.000980265	0.000714 57	0.026751	16.3557343	139.45	0.105919973	1.732398 94	
SLB	0.001572352	0.001291 401	0.044361 05	21.0620641	84.57	0.064235584	1.352933978	
EOG	0.000413747	0.000364 9	0.011923 94	10.9196774	76.5	0.058105973	0.634498483	
SO	0.000943354	0.000768 489	0.026551 97	16.2947743	75.44	0.057300845	0.933704328	
EPD	0.009901983	0.007980 829	0.277847 95	52.711 284	57.92	0.043993437	2.318950576	
OXY	0.001401183	0.001150 505	0.039528 71	19.8818277	56.9	0.043218691	0.859266572	
PED	0.002314186	0.001867 608	0.064959 79	25.4872103	55.29	0.041995807	1.070355972	

Although our results were reasonable, some things could be improved. Certain companies within a sector demonstrated anomalously high VIX values, leading to high VIX values in the whole industry. Johnson & Johnson and Baxter International showed much higher VIX than UnitedHealth Group in healthcare, likely stemming from divergent implied volatilities as shown in Figure 6 [13]. However, comparing the implied volatilities revealed that this only explained Baxter's result. As the graph shows below, the implied volatilities of Baxter are much higher than the other two companies, and it could be considered with the high VIX value of Baxter. When we compared Johnson and Johnson and United Health, they have the same implied volatility, suggesting that other factors must influence

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Johnson & Johnson's elevated VIX. Investigating the root causes of these idiosyncrasies could be our future research topic.

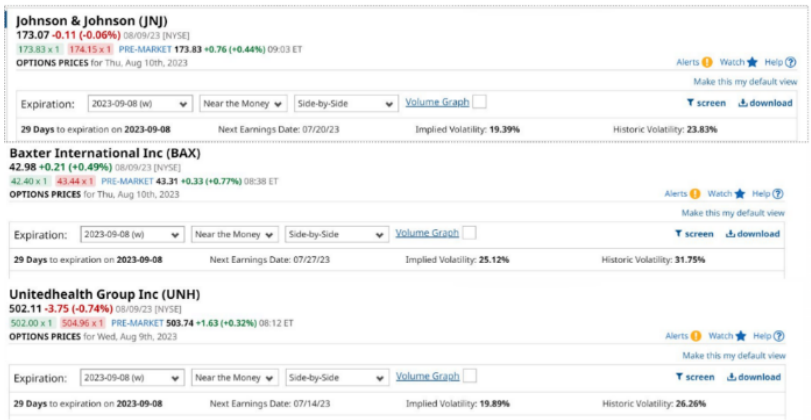

Figure 6: Barchart, "Implied Volatility, Historical Volatility for JNJ, BAX, UNH"

Additionally, market capitalization furnishes a simple yet suboptimal technique for weighting sector constituents. It may still result in inaccurate results. For instance, in the financial sector, high market capitalization and high volatility firms like Visa cause the financial sector to have the highest VIX value over the five sectors. At the same time, most other firms in this sector have only about 16 percent of VIX value. Adopting an approach akin to the S&P 500 methodology could improve accuracy, which is one of our future directions.

In summary, this research over two weeks afforded informative experience and insights into calculating sector-level VIX metrics. While initial attempts encountered challenges, thoughtful inspection of the methodology and outputs highlighted avenues to develop more robust and meaningful volatility measures. We look forward to applying these lessons in subsequent research efforts.

4. Conclusion

This research focuses on developing sector-based VIX indexes to analyze market risks and expectations. The VIX, introduced by the Chicago Board Options Exchange, measures market volatility using options on the S&P 500 index. As such, it reveals market fear and investor sentiment. Moreover, the VIX and S&P 500 tend to be negatively correlated, reflecting investor behavior. Inspired by other specialized volatility indexes like OVX and GVZ, we derive sector-based VIX measures. Our methodology proceeds in steps: First, selecting top companies in a sector based on market capitalization. Second, calculating company-level VIX measures. Third, weighting by market capitalization to derive the sector-level VIX. Using this approach, we have calculated VIX measures for the healthcare, finance, technology, consumer discretionary, and utilities sectors.

Sector-based VIX indexes enable several analyses. They reveal correlations between sectors. Investors can use them for risk management and identifying trading opportunities. However, calculating these measures has challenges. Obtaining suitable options data is difficult, yet historical data is critical.

Future research can improve this methodology. Weighting schemes could increase sensitivity to events while reducing the influence of large individual companies. Machine learning may enable updating the indexes dynamically. Analyzing correlations between sector-based VIX measures and other indexes could provide additional insights. Extending this sector analysis across regions and countries is another potential area for investigation.

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