Corcoran *et al. Financial Innovation* (2025) 11:127
https://doi.org/10.1186/s40854-025-00871-z

Financial Innovation

RESEARCH

Open Access

A spatial analysis of the use of Bitcoin as a medium of exchange

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Abstract

We present a spatial analysis of Bitcoin-accepting merchants using BTC Map, a global crowdsourced dataset built on OpenStreetMap, to provide ground-level evidence on Bitcoin's payment ecosystem. While prior research emphasizes macroeconomic drivers, our analysis of approximately 11,000 merchants shows that local adoption is more strongly shaped by community dynamics and sectoral niches. Acknowledging quality variance in crowdsourced data, we focus on verified regional clusters. We find a global concentration of adoption in the hospitality sector, localised clusters driven by grassroots initiatives rather than national policy and significant presence in alternative healthcare and IT services. These findings highlight the limits of top-down interventions such as El Salvador's legal tender law and underscore the role of social networks in sustaining adoption. By contrasting spatial micro-level evidence with national studies, this work positions merchant data as a key lens for understanding Bitcoin's evolving role as a medium of exchange.

Keywords: Bitcoin, Medium of Exchange, Crowdsourcing, Spatial Analysis

Introduction

Bitcoin is a cryptocurrency or digital currency that is not issued or controlled by a centralised authority (Nakamoto 2008). Given the decentralised and pseudo-anonymous nature of Bitcoin, it is difficult to quantify the levels of its adoption across different regions of the world. Here we define adoption as the proportion of individuals that regularly use Bitcoin in some way including as a store of value or as a medium of exchange. Several studies have found that over 10 percent of the people in developed countries, including the UK and USA, have previously used a cryptocurrency with adoption growing over time (Chainalysis 2023). The level of adoption is notably high in countries such as El Salvador, where Bitcoin is legal tender but its acceptance is voluntary rather than mandatory. Furthermore, studies have found that adoption is greatest among young males, but is otherwise diverse (Perkins and Cross 2024). Due in part to the development of advanced payment systems such as the Lightning Network, Bitcoin is increasingly being used as a medium of exchange (River 2023).

To date, little analysis and modelling of the use of Bitcoin as a medium of exchange has been performed. Most existing analyses of Bitcoin spending patterns focus exclusively on the transfer of Bitcoin between individuals without considering that such transfers commonly form part of a medium of exchange for products or services. This contrasts with traditional fiat currencies, such as the Euro and pound sterling, for which there exists much publicly available data regarding their spending patterns. For example, Barclays Bank publishes several annual reports describing the spending patterns of the pound sterling such as their UK Consumer Spending Report.[1] This type of analysis is straightforward for Barclays Bank because they can link payments made by their customers at different merchants to the types of products and services sold by these merchants. The lack of analysis and modelling of the use of Bitcoin as a medium of exchange can be attributed to the difficulty of obtaining Bitcoin payment information. For a given payment, the public Bitcoin blockchain ledger records the pseudonymous addresses of its sender and receiver, along with the payment amount. No information regarding the product or service that was paid for nor the geographical location of the payment is recorded. Furthermore, additional privacy-preserving mechanisms such as the Lightning Network payment system further obfuscate payment information. This lack of Bitcoin payment information means that it is challenging to perform a corresponding analysis and modelling. Given the ever-growing use of Bitcoin as a medium of exchange, we argue that this represents a challenge with growing significance. In this work, we propose to mitigate this challenge by performing a spatial analysis and modelling of merchants accepting Bitcoin payments.

BTC Map (https://btcmap.org/) was launched in 2022 as a free and open-source crowdsourcing project that maintains a worldwide geographical map of all brick-and-mortar merchants accepting Bitcoin payments. A brick-and-mortar merchant is defined as a merchant who operates in a building with a geographical location. This contrasts with a clicks-only merchant who only has an online presence. The stated purpose of the BTC Map project is to enable Bitcoin holders to spend Bitcoin directly, without converting to a local fiat currency. Figure 1 displays a snapshot of the BTC Map website showing a subset of merchants from Arnhem, a Dutch city, that accept Bitcoin payments. The merchant 'The Cavern Café' is highlighted with additional details including the date when the information corresponding to this merchant information was last verified.

As of July 2024, BTC Map contains information about approximately 11,000 merchants that accept Bitcoin payments. Merchant information includes its location and, where available, attributes such as the types of products and services they sell. Due to the use of crowdsourcing, the quality of BTC Map can vary spatially where quality is measured along several dimensions, including positional accuracy, attribute accuracy and completeness. In some geographical regions, BTC Map data is of high quality. Such regions include the city of Berlín in El Salvador, which has a large pro-Bitcoin community and an active community of volunteers contributing data to the BTC Map project. Conversely, there exist many regions, such as North Wales, where BTC Map data is of poor quality. If BTC Map provides high quality data for a given region, this data can act as an indicator of the use of Bitcoin as a medium of exchange. For example, if a significant number of cafés in a given region accept Bitcoin payments, this likely indicates

[1] https://www.barclayscorporate.com/insights/industry-expertise/uk-consumer-spending-report/

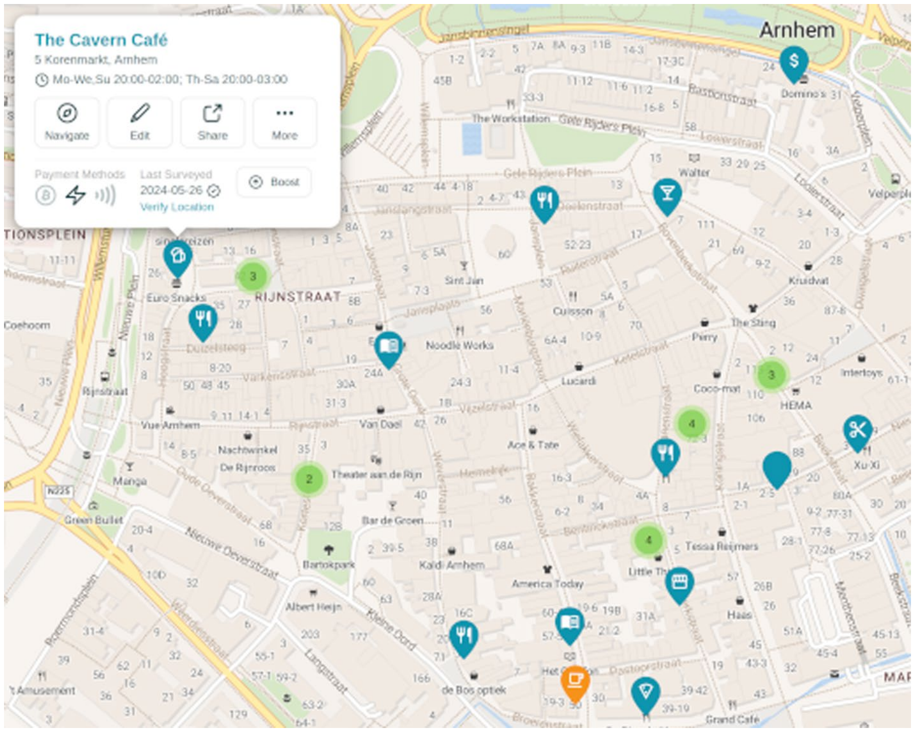


Fig. 1 A screenshot of BTC Map website showing a subset of the merchants in Arnhem City in the Netherlands that accept Bitcoin payments. A single merchant entitled 'The Cavern Café' is highlighted and additional details about this merchant are displayed

some corresponding usage of Bitcoin to purchase products sold by cafés. This inference assumes that a merchant's decision to install the necessary infrastructure to accept Bitcoin payments is motivated by market demand. This assumption may not always be valid and, in some cases, a merchant's decision to accept Bitcoin payments may stem from various factors beyond immediate demand. However, we argue that as the number and percentage of merchants that accept Bitcoin payments in a given region increases, so does the likelihood that a corresponding market demand exists. It is important to note that the proposed indicator is only an indicator of the use of Bitcoin as a medium of exchange; it is not a measure of the number or proportion of payments made using Bitcoin. To accurately estimate this, one would need additional data regarding the number or proportion of payments each merchant receives via Bitcoin. Using BTC Map merchant information to indicate the use of Bitcoin as a medium of exchange is similar to using footfall data to indicate commercial retail activity.

This work aims to answer the following research questions: (1) How can we extract the necessary merchant data from BTC Map to perform a spatial analysis of the use of Bitcoin as a medium of exchange? (2) How can we measure the quality of this data to ensure reliable analysis? (3) What insights can be gained about the use of Bitcoin as a medium of exchange in geographical regions with high quality merchant data? (4) How can the quality of BTC Map information be improved to enable a more comprehensive analysis of the use of Bitcoin as a medium of exchange?

The remainder of this article is structured as follows. Section "Related work" presents a review of related work. Section "Spatial indicator of bitcoin as a medium of exchange" describes the proposed methodology for extracting merchant data from BTC Map and using this as a spatial indicator of the use of Bitcoin as a medium of exchange. This methodology builds on previous research on the analysis of crowdsourced spatial data. Section "Spatial analysis of merchants" subsequently presents a spatial analysis performed using this indicator. Section "Discussion" then provides a discussion that positions our findings within the broader literature on Bitcoin adoption and highlights their theoretical and practical implications. Finally, Section "Conclusions synthesises the results in light of the research questions and outlines avenues for future investigation.

Related work

This section provides an overview of existing research on Bitcoin adoption and usage, examining the factors that drive its acceptance among individuals, businesses, and broader economic systems.

Alzahrani and Daim (2019) conducted an extensive meta-analysis of existing literature on cryptocurrency adoption. Their findings highlight several key factors influencing user adoption, including investment opportunity, anonymity, acceptance as a method of payment, payment latency, low transaction fees and technology curiosity. They also suggested that the number of users on cryptocurrency exchanges serves as a useful estimate for the total number of cryptocurrency users. Interestingly, a study by Perkins and Cross (2024) on Bitcoin adoption in the USA found no meaningful differences in ownership based on race, ethnicity, religion, relationship status, income, education, or financial literacy. However, they did identify a moderate correlation between identifying as libertarian and Bitcoin ownership.

While individual adoption is important, understanding corporate and national adoption rates provides a broader picture. Jonker (2019) investigated cryptocurrency adoption by online retailers in the Netherlands, identifying consumer demand, transactional benefits, and perceived accessibility as the most significant drivers. Expanding on this, Gschnaidtner et al. (2024) explored blockchain adoption among companies in Germany, Austria, and Switzerland, revealing that less than one percent of companies had integrated this technology. However, they noted higher adoption rates, ranging from three to five percent, in sectors such as Information and Communication Technology (ICT), banking and finance, and consulting. This trend of increasing corporate adoption, particularly in the USA, was also highlighted by River (2024).

The geographical and socio-economic factors influencing cryptocurrency adoption have also been a focus of research. Huang et al. (2020) performed a spatial analysis of Initial Coin Offerings (ICOs), finding that they primarily occur in countries with developed financial systems, public equity markets, and advanced digital technologies. Building on this, Bellavitis et al. (2021) conducted a spatio-temporal analysis of ICOs, observing significant changes over time in the number of ICOs, the amount of money raised, their geographic distribution, and associated regulations. From a socio-economic perspective, Saiedi et al. (2021) found that cryptocurrency adoption is highest in countries characterized by distrust in traditional banks and financial systems, as well as those experiencing high inflation.

While the aforementioned studies offer valuable insights into the broader trends and factors influencing Bitcoin adoption, a critical aspect of its real-world utility lies in its acceptance by merchants as a medium of exchange. To this end, several projects have emerged to compile databases of merchants that accept Bitcoin payments. Among these, BTC Map stands out as a prominent initiative. Other notable efforts include Satmap, an online directory for Bitcoin accepting merchants and businesses. Distinct from BTC Map, which focuses solely on physical brick-and-mortar establishments, Satmap accommodates both online and "clicks-only" businesses. However, as of July 22, 2024, Satmap listed fewer than one hundred businesses. Similarly, Airbtc, a directory akin to Airbnb for Bitcoin-based property rentals, contained details for fewer than one hundred properties on the same date. The limited number of listings in both Satmap and Airbtc suggests they have been considerably less successful than BTC Map. Critically, to the authors' knowledge, there is a notable absence of existing analysis concerning the merchant and business data collected by these projects.

Most existing analyses of Bitcoin and cryptocurrency transactions have focused on the transfer of Bitcoin between individuals without considering that such transfers commonly form part of a medium of exchange. Since such analysis considers only data contained in the corresponding blockchain, it is commonly referred to as blockchain analysis or chain analysis. The majority of Bitcoin transactions correspond to the transfer of Bitcoin between pseudonymous Bitcoin addresses where a single individual or entity may control several addresses. Broadly speaking, most existing Bitcoin blockchain analysis aims to solve the following two problems. The first problem concerns identifying the individual or entity that controls a single Bitcoin address (Meiklejohn et al. 2013). The second problem concerns clustering individual Bitcoin addresses that are controlled by the same individual or entity. These two problems are complementary; by identifying the individual or entity that controls a single address that is an element of a larger cluster, we can infer that the individual or entity controls all addresses in the cluster.

Several methods exist that are used to identify the individual or entity that controls a single Bitcoin address. The most commonly used method involves government regulation of cryptocurrency exchanges enforcing implementation of Know Your Customer (KYC) practices. The individual or entity that controls a single Bitcoin address can also be revealed if the information is publicly shared (Spagnuolo et al. 2014). For example, an individual may share a Bitcoin address they control online when requesting payment or donations. The clustering of individual Bitcoin addresses is commonly done using heuristics that attempt to infer distinct Bitcoin addresses controlled by the same individual or entity (Kappos et al. 2022). For example, the common-input-ownership heuristic assumes that all Bitcoin addresses forming inputs to a given transaction are controlled by the same individual or entity. However, these clustering heuristics are not perfect and users can use methods to break them and maintain privacy. For example, a coinjoin is a transaction where all the inputs are not controlled by the same individual or entity thereby breaking the common-input-ownership heuristic.

More recent blockchain analysis has moved beyond the analysis of single individuals or entities and identified broader patterns of Bitcoin transactions. Liu et al. (2023) demonstrated that single individuals or entities controlling Bitcoin addresses can be clustered into groups with distinct trading patterns. Zhang et al. (2024) demonstrated the potential of signal processing methods for predicting Bitcoin price bubbles and crashes.

Spatial indicator of Bitcoin as a medium of exchange

As described in the introduction, we aim to analyse the representation of merchants accepting Bitcoin payments in BTC Map. Merchant data in BTC Map are a form of crowdsourced geographical data. Such data is commonly referred to as Volunteered Geographic Information (VGI) in the Geographic Information Science (GIS) community (Goodchild 2007). The quality of crowdsourced geographical data will vary as a function of the number of contributors and the particular knowledge of each contributor (Haklay 2012; Mooney and Corcoran 2012b). These properties may vary over space and time and in turn the quality of the data in question may not be uniformly of high quality. Given the necessity of high quality data for performing useful analysis, performing a global analysis of merchants accepting Bitcoin payments is challenging. To mitigate this challenge, we propose to analyse geographical regions where there exists a relatively large number of merchants that accept Bitcoin payments and the corresponding BTC Map data is of high quality.

The remainder of this section is structured as follows. Section "Merchant data extraction" describes the methodology used to extract merchant data from BTC Map. Section "Measuring the quality of merchant data" describes the methodology used to measure the quality of these data and identify geographical regions where the corresponding data is of high quality.

Merchant data extraction

When contributors add merchant information to the BTC Map project, it gets stored into the OpenStreetMap (OSM) database, a crowdsourced mapping project that can be considered a Wikipedia for maps or spatial data. Therefore, BTC Map functions as a social layer built upon OSM. OSM contains information about a wide spectrum of geographical objects such as Points of Interest (POIs) and street networks. Each geographical object is represented using a combination of spatial and semantic attributes. Spatial attributes specify the geographical location of the object, which can be represented as a point, a line or a polygon. Semantic attributes specify the type of the object and are represented using a set of tags or key-value pairs. For example, one may represent an object corresponding to a café using a point to represent its location and a tag "amenity=cafe" to specify its type. While OSM does not constrain the tags that contributors can add, there are conventions recommended to ensure some consistency regarding the meaningful use of tags (OpenStreetMap 2024). For example, it is an agreed convention that cafés should be tagged with the key-value pair "amenity=cafe". Another convention is to tag objects using the English language, regardless of geographical location. The resulting consistency of OSM data greatly simplifies its analysis across a diverse set of geographical regions.

The OSM convention for tagging merchants accepting Bitcoin payments has changed over time. Initially, Bitcoin was treated as a payment method by the OSM community. Hence, the convention was to tag merchants who accept and do not accept Bitcoin payments using the key-value pairs "payment:bitcoin=yes" and "payment:bitcoin=no" respectively. Later, Bitcoin was treated as a currency by the OSM community. Hence, the convention became to tag merchants who accept and do not accept Bitcoin payments using the key-value pairs “currency:XBT=yes” and “currency:XBT=no” respectively. This is the current convention. OSM also has a convention for specifying the methods by which a given merchant accepts Bitcoin payments. For example, the convention states that a merchant should be tagged as “payment:lightning=yes” if they accept Bitcoin payments using the Lightning Network (BTCMap 2023). Figures 2a and b display the number of OSM objects versus time tagged using the legacy convention “payment:bitcoin=yes” and the current convention “currency:XBT=yes” respectively. We see that in 2014 over 7,000 merchants were tagged using the legacy convention. After the introduction of the current convention in 2022, contributors started verifying and retagging these merchants using this convention. Hence, the number of merchants tagged using the legacy convention went to almost zero. Finally, OSM has a convention for specifying the most recent date a merchant’s Bitcoin payment status was verified. This convention states that a merchant should be tagged as “survey:date=yyyy-mm-dd” when verified in person and tagged as “check_date=yyyy-mm-dd” or “check_date:currency:XBT=yyyy-mm-dd” when verified remotely. The BTC Map project outlines several ways to remotely verify a merchant including contacting the merchant via telephone, email or social media, asking a local resident from the area, and checking online sources such as their website or business registries. Business registries can be used to determine if a given merchant has ceased operations and should be removed. The ability of contributors to remotely add, update, delete and verify information has led to the emergence “super-taggers”, who contribute a significant proportion of merchant information. The BTC Map project maintains a leaderboard ranking top contributors based on their contribution volume. Where payment details are available, the project facilitates Bitcoin donations or tips to these ranked individuals.

To extract the merchant data from OSM, we used three free and publicly available APIs; the OSM API, the Taginfo API and the Overpass API. The Taginfo API provides several useful methods for extracting both current and historical information regarding OSM object tags. However, its ability to extract object spatial information is limited. The Overpass API provides the ability to extract both current and historical information

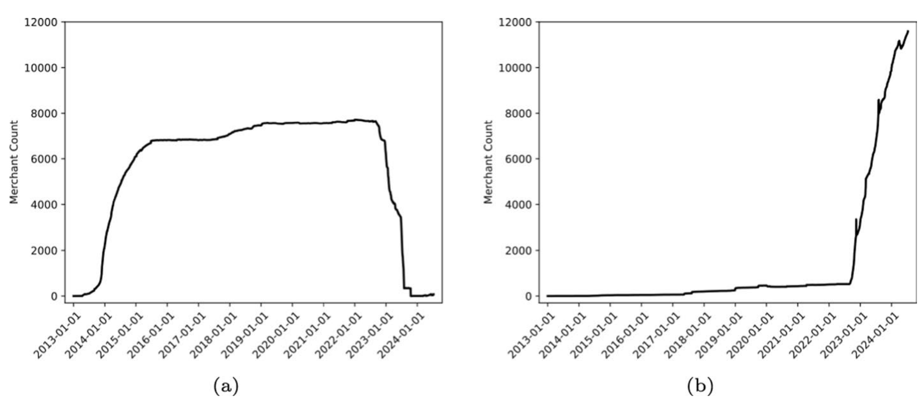


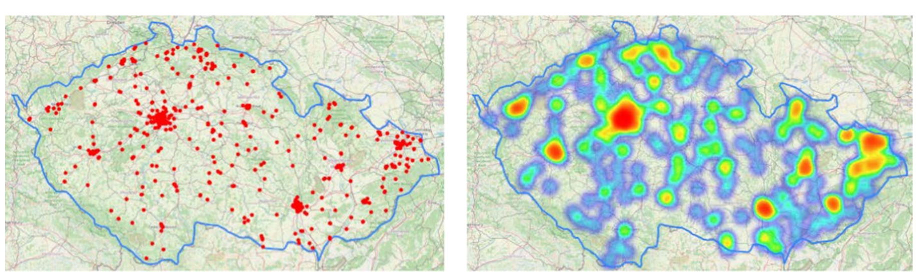
Fig. 2 The graphs in (**a**) and (**b**) display the number of OSM objects tagged using the legacy convention “payment:bitcoin=yes” and the current convention “currency:XBT=yes” respectively versus time

regarding OSM. With this API, requests are specified using the Overpass Query Language, a programming language specific to this API. Unlike the Taginfo API, the Overpass API is not limited with respect to its ability to extract spatial information. To illustrate the capabilities of the Overpass API, Figure 3 displays the sets of merchants in the Czech Republic tagged with the key-value pair "currency:XBT=yes" on 1 July 2024. The number of merchants is 857. The area of the region, calculated as that of the region enclosed by the finite precision polygon representation, is 78,754 square kilometres. All analyses presented in the following sections were performed using the merchant data from OSM on 1 July 2024.

Measuring the quality of merchant data

The quality of data can be defined as a measure of its fitness for purpose for a particular task. In many cases, data will generally not be of perfect quality and this can be a consequence of several factors (Soh and Samal 2008). This includes the use of sensors with finite precision and the fact that obtaining data can be both costly and time-consuming. The quality of spatial or geographical data can be measured along several dimensions including positional accuracy, temporal accuracy, attribute accuracy, completeness, logical consistency, and lineage (Guptill and Morrison 2013). The dimensions that are relevant depend on the task for which the data will be used. In the context of the current work, that involves the analysis of merchants accepting Bitcoin payments, it is necessary that the representation of merchants in BTC Map has the properties of positional accuracy, temporal accuracy, attribute accuracy and completeness. Positional and temporal accuracy are necessary given that we wish to perform a spatial analysis of current merchants. Attribute accuracy is necessary given that we wish to identify merchants accepting Bitcoin payments and analyse the properties of these merchants. Finally, completeness is necessary given that we wish to perform an analysis that considers all merchants accepting Bitcoin payments.

Merchant data in BTC Map is a form of crowdsourced geographical data or Volunteered Geographic Information (VGI) (Goodchild 2007). Measuring the quality of crowdsourced geographical data is challenging and cannot be achieved using existing methods designed to measure the quality of authoritative geographical data such as that produced by a national mapping agency. For example, the ISO data quality standards require reference to a ground truth data or specification, which are not available in the



(a) (b)

Fig. 3 The sets of merchants tagged with the key-value pair "currency:XBT=yes" on 1 July 2024 in the Czech Republic are displayed using a scatter plot and a heat map in (**a**) and (**b**) respectively. The region boundaries and merchants are represented by blue lines and red circles respectively context of crowdsourced geographical data (Antoniou 2023). Furthermore, as mentioned above, the quality of crowdsourced geographical data may vary over space and time as a function of contributors. In such cases, computing a global measure of data quality is challenging and it is instead more appropriate to compute a local measure. Since direct quality assessments are often difficult, heuristics that analyse data characteristics are commonly used to infer the quality of crowdsourced geographical data.

Goodchild and Li (2012) defined three general approaches to measuring the quality of crowdsourced geographical information. The first approach is entitled the *crowdsourcing approach*. This approach is based on the heuristic that a set of contributors can verify or correct an error in the information provided by a single contributor. Therefore, if a sufficiently large number of contributors have verified a piece of information, its quality can be inferred to be high. It has been demonstrated that this approach is commonly realised in OSM whereby contributors correct perceived errors made by others (Mooney and Corcoran 2012). In BTC Map, contributors can verify the Bitcoin payment information for a given merchant. This is illustrated in Figure 1 where we can see that the merchant 'The Cavern Café' was last surveyed or verified on the date 2024-05-26. The second approach defined by Goodchild and Li (2012) is entitled the *social approach*. This approach is based on the heuristic that a measure of contributor trust can be computed. For example, a contributor who makes a large number of contributions that are consistently verified by other contributors can be considered highly reliable. This measure of trust can in turn be used to determine a hierarchy of contributors in which higher-rank contributors can veto contributions made by lower-rank contributions. This approach is implemented in many successful crowdsourcing projects, including Wikipedia and OSM. OSM implements a two-tier hierarchy of contributors corresponding to ordinary users and the Data Working Group. Furthermore, OSM implements a reputation system, where a contributor who adds erroneous data will be subject to greater scrutiny by their peers and may be banned. Since all additions are public and open for review, a contributor who adds a large volume of data that is not determined as being erroneous will accumulate a strong reputation. In turn, their additions will be subject to less scrutiny by their peers. The third approach defined by Goodchild and Li (2012) is entitled the *geographic approach*. This approach is based on the heuristic that a measure of geographical feasibility can be defined. For example, it is unlikely that a café is located in the middle of the ocean. Using such a measure of feasibility, one could infer that a given geographic data are of low quality if a significant proportion of its elements are not feasible.

Since BTC Map is built upon OSM, it inherits its approaches to quality assurance described above. Furthermore, BTC Map additionally encourages the creation of communities. A community corresponds to a set of BTC Map contributors that contribute information regarding merchants in a given region. Each community has three stated responsibilities two of which are concerned with supporting the adoption of Bitcoin as a medium of exchange. The third responsibility concerns ensuring that the BTC Map representation of merchants accepting Bitcoin payments in the community's region is accurate. As of the date of our analysis, BTC Map has 457 communities, the majority of which correspond to urban areas. Examples of communities include the city of Berlín in El Salvador, the city of Prague in the Czech Republic and the island of Madeira. As described in Section "Merchant data extraction", the ability to remotely contribute merchant data has resulted in the emergence of super-taggers, that contribute a large proportion of BTC Map data. Note that this is also a property of many other successful crowdsourcing projects including Wikipedia. Although remotely contributing data may be less accurate than performing a ground survey, it is necessary to enable super-taggers to significantly increase the quality of the data with respect to completeness. Hence, there exists a potential trade-off between completeness and other dimensions of quality. Finally, as described in Section “Merchant data extraction”, BTC Map facilitates the payment of tips to the most highly ranked contributors. However, due to the reputation system described above, this does not incentivise contributors to add inaccurate data.

As described in the introduction to this section, to mitigate the challenge of data quality, we propose to perform an analysis of geographical regions where BTC Map contains a relatively large number of merchants and the corresponding data is of high quality. We used a crowdsourcing approach to determine data quality. Specifically, we define the data corresponding to a given merchant to be high quality if the Bitcoin accepting status of that merchant has been verified in the past twelve months. If a merchant has not been verified in the past twelve months, we say that the quality of the corresponding data cannot be determined. In turn, we define the data corresponding to a given region to be high quality if the Bitcoin accepting status of the majority of merchants in that region have been verified in the past twelve months. This twelve-month verification window is a key quality measure used by the BTC Map project itself. It is based on the observation that the frequency with which merchants alter their Bitcoin acceptance status is generally much lower than this period. Furthermore, if the majority of merchants have been recently verified, this implies the existence of an active set of BTC Map contributors in the region. To empirically support the use of a twelve month window, we extracted all historical versions of each merchant in BTC Map and analysed the corresponding verifications. In total, there were 38,325 verifications of all merchants. The mean and standard deviation of the time been consecutive verifications of the same merchant were 336 and 511 days respectively. Critically, 96% of these consecutive verifications indicated no change in the merchant’s Bitcoin acceptance status. This demonstrates that a merchant verified within the past twelve months has a very high probability of having maintained their Bitcoin acceptance status during that period.

Spatial analysis of merchants

In this section we perform an analysis of merchants accepting Bitcoin payments using data from BTC Map. Section "Merchant tagging analysis" presents a global or non-spatial analysis of the tags assigned to merchants accepting Bitcoin payments. Section "Merchant spatial analysis" presents a spatial analysis of merchants accepting Bitcoin payments. This analysis includes summary statistics at the country level, as well as an analysis of smaller geographical regions that contain a relatively large number of merchants and the corresponding quality of this data is high. Finally, Section "Consideration of micro- and macroeconomic factors" presents a brief analysis of micro- and macroeconomic factors in merchant Bitcoin adoption.

Merchant tagging analysis

In this section, we present a global (non-spatial) analysis of the tags assigned to merchants accepting Bitcoin payments. As discussed in the previous section, it is challenging to obtain a quality assurance for the global set of BTC Map data. However, of the 11,208 merchants in BTC Map on the date of our analysis, 7,211 or 64% had been verified within the previous twelve months. Hence, the majority of the corresponding data can be considered high quality with respect to most of the dimensions of quality described previously. However, we cannot infer that the data are of high quality with respect to the dimension of completeness. If a given geographical region does not have any active BTC Map contributors, it is not possible to determine if a lack of merchant data for that region is a reflection of reality or a lack of active contributors.

As described in Section "Merchant data extraction", OSM objects are tagged using sets of key-value pairs. OSM does not constrain the tags contributors use but does have agreed tagging conventions. On the date of our analysis, there were 11,208 merchants tagged as accepting Bitcoin payments and these merchants had 1,111 distinct tag keys. Table 1 displays the fifty most frequently occurring keys. The key currency:XBT is the most frequently occurring key since the presence of this key is a requirement for merchants to be considered in our analysis. Apart from the currency:XBT key plus other

Table 1 The fifty most frequently occurring tag keys corresponding to merchants who accepted Bitcoin payments ordered by number

Tag Key	No. Merchants	Tag Key	No. Merchants
currency:XBT	11,208	cuisine	1,175
name	11,053	cash_withdrawal	1,135
payment:onchain	8,249	brand:wikidata	1,104
payment:lightning	8,238	contact:email	1,056
addr:street	7,083	url	1,044
website	6,914	office	1,008
addr:city	6,751	branch	932
addr:postcode	6,096	contact:facebook	901
addr:housenumber	5,941	start_date	901
phone	5,504	payment:debit_cards	882
payment:lightning_contactless	5,394	currency:USD	878
amenity	5,154	addr:suburb	835
check_date	5,042	brand:wikipedia	805
opening_hours	4,914	contact:instagram	804
check_date:currency:XBT	4,603	payment:credit_cards	747
shop	3,765	building	729
survey:date	3,332	level	727
payment:cash	2,745	wheelchair	724
operator	2,559	currency:EUR	720
email	2,127	manufacturer	704
description	1,712	source	693
cash_in	1,378	addr:state	693
brand	1,307	currency:LTC	659
cash_out	1,265	addr:country	621
indoor	1,212	tourism	606

Table 2 The fifty most frequently occurring tag key-value pairs ordered by frequency corresponding to merchants who accepted Bitcoin payments

Tag Key - Value Pair	No. Merchants	Tag Key - Value Pair	No. Merchants
amenity = atm	1519	tourism = apartment	83
amenity = restaurant	1401	shop = electronics	77
shop = supermarket	526	shop = car_repair	68
amenity = cafe	479	shop = furniture	66
shop = department_store	360	office = advertising_agency	65
amenity = fast_food	294	healthcare = doctor	60
amenity = bar	232	office = consulting	60
shop = hairdresser	230	shop = farm	59
shop = clothes	228	shop = mobile_phone	58
tourism = hotel	225	amenity = doctors	58
amenity = bureau_de_change	207	shop = tattoo	56
office = company	206	healthcare = alternative	54
amenity = fuel	142	tourism = hostel	50
amenity = pub	139	amenity = pharmacy	49
shop = convenience	128	healthcare = pharmacy	49
shop = jewelry	124	shop = travel_agency	49
shop = yes	122	craft = photographer	48
office = it	121	office = yes	48
tourism = guest_house	117	shop = bakery	48
shop = beauty	115	shop = gift	47
office = lawyer	111	amenity = ice_cream	46
leisure = fitness_centre	110	office = architect	45
shop = computer	109	office = estate_agent	45
healthcare = dentist	96	shop = massage	42
amenity = dentist	94	office = accountant	40

keys relating to how Bitcoin payments are accepted, some of the most frequently occurring keys include name, addr:street, amenity and check_date. Other less frequently occurring keys included toilets, wheelchair and contact:facebook. In our analysis, we are principally interested in those tags that indicate the types of merchants in question. Many tags provide little insight into the types of merchants. For example, in most cases, it is difficult to directly infer a merchant type from the corresponding name or address. By inspecting the set of keys and their frequencies, we identified the following set of eight keys as providing a useful description of merchant type: amenity, shop, healthcare, leisure, office, tourism, sport and craft. The three most frequently occurring tags with an amenity key were amenity=atm, amenity=restaurant and amenity=cafe. The three most frequently occurring tags with a shop key were shop=supermarket, shop=department_store and shop=hairdresser. The three most frequently occurring tags with a healthcare key were healthcare=dentist, healthcare=doctor and healthcare=alternative. The three most frequently occurring tags with an office key were office=company, office=it and office=lawyer. The three most frequently occurring tags with a leisure key were leisure=fitness_centre, leisure=sports_centre and leisure=pitch. The three most frequently occurring tags with a tourism key were tourism=hotel, tourism=guest_house and tourism=apartment. The three most frequently occurring tags with a sport key were sport=fitness, sport=yoga and sport=tennis. Finally, the three most frequently occurring tags with a craft key were craft=photographer, craft=brewery and craft=electronics_repair. Of the 11,208 total merchants, 11,122 or 99% had at least one tag with a key in the above set.

Considering only the above set of eight keys, Table 2 displays the fifty most frequently occurring key-value pairs. The most frequently occurring key-value was amenity=atm which corresponds to a Bitcoin ATM (automated teller machine), which allows customers to buy and sell Bitcoin. Examining this table reveals the diverse range of merchants accepting Bitcoin payments, from supermarkets and cafés to doctors and car washes. However, the most frequently occurring types of merchants are those in the food and drink industry.

The analysis presented above provides insights into the general types of merchants accepting Bitcoin payments globally. Due to the data quality issues described above, it is not possible to make inferences about the global state of merchants accepting Bitcoin payments. In the following section, we mitigate this limitation by considering smaller geographical regions corresponding to BTC Map communities that contain a relatively large number of merchants and where the data quality is high.

Merchant spatial analysis

In this section, we present a spatial analysis of merchants accepting Bitcoin payments. Figure 4 displays a global heat map showing the locations of the set of merchants tagged with the key-value pair "currency:XBT=yes" on the date of our analysis. From this map, we can see that merchants are not uniformly distributed over space and are instead clustered in a relatively small number of geographical regions. Geographical regions with most merchants include North America, Central America, South America, Europe, Southern Africa and Southeast Asia.

To gain a greater insight into the global spatial distribution of merchants, we considered country boundaries as defined by the level 0 world administrative boundaries published by the World Food Programme (UN agency) (OpenDataSoft 2024). These

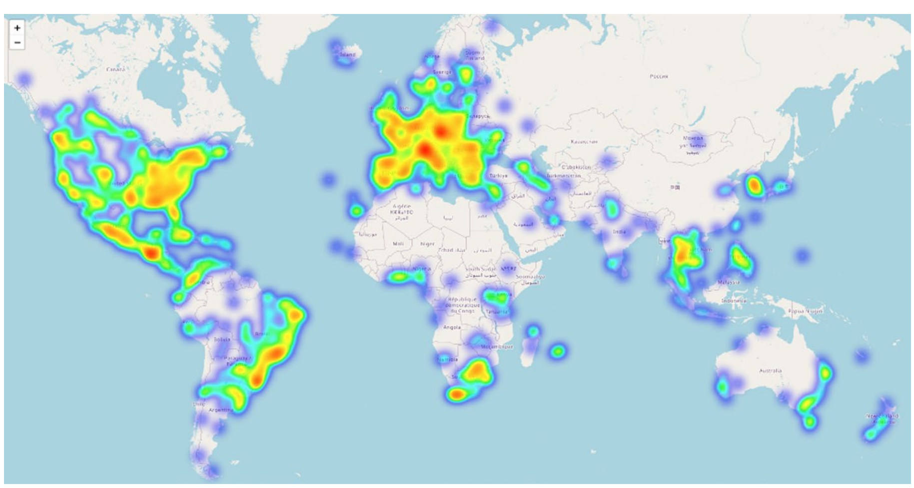


Fig. 4 A global heat map showing the locations of the set of merchants tagged with the key-value pair "currency:XBT=yes" on 1 July 2024 is displayed

boundaries correspond to country boundaries and non-sovereign territory boundaries such as French overseas. In the interests of being concise, we refer to all these countries and territories as countries. Of the 256 countries that are defined, only 131 contained at least one merchant accepting Bitcoin payments. This reflects either the existence of no merchants accepting Bitcoin payments in these countries, poor quality BTC Map data for these countries or both. Table 3 displays fifty countries with the greatest number of merchants accepting Bitcoin payments, along with the number verified in the past twelve months. We can see that both the number of merchants and the corresponding percentage verified in the past twelve months varies greatly. For example, 95% of the merchants in the Czech Republic have been verified in the previous twelve months but only 38% of the merchants in Germany have been verified in the previous twelve months. Unsurprisingly, we found that in most countries the vast majority of merchants were located in larger urban areas. For example, by inspecting the locations of merchants in the Czech Republic displayed in Figure 3, we can see that the majority are located in the cities of Prague, Brno and Ostrava located in the northwest, southeast and east of the country, respectively.

As described in Section "Measuring the quality of merchant data", to encourage the success of the crowdsourcing approach to quality assurance, BTC Map provides the

Table 3 Fifty countries with the greatest number of merchants accepting Bitcoin payments ordered by number plus the corresponding number verified in the past twelve months

Country	No. Merchants	No. Verified	Country	No. Merchants	No. Verified
Brazil	1,055	881	Philippines	81	9
United States of America	1,017	706	Belgium	72	28
Czech Republic	857	800	Netherlands Antilles	71	70
Italy	834	560	Costa Rica	69	24
South Africa	510	116	Venezuela	62	15
Germany	502	193	Romania	52	44
Switzerland	497	235	Republic of Korea	50	42
Mexico	472	76	Honduras	48	31
El Salvador	434	328	Colombia	41	32
Spain	328	264	Isle of Man	38	2
Canada	320	262	Greece	37	32
Poland	286	245	New Zealand	35	22
Netherlands	267	187	Cuba	29	29
Georgia	250	237	Dominican Republic	26	23
United Kingdom	233	116	Finland	24	15
Guatemala	204	63	Japan	23	12
Argentina	197	173	Croatia	21	13
France	149	86	Tanzania	21	16
Slovakia	138	126	Ireland	20	6
Bulgaria	125	106	Iran	20	16
Australia	113	51	Kenya	19	14
Austria	112	43	Chile	18	16
Portugal	101	83	Lebanon	17	8
Thailand	89	81	Malaysia	17	7
Madeira Islands	86	86	Armenia	17	10

ability to create communities. On the date of our analysis, BTC Map contained 457 communities. Of these, 340 communities contained at least one merchant accepting Bitcoin payments. Furthermore, 130 communities contained 10 or more merchants accepting Bitcoin payments. Table 4 displays the fifty communities with the greatest number of merchants accepting Bitcoin payments plus the corresponding number verified in the past twelve months. The five communities Satoshi Spritz, Einundzwanzig Deutschland, Bitcoin Association Switzerland, Dezentralschweiz and Dwadzieścia Jeden with the greatest number of merchants all correspond to countries. For example, Satoshi Spritz corresponds to Italy. As previously mentioned, most communities correspond to urban regions, though the permissionless nature of BTC Map allows contributors to add larger communities. The percentage of merchants verified in the previous twelve months varies considerably between communities. For example over 90% of the merchants in the communities of Jednadvacet Praha and Bitcoin Berlín - El Salvador have been verified in the past twelve months. On the other hand, only 36% of the merchants in the community Lugano Plan B have been verified in the past twelve months.

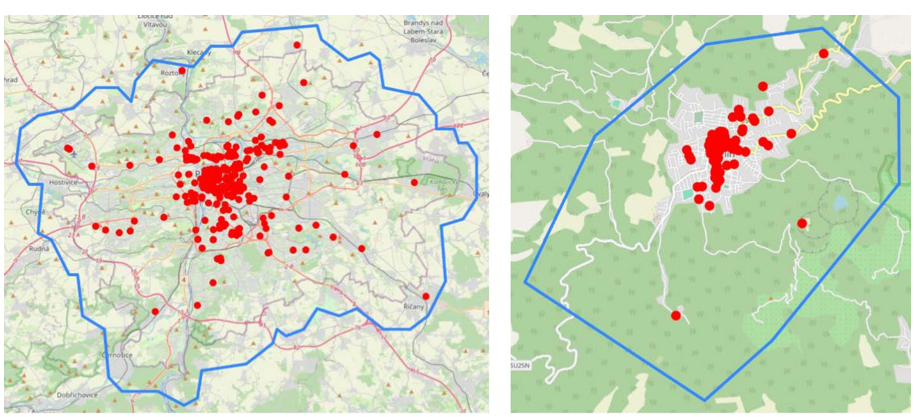
Given that many of the communities have data of lower quality, we decided to focus our analysis on the communities of Jednadvacet Praha and Bitcoin Berlín - El Salvador because both communities contain a relative large number of merchants and,

Table 4 The fifty communities with the largest number of merchants that accept Bitcoin payments, along with the number verified in the past twelve months

Community	No. Merchants	No. Verified	Community	No. Merchants	No. Verified
Satoshi Spritz	836	560	BitDev Chilangos	59	18
Einundzwanzig Deutschland	500	193	Rome Bitcoin Forum	56	39
Bitcoin Association Switzerland	498	235	Vancouver Bitcoiners	56	44
Dezentralschweiz	498	235	Satoshi Spritz Milano	55	32
Dwadzieścia Jeden	287	246	Berlin 2140	53	29
Jednadvacet Praha	269	243	Satoshi en Venezuela	51	6
Lugano Plan B	262	95	Einundzwanzig Berlin	49	26
Bitcoin é aqui! Rolante	203	142	São Paulo - Go BTC	49	48
Mi Primer Bitcoin	168	107	Bitcoin Valley	49	41
Bitcoin Island Philippines	163	13	La cherada bitcoiner	46	34
Bitcoin Bulgaria	134	114	Bitcoin Embassy London	44	30
Bitcoin Berlín - El Salvador	115	115	Colorado Bitcoin	44	23
Bitcoin Austria	114	45	London Bitcoin Space	44	30
Porto Alegre Bitcoin	111	85	Isle of Man	43	2
Free Madeira	93	93	Bitcoin Jungle	41	10
Bitcoin Lake Guatemala	89	11	Satoshi Spritz Rovereto	37	34
Bitcoin Night	75	73	Barcelona Bitcoin Only	36	27
Belgian Bitcoin Embassy	72	27	Grand Paris	35	20
Jednadvacet Brno	72	66	Bitcoin Paris	35	20
Arnhem Bitcoin City	71	68	Greek Bitcoin Network	35	30
BTC Curacao	71	70	BitDevs Amsterdam	34	16
Dwadzieścia Jeden Warszawa	66	64	Bitcoin Montreal	34	29
Bitshack	66	19	De Bitcoin Meetup	34	16
Bitcoin Community Roatan	60	40	Montanha Bitcoin	34	27
Bitcoin MaxiMex Club	59	18	Bitcoin Social Club MADRID	32	25

as mentioned above, a large percentage of these have been verified in the past twelve months. These communities principally contain the cities of Prague in the Czech Republic and Berlín in El Salvador respectively, and are displayed in Figure 5. The Jednadvacet Praha community contains 269 merchants and corresponds to a region of 735 square kilometres. The city of Prague contained in this community has a population of approximately 1.4 million. The Bitcoin Berlín - El Salvador community contains 115 merchants and corresponds to a region of 19 square kilometres. The city of Berlín contained in this community has a population of approximately 20 thousand. The maps in Figure 5 show that in both cases the majority of merchants are located in the city centre. The Bitcoin Berlín - El Salvador is a high profile community; an article describing its growth was published in Bitcoin Magazine (Bitcoin Magazine 2024). In this article, the authors attribute the growth in the number of merchants accepting Bitcoin payments in this region to the dedication of a few individuals who successfully promoted the benefits of using Bitcoin as a medium of exchange.

Table 5 displays the set of 46 key-value pairs ordered by frequency for merchants accepting Bitcoin payments in the Jednadvacet Praha community. Four of the five most frequently occurring key-value pairs are: amenity - restaurant, amenity - cafe, amenity - bar and amenity - pub. This indicates that most merchants belong to the food and drink industry. Other less frequently occurring types of merchants include hairdressers and photographers. Table 6 shows 50 most frequently occurring tag key-value pairs for all features in the Jednadvacet Praha community. That is, considering all features, not just those with the key-value pair “currency:XBT=yes”. For example, the most frequently occurring tag is “amenity=bench”, and in most cases a feature with this tag would not also have the tag “currency:XBT=yes”. By comparing the counts in Table 5 and Table 6, we can estimate the percentage of merchants of a given type accepting Bitcoin payments. For example, 154 merchants accept Bitcoin payments with the tag “amenity=restaurant”. On the other hand, there is a total of 2,648 with the tag “amenity=restaurant”. Therefore, an estimate of the percentage of merchants with the tag “amenity=restaurant” accepting Bitcoin payments is 154/2648 or approximately 6%. An estimate of the percentage of



(a) (b)

Fig. 5 Merchants tagged with the key-value pair “currency:XBT=yes” on 1 July 2024 in the city of Prague in the Czech Republic and the city of Berlín in El Salvador are displayed in (**a**) and (**b**) respectively. The region boundaries and merchants are represented by blue lines and red circles respectively

Table 5 The set of 46 tag key-value pairs ordered by frequency corresponding to merchants who accepted Bitcoin payments in the Jednadvacet Praha community in the Czech Republic

Tag Key - Value Pair	No. Merchants	Tag Key - Value Pair	No. Merchants
amenity = restaurant	154	leisure = sports_centre	1
amenity = cafe	21	sport = squash	1
amenity = atm	18	craft = brewery	1
amenity = bar	9	shop = bakery	1
amenity = pub	8	office = it	1
shop = hairdresser	7	shop = cannabis	1
craft = photographer	3	leisure = fitness_centre	1
office = company	3	sport = fitness	1
amenity = bureau_de_change	3	shop = country_store	1
office = architect	3	shop = stationery	1
shop = beverages	2	shop = laundry	1
amenity = fast_food	2	office = coworking	1
shop = electronics	2	tourism = hotel	1
shop = clothes	2	leisure = sauna	1
shop = tattoo	2	tourism = apartment	1
shop = kiosk	2	tourism = gallery	1
healthcare = physiotherapist	2	shop = mobile_phone	1
shop = water_sports	1	craft = electrician	1
office = yes	1	craft = painter	1
shop = confectionery	1	craft = restoration	1
leisure = hackerspace	1	shop = farm	1
shop = bicycle	1	shop = pasta	1
shop = coffee	1	shop = massage	1

merchants with the tag “amenity=cafe” accepting Bitcoin payments is 21/938 or approximately 2%. These relatively small percentages imply that the relative use of Bitcoin as a medium of exchange in this community is currently small.

Table 7 displays the 50 most frequent key-value pairs, ordered by frequency, for merchants accepting Bitcoin payments in the Bitcoin Berlín - El Salvador community. Similar to the previous community discussed, most merchants belong to the food and drink industry. However, the diversity of merchant types in the Bitcoin Berlín - El Salvador community is greater, with a larger percentage of key-value pairs not corresponding to the food and drink industry. Table 8 displays the 50 most frequently occurring tag key-value pairs for all features in the Bitcoin Berlín - El Salvador community. As before, by comparing the counts in Table 7 and Table 8, we can estimate the percentage of merchants of a given type accepting Bitcoin payments. An estimate of the percentage of merchants with the tag “amenity=restaurant” accepting Bitcoin payments is 25/33 or approximately 76%. An estimate of the percentage of merchants with the tag “shop=supermarket” accepting Bitcoin payments is 9/9 or 100%. These relatively large percentages imply that the relative use of Bitcoin as a medium of exchange in this community is large. However, the absolute use measured in terms of the total number of merchants is still small.

Table 6 The fifty most frequently occurring tag key-value pairs plus counts in the Jednadvacet Praha community in the Czech Republic

Tag Key - Value Pair	No. Key-Value Pairs	Tag Key - Value Pair	No. Key-Value Pairs
amenity = bench	13,543	shop = clothes	601
amenity = parking	9,690	sport = climbing	553
leisure = garden	8,061	amenity = bar	500
amenity = recycling	3,477	amenity = school	488
tourism = information	3,130	amenity = waste_disposal	471
amenity = restaurant	2,648	amenity = pub	457
leisure = pitch	2,559	shop = hairdresser	423
amenity = waste_basket	2,461	amenity = kindergarten	395
amenity = bicycle_parking	2,384	sport = soccer	391
amenity = vending_machine	1,948	tourism = viewpoint	377
amenity = parking_space	1,923	amenity = toilets	374
leisure = playground	1,704	shop = supermarket	365
amenity = shelter	1,131	amenity = pharmacy	348
amenity = cafe	938	healthcare = pharmacy	345
amenity = post_box	818	amenity = place_of_worship	332
shop = convenience	812	leisure = sports_centre	315
amenity = parking_entrance	803	leisure = picnic_table	304
leisure = park	777	sport = multi	299
amenity = fast_food	772	amenity = fountain	297
tourism = artwork	764	amenity = bank	280
amenity = parcel_locker	713	sport = fitness	271
leisure = swimming_pool	702	amenity = charging_station	270
sport = tennis	694	tourism = attraction	246
amenity = atm	663	leisure = fitness_station	237
tourism = hotel	621	shop = florist	236

Consideration of micro- and macroeconomic factors

A comprehensive analysis of micro- and macroeconomic factors in Bitcoin adoption is beyond the scope of the current study. In this section, we aim to demonstrate types of analyses possible that in the future may be able to provide more interesting insights on the reasons for different Bitcoin spending patterns. Conveniently, the OSM reverse geocoding tool Nominatim uses the ISO3166-2-lvlX notation, which is used to represent different administrative levels within a country. The ISO 3166-2 standard is part of the ISO 3166 international standard for defining codes that represent the subdivisions of countries (e.g. states, provinces, regions). The suffix lvlX refers to the administrative level within a country, with lower numbers representing larger divisions and higher numbers representing smaller subdivisions. This enables the study of Bitcoin spending patterns at a macroeconomic level. For illustration purposes, we focused on mid-tier subdivisions (i.e. level lvl4) to analyse Bitcoin adoption in American states. The regulatory landscape for Bitcoin and other cryptocurrencies in the United States varies significantly across states. Some states have embraced digital assets, proposing or enacting legislation to integrate them into their financial systems, while others have imposed strict regulations or have yet to address the issue comprehensively. We integrated the BTC Map data with USA Bitcoin reserve status by state (Bitcoin Reserve Monitor 2025)

Table 7 The fifty most frequently occurring tag key-value pairs plus counts corresponding to merchants who accepted Bitcoin payments in the Bitcoin Berlín - El Salvador community in El Salvador

Tag Key - Value Pair	No. Merchants	Tag Key - Value Pair	No. Merchants
amenity = restaurant	25	shop = dairy	1
shop = supermarket	9	shop = beverages	1
shop = convenience	7	amenity = community_centre	1
amenity = cafe	5	craft = key_cutter	1
shop = clothes	5	shop = stationery	1
amenity = fast_food	4	amenity = atm	1
shop = mobile_phone	3	shop = garden_centre	1
tourism = hotel	3	tourism = hostel	1
shop = yes	3	amenity = car_rental	1
amenity = internet_cafe	3	shop = laundry	1
shop = gift	3	office = financial_advisor	1
shop = accessories	2	amenity = veterinary	1
shop = hairdresser	2	shop = motorcycle_repair	1
shop = hardware	2	shop = florist	1
shop = butcher	2	craft = metal_construction	1
amenity = fuel	1	shop = games	1
shop = printer_ink	1	amenity = pharmacy	1
shop = shoes	1	healthcare = pharmacy	1
shop = party	1	shop = houseware	1
craft = handicraft	1	shop = beauty	1
tourism = attraction	1	shop = electronics	1
amenity = car_wash	1	tourism = motel	1
shop = coffee	1	tourism = guest_house	1
amenity = bar	1	office = lawyer	1
shop = general	1	craft = upholsterer	1

to analyse the relationship between this status and Bitcoin merchant adoption. The status is divided into four categories: proposed (20), not proposed (25), rejected (3) and in progress (2). We compared the first two categories of states, i.e. proposed vs not proposed. Further, to normalise the state data for fair comparison, we used information from additional sources. Specifically, we used the official USA state population estimates from the US Census Bureau (US Census Bureau 2023). In addition, we used the data from the US Census Bureau's Statistics of US Businesses (SUSB) and the Small Business Administration (SBA). These data include all registered businesses, including small and large enterprises.

Figures 6 and 7 show the distribution of merchants per million people and per million businesses, respectively. As all p-values were less than 0.05 (see Table 9), Shapiro-Wilk test confirmed that the data were not normally distributed. Hence, we proceeded to compare whether there is a significant difference in the median between the two lists using the Mann–Whitney U test. The p-values obtained for data normalised by population and businesses were 0.5655 and 0.4858, respectively. As both p-values were found to be greater than 0.05, we fail to reject the null hypothesis, meaning there is no significant difference.

Table 8 The fifty most frequently occurring tag key-value pairs plus counts in the Bitcoin Berlín - El Salvador community in El Salvador

Tag Key - Value Pair	No. Key-Value Pairs	Tag Key - Value Pair	No. Key-Value Pairs
amenity = restaurant	33	shop = florist	2
shop = supermarket	9	shop = beauty	2
shop = convenience	9	shop = bakery	2
shop = clothes	8	amenity = ice_cream	2
amenity = place_of_worship	8	shop = motorcycle_repair	2
leisure = park	8	shop = butcher	2
amenity = cafe	7	leisure = pitch	2
shop = hardware	5	sport = soccer	2
amenity = school	4	tourism = camp_site	1
tourism = hotel	4	tourism = viewpoint	1
shop = yes	4	amenity = townhall	1
shop = gift	4	shop = kiosk	1
amenity = fast_food	4	shop = printer_ink	1
amenity = hunting_stand	3	shop = party	1
shop = mobile_phone	3	craft = handicraft	1
amenity = internet_cafe	3	tourism = attraction	1
tourism = guest_house	2	amenity = car_wash	1
tourism = hostel	2	shop = coffee	1
amenity = atm	2	amenity = bar	1
amenity = fuel	2	shop = general	1
shop = accessories	2	shop = dairy	1
shop = shoes	2	shop = beverages	1
shop = hairdresser	2	amenity = community_centre	1
shop = stationery	2	craft = key_cutter	1
amenity = veterinary	2	shop = garden_centre	1

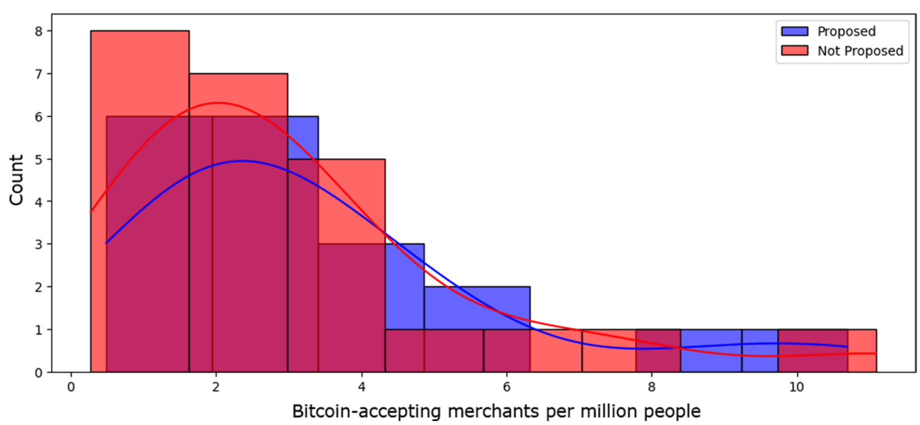


Fig. 6 The distribution of Bitcoin-accepting merchants normalised by population

To illustrate potential analyses involving microeconomic factors, we singled out tags with keys healthcare and office, and extracted distribution of their values globally as well as the USA alone (see Figs. 8 and 9). Some interesting patterns can be observed. For example, alternative medicine is the third most frequent type of a healthcare provided

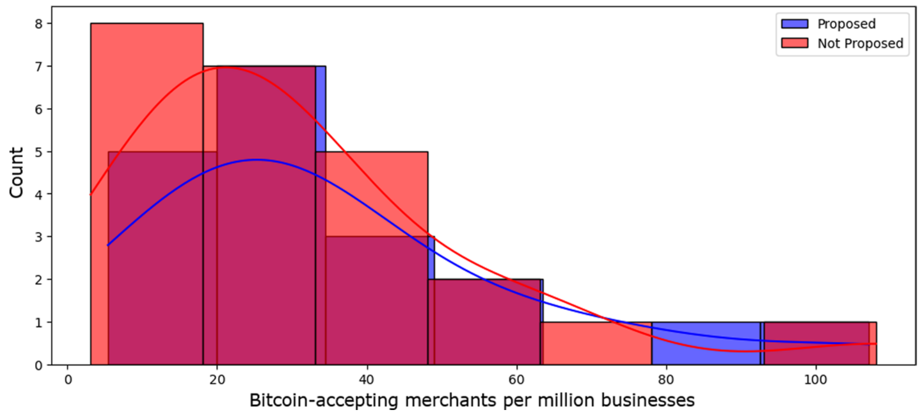


Fig. 7 The distribution of Bitcoin-accepting merchants normalised by the number of businesses

Table 9 Testing the normality of merchant data normalised by population and businesses, respectively. The table provides *p*-values obtained using the Shapiro-Wilk test

	Population	Businesses
Proposed	0.0025	0.0156
Not proposed	0.0006	0.0020

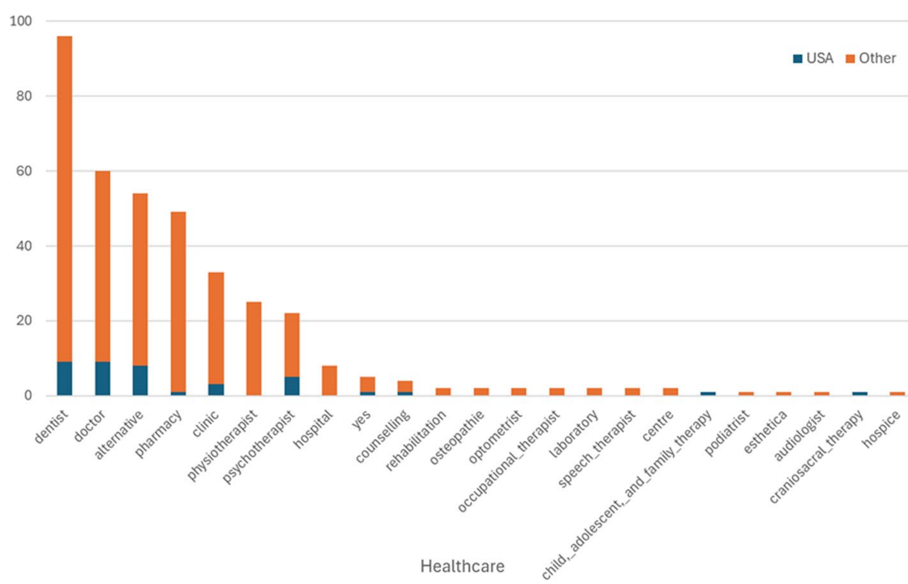


Fig. 8 The distribution of values of the healthcare tag

both globally and nationally. Libertarians are more likely to use alternative medicine due to their core beliefs in personal freedom, scepticism of government regulations and preference for decentralised solutions. This seems aligned with the observation of Perkins and Cross (2024) who found a moderate correlation between libertarian views and Bitcoin ownership.

On the other hand, IT was the second most frequent type of office accepting Bitcoin both globally and the third nationally. This may be due to several key factors related to

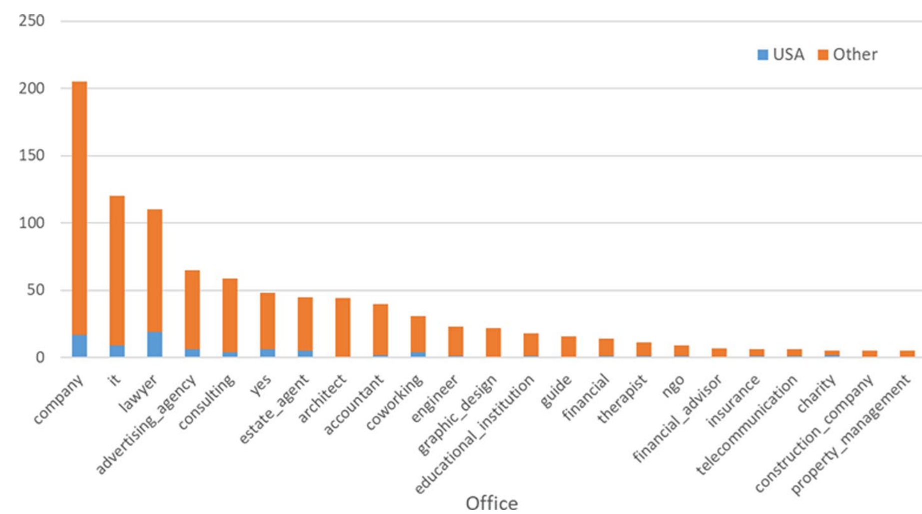


Fig. 9 The distribution of values of the office tag

their industry, mindset, and familiarity with technology. Although not uniformly libertarian, the IT industry exhibits stronger libertarian tendencies compared to other industries. In addition, many IT professionals are more familiar with digital and decentralised technologies. Conversely, many IT firms serve tech-savvy customers and early adopters, some of whom already use Bitcoin.

The continued growth and curation of the crowdsourced BTC Map data will enable more sophisticated economic studies of Bitcoin to be conducted in the future.

Discussion

Our spatial analysis of merchants provides a granular, ground-level perspective on Bitcoin adoption that complements and challenges existing literature, which has largely focused on national-level statistics, user surveys or blockchain data. The findings from this study allow for a direct engagement with modern theories of technology adoption and economic sociology, revealing an interplay between macro-economic drivers, community-level dynamics and individual merchant decisions.

Micro-level dynamics versus macro-economic drivers

A significant body of research points to macro-economic factors such as high inflation, distrust in traditional financial systems and favorable national regulations as primary drivers of cryptocurrency adoption (Saiedi et al. 2021). While these factors undoubtedly shape the environment for adoption, our findings suggest they are insufficient to explain the emergence of functional, local payment ecosystems. The stark contrast between the merchant landscapes in Prague and Berlín, El Salvador, is illustrative. Despite El Salvador's national policy that had made Bitcoin legal tender, the high density and diversity of adoption in the city of Berlín is attributed in the Bitcoin community not to top-down policy, but to the dedicated, grassroots efforts of a few individuals.

This observation underscores the critical role of social influence in economic action. Large-scale experiments in online networks have shown that social signals are a primary driver of the spread of behaviours, from political mobilisation to consumer choice (Bond et al. 2012). The success in Berlín, El Salvador, can be interpreted as a case where 'community champions' or early adopters actively created a network of trust and utility, lowering the barrier to entry for other local merchants. This suggests that for Bitcoin to transition from a speculative asset to a widely used medium of exchange, bottom-up, socially-driven initiatives may be as, or even more, critical than top-down legislative support. Our finding that there is no significant difference in merchant adoption in U.S. states with proposed pro-Bitcoin legislation versus those without further supports this view.

Merchant types and theories of technology acceptance

Our analysis revealed a global prevalence of merchants in the food and drink industry (e.g. restaurants, cafés, bars). This specific pattern of adoption can be contextualised using contemporary models of technology acceptance, such as the extended Unified Theory of Acceptance and Use of Technology, which emphasises factors like hedonic motivation and habit in consumer technology use (Venkatesh et al. 2012). For high-frequency, low-value transactions typical of the hospitality sector, the ease of use and customer experience are critical. The adoption by these merchants may indicate that they perceive Bitcoin payment systems as sufficiently user-friendly for both their staff and technology-savvy customers. Furthermore, the motivation may not stem from replacing traditional payments, but from attracting a new demographic or signalling technological progressiveness, aligning with hedonistic or identity-based drivers of adoption.

This contrasts with the drivers for corporate adoption, where systematic reviews have shown that the decision to integrate blockchain technology is often driven by anticipated performance gains, competitive pressure and organisational readiness rather than consumer-facing motivations (Frizzo-Barker et al. 2020). The concentration in hospitality suggests that Bitcoin's current role as a medium of exchange is strongest in consumer-facing environments where the social and experiential aspects of the transaction are high.

On-the-ground evidence for ideological drivers

Our data provides tangible, spatial evidence supporting foundational reviews on the motivations behind Bitcoin adoption. Foundational economic analyses of Bitcoin identify its appeal not just as a novel payment system, but also as a censorship-resistant and decentralised alternative to conventional finance (Böhme et al. 2015). Our finding that 'alternative' healthcare and IT services are among the more frequent office types accepting Bitcoin gives a commercial dimension to these non-financial motivations. The prevalence of merchants in these specific sectors suggests that for a subset of the business community, the decision to accept Bitcoin is not purely an economic calculation but is also an expressive act that aligns with values of technological pioneering and skepticism of centralised institutions. The spread of such behaviours is heavily influenced by network structure, where adoption can be accelerated through social reinforcement within ideologically-aligned communities (Centola 2010).

Open questions and future directions

Finally, our findings also address several open questions in the literature. First, while prior work highlights inflation and distrust in financial institutions as macro-level drivers of adoption (Saiedi et al. 2021), our analysis suggests that grassroots, community-driven dynamics may be equally decisive, raising the question of whether national policy or local networks ultimately drive sustainable adoption. Second, the predominance of hospitality merchants accepting Bitcoin invites further research into whether such concentration reflects a transient stage in technology diffusion or a persistent niche of consumer-facing sectors, as suggested by prior work on online retailers (Jonker 2019). Third, the notable presence of alternative healthcare and IT service providers aligns with findings that ideological commitments and libertarian-leaning demographics correlate with Bitcoin use (Perkins and Cross 2024), but it remains an open question whether these ideological motivations will continue to underpin adoption as Bitcoin matures. In this way, our spatial analysis not only complements existing macroeconomic and survey-based studies, but also highlights how micro-level merchant decisions can inform ongoing debates about the drivers, sectoral distribution and long-term trajectory of Bitcoin as a medium of exchange.

Conclusions

To the best of the author's knowledge, this work represents the first spatial analysis of the use of Bitcoin as a medium of exchange. In the introduction to this article, we proposed four research questions and focused all subsequent analysis around these questions. In the following, we consider and attempt to answer each of these questions in turn.

The first research question asked, how can we extract the necessary merchant data from BTC Map to perform a spatial analysis of the use of Bitcoin as a medium of exchange? In our research we demonstrated that the data in question can be extracted from OSM, upon which BTC Map is built, using free and publicly available APIs. The second research question asked, how can we measure the quality of this data to ensure reliable analysis? Due to the use of crowdsourcing, the quality of BTC Map can vary spatially where quality is measured along several dimensions. Hence performing a global analysis of merchants accepting Bitcoin payments using BTC Map data is not feasible. Drawing from existing research on the topic of geographical information crowdsourcing, it is possible to define heuristic measures of quality. These heuristic measures can in turn be used to identify smaller geographical regions with high quality merchant data. The third research question asked, what insights can be gained about the use of Bitcoin as a medium of exchange in geographical regions with high quality merchant data? Since BTC map only contains data about the locations and types of merchants accepting Bitcoin payments, it can only be used as an indicator of the use of Bitcoin as a medium of exchange. Despite this data limitation, our analysis and modelling reveal several insights. In those regions where there exists a relatively larger number of merchants accepting Bitcoin payments, we found that most merchants are in the food and drink industry. Furthermore, the proportion and diversity of merchants that accept Bitcoin payments vary spatially. Most geographical regions contain little or no merchants that accept Bitcoin payments. However, in some regions, such as Berlín in El Salvador, there exists a large proportion of merchants that accept Bitcoin payments. The final research question asks, how can the quality of BTC Map information be improved to enable a more comprehensive analysis of the use of Bitcoin as a medium of exchange? As mentioned above, BTC Map data can only be used as an indicator of this use. It cannot be used as a measure of the number or proportion of payments made using Bitcoin. To accurately estimate this, one would need additional data regarding the proportion of payments each merchant receives via Bitcoin. This data could potentially be obtained by conducting a representative survey of merchants. Ideally, a ground survey would be performed to avoid selection issues that may occur if the survey was conditioned on respondents being remotely contactable. A significant proportion of BTC Map's merchant data is contributed by a relatively small number of users. This potentially negatively affects data quality as many merchants are remotely added and verified without ground surveys. This centralisation can in part be attributed to the project being relatively new having only launched in 2022. It is hoped that, as the project's popularity increases over time, the number of contributors will increase and decentralisation will improve. However, we anticipate that some remote addition and verification of merchants will always be necessary to address gaps in the data. In this work, we assessed data quality by determining whether merchant data had been recently verified and performed an empirical analysis of past verifications to justify the use of this approach. However, there exists the potential to develop more robust methods for assessing data quality that, for example, integrate some aspect of contributor trust.

Beyond the research questions considered in this work, there are several other potential avenues for future research and analysis of the use of Bitcoin as a medium of exchange. For example, the analysis presented only considers the merchants who existed on the date 1st July 2024. Future research could consider a temporal analysis of how the use of Bitcoin as a medium of exchange develops over time.

Acknowledgements
The authors would like to sincerely thank Igor Bubelov and Nathan Day from the BTC Map project for answering many questions about the origins and inner workings of the project.

Author Contributions
Padraig Corcoran lead and contributed to all aspects of the research. Anqi Liu contributed to the writing of the initial and revised versions of the article. Jing Chen contributed to the writing of the initial and revised versions of the article. Irena Spasic contributed to the writing of the initial and revised versions of the article. She also contributed to the data analysis.

Funding
This research was funded in part by the Rapid Response Fund of the AI for Collective Intelligence (AI4CI) hub, a UKRI National AI Research Hub (grant ref EP/Y028392/1).

Data Availibility
No new data was created during this study. All data used in our analysis is contained in the OpenStreetMap database and is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF).

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
Not applicable.

Received: 6 September 2024 Accepted: 6 November 2025
Published online: 26 November 2025

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