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Bitcoin investments and climate change: A financial and carbon intensity perspective

Dirk G. Baur[a,1,*], Josua Oll[b]

[a] University of Western Australia
[b] University of Oldenburg

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ABSTRACT

Climate-related criticism of Bitcoin is primarily based on the network's absolute carbon emissions, without considering its market value. Taking a relative emission perspective and utilizing the mean–variance portfolio optimization framework, we study the financial and carbon-related implications of Bitcoin investments. The results of our in-sample analysis show that adding Bitcoin to a diversified equity portfolio can both enhance the risk–return relationship of the portfolio and reduce the portfolio's aggregate carbon emissions. This finding persists under various assumptions regarding Bitcoin prices, carbon emission estimates, and carbon prices.

1. Introduction

Investors are increasingly acknowledging their critical role in tackling anthropogenic climate change as well as that climate risks have material monetary implications for their portfolios (Krueger et al., 2020; Mohsin et al., 2020; Zhang et al., 2019). In an ideal world, accurate and reliable information on any asset's carbon emissions would be readily available, allowing the integration of climate considerations into the investment process. The investment reality, however, is very different, as carbon information and respective emission estimates are often inaccurate, unreliable, or even unavailable (Busch et al., 2020; Talbot and Boiral, 2018). Therefore, assessing the true impact of investments on the climate is often challenging and associated with a high degree of uncertainty. In this context, Bitcoin investments arguably represent a prominent and extreme instance of unresolved climate implications, as the decentralization of Bitcoin mining complicates the assessment and accountability of the network's actual carbon footprint. A key and widely praised characteristic of Bitcoin—its decentralized nature—thus entails adverse consequences from a climate change perspective.

Bitcoin refers to a decentralized peer-to-peer electronic cash system, enabling online payments without the intervention of any bank, government, or central authority (Nakamoto, 2008). Since Bitcoin's creation in 2008, the volatility of Bitcoin prices and the opportunity to profit from extreme price increases has sparked a surge of interest among investors. Between January and September

* Corresponding author.
E-mail address: dirk.baur@uwa.edu.au (D.G. Baur).

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Table 1
Overview of carbon emission estimates.

Source	Carbon emission estimates (range)
Krause, M. J., & Tolaymat, T. (2018). Quantification of energy and carbon costs for mining cryptocurrencies. Nature Sustainability, 1(11), 711–718.	2.9–13.5 Mt CO2 emissions range calculated from January 2016 to June 2018; corresponds to an emission range of 1.2–5.2 Mt CO2 per year
Houy, N. (2019). Rational mining limits Bitcoin emissions. Nature Climate Change, 9 (9), 655–655.	Estimate for the 2017 carbon footprint of Bitcoin is 15.5 Mt CO2; emissions from the least and most polluting hardware: 2.9 and 35.1 Mt CO2
Masanet, E., Shehabi, A., Lei, N., Vranken, H., Koomey, J., & Malmodin, J. (2019). Implausible projections overestimate near-term Bitcoin CO2 emissions. Nature Climate Change, 9(9), 653–654.	Estimate for the 2017 carbon footprint of Bitcoin is 15.7 Mt CO2.
Köhler, S., & Pizzol, M. (2019). Life cycle assessment of Bitcoin mining. Environmental Science & Technology, 53(23), 13,598–13,606.	Estimate for the 2018 carbon footprint of Bitcoin is 17.29 Mt CO2.
Stoll, C., Klaaßen, L., & Gallersdörfer, U. (2019). The carbon footprint of Bitcoin. Joule, 3(7), 1647–1661.	Bitcoin's annual carbon emissions range from 22.0 to 22.9 Mt CO2 (as of November 2018).
Foteinis, S. (2018). Bitcoin's alarming carbon footprint. Nature, 554(7691), 169.	Annual carbon footprint for Bitcoin and Ethereum mining amounts to 43.9 Mt CO2.
Digiconomist. (2021). Bitcoin energy consumption index. www.digiconomist.net/bitcoin-energy-consumption	Bitcoin's annual carbon footprint is 76.08 Mt CO2 (as of September 2021).
Mora, C., Rollins, R. L., Taladay, K., Kantar, M. B., Chock, M. K., Shimada, M., & Franklin, E. C. (2018). Bitcoin emissions alone could push global warming above 2 °C. Nature Climate Change, 8(11), 931–933.	In 2017, Bitcoin usage emitted 69 Mt CO2.
De Vries, A. (2021). Bitcoin boom: What rising prices mean for the network's energy consumption. Joule, 5(3), 509–513.	Projects a carbon footprint of 90.2 Mt CO2
Jiang, S., Li, Y., Lu, Q., Hong, Y., Guan, D., Xiong, Y., & Wang, S. (2021). Policy assessments for the carbon emission flows and sustainability of Bitcoin blockchain operation in China. Nature Communications, 12(1), 1–10.	Projects that the Bitcoin blockchain in China will generate 130.50 Mt CO2 in 2024

2021, the Bitcoin market capitalization fluctuated between 500 and 1,200 billion U.S. dollars, accounting for more than 50% of the total market capitalization of all cryptocurrencies (CoinMarketCap, 2021). This not only makes Bitcoin the world's leading cryptocurrency but also exemplifies the largest and most successful implementation of blockchain technology (Cheng et al., 2019). However, Bitcoin is also facing mounting backlash in response to environmental issues (Cambridge Centre for Alternative Finance, 2021). As the Bitcoin network consumes more energy than most countries, industry observers attest to a "growing energy problem" (De Vries, 2018) and refer to the need for electricity as Bitcoin's "Achilles heel" (Forbes, 2018). While the staggering energy intensity of Bitcoin is largely undisputed, this does not hold true for the network's corresponding carbon footprint (Dittmar and Praktiknjo, 2019; Masanet et al., 2019; Mora et al., 2018). As the great majority of Bitcoin mining companies do not report their carbon emissions, different estimation approaches have been utilized in prior research (Stoll et al., 2019). However, due to differences in underlying assumptions and variation in the coverage of time periods and forecast horizons, these studies provide "wildly varying" (Howson, 2019, p. 644) carbon footprint estimates (see Table 1), spanning from 1.2 to 5.2 Mt CO2 (Krause and Tolaymat, 2018) to 130.50 Mt CO2 per year (Jiang et al., 2021).

Bitcoin's carbon footprint estimates, especially in the higher ranges, have received considerable attention in academic and public debate alike. However, the discourse tends to focus on Bitcoin's absolute carbon emissions and on the network's emissions compared to entire countries (e.g., Howson, 2019; Stoll et al., 2019). Relative measures that connect Bitcoin's carbon emissions to its market value are not yet an essential part of the debate. This fact is remarkable from an investment perspective, as the majority of investors either apply a purely financial perspective on investment decision making or blend financial and sustainability concerns. Hence, the debate's focus on absolute carbon emissions neglects the financial or value dimension of Bitcoin investments. Furthermore, conceiving absolute carbon emissions as the dominant criterion would exclude any investments in large companies with high absolute carbon emissions. In this study, we thus suggest directing more attention to Bitcoin's relative carbon emissions, based on the following rationale: If the value-neutral addition (e.g., $10,000 of an existing portfolio is swapped with $10,000 of an alternative asset) of Bitcoin to a diversified portfolio lowers the aggregate carbon emissions of the portfolio (Baur and Oll, 2019), Bitcoin's carbon emissions are low compared to its market value, implying that Bitcoin is characterized by a lower carbon intensity than the average asset in the portfolio. Thus, an isolated focus on Bitcoin's absolute carbon emissions can be highly misleading from an investment and portfolio perspective.

Against this backdrop, we take a relative emission perspective and utilize the mean–variance portfolio optimization framework to study the financial and carbon implications of adding Bitcoin to a diversified equity portfolio (proxied by the S&P500). The results of our in-sample analysis show that adding Bitcoin to a diversified equity portfolio can both enhance the risk–return relationship and lower the aggregate carbon footprint. The novel finding that Bitcoin investments can be less carbon intensive than standard equity investments holds true under various assumptions about Bitcoin prices, carbon emission estimates, and carbon prices.

The remainder of this paper is structured as follows. Section 2 describes the data set and the methodological approach. Section 3 presents the results, and Section 4 is the conclusion.

2. Data and methodology

This section describes the methodology to assess the carbon intensity of Bitcoin compared to a diversified equity portfolio and the calculation of the optimal mean–variance efficient weight of Bitcoin from a purely financial perspective and from a combined carbon–financial perspective. The analysis comprises four parts.

First, we calculated the carbon intensity of Bitcoin and the S&P500 (as a proxy for a diversified equity portfolio) and then compared the derived measures. In general terms, "[*c*]arbon intensity relates to a company's physical carbon performance and describes the extent to which its business activities are based on carbon usage for a defined scope and fiscal year" (Hoffmann and Busch, 2008, p. 509). Thus, the concept of carbon intensity refers to a ratio that divides absolute carbon emissions by a "related business metric" (Hoffmann and Busch, 2008, p. 509) and can provide insights into an investment's carbon efficiency (S&P Global, 2016). In previous research, the carbon intensity of diverse entities, such as companies, industries, and equity funds, among others, has been studied (Hoffmann and Busch, 2008; Hunt and Weber, 2019). Furthermore, different metrics can be used to operationalize the ratio's denominator (i.e., the "business metric"), including unit of production, sales/revenue, and market capitalization (Hoffmann and Busch, 2008; S&P Global, 2016). To obtain the carbon intensity measures, we followed existing works (e.g., Baur and Oll, 2019; Ilhan et al., 2021; S&P Global, 2016; Trinks et al., 2022) and scaled Bitcoin's and S&P500 firms' carbon emissions by their respective market values. Our motivation to utilize market values as the denominator was twofold: First, market cap–based carbon intensity measures provide "a common-sense estimate of what an investor is 'responsible' for" (S&P Global, 2016, p. 7). Second, there is no productive output (e.g., sales/revenue) associated with Bitcoin, thus making market value the only metric available to compare Bitcoin with equity investments.

We subsequently used these carbon intensity measures to decide whether Bitcoin can reduce the total carbon footprint of a portfolio. If the carbon intensity of Bitcoin is lower than the carbon intensity of a benchmark portfolio, Bitcoin reduces the aggregate carbon emissions of a portfolio if added to the portfolio by swapping a fraction of the portfolio with Bitcoin (value-neutral addition).

To calculate the carbon intensity measures of Bitcoin, we considered carbon emission estimates between 1 and 150 Mt CO2 and market values between $100 bn and $1,200 bn. The S&P500 carbon intensity was based on a $30 trillion market capitalization and 3,000 Mt CO2 emissions. Emission data for the S&P500 are obtained from Trucost (S&P Global) as of December 29, 2017 (Trucost, 2018). The sum of direct and first-tier supply chain emissions of all constituents in the S&P500 amounts to about 3,000 Mt CO2 emissions (Trucost, 2018), whereas direct emissions only account for close to 2,000 Mt CO2 emissions (S&P Dow Jones Indices, 2018). As emission estimates for Bitcoin include emissions for running the network, we deemed the 3,000 Mt CO2 emissions for the S&P500 (direct plus first-tier emissions) as the more comparable estimate.

Second, we conducted a classical mean–variance portfolio analysis (Markowitz, 1952) to identify the optimal risk–return relationship and implied weight of Bitcoin in a diversified equity portfolio.[2] Investors with purely financial concerns (profit-focused) would only invest in Bitcoin if the implied weight is larger than zero, and investors with financial *and* carbon concerns (carbon-conscious) would only invest in Bitcoin if the implied weight is larger than zero *and* if Bitcoin lowers the carbon intensity of the diversified equity portfolio.

Third, as an alternative to the two-step approach for carbon-conscious investors, we employed hypothetical carbon prices to enable the integration of carbon emissions into the portfolio optimization framework. We then analyzed how the integration of carbon emission costs changes the optimal portfolio allocation, assuming positive carbon prices of up to $1,250 per t CO2.

Fourth, we also accounted for uncertainty in the CO2 estimates of Bitcoin by studying how increasing standard deviations in emission estimates affect the optimal weight of Bitcoin in the portfolio.

3. Results

Overall, our analysis provides two main findings. In line with extant research documenting the diversification benefits of Bitcoin in the portfolio context (e.g., Akhtaruzzaman et al., 2020; Briere et al., 2015; Ghabri et al., 2021; Guesmi et al., 2019; Kajtazi and Moro, 2019; Klein et al., 2018; Platanakis and Urquhart, 2020; Rehman et al., 2020; Shahzad et al., 2020; Symitsi and Chalvatzis, 2019), our results show that the addition of Bitcoin to an equity portfolio can enhance the portfolio's risk–return relationship. Importantly, in contrast to the widespread negative perception of Bitcoin in the climate change debate, we also find that Bitcoin investments can be less carbon intensive than standard equity investments. The addition of Bitcoin to a diversified equity portfolio can thus lower the portfolio's aggregate carbon footprint. Hence, our analysis brings to light a different picture that emerges as soon as the absolute emissions of Bitcoin are related to Bitcoin's market value.

Fig. 1 presents the carbon intensity measures (t CO2 per $10,000) of Bitcoin for different carbon emission estimates (1–150 Mt CO2) and market values ($100–1,200bn) in comparison to the carbon intensity measure of the S&P500 (1 t CO2 per $10,000). Specifically, Fig. 1 shows different scenarios under which the value-neutral addition of Bitcoin reduces or increases the carbon emissions of the aggregate portfolio. Therefore, Fig. 1 is of central importance to carbon-conscious investors, as it illustrates when the carbon intensity of Bitcoin aligns with investors' carbon concerns—a necessary but not sufficient condition for adding Bitcoin to the portfolio. Ratios smaller than one indicate scenarios in which Bitcoin has a lower carbon intensity than the benchmark portfolio, thereby decreasing the portfolio's aggregate carbon footprint; on the other hand, those larger than one indicate a higher carbon

[2] The mean return, variance, and correlation estimates are based on the returns of end of month log prices for Bitcoin and the S&P500 from December 2011 to August 2021. The resulting optimal weights are in-sample estimates and may not be optimal out-of-sample.

	CO2 emissions (m t p.a.)	Bitcoin market value (in bn US$)											
			Low				Medium				High		
		100	200	300	400	500	600	700	800	900	1,000	1,100	1,200
	1	0.10	0.05	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Low	5	0.50	0.25	0.17	0.13	0.10	0.08	0.07	0.06	0.06	0.05	0.05	0.04
	10	1.00	0.50	0.33	0.25	0.20	0.17	0.14	0.13	0.11	0.10	0.09	0.08
	20	2.00	1.00	0.67	0.50	0.40	0.33	0.29	0.25	0.22	0.20	0.18	0.17
	30	3.00	1.50	1.00	0.75	0.60	0.50	0.43	0.38	0.33	0.30	0.27	0.25
	40	4.00	2.00	1.33	1.00	0.80	0.67	0.57	0.50	0.44	0.40	0.36	0.33
	50	5.00	2.50	1.67	1.25	1.00	0.83	0.71	0.63	0.56	0.50	0.45	0.42
Medium	60	6.00	3.00	2.00	1.50	1.20	1.00	0.86	0.75	0.67	0.60	0.55	0.50
	70	7.00	3.50	2.33	1.75	1.40	1.17	1.00	0.88	0.78	0.70	0.64	0.58
	80	8.00	4.00	2.67	2.00	1.60	1.33	1.14	1.00	0.89	0.80	0.73	0.67
	90	9.00	4.50	3.00	2.25	1.80	1.50	1.29	1.13	1.00	0.90	0.82	0.75
	100	10.00	5.00	3.33	2.50	2.00	1.67	1.43	1.25	1.11	1.00	0.91	0.83
	110	11.00	5.50	3.67	2.75	2.20	1.83	1.57	1.38	1.22	1.10	1.00	0.92
High	120	12.00	6.00	4.00	3.00	2.40	2.00	1.71	1.50	1.33	1.20	1.09	1.00
	130	13.00	6.50	4.33	3.25	2.60	2.17	1.86	1.63	1.44	1.30	1.18	1.08
	140	14.00	7.00	4.67	3.50	2.80	2.33	2.00	1.75	1.56	1.40	1.27	1.17
	150	15.00	7.50	5.00	3.75	3.00	2.50	2.14	1.88	1.67	1.50	1.36	1.25

Fig. 1. Inclusion of Bitcoin into a diversified equity portfolio (S&P500) from a carbon (intensity) perspective
The table shows whether $10,000 invested in Bitcoin is more, less, or equally carbon intensive than $10,000 invested in the S&P500. The estimates indicate how the (value-neutral, constant portfolio value) inclusion of Bitcoin in an S&P500 portfolio affects the carbon footprint of a Bitcoin–S&P500 portfolio for different Bitcoin market values (horizonal axis) and CO2 emission estimates (vertical axis). If the number is larger (smaller) than 1.00, the inclusion of Bitcoin increases (decreases) the carbon footprint of the portfolio. If the number is 1.00, the addition of Bitcoin does not change the carbon footprint. The benchmark is 1t of CO2 for a US$10,000 investment in the S&P500.

Table 2

Inclusion of Bitcoin into a diversified equity portfolio (S&P500) from a financial perspective

The table presents optimal risk–return (Sharpe and Sortino) ratios for different weights of Bitcoin in a Bitcoin–S&P500 portfolio. The analysis is based on monthly returns from 31/12/2011 to 31/8/2021. Panel A presents the risk-return calculations excluding carbon prices whereas Panel B includes carbon emissions at a price of $100 per ton of CO2. Comparing the returns in Panel A (Ret) and B (Ret-CO2) indicates that the assumed carbon price of $100 per ton of CO2 lowers portfolio returns by 1%. The optimal asset allocation shifts toward Bitcoin (from 10% to 12.5%) as Bitcoin's higher returns, in comparison to the S&P500, can better absorb the return-reducing effect of priced carbon emissions. The risk-free rate is assumed to be zero. *Risk* denotes the standard deviation of returns, and *Risk(-)* denotes the downside standard deviation of returns. *CO2* denotes CO2 emissions in tons per $10,000 investment.

	Return	Risk	Risk(-)	t CO2	CO2 risk	Carbon price
Bitcoin	96.5%	98.7%	44.9%	100	0%	$100
S&P500	13.2%	13.0%	10.9%	100	0%	$100
Correlation		0.24				

Panel A: Risk - return analysis without carbon					Panel B: Risk - return analysis including priced carbon emissions				
Weight in Bitcoin	Ret	Risk	Sharpe	Sortino	CO2	Ret-CO2	Risk	Sharpe	Sortino
0.000	0.13	0.130	1.0199	1.220	100	0.12	0.130	0.9429	1.127
0.025	0.15	0.135	1.1379	1.404	100	0.14	0.135	1.0636	1.313
0.050	0.17	0.143	1.2133	1.572	100	0.16	0.143	1.1436	1.482
0.075	0.19	0.155	1.2531	1.719	100	0.18	0.155	1.1888	1.631
0.100	0.22	0.170	1.2677*	1.844	100	0.21	0.170	1.2089	1.759
0.125	0.24	0.187	1.2663	1.948	100	0.23	0.187	1.2128*	1.865
0.150	0.26	0.205	1.2560	2.031	100	0.25	0.205	1.2071	1.952
0.175	0.28	0.224	1.2410	2.097	100	0.27	0.224	1.1964	2.022
0.200	0.30	0.244	1.2240	2.148	100	0.29	0.244	1.1831	2.077
0.225	0.32	0.265	1.2066	2.187	100	0.31	0.265	1.1688	2.119
0.375	0.44	0.398	1.1180	2.267	100	0.43	0.398	1.0929	2.216
0.400	0.47	0.420	1.1067	2.268*	100	0.46	0.420	1.0829	2.219
0.425	0.49	0.443	1.0962	2.266	100	0.48	0.443	1.0736	2.219*
0.450	0.51	0.467	1.0865	2.263	100	0.50	0.467	1.0650	2.218
0.475	0.53	0.490	1.0775	2.259	100	0.52	0.490	1.0570	2.216
0.500	0.55	0.513	1.0691	2.255	100	0.54	0.513	1.0496	2.214

intensity and thus increase the portfolio's aggregate carbon footprint.[3] A ratio of one implies that the carbon intensity of Bitcoin and the S&P500 are the same and that any value-neutral addition of Bitcoin to the benchmark portfolio does not affect the aggregate carbon footprint of the portfolio. Fig. 1 shows that Bitcoin reduces the aggregate CO2 emissions of a portfolio for relatively low Bitcoin CO2 estimates irrespective of the market value and for medium to high emission estimates if Bitcoin market values are medium to high. More specifically, our analysis indicates that for high market values of Bitcoin, as reached in early 2021, Bitcoin exhibits a relatively low carbon intensity even for high carbon emission estimates of up to 100 Mt p.a.

For profit-focused investors, in contrast, only financial concerns matter. Table 2 presents the mean, variance, and mean/variance (Sharpe ratio and Sortino ratio) estimates for different combinations of Bitcoin and the diversified portfolio (proxied by the S&P500) in increments of 2.5%. Table 2 Panel A indicates that the optimal (maximum) Sharpe ratio implies a 10% weight in Bitcoin and a 90% weight in the S&P500,[4] irrespective of Bitcoin's carbon intensity, if returns are the only or dominant criterion for an investor. The same optimal weight in Bitcoin also applies to carbon-conscious investors, but only when the addition of Bitcoin decreases the portfolio's aggregate carbon footprint (see Fig. 1).

Table 2 Panel B integrates a carbon price of $100 per t CO2 into the analysis and shows that the optimal Bitcoin weight increases from 10% to 12.5%.[5] Fig. 2 displays how different carbon prices affect the optimal asset allocation and reveals that Bitcoin weights increase for assumed carbon prices above $50 per t CO2. The increasing weight can be attributed to Bitcoin's high returns, which absorb the carbon-related costs better than the comparatively low returns of the equity portfolio.[6]

As the carbon footprint estimates for Bitcoin vary significantly (as reflected in Table 1), we also accounted for this variation by adding carbon emission risk to the standard return risk. Assuming a 20% standard deviation in the carbon emission estimates increases the overall risk of Bitcoin and decreases the optimal weight. The optimal weight of Bitcoin drops to zero for carbon risk exceeding 70% (see Fig. 3). If the emission estimates are assumed to be similarly risky for both Bitcoin and the equity portfolio (not shown in Fig. 3), the weights tend to change in favor of Bitcoin as the relative risk differential between the two assets decreases.

[3] If 2,000 Mt CO2 (only direct) emissions are used for the S&P500, the benchmark becomes 0.67 t CO2 per $10,000 and all numbers in Figure 1 must be compared to 0.67.

[4] Note that all weights are in-sample weights and that optimal out-of-sample weights may be very different.

[5] The estimates in Table 2 are based on 100t CO2 emissions per $10,000 investment for both Bitcoin and the S&P500.

[6] This finding is robust to the inclusion of transaction costs that may change the optimal weights but do not alter the results qualitatively.

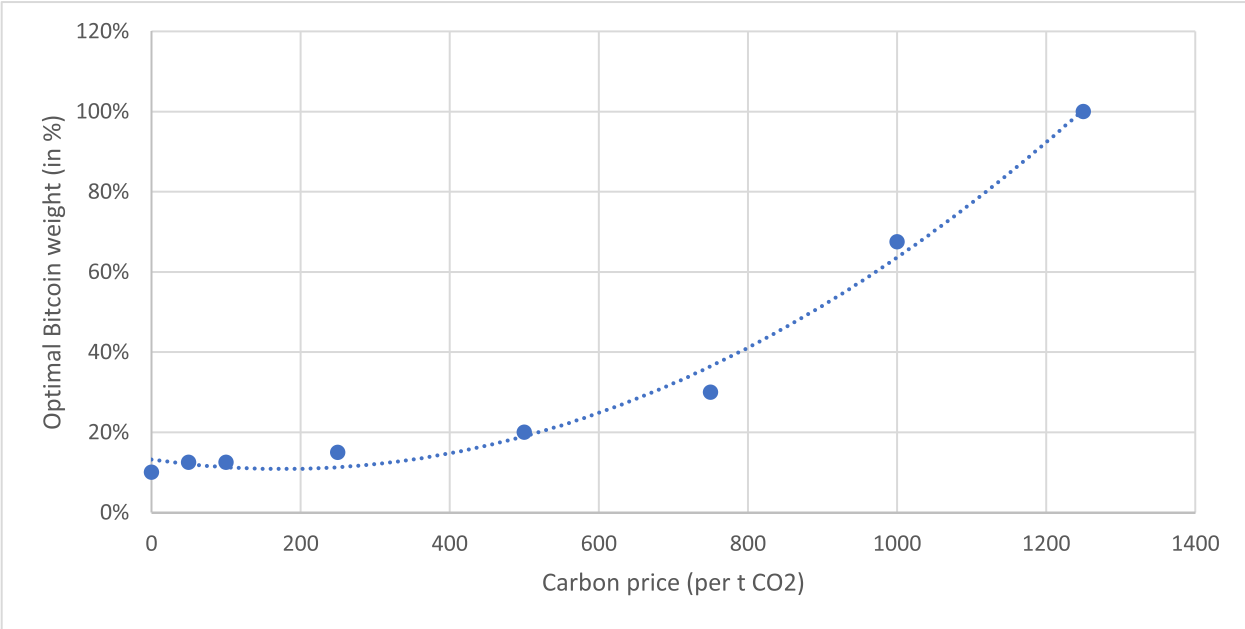

Fig. 2. Optimal weight of Bitcoin for different carbon prices
The inclusion of a carbon price increases the optimal weight of Bitcoin in a portfolio (see Table 2). This plot shows how different carbon prices affect the optimal weight (in%) of Bitcoin in a Bitcoin–S&P500 portfolio. The higher the assumed carbon price is, the higher will be the optimal weights of Bitcoin. Since the carbon price affects both Bitcoin and the S&P500, the comparatively higher returns of Bitcoin investments can better absorb higher carbon costs than S&P500 investments. The estimates are based on a \$1 m portfolio and 100 t CO_2 emissions for both Bitcoin and the S&P500. At a CO_2 price of \$100 per ton, the return of an investment decreases by \$10,000 or 1%.

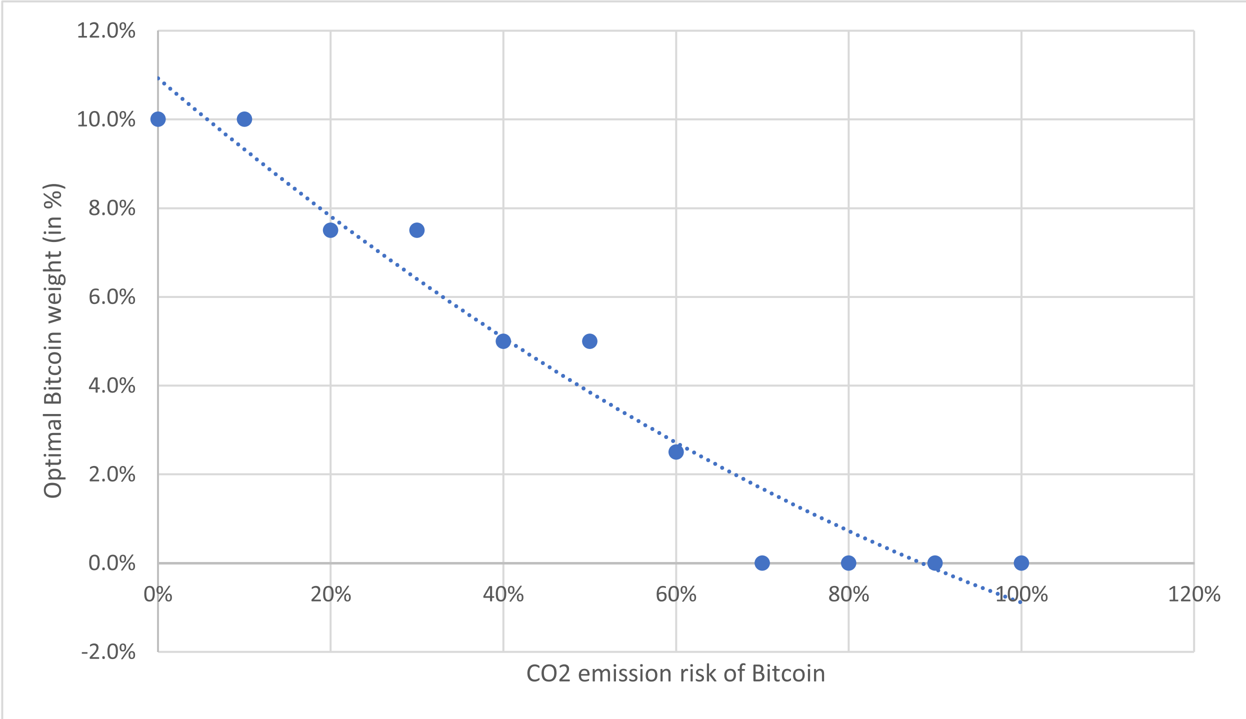

Fig. 3. Optimal weight of Bitcoin for different CO2 emission risks
As Bitcoin's carbon footprint estimates vary widely, this plot shows how the optimal Bitcoin weight (in%) changes if the risk of lower or higher Bitcoin CO2 emission estimates are accounted for by adding such risks to the financial risk (return risk). As the S&P500 emission estimates remain unchanged, higher Bitcoin CO2 emission estimates make Bitcoin riskier in comparison to the S&P500. As a result, the optimal Bitcoin weight decreases as Bitcoin's CO2 emission risk increases. The CO2 emission risk component of a portfolio is calculated with the same formula as standard portfolio risk. The estimates are based on a carbon price of $100 per t CO2.

4. Conclusion

The tremendous growth in the market capitalization of Bitcoin has been remarkable, given the controversy surrounding the network's carbon footprint and claims that an increasing number of investors are integrating climate considerations into their investment process. Surprisingly, the debate on the Bitcoin–climate change nexus almost exclusively focuses on the network's absolute carbon emissions or compares Bitcoin's emission estimates to those of entire countries. Carbon intensity measures, i.e., measures that relate carbon emissions to the underlying asset's value, are common in financial research and practice but remain absent in the Bitcoin literature. While we fully acknowledge the importance of considering Bitcoin's absolute emissions in the context of climate change mitigation, this study's proposed relative emissions and carbon intensity measures presented a new perspective to the Bitcoin–climate change debate. Furthermore, our approach generated a novel and potentially unexpected finding that has not come up in existing studies: Bitcoin investments can be less carbon intensive than standard equity investments and thus reduce the total carbon footprint of a portfolio. While this finding rests on several assumptions, it holds true for various Bitcoin prices, carbon emissions, and carbon prices.

Credit author statement

Dirk Baur & Josua Oll: Conceptualization, Methodology, Dirk Baur: Data, Estimation, Visualization, Dirk Baur & Josua Oll: Formal Analysis, Investigation, Writing - Original draft preparation, Writing- Reviewing and Editing.

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