

Dimitar Rafailov**AI: a Good Investment or a Bubble?**

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Abstract Artificial Intelligence (AI) has considerable potential benefits for the companies that develop and implement it, but it may also contribute to the formation of a speculative bubble in financial markets. This study examines the performance of a portfolio of AI-related stocks during the period 2020–2024, with a focus on its return and risk.

The investment in AI stocks has demonstrated relatively strong performance, with the risk-return ratio outperforming that of major market indices. Despite concerns about a potential AI bubble, no such phenomenon has been observed – while AI stock prices have experienced corrections, there have been no episodes of explosive growth followed by collapse.

Keywords Artificial Intelligence, Investment Performance, Market Bubble

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Introduction

The resurgence of AI technologies over the past five years holds the potential to significantly transform the economy. The adoption of artificial intelligence by businesses can enhance productivity and profitability by enabling the creation of products that better meet consumer needs, improving customer experience, enhancing risk management, reducing costs, and optimizing supply chains. On the other hand, the development of AI technologies requires substantial financing, and their improper implementation in business operations may prove counterproductive.

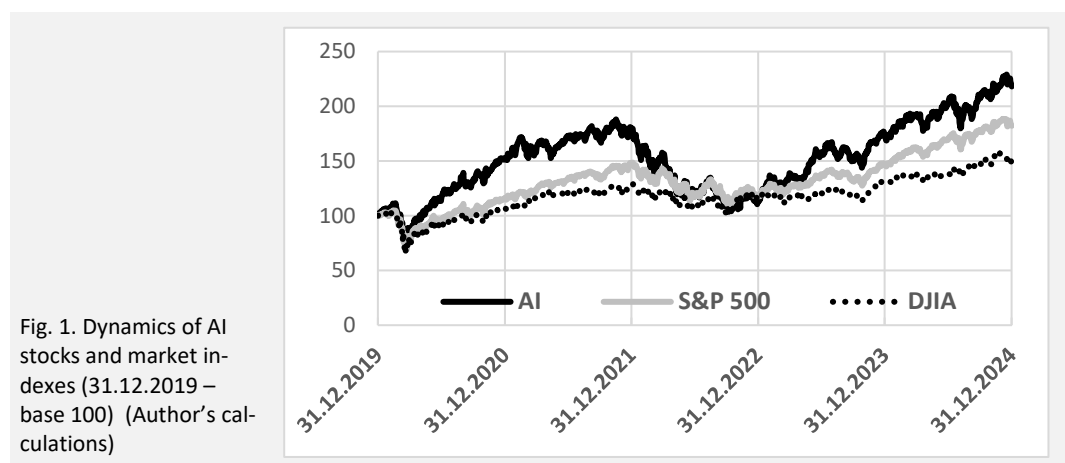
The effects of AI are reflected in the stock prices of companies that develop and utilize such technologies. If investors believe that the benefits of AI significantly outweigh the associated costs, the stocks of these companies are expected to outperform financial markets in terms of return and risk. However, the emergence of new technologies is often not objectively assessed by market participants, frequently resulting in speculative bubbles – where initial enthusiasm and surging asset prices are followed by disappointment and collapse. Given the development of many new AI technologies and the investor excitement in recent years, the question of whether AI-related stocks represent a sound investment or constitute yet another speculative bubble is both timely and of considerable interest.

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1. Performance of AI stocks

1.1. Return and risk

The performance of AI companies' stocks can be analyzed based on the daily values of Global X Artificial Intelligence & Technology ETF. The fund's portfolio includes exchange-traded companies¹ from 25 countries that develop and utilize AI technologies (Global X, 2025a). These are big AI developers and producers of AI and Big Data Analytics hardware. Investments in AI stocks are compared with two indices reflecting stock market movements – the Standard and Poor's 500 (S&P 500) and Dow Jones Industrial Average (DJIA). The period of analysis includes the years 2020 to 2024. The current AI boom started in 2020 with the release of GPT-3 by OpenAI. It was the first AI model which achieved impressive performance on a wide variety of tasks (including conversation, answering questions, writing and coding) with only pre-training (Thorn, 2020). The dynamics of the three metrics are presented in Fig. 1.



AI stocks had the largest increase over the entire period (more than double), but they also had larger volatility compared to market indices. This is due to the relatively new technology, which is difficult for investors to evaluate. On the one hand, news of new and better AI models had led to great enthusiasm and strong growth in 2020 and 2023-2024. On the other, the lack of robust financial results from the application of AI made the stocks of these companies more vulnerable in 2022 – a period of market downturn and uncertainty.

Market movements are reflected in return and risk of investments in AI companies. Table 1 presents the annualized return and standard deviation as a measure of the risk of AI

¹ Currently, ETF holdings include 85 companies from United States, China, South Korea, Ireland, Taiwan, Germany, Canada, Japan, Netherlands, Israel and other countries (Global X, 2025b).

stocks and the market indices. The indicators are calculated based on daily values for respective periods and then annualized.

Table 1. Comparison of AI stocks and market indexes

Period	Measure	AI	S&P 500	DJIA
2020	Annual return	52.9%	16.3%	7.2%
	Annual standard deviation	32.8%	34.4%	36.8%
2021	Annual return	17.1%	26.9%	18.7%
	Annual standard deviation	20.3%	13.1%	12.4%
2022	Annual return	-36.6%	-19.4%	-8.8%
	Annual standard deviation	34.9%	24.2%	19.8%
2023	Annual return	55.1%	24.2%	13.7%
	Annual standard deviation	19.6%	13.1%	11.4%
2024	Annual return	23.9%	23.3%	12.9%
	Annual standard deviation	19.4%	12.6%	11.4%
2020-2024	Annual return	16.9%	12.7%	8.3%
	Annual standard deviation	26.4%	21.3%	20.8%

Source: Author's calculations

Over the entire period (2020-2024), the AI stocks portfolio's average annual return (16.9%) was higher than the market returns of S&P 500 (12.7%) and DJIA (8.3%). On the other hand, the risk of AI investments was also higher – the standard deviation was 26.4% versus 21.3% and 20.8%. The higher risk came from the greater year-over-year fluctuations. AI portfolio reached over 50% returns in 2020 and 2023. In that years new and more advanced AI models and technologies were released², which attracted many investors. It is interesting to note that in 2020, when the COVID-19 pandemic began, AI stocks had higher return and lower standard deviation (52.9% and 32.8%) compared to the S&P 500 (16.3% and 34.4%) and DJIA (7.2% and 36.8%). In periods of market downturns, however, AI companies fell much more than market indices. In 2022, the strong downside market's movement are driven by rising interest rates and global instability caused by the war in Ukraine. The AI portfolio had a return of -36.6% and a standard deviation of 34.9%. By comparison, in 2022, the S&P 500's losses were lower (-19.4%) with lower risk (24.2%). Thus, the AI stocks resemble those of cyclical companies. The performance of AI stocks has potential of excess returns for investors with good market timing. For this, investors should keep track of innovations in the field of AI and invest in stocks when new technological

² For example, in 2020 were introduced GPT-3 (by OpenAI) and AlphaFold 2 (by DeepMind/Google). In the end of 2022 and 2023 were released ChatGPT (OpenAI), LLaMA (Meta), GPT-4 (OpenAI), PaLM 2 and Gemini (Google/DeepMind), Claude 2 (Antropic), Mixtral (Mistral), Grok (xAI) (Spoeth, 2025).

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advancements are made. If markets show sign of increased volatility and downward trend, investors should look to other assets.

1.2. Comparative performance

A more in-depth evaluation of the investments in AI companies requires a comparison with the performance of stock markets. If the portfolio of AI stocks is a good investment, it will "beat" the markets by providing a higher return per unit of risk. Various indicators can be used for such a comparative analysis, with the most commonly used being the Sharpe ratio and the Information ratio.

The Sharpe ratio is based on absolute measures of return and risk. The indicator (S) compares excess of the portfolio return over risk-free rate to total portfolio risk (Sharpe, 1966):

$$S = \frac{r_p - r_f}{\sigma_p}, \quad (1)$$

where: r_p – portfolio return;

r_f – risk-free rate of return;

σ_p - standard deviation of portfolio returns.

The ratio gives the reward for an investor per unit of risk. The higher the Sharpe ratio, the better portfolio performance. Fig. 2 presents the values of Sharpe ratio, based on the 90-day US treasury bills yields as risk-free rate of return.

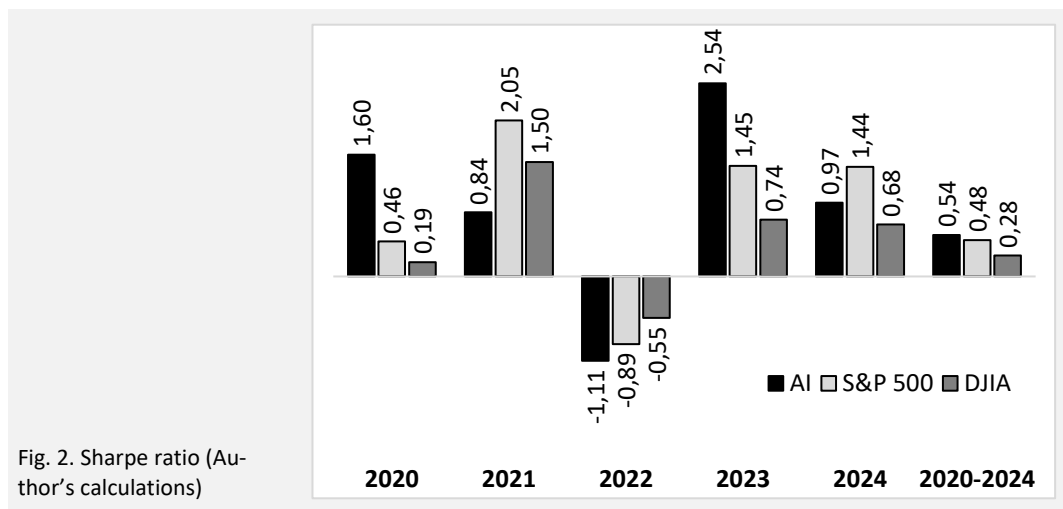


Fig. 2. Sharpe ratio (Author's calculations)

AI stocks have unstable performance. In 2020, and especially in 2023, their Sharpe ratio was significantly higher than that of the market indices. On the other hand, in 2021 and 2024, the markets outperformed the AI portfolio. The situation in 2022 is particularly interesting, when the values were negative. In this case, market portfolios again performed

better – a less negative Sharpe ratio means that the losses for investors per unit of risk were smaller compared to AI stocks. This confirms the conclusion, drawn from observing returns and standard deviations, about the cyclical nature of these stocks.

The overall performance of the AI portfolio is positive. For the period 2020–2024, the Sharpe ratio (0.54) exceeded that of the S&P 500 (0.48) and the DJIA (0.28), indicating that investments in AI had better risk-return trade-off. With active portfolio management, it is possible to achieve an even higher reward for the risk taken by reallocating funds toward companies that are at the forefront of technological innovation and product development.

A limitation of the Sharpe ratio is that it is based on total risk, whereas financial markets typically account for systematic risk. In this context, another commonly used metric for evaluating portfolio performance is the Information ratio. Unlike the Sharpe ratio, the Information ratio (IR) is based on a relative measure of risk – the tracking error (Mondello, 2023: 243):

$$IR = \frac{r_p - r_b}{\sigma_A} = \frac{r_A}{\sigma_A}, \quad (2)$$

where: r_p – portfolio return;

r_b – benchmark return;

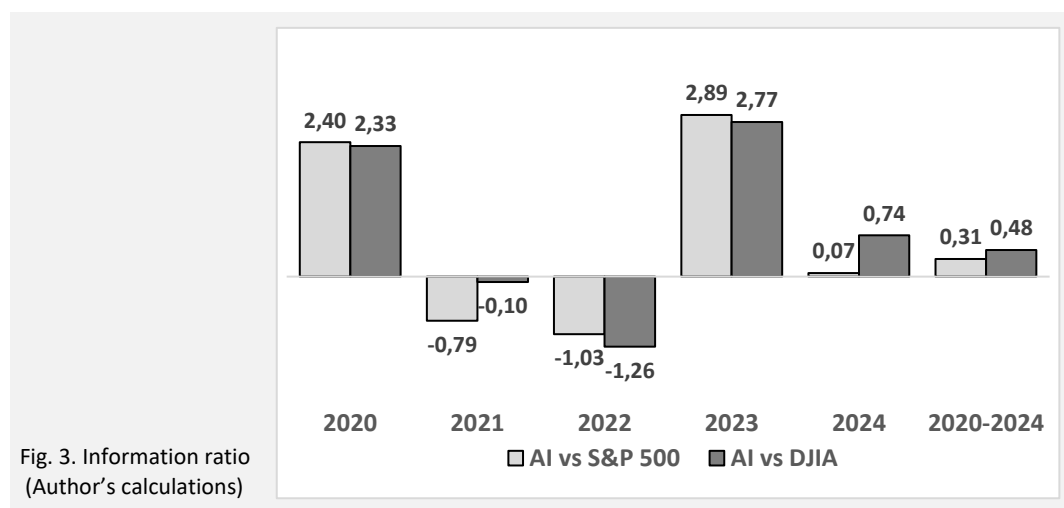
r_A – excess return ($r_p - r_b$);

σ_A – tracking error (standard deviation of excess returns).

The Information ratio measures the realized excess return per unit of additional risk relative to a benchmark (also referred to as relative or active risk). It provides insight into the effectiveness of a given investment strategy compared to an appropriate market benchmark. Positive values indicate returns that exceed those of the benchmark. Higher values are interpreted as evidence of better portfolio management. Opinions on the practical interpretation of the Information ratio vary, but it is generally accepted that values above 0.5 indicate good performance, while values above 1 are considered exceptional (Grinold and Kahn, 2000: 109). Fig. 3 presents the Information ratio relative to the two market indices—S&P 500 and DJIA.

Similar to the results of the Sharpe ratio, the years 2020 and 2023 stand out as exceptional for the performance of the AI stock portfolio, during which the Information ratio significantly exceeded 1. In the remaining years, the AI portfolio recorded weaker results, with returns falling below the market in 2021 and 2022, resulting in negative Information ratios. Over the entire period (2020 – 2024), the Information ratios remain positive and are relatively close to 0.5. This suggests that investments in AI stocks had yielded returns above the market average, though performance could have been improved. The primary reason for this moderate outcome is that the examined AI portfolio follows an index-based approach, i.e., it is passively managed. The high Information ratios observed in 2020 and

2023 suggest that with active management an AI portfolio has the potential to outperform market indices.



2. AI stocks – is there a bubble?

2.1. Potential for a market bubble

The transformational potential of AI undoubtedly creates conditions to the emergence of a financial market bubble. A speculative bubble is typically characterized by three factors: disruption, ample liquidity and credit, and irrational behavior (Aliber et al., 2023). AI technologies have the capacity to significantly reshape economic processes, affecting productivity, labor markets, income levels, and income distribution. From this perspective, the disruptive potential of AI attracts new investors seeking excess returns. This surge in investor interest often results in an initial price increase in AI stocks, potentially marking the beginning of a speculative bubble. In recent years, AI companies have attracted substantial capital, which raises the possibility of their overvaluation.

For the initial rise in AI stock prices to evolve into a self-reinforcing upward trend, sufficient market liquidity is necessary, with easy access to credit serving as the primary driver. Indeed, in the wake of the COVID-19 pandemic (2020–2021), central banks around the world adopted expansionary monetary policies, characterized by increased money supply, lower interest rates, and easy access to credit. These measures supported speculative demand for AI stocks and contributed to the formation of a potential market bubble. However, following 2022, as part of efforts to combat accelerating inflation, these expansionary monetary policies were reversed. Central banks began tightening the money supply, restricting credit availability, and increasing interest rates. Consequently, the impact of

liquidity and credit as bubble drivers on financial markets became more ambiguous and less conducive to speculative growth.

The third condition for the formation of a speculative bubble is the irrational investor behavior. This typically manifests in asset purchases driven not by fundamental factors but by the belief that prices will continue to rise. Such irrationality can trigger a positive feedback loop, leading to an explosive increase in asset prices far above their intrinsic value. Such investor behavior has been observed in the market of AI stocks, particularly following the release of ChatGPT in November 2022. This event generated widespread excitement among investors and the media, resulting in a rapid surge in AI stock prices (Floridi, 2024). However, by 2024, market participants began to exhibit a more cautious outlook, increasingly questioning the real value of AI in light of unresolved problems and technological limitations (Widder and Hicks, 2024). This shift in sentiment prompted a cooling-off period and subsequent market correction.

In summary, there is potential for a speculative bubble in the AI sector, fueled by the disruptive nature of the technology and amplified by investor enthusiasm. However, this process is counterbalanced by limited access to credit and growing skepticism among certain market participants.

2.2. Bubble detection

The potential bubble in the market of AI stocks raises the question of whether such a phenomenon truly exists. To address this, one can analyze the actual changes in the value of the shares of the AI fund whose performance was examined in the previous section. The identification of a market bubble can be based on the presence of an explosive change in market prices, where a period of rapid growth is followed by a sharp decline. The previously applied Augmented Dickey-Fuller (ADF) test has shown limited effectiveness in detecting such boom-and-bust episodes (Evans, 1991). In response, more appropriate techniques have been developed – namely, the Supremum Augmented Dickey-Fuller (SADF) test and the Generalized Supremum Augmented Dickey-Fuller (GSADF) test.

The SADF test (Phillips et al., 2011) sequentially searches for the presence of a market bubble by employing an expanding window of observations. The null hypothesis assumes the absence of explosive behavior, while the alternative hypothesis posits its existence. To test these hypotheses, the SADF statistic is estimated.

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF_0^{r_2}, \quad (3)$$

where: r_0 – minimum window size;

r_2 – endpoint of each subsample;

ADF – standard ADF statistics (Vasilopoulos et al., 2022).

If SADF statistic is bigger than the right-tailed critical value from its limit, the null hypothesis is rejected and a bubble is detected. The SADF test is effective in detecting a single bubble within the examined period; however, it may yield inconsistent results in the presence of multiple bubbles. To analyze periods with multiple episodes of explosive dynamics, the technique has been extended to the GSADF test (Phillips et al., 2015):

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1], r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2}, \quad (4)$$

where: r_1 – starting point of each subsample.

In this test, the null hypothesis again assumes the absence of a market bubble and is rejected if the GSADF statistic exceeds the critical values.

The tests described above are applied to the daily values of the AI ETF fund whose performance was analyzed earlier. The test statistics and corresponding critical values were computed using the exuber package for R, version 1.0.2 (Vasilopoulos et al., 2023).

The test statistics for the individual years (Table 2) are lower than the critical values at all significance levels. Therefore, the null hypothesis of no bubble in the AI stocks cannot be rejected. An exception is observed in 2020, when the SADF test indicates explosive dynamics at the 95% significance level. However, considering that 2020 was marked by a sharp market decline due to the onset of the COVID-19 pandemic – followed by a rapid recovery – no actual market bubble is observed. This conclusion is further supported by the GSADF statistic, which is more appropriate in such contexts.

Table 2. Yearly test statistics and critical values

Test statistics	2020	2021	2022	2023	2024	Critical values at		
						90%	95%	99%
ADF	-0.138	-2.450	-2.690	-1.420	-1.570	-0.475	-0.118	0.595
SADF	1.450	-1.010	-1.010	-0.160	-0.618	1.100	1.390	1.950
GSADF	1.480	-0.037	0.223	1.650	0.556	1.880	2.110	2.550

Source: Author's calculations

The absence of a market bubble is also confirmed by the analysis of the entire period (Table 3). Once again, the test statistics are lower than the critical values, and the null hypothesis cannot be rejected.

Table 3. Test statistics and critical values for 2020 - 2024

Test statistics	2020-2024	Critical values at		
		90%	95%	99%
ADF	-0.927	-0.451	-0.059	0.666
SADF	0.477	1.330	1.590	2.100
GSADF	1.490	2.160	2.340	2.770

Source: Author's calculations

Despite isolated episodes of rapid increases followed by declines in the AI stocks, the overall trend remains positive, and there is no evidence of a price bubble. This is further supported by developments in the equity markets in early 2025. Against the backdrop of a general market downturn, AI stocks have not exhibited significantly greater depreciation, nor has there been a notable withdrawal of investors from the AI sector.

Conclusion

The investment in AI stocks has demonstrated relatively strong performance, with the risk-return ratio outperforming that of major market indices. Despite concerns about a potential AI bubble, no such phenomenon has been observed – while AI stock prices have experienced corrections, there have been no episodes of explosive growth followed by collapse. Nonetheless, the outlook for AI investments remains uncertain. If the new AI technologies currently being integrated into the economy lead to an increase in productivity, AI company stocks hold significant potential. Conversely, if the anticipated substantial benefits fail to materialize, AI may become yet another “miracle technology” that ultimately falls short of the high expectations it has generated.

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