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Panic to Profits: Time Series Evidence Between GPRD and DeFi Token Prices

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Abstract This paper investigates the dynamic relationship between geopolitical uncertainty and decentralized finance (DeFi) token prices using a nonlinear, time-series-based framework. Leveraging the GPRD index as a proxy for global risk sentiment, the study examines seven prominent DeFi tokens representing diverse functional roles within the ecosystem. Through a layered empirical strategy - including Transfer Entropy, Mutual Information, Kernel-based Granger Causality, and Structural Time Series. Modeling - the analysis identifies both predictive and structural dependencies between GPRD and token valuations. The results reveal that tokens associated with financial-layer functions such as lending, collateralization, and liquidity rebalancing (e.g., Maker, Aave, BAL) exhibit stronger and more persistent exposure to geopolitical shocks than exchange-layer tokens like Uniswap or PancakeSwap. Kernel Granger causality confirms significant nonlinear predictive power of GPRD across all tokens, while structural decomposition shows that GPRD systematically depresses the long-term trend component of financial DeFi tokens. These findings indicate that global uncertainty operates not only through short-term volatility, but also as a sustained driver of DeFi asset repricing. By combining information-theoretic and structural techniques, the study provides a comprehensive empirical lens through which to evaluate systemic risk transmission into DeFi markets. The results underscore the heterogeneous macro-financial sensitivity of decentralized protocols and suggest the need for differentiated risk assessment frameworks in crypto-asset research and governance.

Keywords Decentralized Finance (DeFi), Geopolitical Risk (GDPR), Transfer Entropy, Kernel Granger Causality.

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Introduction

The rapid rise of decentralized finance (DeFi) has redefined how value is stored, exchanged, and leveraged in digital ecosystems. Unlike traditional financial systems, DeFi protocols operate without centralized intermediaries, relying instead on algorithmic rules and smart contracts. Yet despite their decentralization, DeFi assets are not insulated from broader macroeconomic forces. As capital increasingly flows into crypto-financial instruments, the question of how exogenous shocks—particularly geopolitical risk and uncertainty—transmit into token valuations has become both economically and strategically urgent. Understanding this transmission is analytically challenging. DeFi markets are characterized by extreme volatility, feedback loops, fragility liquidity, and heterogeneous investor behavior. Traditional linear models struggle to capture the complex, nonlinear dynamics governing price formation in these ecosystems. Moreover, DeFi tokens differ in their economic function: while some serve as exchange-layer assets (e.g., Uniswap, PancakeSwap), others represent foundational financial infrastructure, offering lending (Aave), stablecoin issuance (Maker), or liquidity balancing (Balancer). These differences likely mediate how each token responds to global uncertainty yet remain underexplored in empirical literature.

This study addresses that gap by examining the relationship between the Geopolitical Risk and Policy Uncertainty index (GPRD) and a selected set of DeFi token prices. To do so, it applies a sequence of advanced time series methods—Transfer Entropy, Mutual Information, Kernel Granger Causality, and Structural Time Series Models—to detect predictive, nonlinear, and structural linkages. In doing so, it offers new insight into the asymmetric vulnerability of DeFi protocols to global shocks and highlights the need for more nuanced modeling frameworks in crypto-asset research. The relationship between geopolitical uncertainty and financial markets has long attracted scholarly attention, as researchers have sought to understand how macro-level instability affects investor behavior, capital allocation, and systemic risk. Classical economic literature establishes that geopolitical shocks—ranging from wars and terrorism to diplomatic disputes and regional conflicts—can trigger capital flight, elevate volatility, and induce structural breaks in asset pricing models (Bekaert et al., 2014; Caldara & Iacoviello, 2022). These effects manifest across asset classes, including equities, bonds, and commodities, and are typically transmitted through channels such as heightened risk aversion, liquidity disruptions, and abrupt shifts in policy expectations. More recently, the growing entanglement between traditional financial systems and emergent decentralized ecosystems has intensified scholarly interest in how global risk variables affect digital asset pricing.

1. Related work

Decentralized finance (DeFi) introduces novel mechanisms of capital formation, lending, and exchange, operating through blockchain-based smart contracts that eliminate traditional intermediaries. The valuation of DeFi tokens is influenced not merely by speculative demand but also by internal protocol mechanics such as liquidity pool utilization, governance decisions, collateral ratios, and stablecoin pegs (Schär, 2021). These systems are structurally distinct from centralized financial intermediaries but remain functionally susceptible to macro-financial volatility. The decentralized yet interlinked nature of DeFi suggests that while such assets are technologically disintermediated, they are not economically immune to global uncertainty. As institutional capital increasingly engages with DeFi protocols, it becomes crucial to examine how tokens respond to geopolitical events and macro-risk sentiment.

However, existing empirical approaches are often ill-suited for analyzing such complexities. Much of the early work in crypto-asset literature has relied on linear models or event studies, focusing on short-term reactions to specific announcements or market events. These models are limited in their ability to detect nonlinearities, asymmetric dependencies, and dynamic causal pathways. In contrast, the unique structure of DeFi markets demands a methodological approach that accounts for time-varying relationships and nonlinear transmission mechanisms. Emerging studies have attempted to address these gaps using information theory, entropy-based methods, and nonlinear Granger causality to explore interdependencies within crypto markets (Koutmos, 2019; Corbet et al., 2020).

Zhao (2024) situates the analysis of digital money and cross-border payments within the context of geopolitical instability, highlighting the complexities introduced by fragmented regulatory regimes and the risks of financial decoupling in a multipolar world. Guesmi, Su, and Lucey (2024) examine risk spillovers across healthcare-related cryptocurrencies, DeFi tokens, and NFTs, showing that the effects of global uncertainty are neither homogeneous nor temporally stable. Their findings underscore the need for models that accommodate shifting causal intensities and multidimensional linkages. Kyriazis and Economou (2025) contribute further by analyzing how geopolitical shocks shape the transition toward decentralized financial architectures, revealing that such transitions are highly sensitive to global risk sentiment and may either accelerate or decelerate depending on the type and magnitude of the shock.

These developments in the literature reinforce the need to differentiate DeFi protocols not only by technical architecture but also by economic function. Tokens such as Uniswap and PancakeSwap, which serve primarily as decentralized exchange (DEX) platforms, may be less sensitive to global risk than tokens like Maker, Aave, and BAL, which are embedded in lending, liquidity provisioning, and collateral management. Theoretically, protocols that mimic traditional financial services—such as credit creation and liquidity balancing—should exhibit stronger structural responses to global uncertainty, particularly when investor behavior shifts in response to exogenous shocks. This functional differentiation forms the theoretical basis for examining DeFi tokens through a lens of macro-financial vulnerability.

2. Methodology

In this article, the methodological framework is constructed to explore the complex dependencies between global geopolitical uncertainty—captured through the Global Policy and Risk Disturbance (GPRD) index—and the dynamics of decentralized finance (DeFi) token prices. The decentralized financial ecosystem is characterized by elevated volatility, market segmentation, composability between protocols, and a high degree of investor reflexivity. Given these features, there is no theoretical or empirical justification to assume that the relationship between global uncertainty and token prices follows a linear path. On the contrary, the intricate structure of decentralized markets—with feedback mechanisms, endogenous liquidity dynamics, and heterogeneous investor behavior—makes it highly implausible that their sensitivity to exogenous shocks such as GPRD would manifest in a linear or time-invariant form. For this reason, the methodology is designed around flexible, information-theoretic and structural time series models that allow directionality, asymmetry, and temporal evolution of the relationships under study.

The dataset comprises daily time series of seven prominent DeFi tokens: Uniswap (UNI), SushiSwap (SUSHI), PancakeSwap (CAKE), Maker (MKR), Compound (COMP), Aave (AAVE), and Balancer (BAL), paired with the GPRD index. These tokens reflect distinct functional roles within the DeFi ecosystem. Uniswap, SushiSwap, PancakeSwap, and Compound function primarily as decentralized exchange (DEX) protocols and liquidity facilitators, centered around token trading and automated market-making. In contrast, Maker and Aave are core lending and collateralization protocols, with Maker additionally underpinning the DAI stablecoin system, making them structurally linked to credit risk and monetary stability. Balancer serves as a liquidity pool and portfolio rebalancing platform, managing automated allocation and exposure. These latter protocols—lending, stablecoin infrastructure, and liquidity management—resemble traditional financial services more closely and are therefore expected to exhibit heightened sensitivity to global macro-financial risk, such as that represented by the GPRD index.

To assess whether global uncertainty drives directional influence on token behavior, the first step is to apply the transfer entropy estimation from GPRD to each token series. Transfer entropy is an asymmetric, nonlinear metric rooted in information theory, which evaluates whether the past trajectory of GPRD improves the predictability of a token's future path, beyond what is captured by the token's own historical dynamics. This makes it particularly suited to detecting time-directed causal effects under non-Gaussian, regime-switching environments.

The second stage of the analysis estimates mutual information between the GPRD index and each token series. This step is necessary to quantify the total statistical dependence between the variables, irrespective of directionality or temporal structure. Mutual information provides a nonparametric metric that captures both linear and nonlinear associations without imposing any assumptions on the underlying functional form. In contrast to transfer entropy—which isolates time-directed, predictive effects—mutual information identifies whether any form of dependency exists between the series. The joint interpretation of these two measures enables a more precise differentiation between tokens that exhibit contemporaneous co-movement with global uncertainty and those for which GPRD possesses genuine forward-looking informational value.

To account for the possibility that the relationship between GPRD and token prices may involve complex, nonlinear causal mechanisms, the methodology proceeds by implementing kernel-based Granger causality tests. This approach extends the classical linear Granger framework by employing reproducing kernel Hilbert space mappings to accommodate arbitrary nonlinearities in the data-generating process. In the context of DeFi markets—where token valuations are shaped by composability, investor reflexivity, and adaptive liquidity mechanisms—kernel Granger methods offer a robust tool for uncovering causal structure that may be obscured under linear parametric assumptions.

The final stage involves the application of a multivariate structural time series model (STSM) in order to assess the persistent impact of GPRD on the underlying trend dynamics of token prices. Each series is decomposed into latent components, including a stochastic trend, irregular short-run movements, and a GPRD-induced exogenous channel. The model is estimated using the Kalman filter, which allows for time-varying parameter inference and dynamic tracking of how GPRD shocks influence the long-term evolution of token values.

3. Empirical analysis

The implementation of transfer entropy allows for the detection of time-directed, nonlinear information flow from global geopolitical uncertainty (as proxied by the GPRD index) to DeFi token prices. This approach identifies whether the past trajectory of GPRD contains unique predictive information about future token behavior, beyond what is explained by each token's own past. The results of this analysis are presented in Table 1.

Table 1. Transfer Entropy results

Token	Transfer Entropy	p-value
Uniswap	0.1292	0.024
SuchiSwap	0.1623	0.43
PancakeSwap	0.1292	0.034
Maker	0.2985	0.0
Compound	0.1076	0.209
Aave	0.3109	0.0000
BAL	0.5133	0.1640

Source: (Own calculations)

Among the seven tokens examined, statistically significant transfer entropy values are observed for Uniswap (TE = 0.1292, p = 0.0240), PancakeSwap (TE = 0.1292, p = 0.0340), Maker (TE = 0.2985, $p < 0.001$), and Aave (TE = 0.3109, $p < 0.001$), indicating a robust predictive flow of information from GPRD to these assets. In contrast, SuchiSwap and BAL exhibit relatively high transfer entropy values (TE = 0.1623 and 0.5133, respectively), but their associated p-values (0.4300 and 0.1640) suggest that these estimates are not statistically distinguishable from random noise under the null hypothesis of no information transfer. Compound also fails to reject the null, with TE = 0.1076 and p = 0.2090. These findings suggest that only a subset of DeFi tokens demonstrate meaningful sensitivity to geopolitical uncertainty in a predictive, time-asymmetric manner. Notably, the tokens with significant TE—such as Maker and Aave—are also those most closely tied to credit issuance and liquidity provisioning functions, reinforcing the hypothesis that structurally financial DeFi protocols are more directly exposed to macroeconomic and geopolitical shocks.

After the transfer entropy analysis, the next step—both methodologically and logically—is to evaluate the overall strength of association between the GPRD index and DeFi token prices using mutual information (MI). Unlike transfer entropy, which captures time-directed and predictive causality, mutual information provides a nonparametric measure of statistical dependence that encompasses both linear and nonlinear interactions without assuming any temporal structure or direction. This allows us to assess whether GPRD and token valuations share common informational content, even in the absence of lagged causality. The results, summarized in Table 2, reveal clear heterogeneity across tokens.

Table 2. Mutual information results

Token	Mutual Information
Uniswap	0.2107
SuchiSwap	0.1905
PancakeSwap	0.2107
Maker	2.0724
Compound	0.187
Aave	1.9511
BAL	1.9511

Source: (Own calculations)

The strongest dependencies are observed for Maker (MI = 2.0724), Aave (MI = 1.9511), and BAL (MI = 1.9511), indicating a substantial amount of shared information with GPRD. These protocols are functionally linked to credit issuance, stablecoin backing, and liquidity management—domains that are structurally exposed to macroeconomic uncertainty. In contrast, Uniswap (MI = 0.2107), PancakeSwap (MI = 0.2107), and SuchiSwap (MI = 0.1905) exhibit markedly lower mutual information scores, consistent with their primary role as decentralized exchanges rather than financial intermediaries. Compound (MI = 0.1870) also shows weak association, possibly due to idiosyncratic protocol factors or differences in sensitivity to exogenous shocks. Overall, the mutual information results reinforce the notion that DeFi tokens differ systematically in their informational exposure to geopolitical risk, with structurally financial protocols appearing more tightly coupled to the GPRD index.

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Building on the preceding results from the transfer entropy and mutual information analyses, the third step in the empirical strategy involves the implementation of kernel-based Granger causality testing. While the transfer entropy framework identified time-directed informational dependencies and mutual information revealed the strength of statistical association, neither method directly tests for predictive causality in a nonlinear regression context. To address this gap, the kernel Granger causality test is employed. This approach generalizes the classical linear Granger causality test by incorporating nonlinear functional forms through kernel-based transformations, enabling the detection of complex, nonlinear causal relationships that are especially relevant in the context of decentralized finance markets.

The results, presented in Table 3, indicate highly significant nonlinear Granger causality from GPRD to all examined DeFi tokens

Table 3. Transfer Entropy results

Token	Test Statistic	p-value
Uniswap	26.352	0.0
SuchiSwap	21.324	0.0
PancakeSwap	26.352	0.0
Maker	120.9615	0.0
Compound	54.0752	0.0
Aave	120.5299	0.0
BAL	120.5299	0.0

Source: (Own calculations)

Maker, Aave, and BAL exhibit the strongest causal linkages, with test statistics of 120.96, 120.53, and 120.53 respectively, suggesting that geopolitical uncertainty contains substantial predictive content for protocols that are directly involved in lending, stablecoin issuance, and liquidity rebalancing. Compound also shows a strong causal response (test statistic = 54.08), confirming its exposure despite weaker signals in mutual information. The exchange-focused tokens—Uniswap, PancakeSwap, and SuchiSwap—record lower, yet still statistically significant test statistics (ranging from 21.32 to 26.35), consistent with their role as trading infrastructure rather than credit engines. The uniform significance of results across all tokens ($p < 0.001$) confirms that GPRD exerts widespread nonlinear predictive influence across the DeFi spectrum, though the intensity of this influence varies meaningfully depending on the economic function of each protocol.

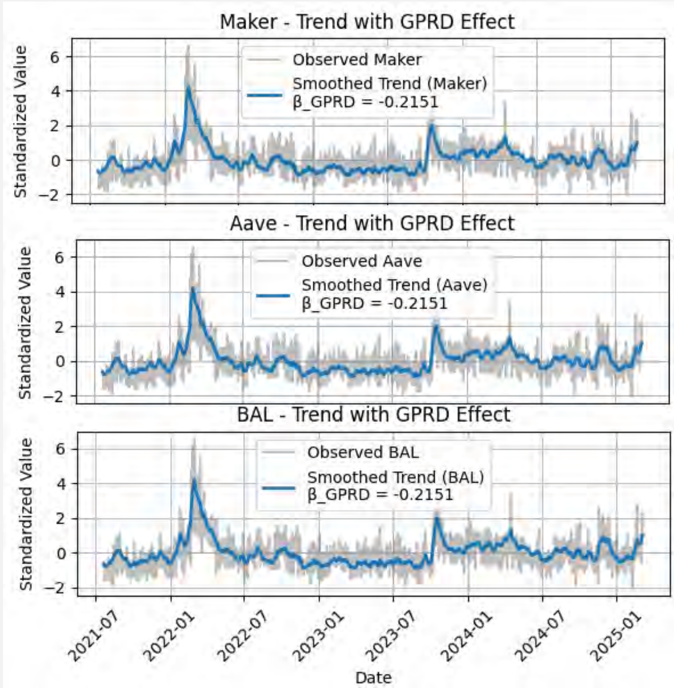

Fig. 1. Smoothed Trend Decomposition of DeFi Tokens (Maker, Aave, BAL) with GPRD Effect (2021–2025)

To assess the long-term structural influence of geopolitical uncertainty on DeFi markets, the final step of the empirical analysis implements a multivariate structural time series model (STSM) using the Kalman filter framework. This approach allows for the decomposition of observed token prices into latent components—including stochastic trends, short-term irregular movements, and exogenous drivers such as GPRD. Unlike prior models that capture predictive or nonlinear dependencies over short time horizons, the STSM isolates the persistent, cumulative effect of global risk sentiment on the long-run valuation trajectory of DeFi protocols. The selection of Maker (MKR), Aave (AAVE), and Balancer (BAL) for the final stage of the analysis is driven both by empirical and structural considerations. From an empirical perspective, these tokens exhibited the strongest and most statistically significant test statistics in the kernel-based Granger causality tests, indicating robust nonlinear predictive relationships from global geopolitical uncertainty (GPRD) to their price dynamics. From a structural standpoint, these protocols share a common functional role within the DeFi ecosystem: they are foundational to lending, collateral management, and liquidity balancing—core financial operations that are inherently more sensitive to changes in macroeconomic and geopolitical risk sentiment. Unlike DEX-centric tokens, which primarily facilitate trading, Maker, Aave, and BAL integrate deeper financial mechanisms such as stablecoin issuance, credit provisioning, and portfolio-based liquidity optimization. This dual rationale—strong causal signals and shared financial architecture—makes these tokens ideal candidates for testing whether GPRD not only predicts short-term price movements but also exerts lasting influence on long-run valuation trends. The results, visualized in Figure 1, reveal a consistent negative effect of GPRD on the long-term trend component of all three token prices.

The estimated β coefficients are −0.2180 for Maker, −0.2151 for Aave, and −0.2151 for BAL. These values suggest that heightened geopolitical uncertainty exerts a dampening effect on the structural valuation trajectory of these tokens, likely due to declining demand for leverage, diminished risk appetite, and liquidity reallocation away from complex DeFi protocols during periods of elevated global tension. The persistence of these effects in the smoothed trend, rather than the transitory irregular component, reinforces the interpretation that GPRD shocks are not merely short-lived noise, but rather structural forces with the capacity to reshape investor expectations and usage patterns in the DeFi space.

Conclusion

This study provides robust empirical evidence that global geopolitical uncertainty, measured by the GPRD index, significantly influences DeFi token prices in nonlinear and structurally persistent ways. Using a stepwise methodology combining Transfer Entropy, Mutual Information, Kernel Granger Causality, and Structural Time Series Models, we uncover that not all tokens respond equally—nor through the same channels. Transfer Entropy revealed significant directional information flow from GPRD to Maker, Aave, PancakeSwap, and Uniswap, suggesting predictive influence. Mutual Information confirmed stronger dependence for Maker, Aave, and BAL, supporting the hypothesis that structurally financial protocols—those involved in credit, stablecoins, or liquidity balancing—are more exposed to macro risk. Kernel Granger causality tests further reinforced these results: all tokens exhibited statistically significant nonlinear causality from GPRD, with the highest test statistics again concentrated among Maker, Aave, and BAL. To test for long-term structural effects, we estimated multivariate structural time series models for these three tokens. The results showed persistent negative GPRD coefficients ($\beta \approx -0.215$ to -0.218), indicating that geopolitical uncertainty exerts a dampening effect not just on short-term prices, but on the trend component of token valuations. These findings confirm that the transmission of global risk into DeFi markets is nonlinear, asymmetric, and protocol-specific. Financial-layer DeFi tokens—those mimicking credit and liquidity institutions—are the most vulnerable. This has implications for both risk modeling and governance in decentralized finance, where structural exposure to macro-financial shocks cannot be ignored.

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