

An Analysis of Semiconductor Stocks as an Opportunity for Portfolio Diversification

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Abstract. *The semiconductor industry is a key driver of technological progress due to essential parts that are integrated in widely used electronic devices nowadays. Given its critical importance, this industry is constantly evolving in order to adapt to market requirements led by fast-paced consumer trends. Meanwhile, the global supply chain is undergoing pressure from other conditional factors, mostly the pandemic and trade restrictions in recent times. With potential to grow due to digitalization, semiconductor companies can be an attractive option to invest in. Building an investment portfolio is a challenging process regardless of the risk preference of an investor. Based on the concept of diversification, combining low-correlated assets from various industries can lead to an overall efficient portfolio with acceptable risk levels. The aim of this study is to analyze the evolution of eight selected semiconductor stocks from 2018 to 2022 and evaluate their relative performance to the benchmark index by using descriptive statistics and risk metrics drawn from their daily returns. Having an insight on the results obtained from historical data allows us to examine whether diversifying portfolios with semiconductor stocks represents an opportunity, mainly contributing to a pre-selection of stocks to mitigate the risk and support the investment decision.*

Keywords: semiconductor industry, stocks, return, risk, diversification.

Introduction

The rapid evolution of modern technology facilitated the integration of the world economies into an interdependent global system. Globalization has been accelerating economic development by enhancing productivity, international trade, and capital mobility to encourage the expansion of businesses outside national borders by increasing the participation of countries in foreign investment.

Financial instruments are traded on financial markets and the composition of a portfolio depends on the risk level accepted by the investor with the main objective of maximizing returns. Financial globalization has also raised opportunities for investors around the world to diversify portfolios internationally and select an optimal combination of financial instruments to reduce the risk and increase expected returns. Investors and savers can also benefit from more advantageous conditions on their financing but without overseeing volatility or the exposure to the still existing systematic risk.

Amid the digital transformation, the semiconductor industry holds a vital role in technological progress. Semiconductors, or chips, are generally key components in manufacturing modern electronic applications. Nowadays, the population uses a wide range of consumer electronics including smartphones, computers, and wearable devices among many other products on a daily basis. This leads to rapidly changing consumer trends that pose a challenge for companies to adapt and operate in a business environment driven by innovation.

As reported by the Semiconductor Industry Association (2023), worldwide sales in the semiconductor industry reached the highest annual value amounting to \$573.50 billion dollars in 2022. Even with fluctuations during the year, the long-term prospective is favorable to growth given the importance of chips in electronic devices. Despite following a decreasing trend, China

continues to be the prime sales market for semiconductors while the Americas registered the biggest increase of 16% in 2022.

To address the question on whether diversifying portfolios with semiconductor stocks represents an opportunity, eight major components of the Philadelphia Stock Exchange (PHLX) Semiconductor Index have been analyzed based on their return distribution. This paper contributes to understanding the semiconductor industry's performance between 2018 and 2022 based on historical data which allows to comparatively assess alternate investment opportunities with different realized returns and associated risk while referencing the benchmark index to determine patterns and fund the investment decision.

This paper is organized as follows: the next section comprises an overview of the portfolio diversification concept and the semiconductor sector. The methodology section presents the main statistical indicators and risk metrics along with data collection and processing. The results are presented and discussed in the following section by assessing the return distribution of the stocks. The last section is reserved for concluding remarks.

Literature review

Portfolio diversification

Investment strategies are essential for earning prospects while assessing the performance of securities if considering the desirable state of obtaining higher returns with the lowest possible risk level. Regardless of an investor's attitude towards risk, selecting a portfolio is a challenging process. Pioneering the modern portfolio theory, the seminal work of Markowitz (1952) addressed the key concept of diversification. As a practical strategy, combining securities allows the investor to build an overall efficient portfolio with acceptable risk levels.

The correlation between security returns is an important factor for diversification. Particularly of interest when having high and positive correlation in the securities of a local economy, Levy and Sarnat (1970) explored the benefits of diversifying into foreign securities to reduce portfolio's risk by finding low correlations between the securities of different countries. Solnik (1974) also recognized the gains of diversifying portfolios internationally. The overall risk of a portfolio is reduced not only by an increased number of securities, but rather from whether they belong to different industries and the extent to which they are independent from each other. The lower the correlations, the more substantial the gains are while minimizing the risk.

Levy and Lim (1994) further argued that portfolio performance is not consistently enhanced by international diversification when investing in international assets is subject to exchange rate volatility and therefore the need to also assess currency risk. Despite having less impact on developed economies, for a developing one, Abidin et al. (2004) implied that domestic portfolios might overcome internationally diversified ones but depending on market conditions. In favor of diversifying portfolios with foreign stocks are also Coeurdacier and Guibaud (2011) who found it provides better opportunities to investors.

Semiconductor sector

According to Gruber (1994), the semiconductor industry is a "remarkable example of a fast growing high-technology industry" with a rapid evolution of memory chips while considering the relative short-term lifecycle of a chip generation. The market fluctuations are reflected by the semiconductor industry cycles. Recurring to an econometric approach, Liu (2005) applied a vector autoregressive model to identify the determinants of the cyclicity for the United States showing that the semiconductor inventory and the fabrication plant capacity are significant factors of

influence, and the semiconductor industry cycles were mostly triggered by an overcapacity issue. As semiconductors are a cyclical industry, Tan and Mathews (2010) underline the importance of cycles not only at a firm level for strategic innovation but also at industry level for technological advances. Based on the frequency domain, they identified prominent cyclical components of four years on average and below.

Gubareva et al. (2022) analyzed the effects of the pandemic outbreak on both energy and semiconductor industries. Their results showed that the semiconductor sector has potential for investment diversification during systemic shocks or low coherence periods and it was surpassing the energy sector in terms of volatility during the recovery period.

Methodology

The methodological framework employs a fundamental statistical concept to assess stocks by providing a comparative overview to facilitate the selection of stocks into a portfolio composition. Considering the historical performance of stocks, the analysis covers descriptive statistics by using measures of the central tendency and variability.

For a data set $X = \{x_1, x_2, \dots, x_n\}$, the arithmetic mean (\bar{x}) is defined as:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad (1)$$

The variance (σ^2) measures the variability from the mean:

$$\sigma^2 = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n} \quad (2)$$

As the square root of the variance, the standard deviation (σ) measures the degree of dispersion relative to the mean:

$$\sigma = \sqrt{\sigma^2} \quad (3)$$

The standard deviation can be used as a risk measurement metric. It is therefore necessary to measure the width of the probability distribution. The lower the standard deviation is, the narrower the probability distribution which indicates a low risk associated with the stocks. By contrast, a stock with a high standard deviation is riskier. Although it is widely applied, the accuracy of the standard deviation as a risk indicator has been contested over time. While acknowledging some limitations including the dependence on historical data, the timeframe, and the ability to measure expected and not potential risk, Wander and D'Vari (2003) concluded that the standard deviation can be eloquent when assessed properly.

The strength of the linear relationship between two variables x and y is given by the correlation coefficient (ρ_{xy}) as the ratio of the covariance (σ_{xy}) to the individual standard deviation (σ_x and σ_y):

$$\rho_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \quad (4)$$

where $\rho_{xy} \in [-1, 1]$ with -1 or 1 indicating a perfect negative or positive correlation respectively.

Skewness (γ) is an indicator of the asymmetry of a distribution. Under a standard approach, the distribution is right-skewed for positive values indicating returns frequently lower than the mean and left-skewed for negative values having mostly returns higher than the mean. It can be calculated as follows:

$$\gamma = \frac{\sum_{i=1}^n (x_i - \bar{x})^3}{n\sigma^3} \quad (5)$$

Kurtosis (ψ) is an indicator for the tail of a distribution compared to the standard distribution ($\psi = 3$) calculated as:

$$\psi = \frac{\sum_{i=1}^n (x_i - \bar{x})^4}{n\sigma^4} \quad (6)$$

with $\psi > 3$ showing a leptokurtic distribution with heavier tails and higher peak whereas $\psi < 3$ corresponds to a platykurtic distribution with lighter tails and flatter (DeCarlo, 1997). High kurtosis values imply fluctuations in the return distribution.

Another controversial yet commonly used indicator is the Sharpe ratio (SR). Introduced by Sharpe (1966) as a reward-to-variability ratio, the SR has been popularized in the modern finance industry as a measure to evaluate portfolio performance but also widely argued for its appropriate use to fundamental decisions without any limitations (Lo, 2002). Nonetheless, the SR can still enhance the investment capabilities when considering several factors including the time span, the asymmetry, and the shape of the return distribution (Bailey & López de Prado, 2011) or when standard deviation properly measures the risk (Zakamouline and Koekebakker, 2009). The SR can be calculated as the ratio between the mean and the standard deviation (Mollick & Assefa, 2013):

$$SR = \frac{\bar{x}}{\sigma} \quad (7)$$

Thus, the SR can be used to measure how satisfactory an investor's return is in relation to the risk taken measuring the excess returns per unit of risk, but it requires precaution in interpretation as a sole indicator. However, evaluated in combination with multiple measures, it can contribute to adjusting the risk and support the investment decision-making process.

Data

The database contains the PHLX Semiconductor Index (SOX) and eight of its components based on market capitalization. The initial data was collected as the daily adjusted close price from Yahoo!Finance from January 2018 until December 2022. The values have been transformed into daily returns by using the following calculation:

$$R_{it} = \frac{P_{it}}{P_{it-1}} - 1 \quad (8)$$

where:

- R_{it} is the return of stock i on day t ;
- P_{it} is the Adjusted Closed Price of the stock i on day (t);
- P_{it-1} is the Adjusted Closed Price of the stock i on the previous day ($t-1$).

Considering a five-year period meaningful to evaluate stock performance and comprehensive enough to cover cyclicity in the semiconductor industry, an overview of the returns and associated risk for the selected stocks is presented in the section below. The data is processed by using the statistical software R 3.6.0.

Results and discussions

The PHLX Semiconductor Index (SOX) comprises 30 companies (see appendix 1). By the end of 2022, eight companies had a market capitalization over \$100 billion dollars by the end of 2022 (see figure 1): Taiwan Semiconductor Manufacturing Company Limited (TSM), NVIDIA Corporation (NVIDIA), Broadcom Inc. (AVGO), ASML Holding N.V. (ASML), Texas Instruments Incorporated (TXN), QUALCOMM Incorporated (QCOM), Intel Corporation (INTC) and Advanced Micro Devices, Inc. (AMD). Together, these eight companies represented approximately 73.53% of the cumulative market capitalization of all SOX components for 2022.

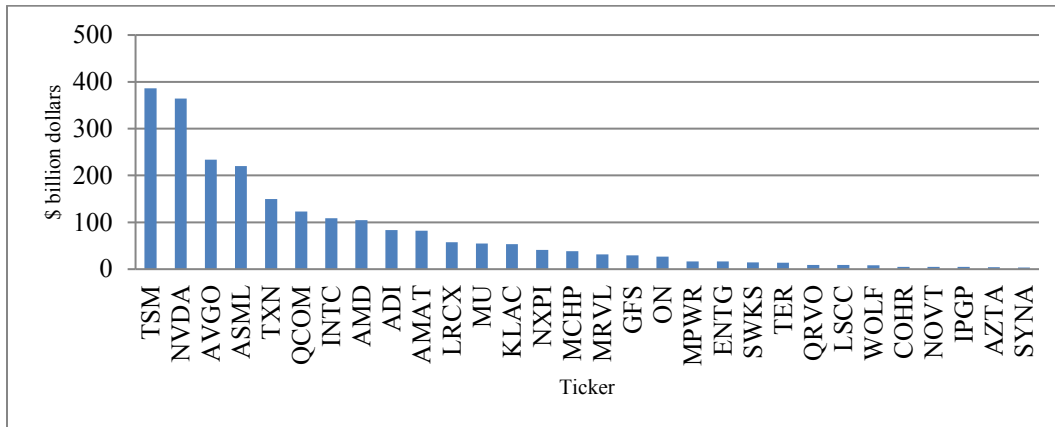


Figure 1. Semiconductor companies by market capitalization

Source: Author's representation based on data retrieved from <https://companiesmarketcap.com/>

The evolution of the daily returns for the selected stocks (see figure 2) indicates significant fluctuations at short intervals. Abrupt increases and decreases can be observed during the whole period especially between 2018 and 2020 when the QCOM registered the highest return rate and AVGO the lowest return rate from the whole observed period. Throughout 2021, the evolution is more compact until October 2022 when the returns started to have denser oscillations with more frequency.

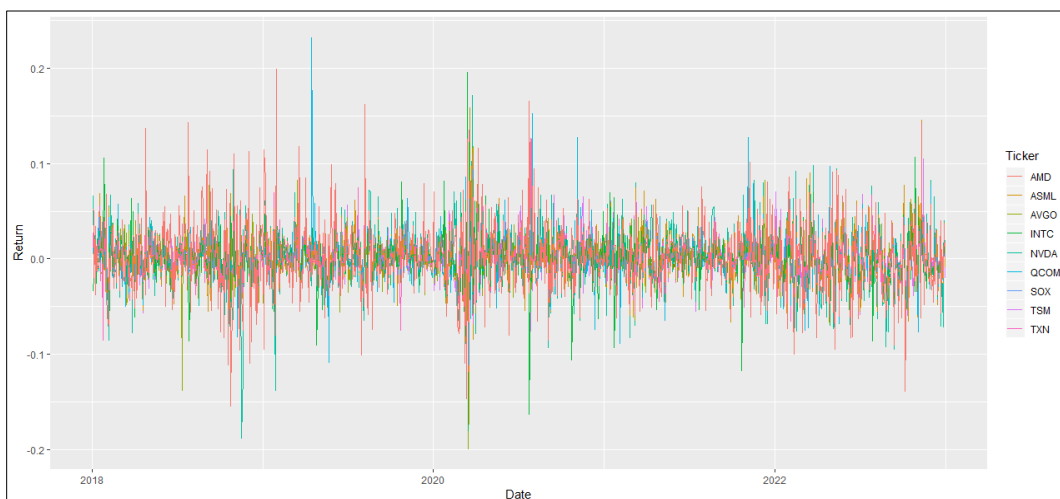


Figure 2. Evolution of daily returns (2018-2022)

Source: Author's own representation.

Based on the summary report (see table 1), the average returns have positive values except for INTC. While AMD has the highest average return, it is also the riskier stock. TXM is the safest stock with the lowest risk but despite minimizing the losses, the average return is slightly lower than the benchmark index.

Table 1. Descriptive statistics

Indicator	SOX	TSM	NVDA	AVGO	ASML	TXN	QCOM	INTC	AMD
Observations	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258
Minimum	-0.1590	-0.1403	-0.1876	-0.1991	-0.1735	-0.1183	-0.1495	-0.1804	-0.1545
Maximum	0.1115	0.1265	0.1716	0.1583	0.1457	0.1353	0.2321	0.1952	0.1995
Mean	0.0008	0.0008	0.0014	0.0010	0.0013	0.0007	0.0009	-0.0001	0.0020
Standard deviation	0.0227	0.0221	0.0327	0.0235	0.0259	0.0204	0.0262	0.0239	0.0358
Skewness	-0.2197	0.1831	-0.2251	-0.6098	-0.1033	0.0013	0.7328	-0.2108	0.3123
Kurtosis	4.0376	3.4008	3.1050	9.3535	3.3485	4.0750	8.8247	10.4414	2.8612
Sharpe	0.0351	0.0378	0.0428	0.0433	0.0490	0.0328	0.0331	-0.0024	0.0572

Source: Author’s own calculation

The return distributions are slightly asymmetric. Under a standard approach, the return distribution is right-skewed for TXN, TSM, AMD and QCOM anticipating small and frequent losses, with a few large rewards and left-skewed for NVDA, AVGO, ASML and INTC expecting small and frequent rewards, with a few major losses.

The kurtosis coefficient indicates a slightly platykurtic distribution for AMD having the values of daily returns dispersed over a larger range around the mean. For the other stocks, the return distributions are leptokurtic. However, for NVDA, TSM, ASML and TXN the kurtosis coefficient is close to the reference value. The exceptions are QCOM, AVGO and INTC with a more prominent kurtosis coefficient indicating values dispersed over a smaller range around the mean which increases the possibility of extreme values.

The Sharpe indicator measures the risk-adjusted returns. INTC has a negative Sharpe indicating losses or an unbalanced risk level. The highest Sharpe is associated with AMD which would be a better investment option from the selected stocks. TSM is slightly above the benchmark index.

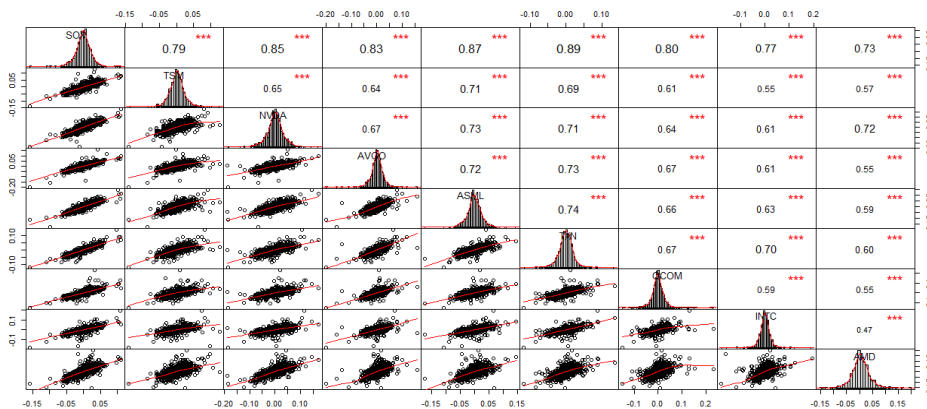


Figure 3. Correlation matrix

Source: Author’s own representation.

The stocks are correlated positively and significantly with the benchmark index (see figure 3) indicating that they move in the same direction. TXN, ASML, AVGO, NVDA and QCOM are strongly correlated with SOX. Between stocks, AMD and INTC have a moderate positive correlation which is also the lowest value from the analyzed sample, while the highest value is between TXN and ASML indicating a strong positive correlation.

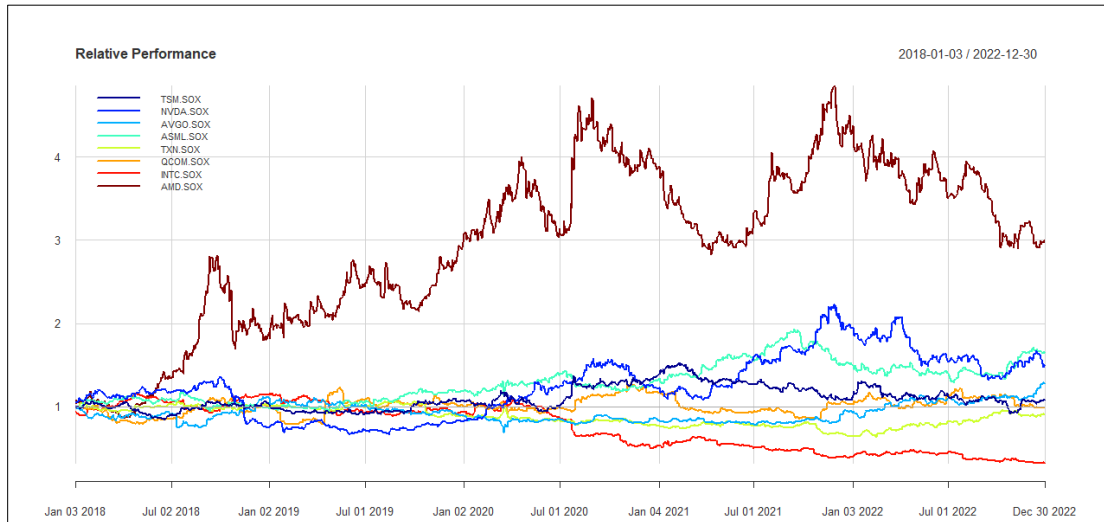


Figure 4. Relative performance of stocks to the benchmark index

Source: Author's own representation.

The relative performance of the selected stocks to the benchmark index (see figure 4) is using the ratio of the cumulative performance between 2018 and 2022. A positive slope indicates that the stock is outperforming the benchmark index and vice versa. AMD is a volatile stock alternating between different periods. INTC has been following on overall descending pattern relative to the SOX most noticeable since 2020. AVGO and TXN appear to be outperforming the SOX in 2022.

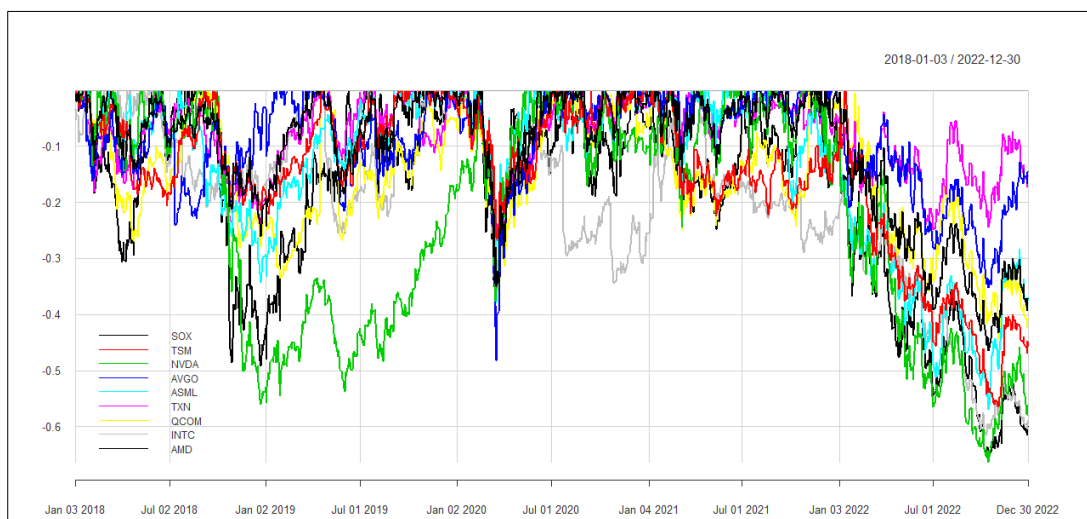


Figure 5. Drawdown chart

Source: Author's own representation

Measuring downside volatility, the drawdown chart (see figure 5) shows how much the return of a stock dropped from the peak to a trough before reaching a new peak. NVDA experienced the maximum drawdowns taking longer to recover. By comparison, TXN has smaller peak-to-trough returns. AMD shows frequent significant declines but with fast recoveries. INTC is undergoing a decline from mid-2021.

In 2020, all selected stocks had an abrupt drawdown but recovered quickly. Throughout 2022, all stocks were showing a collective decline. Except for AVGO which had its bottom value in 2020, the stocks registered their maximum drawdowns levels. Nonetheless, TXN, AVGO, QCOM were above benchmark index compared with TSM, ASML, AMD, INTC and NVDA during 2022.

Conclusions

Technological progress makes the semiconductor industry an attractive investment option. Most notably, advanced chips are essential parts of the electronic devices used worldwide on a regular basis. Given the growing importance of semiconductors for modern technology, an analysis was carried out on the semiconductor stock market represented by the PHLX Semiconductor Sector (SOX). The selected stocks are the largest components of the benchmark index by market capitalization, as of 2022, and traded on the stock market in the United States with the following tickers: TSM, NVDA, AVGO, ASML, TXN, QCOM, INTC and AMD.

Starting from the concept of portfolio diversification, this paper provided an overview of the stocks by evaluating their performance to facilitate the pre-selection of semiconductor stocks as potential investment choices to mitigate the financial risk. To conduct the analysis, daily returns were calculated over five years and examined by using descriptive statistics and specific risk measures.

Financial markets can experience unexpected returns. The evolution throughout time of the returns experienced sudden fluctuations of significant positive and negative magnitudes. All the selected stocks are highly correlated with the benchmark index with TXN having the highest correlation coefficient and therefore it would be the first stock from the sample to move in line with the market. The ranking of the selected stocks in a descending order by their average return is AMD, NVDA, ASML, AVGO, QCOM, TSM, TXN and INTC, where the latter is the only stock with a negative average return. The ranking of the stocks from the safest to the riskiest by standard deviation is TXN, TSM, AVGO, INTC, ASML, QCOM, NVDA and AMD.

Based on the overall results, TXN appears to be a low risk, low return stock but quickly recovering from negative periods. It also has an increasing relative performance against the SOX during 2022 which indicates this stock would be most suitable for risk averse investors. On the opposite, AMD registered the best average return but had the highest risk which underlines its volatility. Despite having the highest reward-to-risk ratio, AMD's performance during 2022 followed a descending pattern with significant declines and potential longer recovery periods.

In terms of limitations, this analysis is based on historical and not forecasted data. Thus, the conclusions are retrieved from past observations and do not predict future returns. While this study facilitates a pre-selection of stocks depending on the attitude towards risk, a more in-depth analysis is required on actual diversified portfolios to determine an optimal combination.

Further research can be oriented towards behavioral economics and study how the historical performance of stocks is affecting the investment decisions of an individual. Another research director might focus on the influence of trade restrictions on the evolution of semiconductor stocks,

especially considering the actual divergences between the United States and China in the technology field.

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Appendix

Appendix 1. Components of the Philadelphia Stock Exchange (PHLX) Semiconductor Index

Ticker	Company Name
TXN	Texas Instruments Incorporated
ADI	Analog Devices, Inc.
IPGP	IPG Photonics Corporation
AVGO	Broadcom Inc.
COHR	Coherent Corp.
AZTA	Azenta, Inc.
NOVT	Novanta Inc.
GFS	GLOBALFOUNDRIES Inc.
NXPI	NXP Semiconductors N.V.
MRVL	Marvell Technology, Inc.
MCHP	Microchip Technology Incorporated
INTC	Intel Corporation
KLAC	KLA Corporation
ASML	ASML Holding N.V.
TSM	Taiwan Semiconductor Manufacturing Company Limited
SWKS	Skyworks Solutions, Inc.
LSCC	Lattice Semiconductor Corporation
AMAT	Applied Materials, Inc.
AMD	Advanced Micro Devices, Inc.
QRVO	Qorvo, Inc.
MU	Micron Technology, Inc.
MPWR	Monolithic Power Systems, Inc.
ENTG	Entegris, Inc.
TER	Teradyne, Inc.
LRCX	Lam Research Corporation
ON	ON Semiconductor Corporation
QCOM	QUALCOMM Incorporated
WOLF	Wolfspeed, Inc.
SYNA	Synaptics Incorporated
NVDA	NVIDIA Corporation

Source: <https://finance.yahoo.com/quote/%5ESOX/components/>