Poznań University of Economics and Business

PUEB for Economy 5.0:

Regional Initiative – Global Effects (RIGE)

Regionalna Inicjatywa Doskonałości

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

PUEB for Economy 5.0:
Regional Initiative – Global Effects (RIGE)

Regionalna Inicjatywa Doskonałości

Poznań University of Economics and Business

Bitcoin efficiency across cryptocurrency platforms

HANNA KOŁODZIEJCZYK
hanna.kolodziejczyk@ue.poznan.pl
Poznań University of Economics and Business
al. Niepodległości 10, 61-875 Poznań
ORCID ID: 0000-0002-2637-5172

KLAUDIA JARNO
klaudia@jarno.pl
ORCID ID: 0000-0001-9034-9246

1st International On-chain Economy Conference, May 23-25, 2025, Warsaw, Poland

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Research gap: market efficiency (EMH)

- Bitcoin market is (nearly) efficient
  - Nadarajah & Chu (2017), Bariviera (2017), and Tiwari et al. (2018)
- Bitcoin market hasn't reached efficiency
  - Urquhart (2016), Kristoufek (2018), and Selmi, Tiwari & Hammoudeh (2018)
- Proponents of alternative theories:
  - AMH - Khuntia & Pattanayak (2018), Khursheed et al. (2020), López-Martín, Benito Muela & Arguedas (2021), Noda (2021), and Naeem et al. (2021)
  - FMH - Naeem et al. (2021) and Kakinaka & Umeno (2022a, 2022b)

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

"a homogenous, virtual good that is completely identical across all online markets in which it is sold"

Pieters & Vivanco (2017)

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Research gap: cryptocurrency platforms

- There is a significant number of cryptocurrency trading platforms
  - From 225 (August 22, 2023) to 820 (today) according to coinmarketcap.com
- Price dynamics vary across different platforms
  - Pieters & Vivanco (2017) – analysis of 11 markets revealed LOOP is not observed and KYC-type regulations are a key factor
  - Matkovskyy (2018) – compared the euro, U.S. dollar, and British pound sterling (GBP) centralized and decentralized bitcoin markets, identifying differences in return volatility and interdependency
  - Kliber & Włosik (2019) - examined price and volume spillovers to determine whether cryptocurrency platforms are integrated or form distinct, isolated clusters. They found that exchanges are more isolated in terms of volume spillovers than price spillovers

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Research gap: market evolution

- Crepelliere et al. (2023) documented the arbitrage opportunities arising on different platforms, stating that their size has significantly decreased since April 2018, contributing to increased market efficiency.
  - They attributed this change to the growing interest in the market from institutional investors
- Crisis phenomena, such as the COVID-19 pandemic, impact changes in efficiency across many markets
  - Naem et al. (2021) – pandemic adversely affected cryptocurrency market efficiency
  - Kakinaka & Umeno (2022) – efficiency in cryptocurrency markets decreased for short investment horizons, but not for long ones

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Research aim and research questions

The aim of this research is to measure the informational efficiency of bitcoin across multiple exchanges using daily data.

- (a) Are there significant differences in market efficiency levels across exchanges?
- (b) Which exchange is the most efficient, and which is the least?
- (c) How has efficiency evolved over time?

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Poznań University of Economics and Business

Cryptocurrency exchanges included in the study

Exchange	Established	Transaction volume (24h)	Visits per week	Currency pairs	Cryptocurrencies offered
Bitfinex	2012	$ 340 286 524	71 617	316	134
Bitstamp	2011	$ 438 411 567	139 073	231	109
Cex.io	2013	$ 19 145 748	62 249	559	224
Coinbase	2012	$ 4 244 476 963	38 874	438	292
Exmo	2014	$ 40 685 236	17 136	205	93
Gemini	2014	$ 421 716 853	250 582	139	82
Kraken	2011	$ 1 916 432 696	1 150 678	1 329	510

Source: *Top Cryptocurrency Spot Exchanges*, 2025, https://coinmarketcap.com/rankings/exchanges/

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Data

- Only dollar-to-BTC pair on fiat-to-crypto exchanges
- The data covers the period from January 1, 2017, to September 30, 2024.
- This range includes 2,830 daily BTC price quotations expressed in USD translating to 82 windows.
- Missing data ranged from 0% (Bitfinex, Exmo and Kraken) to 0.37% (Cex.io) of the series and were filled in.
- The data source is bitcoinity.org.
- Calculations were programmed in Python 3.9 using the pandas, numpy, scipy, and statsmodels packages.

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

PUEB for Economy 5.0:
Regional Initiative – Global Effects (RIGE)

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Methodology: EMH tests

- **Long memory**, which is understood as a long-term dependency manifested by the autocorrelation function of returns decaying at a slower-than-exponential rate is used to determine whether a market is efficient (weak form).
- One of the methods for estimating the memory of a process is the Hurst exponent (1951), based on the rescaled range (R/S) analysis.
- The shortcomings of the Hurst exponent have led to modifications, such as the **generalized Hurst exponent** used in studies by Di Matteo et al. (2005) and Sensoy & Tabak (2015).

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Generalized Hurst Exponent

- To assess the degree of persistence in a stochastic process X(t) the H(q) exponent is calculated as a measure of long memory.
  - In financial applications X(t) is typically the series of price logarithms.
- Next, we analyze the distribution of increments as a characterization of the evolution of the process X(t)

$$K_q(\tau) = \frac{< |X(t+\tau) - X(t)|^q >}{< |X(t)|^q >}$$

- H(q) is defined as: $K_q(\tau) \sim \tau^{qH(q)}$ or $log(K_q(\tau)) \sim qH(q) \cdot log(\tau) + C$

and estimated using OLS regression.

H(q) = 0.5 means that X(t) does not exhibit long memory.
H(q) > 0.5 means that X(t) exhibits persistence.
H(q) < 0.5 means that X(t) exhibits mean reversion.

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Methodology

1

- Data collected from 7 platforms, covering 93 months, are divded into 12-month rolling windows, which move forward 1 month each time
- For each window, the value of H(q) exponent is calculated

2

- Bootstrap method is used to estimate the errors in the H(q) estimation
- The Wald statistic is calculated
- The null hypothesis is tested, stating that long memory is not present in the series

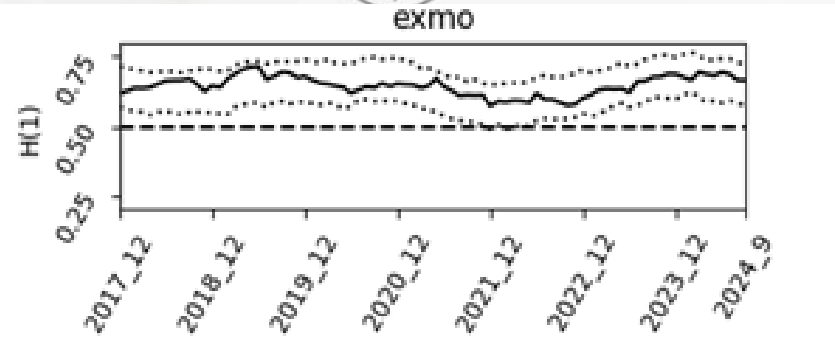
$$W = \left(\frac{H(1)-0.5}{S(H_b(1))}\right)^2$$

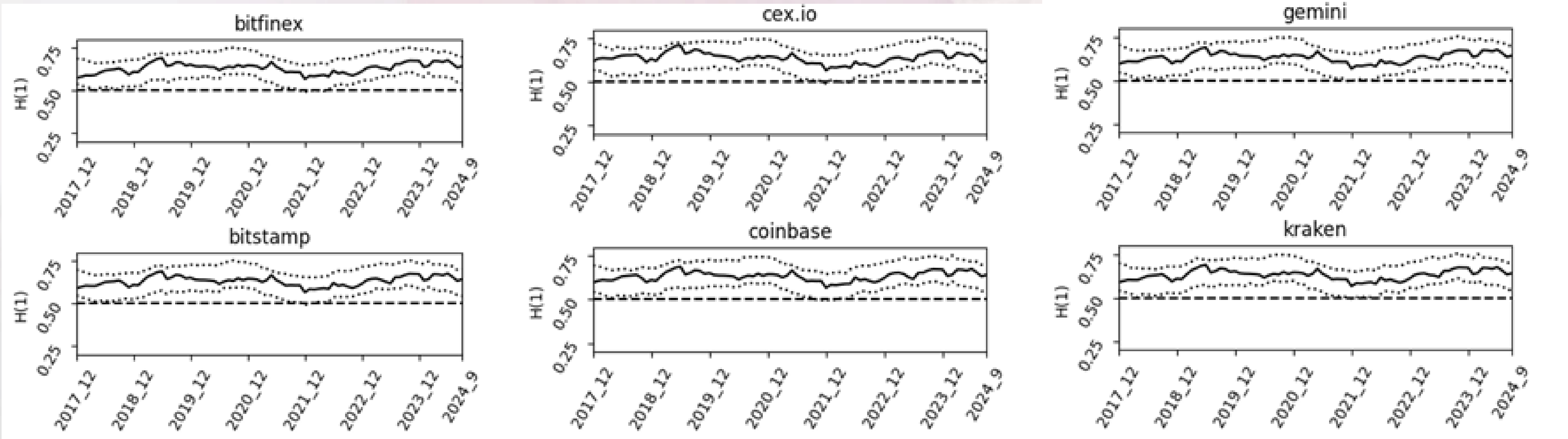
3

- For each platform 82 values of H(q) are calculated over time
- The ratio of windows for which the null hypothesis is rejected to all windows indicates the degree of inefficiency. This conclusion is very strong due to the design of the test

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Charts of H(1) values for seven bitcoin trading platforms obtained using a 12-month rolling observation window:



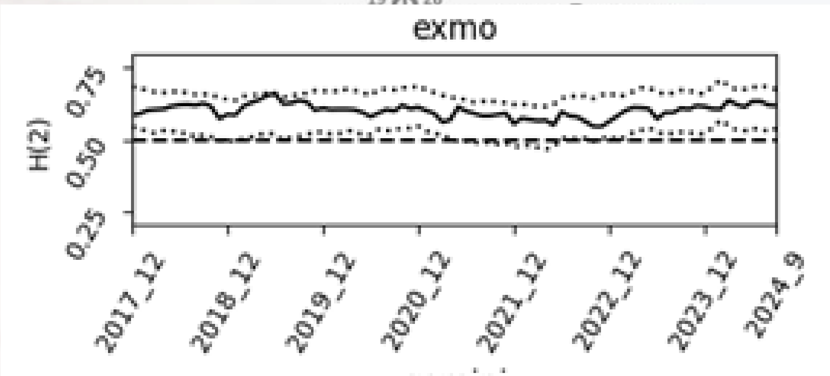


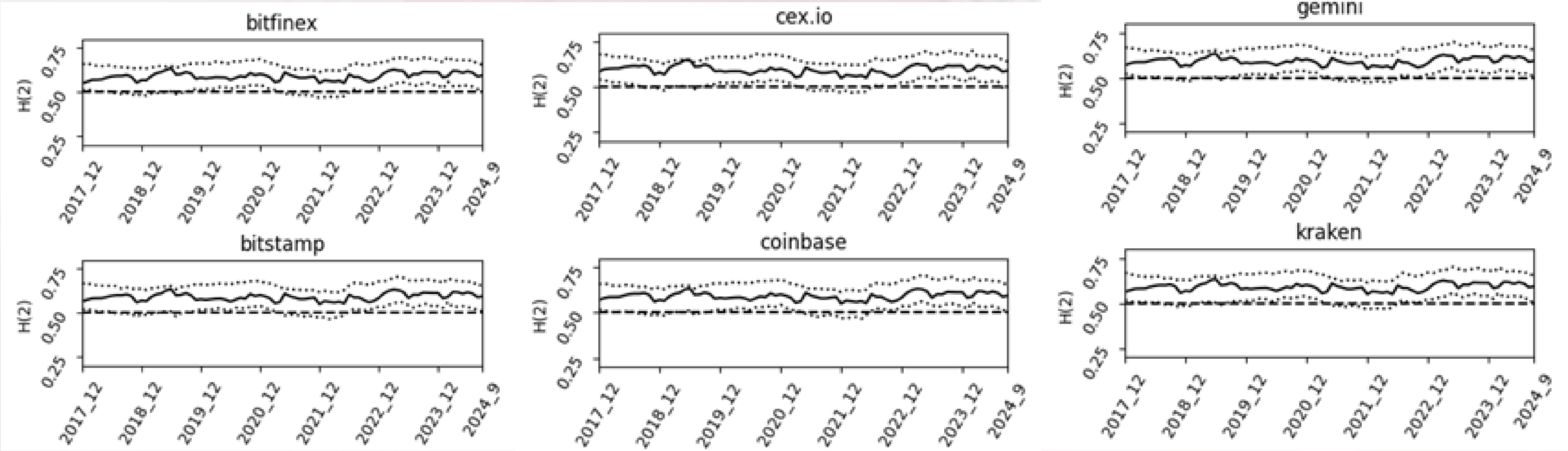
Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Charts of H(2) values for seven bitcoin trading platforms obtained using a 12-month rolling observation window:





Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Results

Bitcoin exchange	Inefficient windows for $q=1$	Inefficiency ratio for $q=1$	Inefficiency rank for $q=1$	Inefficient windows for $q=2$	Inefficiency ratio for $q=2$	Inefficiency rank for $q=2$
Bitfinex	77	0.939	5	53	0.6463	6
Bitstamp	81	0.9878	1	58	0.7073	5
Cex.io	79	0.9634	3	61	0.7439	2
Coinbase	78	0.9512	4	59	0.7195	4
Exmo	78	0.9512	4	63	0.7683	1
Gemini	79	0.9634	3	58	0.7073	5
Kraken	80	0.9756	2	60	0.7317	3

Inefficient windows are those for which the hypothesis stating the absence of long memory was rejected at a given significance level of α = 5%. Overall numer of windows is 82.

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Findings

Ranking of bitcoin trading platform efficiency
from the most efficient (top) to the least efficient (bottom)

Left: H(1)
Right: H(2)

H(1)	H(2)
Bitfinex	Bitfinex
Coinbase Exmo	Bitstamp
Cex.io Gemini	Coinbase
Kraken	Kraken
Bitstamp	Cex.io
	Exmo

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Key takeaways (1/3)

- Our results provide strong evidence against the EMH
  - The bitcoin market is characterized by inefficiency.
  - This is due to long memory, which means that after a positive return on a given day, another positive return can be expected on the following day.
  - Results in line with: Selmi, Tiwari & Hammoudeh (2018) and Lahmiri, Bekiros & Salvi (2018)
  - This effect does not occur at all times.
  - Might lend credence to alternative theories: AMH or FMH

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Key takeaways (2/3)

- Based on $H(2)$, we find that bitcoin exchanges exhibit different degrees of inefficiency
  - Cex.io and Exmo are the most inefficient exchanges
  - Bitfinex is the least inefficient
  - Contributing to the body of literature that directly compares bitcoin markets (Pieters & Vivanco, 2017; Matkovsky, 2018; Duan et al., 2021; Borri & Shakhnov, 2022)
  - We support the findings of Pieters & Vivanco (2017), who concluded that bitcoin markets fail to achieve LOOP
  - With stipulations, we do not observe the leveling of cross-market differences documented by Crépellière, Pelster & Zeisberger (2023)

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

Key takeaways (3/3)

- There does not appear to be a consistent trend toward either increased efficiency or inefficiency in the markets
  - Improved efficiency characteristics: in 2018 and 2021
  - Negative reaction to external events: at the beginning of the COVID-19 pandemic
    - Markets became more inefficient in the short term, but this effect did not persist in the long term – this aligns with Naeem et al. (2021) and Kakinaka & Umeno (2022b)
  - Changes in efficiency do not follow a unidirectional trend

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

PUEB for Economy 5.0:
Regional Initiative – Global Effects (RIGE)

Regionalna Inicjatywa Doskonałości

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS

Thank you!

Bitcoin efficiency across cryptocurrency platforms

HANNA KOŁODZIEJCZYK
hanna.kolodziejczyk@ue.poznan.pl
Poznań University of Economics and Business
al. Niepodległości 10, 61-875 Poznań
ORCID ID: 0000-0002-2637-5172

KLAUDIA JARNO
klaudia@jarno.pl
ORCID ID: 0000-0001-9034-9246

1st International On-chain Economy Conference, May 23-25, 2025, Warsaw, Poland

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education
Republic of Poland

References (selection)

Barabási, A. L., & Vicsek, T. (1991). Multifractality of self-affine fractals. *Physical review A*, *44*(4), 2730-2733. doi: 10.1103/PhysRevA.44.2730

Barunik, J., & Kristoufek, L. (2010). On Hurst exponent estimation under heavy-tailed distributions. *Physica A: statistical mechanics and its applications*, *389*(18), 3844-3855.

Crépellière, T., Pelster, M., & Zeisberger, S. (2023). Arbitrage in the market for cryptocurrencies. *Journal of Financial Markets*, *64*, 100817.

Di Matteo, T., Aste, T., & Dacorogna, M. M. (2005). Long-term memories of developed and emerging markets: Using the scaling analysis to characterize their stage of development. *Journal of banking & finance*, *29*(4), 827-851. doi: 10.1016/j.jbankfin.2004.08.004

Kakinaka, S., & Umeno, K. (2022b). Cryptocurrency market efficiency in short-and long-term horizons during COVID-19: An asymmetric multifractal analysis approach. *Finance Research Letters*, *46*, 102319.

Kliber, A., & Włosik, K. (2019). Isolated islands or communicating vessels?–Bitcoin price and volume spillovers across cryptocurrency platforms. *Finance a Uver*, *69*(4), 324-341.

Matkovskyy, R. (2019). Centralized and decentralized bitcoin markets: Euro vs USD vs GBP. *The Quarterly Review of Economics and Finance*, *71*, 270-279.

Naeem, M. A., Bouri, E., Peng, Z., Shahzad, S. J. H., & Vo, X. V. (2021). Asymmetric efficiency of cryptocurrencies during COVID19. *Physica A: Statistical Mechanics and its Applications*, *565*, 125562.

Pieters, G., & Vivanco, S. (2017). Financial regulations and price inconsistencies across Bitcoin markets. *Information Economics and Policy*, *39*, 1-14.

Sensoy, A., & Tabak, B. M. (2015). Time-varying long term memory in the European Union stock markets. *Physica A: Statistical Mechanics and its Applications*, *436*, 147-158. doi: 10.1016/j.physa.2015.05.034

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

PUEB for Economy 5.0:
Regional Initiative – Global Effects (RIGE)

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS

Supported by funds granted by the Minister of Science of the Republic of Poland under the „Regional Initiative for Excellence" Programme for the implementation of the project " The Poznań University of Economics and Business for Economy 5.0: Regional Initiative – Global Effects (RIGE)".

Regionalna Inicjatywa Doskonałości

Ministry of Science and Higher Education Republic of Poland