https://doi.org/10.17221/377/2025-AGRICECON

Optimising the Stutzer ratio in multivariate agricultural portfolios

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Citation: Živkov D., Kuzman B., Subić J. (2026): Measuring the Stutzer ratio performance of agricultural portfolios. Agric. Econ. – Czech, 72: 475–482.

Abstract: This paper evaluates the risk-adjusted performance of multivariate agricultural portfolios using the Stutzer ratio, an advanced measure that accounts for non-normal return distributions and downside risk. Three four-asset portfolios – grains, softs, and meats – are analysed in this study. The Stutzer ratio incorporates a risk-aversion parameter (θ) that penalises tail risk, providing a more accurate assessment of skewed and fat-tailed returns. Results show that Stutzer-optimised portfolios outperform naïve equal-weight portfolios in risk-adjusted terms, as optimisation effectively balances expected returns and downside exposure. Among the three portfolio categories, the softs portfolio exhibits the highest Stutzer ratio, with the meats portfolio following closely behind. Both portfolios have a relatively high tail-adjustment parameter (theta), indicating a reduced exposure to downside risk and a lower likelihood of extreme negative returns. Consequently, their risk-adjusted performance suggests greater return stability, making them particularly attractive to long-term investors.

Keywords: downside risk; exponential decay factor; risk-adjusted metric

Agricultural commodities represent a distinct asset class that plays a vital role in global financial markets, providing diversification benefits and serving as a hedge against inflation and geopolitical risk. However, their prices are highly sensitive to macroeconomic shocks, policy uncertainty, extreme weather events, and disruptions in global supply chains, all of which can trigger heightened volatility (Khalfaoui et al. 2023). Recent years have witnessed an escalation in such turbulence, marked by intensified market fluctuations and increased uncertainty across commodity markets (Voicilas 2020). In this context, understanding the risk-adjusted performance of agricultural portfolios is of significant importance for both investors and policymakers. This evaluation is particularly important for portfolio optimisation, diversification strategies, and long-term capital allocation decisions, as it helps ensure that agricultural investments deliver compensation for the risks undertaken (Hanif et al. 2023). In addition, measuring performance during periods of elevated volatility not only sheds light on the resilience of agricultural assets but also offers practical insights for risk management and portfolio allocation strategies.

This paper evaluates the risk-adjusted performance of three four-asset agricultural portfolios over a period of almost 10 years, specifically from January 2016 to October 2025. The portfolios represent three classes of agricultural commodities: grains (corn, wheat, soybeans, and oats), softs (cocoa, coffee, sugar, and cotton), and meats (feeder cattle, live cattle, lean hogs, and Class III milk). We construct three portfolios instead of examining all of the commodities within a single portfolio because grains, softs, and meats differ in liquidity, price volatility, and risk exposure. More specifically, grains are the most liquid and widely traded, offering relatively stable returns and serving as a hedge against inflation and global demand shocks (Zhang et al. 2025). Softs tend to be more speculative, with prices strongly influenced by weather conditions, political instability, and currency movements, making them riskier but potentially rewarding during supply disruptions (Živkov et al. 2022; Liu and Yao 2025). The meat commodities

Supported by the MSTDI RS, agreed in decision No. 451-03-136/2025-03/200009 from 4.2.2025.

https://doi.org/10.17221/377/2025-AGRICECON

exhibit unique dynamics linked to biological production cycles and feed costs, providing low correlation with other assets but limited liquidity. By evaluating and comparing the risk-adjusted performance of these portfolios, investors can identify which segments offer superior returns relative to the risks assumed, assess diversification benefits across agricultural sectors, and optimize portfolio construction strategies.

In the process of portfolio performance measurement, one of the most widely applied measures of risk-adjusted performance is the Sharpe ratio, which evaluates the excess return earned per unit of total risk relative to a risk-free asset. However, reliance on the Sharpe ratio can be problematic because it assumes normally distributed returns (Alekneviciene et al. 2018), an assumption that does not hold for many commodity assets characterised by skewness and fat tails. Furthermore, the metric penalises all forms of volatility equally, disregarding the fact that investors typically welcome upside volatility while seeking to limit downside risk.

To address the limitations of the Sharpe ratio, we employ a more sophisticated measure, the Stutzer ratio, developed by Stutzer (2000), which offers an improvement over the Sharpe ratio. It evaluates portfolio performance without assuming that returns are normally distributed, making it particularly useful for assets or strategies with skewed or fat-tailed returns – a common characteristic of agricultural commodities. In other words, the Stutzer ratio is designed to capture downside risk by focusing on the probability of falling short of a predefined benchmark or target return (Bessler et al. 2021). Rather than relying solely on volatility as a risk measure, it evaluates the likelihood of achieving a specified performance level, offering a perspective that is more closely aligned with investor objectives. As highlighted by Zakamouline and Koekebakker (2009), this approach makes the metric particularly intuitive for assessing investment strategies aimed at minimising losses and meeting return expectations. In the context of the Stutzer ratio, the parameter θ (theta) plays a crucial role in quantifying risk preferences and shaping the measure of risk-adjusted performance. Theta is a risk-aversion parameter that reflects the investor's sensitivity to losses. It essentially determines how strongly downside deviations from the target or benchmark are penalised in the Stutzer ratio calculation. A higher θ implies greater concern for downside risk (more risk-averse behaviour), while a lower θ indicates lower sensitivity to negative returns.

This paper contributes to the international literature by being the first to apply the Stutzer ratio to multivariate agricultural portfolios, across grains, softs, and meats. It demonstrates that Stutzer-optimised portfolios offer practical insights for long-term investors and portfolio managers on balancing expected returns with tail risk in agricultural markets.

Regarding the existing literature, there are few studies that have examined the risk-adjusted performance of agricultural portfolios, while no studies have examined the Stutzer ratio in agricultural portfolios. This provides the motivation for this paper. Most of them have focused on risk minimisation. For instance, Hernandez et al. (2020) examine how agricultural commodities contribute to portfolio risk and influence allocation decisions. Their analysis indicates that sugarcane, along with wheat and corn, represents the largest sources of overall portfolio risk, while cocoa, lumber, and cotton contribute relatively little. Among these assets, cocoa and lumber emerge as the most attractive for investors due to their lower risk impact. Ahmadian-Yazdi et al. (2024) analyse the dynamic interactions and spillover effects between key fossil fuel markets (Brent oil and natural gas) and major agricultural commodities (maize, soybeans, and wheat) using a time-varying parameter vector autoregression (TVP-VAR) framework. Their results on optimal portfolio allocations indicate that agricultural commodities should receive higher weightings relative to fossil fuels across all market conditions. Furuoka et al. (2023) explore both short-term and long-term interconnections between energy and agricultural commodities using a TVP-VAR approach. Their portfolio analysis suggests that, to maximise risk-adjusted returns, investors should allocate only a small share of energy assets within combined energy-agricultural commodity portfolios. Zhao and Ju (2025) have examined the dynamic linkages among global biofuel markets and Chinese grain and vegetable oil sectors employing a TVP-VAR model. Their findings indicate that, based on cumulative returns, Sharpe ratios, and hedging effectiveness, a minimum variance portfolio can achieve optimal performance by incorporating biofuel feedstock futures, even when direct biofuel futures contracts are not available.

MATERIAL AND METHODS

Stutzer ratio. The Stutzer ratio offers a refinement over the traditional Sharpe ratio by addressing several of its limitations. In other words, the Stutzer ratio enhances performance evaluation by incorporating a more comprehensive treatment of risk, particularly in markets where return distributions deviate from normality (Haley 2008). Instead of relying solely

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on standard deviation as a risk proxy, the Stutzer ratio leverages an exponentially tilted likelihood function to better account for distributional characteristics such as skewness and kurtosis (Bondarenko 2014), which the Sharpe ratio often overlooks. One critical shortcoming of the Sharpe ratio is its susceptibility to extreme observations, which can artificially inflate or depress risk-adjusted performance measures. By adopting a likelihood-based framework that emphasises the entire distribution of returns rather than a single volatility metric, the Stutzer ratio provides a more robust assessment of portfolio risk (Haley and McGee 2011). Its primary advantage lies in its ability to reward strategies that exhibit consistent, long-term performance, rather than portfolios with high but unstable returns that might still receive favourable evaluations under the Sharpe ratio.

Equation (1) represents the empirical mean return that serves as a baseline for measuring excess returns and evaluating the growth rate of utility under an exponential transformation.

$$\bar{R}_p(T) = \frac{1}{T}\sum_{t=1}^{T} R_{p,t} \tag{1}$$

where: $\bar{R}_p(T)$ – the average (mean) portfolio return over the evaluation period T; $R_{p,t}$ – the return of portfolio p at time t, expressed in excess of the benchmark performance.

According to Stutzer (2000), if a portfolio is anticipated to deliver a positive excess return, the law of large numbers implies that the likelihood of observing a negative sample excess return decreases as the investment horizon T lengthens. The speed of this decline, denoted I_p, is termed a *portfolio performance index*. This measure captures the rate at which the probability of underperformance approaches zero and is computed as shown in Equation (2):

$$I_p = \max_{\theta}\left(-\ln E\left(e^{\theta \bar{R}_p(T)}\right)\right),\ \theta < 0 \tag{2}$$

where: I_p – the Stutzer index (or the Stutzer ratio) for portfolio p; theta (θ) – a risk-adjustment parameter (or exponential tilting parameter); $E(\cdot)$ – the expected value operator.

The Stutzer index (I_p) measures risk-adjusted performance without assuming normality of returns. It penalises large downside deviations by using the exponential function. The optimisation over θ finds the best exponential tilting parameter that captures the trade-off between expected return and tail risk.

The portfolio with a higher rate of decay (higher theta) is considered the better choice. Stutzer (2000) demonstrates that, under the assumption of normally distributed returns, the I_p index is mathematically equivalent to the conventional Sharpe ratio. The empirical estimate of the term on the right-hand side of Equation (2) is obtained using the following expression:

$$\hat{I}_p = \max_{\theta}\left(-\ln\frac{1}{T}\sum_{t=1}^{T} e^{\theta \bar{R}_p(T)}\right) \tag{3}$$

Under the portfolio performance index framework, the optimal asset allocation is determined by solving the maximisation problem presented in Equation (4). In implementing this optimisation for the Stutzer ratio, careful selection of initial parameter values is essential. Stutzer (2000) recommends initialising the procedure with the portfolio weights that maximise the Sharpe ratio as a practical approximation. Likewise, an appropriate starting point for θ is given by the negative ratio of the mean excess return to its variance.

$$I_m = \max_{w_1,\ldots,w_n}\max_{\theta}\left(-\ln\frac{1}{T}\sum_{t=1}^{T} e^{\theta \bar{R}_p(T)}\right) \tag{4}$$

where: I_m – the optimal value of a risk-sensitive (exponential) objective that a portfolio optimiser is trying to maximise; $w_1, \ldots, w_n$ – the weights of assets in the portfolio.

Dataset. The study uses daily futures data for agricultural commodities to construct four-asset portfolios representing different categories: grains, softs, and meats. The portfolios include the largest agricultural markets, i.e. the grains portfolio consists of corn, wheat, soybeans, and oats; the softs portfolio includes cocoa, coffee, sugar, and cotton; and the meats portfolio comprises feeder cattle, live cattle, lean hogs, and Class III milk. All futures time series are obtained from the Investing.com (2025) database. Commodity prices are converted into log returns using the following formula:

$$r_{i,t} = 100 \times \log\left(\frac{P_{i,t}}{P_{i,t-1}}\right) \tag{5}$$

where: P_i – the price of a given commodity.

The Stutzer ratio is computed relative to the benchmark, the S&P GSCI (Goldman Sachs Commodity Index), which measures the performance of global commodity markets. The sample period spans 1 January 2016, to 30 October 2025. The optimisation is performed using the Nonlinear Generalised Reduced Gradient (GRG) algorithm in Excel Solver.

https://doi.org/10.17221/377/2025-AGRICECON

Table 1. Descriptive statistics of returns

	Grains				Softs				Meats			
	corn	wheat	soybeans	oats	cocoa	coffee	cotton	sugar	feeder cattle	live cattle	lean hogs	milk III
Mean	0.001	0.001	0.004	0.003	0.013	0.021	–0.001	0.001	0.012	0.010	0.008	0.004
SD	0.715	0.861	0.547	0.997	0.942	0.711	0.738	0.786	0.536	0.539	1.165	0.756
Skewness	–1.412	0.529	–0.494	–1.882	–0.903	–0.099	–1.651	0.162	0.165	–1.532	–0.943	0.297
Kurtosis	19.715	8.669	7.226	28.771	15.912	5.711	30.706	5.060	11.767	21.152	24.925	15.743

Source: Authors' calculation based on data from Investing.com (2025)

Table 1 reports the four moments of the selected commodities. Most commodities exhibit small average returns, close to zero, whereas coffee (0.021) and cocoa (0.013) recorded the highest growth in the observed sample. Volatility is generally high across commodities, reflecting the inherent risk of commodity markets. Among grains, oats (0.997) and wheat (0.861) are the most volatile, while lean hogs (1.165) present the highest risk among meats. Several commodities display significant skewness, and all exhibit high kurtosis.

Table 2 shows the pairwise correlations of portfolio assets. Pairwise correlations are not explicitly used as inputs in the Stutzer ratio formula like in mean-variance optimisation, but they implicitly affect the portfolio return distribution. In other words, positive correlations can increase the probability of extreme negative portfolio returns, while negative correlations can reduce tail risk. Therefore, the joint behaviour of assets (correlations) influences the portfolio performance index (I_p) because it affects the probability of underperformance.

RESULTS AND DISCUSSION

Portfolio construction. This section presents the results of the portfolios constructed using the Stutzer ratio, with findings reported in Table 3. The Stutzer ratio is a robust metric because it does not assume normality, emphasises downside risk and failure probabilities, and offers deeper insights for skewed or heavy-tailed return distributions (Benson et al. 2008). The Stutzer ratio is a considerably more complex performance measure than the Sharpe ratio because multiple factors influence its value. Specifically, the following factors are important:

i) Expected excess return – assets with higher expected excess returns tend to receive larger weights.

Table 2. Pairwise correlations between commodities

Grains	Corn	Wheat	Soybeans	Oats
Corn	1	0.513	0.561	0.266
Wheat	0.513	1	0.351	0.265
Soybeans	0.561	0.351	1	0.240
Oats	0.266	0.265	0.240	1
Softs	Cocoa	Coffee	Cotton	Sugar
Cocoa	1	0.066	0.007	0.055
Coffee	0.066	1	0.087	0.121
Cotton	0.007	0.087	1	0.142
Sugar	0.055	0.121	0.142	1
Meats	Feeder cattle	Live cattle	Lean hogs	Milk class III
Feeder cattle	1	0.525	0.098	0.005
Live cattle	0.525	1	0.070	0.024
Lean hogs	0.098	0.070	1	0.008
Milk class III	0.005	0.024	0.008	1

Source: Authors' calculation based on data from Investing.com (2025)

https://doi.org/10.17221/377/2025-AGRICECON

Table 3. Structure of the Stutzer portfolios (%)

Portfolio	Commodity	Composition (%)
Grains	corn	0.00
	wheat	0.00
	soybeans	64.46
	oats	35.54
	Σ	100
Softs	cocoa	57.30
	coffee	0.00
	cotton	0.00
	sugar	42.70
	Σ	100
Meats	feeder cattle	100
	live cattle	0.00
	lean hogs	0.00
	milk class III	0.00
	Σ	100

Source: Authors' calculation based on data from Investing.com (2025)

ii) Downside risk and tail heaviness – assets with high downside risk, fat tails, or negative skewness are penalised more heavily.

iii) Dependence structure (covariances) – correlations during downturns are crucial, i.e. assets that help diversify left-tail losses contribute positively to the Stutzer ratio and thus receive higher weights.

iv) The theta parameter – assets with higher theta are favoured in the Stutzer portfolio, reflecting stronger aversion to downside risk.

These factors interact simultaneously. In the grains portfolio, soybeans have the largest share (64.46%), followed by oats (35.54%). Soybeans dominate because they have the highest mean return and a relatively high theta (0.013 385). In contrast, as Table 4 suggests, oats have a relatively high mean but the lowest theta (0.006 102). However, oats are the least correlated with soybeans (0.240), which likely plays an important role in determining its relatively large share.

In the softs portfolio, cocoa and sugar dominate the Stutzer portfolio, with shares of 57.3% and 42.7%, respectively. According to Table 4, although coffee has the highest mean return (0.021), it has a zero share in the portfolio, likely because it has the lowest theta (–0.016 57). Cocoa, on the other hand, has the second-highest mean (0.013) and a negative theta that is still higher than the theta of coffee, which likely explains its dominant position. Sugar has an almost zero average return (0.001) but a relatively high theta (0.010 11), along with positive skewness and low kurtosis. Additionally, sugar has a relatively low correlation with the dominant cocoa (0.055), further supporting its position in the portfolio. Together, these factors determine the allocation of sugar.

In the meats portfolio, feeder cattle are the only asset included in the portfolio. Although they have the lowest (negative) theta, their relatively high mean return (0.012) likely offsets this, justifying their sole inclusion in the portfolio.

Table 5 presents the Stutzer ratio measures for naïve equal-weight and Stutzer-optimised portfolios across three commodity groups. Table 5 reveals an interesting pattern, where all Stutzer ratios are lower in the equal weight portfolios, but with higher theta, while in the optimal portfolio, it is the opposite. This can be explained as follows: all assets are weighted equally in the $1/N$ portfolio, without considering correlations, downside risk, or tail behaviour. Because of this naïve allocation, the

Table 4. Stutzer ratio and theta of the selected agricultural commodities

Portfolio	Commodity	Stutzer ratio
Grains	corn	0.000 16 (0.013 904)
	wheat	0.000 079 (0.010 828)
	soybeans	0.000 095 (0.013 385)
	oats	0.000 018 (0.006 102)
Softs	cocoa	–0.000 11 (–0.003 85)
	coffee	–0.000 33 (–0.016 57)
	cotton	0.000 176 (0.012 745)
	sugar	0.000 245 (0.010 11)
Meats	feeder cattle	–0.000 012 (–0.000 45)
	live cattle	0.000 066 (0.003 16)
	lean hogs	0.000 015 (0.002 286)
	milk class III	0.000 102 (0.009 154)

Theta is in parentheses
Source: Authors' calculation based on data from Investing.com (2025)

https://doi.org/10.17221/377/2025-AGRICECON

Table 5. Stutzer ratio and theta measures in equal weight and optimal portfolios

	Equal weight portfolios			Stutzer portfolios		
	grains	softs	meats	grains	softs	meats
Stutzer ratio	0.000 036 (0.025 789)	–0.000 11 (0.072 361)	–0.000 18 (0.044 253)	0.000 088 (–0.026 6)	0.000 136 (0.028 727)	0.000 112 (0.028 521)

Theta is in parentheses
Source: Authors' calculation based on data from Investing.com (2025)

portfolio may contain assets with very low downside risk but moderate returns, resulting in a high theta. This portfolio may be relatively safe in terms of downside risk. However, because the Stutzer ratio also depends on the mean excess return, the ratio itself is also low, i.e. the equal-weight portfolio does not maximise the trade-off between return and tail risk, so the overall performance remains modest.

On the other hand, in the Stutzer portfolio, the optimisation explicitly maximises the Stutzer ratio, balancing expected return and tail risk. Some assets with higher expected returns but lower theta may get large weights because they improve the risk-adjusted performance despite contributing more to tail risk. As a result, the Stutzer ratio increases because the portfolio is now better optimised for return vs. tail risk. Theta decreases because the portfolio now includes assets with lower downside-aversion characteristics.

To provide a more comprehensive analysis, we compare the descriptive statistics of the equal weight and Stutzer portfolios, with the results presented in Table 6. Stutzer portfolios generally show higher or similar mean returns compared to equal-weight portfolios. For example, grains increase from 0.002 to 0.004, and meats increase from 0.008 to 0.012, indicating that the Stutzer optimisation effectively favours assets with higher expected returns while accounting for downside risk. Standard deviations increase in some Stutzer portfolios (e.g. softs: 0.442 → 0.651) and remain similar in others (e.g. grains: 0.561 → 0.557). This reflects the trade-off in the Stutzer optimisation: the portfolio may accept higher overall risk if it improves the risk-adjusted performance as measured by the Stutzer ratio. Equal-weight portfolios have moderate negative skewness across all groups, reflecting slight asymmetry toward negative returns. Stutzer portfolios generally exhibit stronger negative skew in grains (–1.203) and softs (–0.616), indicating that the optimisation sometimes increases exposure to assets with larger left-tail risk in order to enhance expected returns. Meats, however, shift to slightly positive skew (0.165), suggesting a more favourable return distribution in the optimised portfolio. The Stutzer portfolios exhibit even higher kurtosis in grains (18.006) and softs (11.201), confirming that the optimisation may tolerate extreme outcomes to achieve a better trade-off between expected return and downside risk.

Discussion. The findings indicate that the Stutzer portfolios offer superior risk-adjusted performance compared to equal-weight portfolios, which indicates that optimisation is efficient in all three cases. For investors, this implies that optimisation based on the Stutzer ratio produces portfolios that better balance expected returns with exposure to extreme negative outcomes. For example, the dominance of soybeans and oats in the grains portfolio, and cocoa and sugar in the softs portfolio, reflects the advantage of combining assets with relatively high mean returns and favourable dependence structures that reduce downside tail exposure.

Moreover, the results show that the Stutzer portfolios can exhibit higher skewness and kurtosis. This implies

Table 6. Descriptive statistics of equal weight and optimal portfolios

	Equal weight portfolios			Stutzer portfolios		
	grains	softs	meats	grains	softs	meats
Mean	0.002	0.008	0.008	0.004	0.008	0.012
SD	0.561	0.442	0.437	0.557	0.651	0.536
Skewness	–0.454	–0.372	–0.399	–1.203	–0.616	0.165
Kurtosis	10.784	5.741	9.232	18.006	11.201	11.767

Source: Authors' calculation based on data from Investing.com (2025)

https://doi.org/10.17221/377/2025-AGRICECON

that investors may accept greater exposure to extreme outcomes in exchange for improved long-term performance. From a practical standpoint, this aligns with real-world investment preferences, especially for institutional investors and commodity fund managers. They are often willing to tolerate short-term volatility if compensated by higher expected returns and lower probability of sustained underperformance.

When comparing the three portfolios, the softs portfolio has the highest Stutzer ratio, which means this portfolio offers the highest returns per unit of downside risk. This is in line with papers such as Gorton et al. (2013) and Nguyen and Prokopczuk (2019). The meats portfolio slightly lags behind the softs portfolio in terms of the Stutzer ratio, but both portfolios have a relatively high theta parameter. This implies that these portfolios exhibit lower downside risk or a smaller probability of large losses, i.e. they exhibit robustness to extreme negative returns. Their returns are more concentrated around the mean, with fewer extreme negative outcomes. Their exponential decay rate of bad outcomes is stronger, showing greater stability and reliability of returns over time. These portfolios are therefore more favourable from a long-term investor's perspective.

On the other hand, the grains portfolio has a low (negative) theta, which indicates its returns fluctuate more widely, with a greater probability of extreme negative outcomes. Tail risk (risk of large losses) is higher, while the trade-off between average return and tail risk is less favourable. The exponential decay rate of bad outcomes is weaker, showing less resilience to adverse market shocks. From an investor's perspective, a low θ portfolio may still achieve high short-term returns, but at the cost of higher volatility and greater exposure to tail events. This portfolio appears more sensitive to adverse market conditions over the long term, as its performance depends more heavily on favourable market conditions.

CONCLUSION

This study applies the Stutzer ratio, a likelihood-based, downside-sensitive performance measure, to evaluate and optimise multivariate agricultural portfolios composed of grains, softs, and meats. By explicitly accounting for tail risk and non-normal return distributions, the Stutzer ratio provides a realistic representation of agricultural portfolio performance.

Empirical findings demonstrate that Stutzer-optimized portfolios outperform naïve equal-weight portfolios across all three commodity groups in terms of risk-adjusted performance. The optimisation effectively balances expected returns and downside exposure, yielding portfolios that are more resilient to adverse market conditions. Among the examined portfolios, the softs portfolio achieved the highest Stutzer ratio, followed closely by the meats portfolio, both characterised by relatively high theta values. This indicates a stronger exponential decay of downside outcomes and a lower probability of extreme losses, features particularly desirable for long-term investors seeking stability and the reliability of returns. Conversely, the grains portfolio exhibited a lower and negative theta, suggesting higher tail risk and greater sensitivity to market shocks.

The results underscore the practical relevance of the Stutzer ratio for investors and portfolio managers dealing with non-Gaussian return distributions typical of commodity markets. The measure enables a refined understanding of the trade-off between expected returns and downside risk, which cannot be captured by volatility-based ratios alone. From a strategic investment perspective, portfolios optimised under the Stutzer framework better align with long-term risk management goals, offering improved resilience to asymmetric shocks and extreme events.

Future research could extend this analysis by incorporating time-varying or regime-switching dynamics of the theta parameter, cross-commodity spillovers, and the inclusion of additional asset classes, such as energy or metals, to further enhance portfolio diversification and robustness. Additionally, including transaction costs in the calculation of the Stutzer ratio would be a step forward toward obtaining more realistic results.

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Received: September 12, 2025
Accepted: March 10, 2026
Published online: August 10, 2026