THE UNIVERSITY OF CHICAGO

Examining the Competition, Choices, & Growth of Cryptocurrency Exchanges

A BACHELOR THESIS SUBMITTED TO

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Abstract

In nascent markets, liquidity is always one of the biggest challenges. For markets to gain popularity, they need to be accessible and reachable for those who are interested. As such, cryptocurrency exchanges play a crucial role in the onboarding of new entrants into the market. Exchanges act as a turnstile that allows new market entrants to participate in this new system. In this role, they also become the centralized point of scrutiny, attack (both in terms of media as well as cybersecurity concerns), and regulation. How they operate, however, provides an incredible window on the processes that govern nascent markets. In particular, we examine the existence of embedded costs, network effects, frictions, and barriers (as well as their removals) that are captured by studying how exchanges operate as a rent collector in a growing market. With this information, we uncover how exchanges act similarly to venture capital firms as they decide to differentiate themselves in size and strategy in regards to the adoption and listing of new coins, tokens, and projects en route to different market shares and profit maximization. We conclude that offering more liquid trading pairs on a platform leads to growth in market share, which leads to increased revenue for the exchange.

Acknowledgements

In a 1999 interview, Milton Friedman said: "I think that the internet is going to be one of the major forces for reducing the role of government the one thing that's missing but that will soon be developed is a reliable "e-cash" the method whereby on the Internet you can transfer funds from A to B without knowing B or B knowing the way in which I can take a $ 20 bill and hand it over to you and there's no record of where it came from and you may get that without knowing who I am that kind of thing will develop on the internet and that will make it even easier for people to use the Internet" . It is only fitting that we study Milton's "e-cash" dream two decades later, at the University of Chicago, in the first of hopefully many more papers on blockchain technology and cryptocurrencies at the university.

I would like to thank my thesis advisor Lawrence D.W. Schmidt and Professor Victor O. Lima and Professor Kotaro Yoshida for leading our thesis workshop.

I began my university career with virtually no coding skills. Fintech & cryptocurrencies gave me the motivation to finally learn how to build things myself. Blockchain is a gateway for learning when used correctly, but with great power comes great responsibility. It is up to us to utilize blockchain as an impetus for positive change and solutions to today's biggest challenges. This paper will be one of many steps to hopefully help demystify the world of blockchain and cryptocurrencies en route to actually solving world problems.

This work would not have been possible without the entrepreneurs, fellow classmates, and friends that have helped me learn about the world of cryptocurrencies and blockchain over the last three years. I've hat the fortune to work at incredible firms, on inclusive teams, and with unbelievably great people. Thank you all.

Thanks to my parents (who own no cryptocurrencies - yet) for giving me the love to learning. If you want to donate some crypto to my parents, or if this thesis has taught you something, and you would like to help further the education of blockchain and cryptocurrencies, please feel free to send to the following addresses (ERC-20 tokens and Cryptokitties accepted too!):

BTC: 3ERzucVSM3CnMYv5nhKB5ktfuw2DgpfxJM
ETH: 0x5399D3acfd305Ee1A344Be038702F22387fedc4e

If you have further inquiries about blockchain/crypto, follow me on Twitter @calchulus!

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1 Foreword: A section on Cryptocurrencies

What is cryptocurrency?

Is it a bubble? A currency? An asset? A security? According to Wikipedia, a cryptocurrency is a "digital asset designed to work as a medium of exchange that uses cryptography to secure its transactions, control the creation of additional units, and verify the transfer of assets." What that really means is that cryptocurrencies take on the many use-cases of money without a centralized entity, instead relying upon some computer-based mechanism to determine overall supply and settle transactions without an individual mediator. Using the concept of blockchain technology, cryptocurrencies can be sent from one user's virtual wallet to another by way of a distributed ledger. A private ledger is something like what a grocery store may have: a ledger of all the cash collected on a given week, an internal database of all the transactions or inventory to be kept track of. A distributed ledger is one that any individual can choose to access if they wish to audit the entity's books. Each individual cryptocurrency has its own distributed ledger - a record of all transactions that occur in that currency. Now, being able to simply view the ledger does little good if one can't prevent fraud and actually prevent false transactions and fraud from taking place. This where the cryptographic process - the crypto part of cryptocurrency - comes into play. Using a specific protocol or computer algorithm, computers, acting as nodes on this currency's network, keep a running tab on the entire network, and are rewarded the currency for finding "correct solutions" for verifying the validity of all transactions on the books. Much like a human is paid to act as a security guard or grocery clerk to verify that shoppers didn't sneak in a couple bell peppers into their shopping cart, the computers on the network aggregate, monitor, and ensure the legitimacy of each transaction, such that "double spending" cannot occur.

The "Double Spend Problem"

The fundamental innovation of bitcoin, the first major cryptocurrency, is that it solves the double spend problem. What this refers to is the common concern regarding digital currency - can't anyone just counterfeit some and create some out of thin air?

The classic example to illustrate this is Alice selling apples to Bob. When Alice sells apples in person to Bob, Alice expects some tangible cash in return. If Bob pays Alice the $ 3 Bob owes, Bob no longer has those $ 3 in possession, and cannot go turn around and try to hand Calvin the same money. How does cryptocurrency do this while being virtual? The answer lies within the decentralized ledger - because all the nodes running on the network hold a copy of the verified transactions, it can keep track of Bob's purchase with Alice, such that Bob's attempted transaction with Calvin would be void if he didn't have $ 3 in his

wallet to pay. And because cryptocurrency can only be mined (or generated) via a process set forth in the widely-spread open-source code, it is very difficult to successfully tamper all the copies of the ledgers across all computers on the particular network around the world. That does not mean that there can be no fraud, stealing of passcodes and private keys, spoofing if similar name currencies or websites, or other theft, but that the cryptocurrency's decentralized network, when done correctly, allows for a level of automated security and validity unprecedented in physical money history. It is no longer subject to the whims and political interventions of specific jurisdictions, except the world of the internet.

Decentralization is King

Yet another concern that frequently is raised about cryptocurrencies is that they're decentralized - that they are not backed by a central government or entity. However, here exactly lies the benefit of truly decentralized cryptocurrency - that the currency will always represented the majority rule of the people on that network. If at any point in time, the majority does not agree with any agent of power, they can decide to fork the code, cloning the underlying technology and building on top of it their desired features and changes, and then bring their network of users with them. Essentially, it's a pure democratic process where the simple majority wins. People no longer have the excuse that something is not how they like it - it's up to them to actually go and change it. That's unprecedented power.

Miners, those who run computers to help process transactions and information on the network, are on the individuals who can individually choose which networks to support, and thus by the action of which networks they choose to run on, they help sustain and "vote" for the stability of that network. Miners typically use CPUs (computer processing units), GPUs (graphics processing units), or ASICs (Intrigated Circuits) to process transactions on a network via the predetermined protocol. With many different cryptocurrencies out there, miners are able to choose whichever coin network that is well suited to be supported by their hardware, creating natural price competition. Consequently, a mining rig or individual would choose to leave a network that is no longer being used or supported and instead start to mine on another network; thus, the market would fairly efficiently allocate to more promising, valuable networks, constantly incentivizing innovation.

In a time of economic and geopolitical uncertainty, cryptocurrencies take on a very interesting role as a digital money for many around the world. In countries with hyperinflation, the devaluation of the local currency can be disastrous for individuals. Much as mobile money options tied to mobile phones, cell phone carriers, or transit cards have become the norm

in many developing countries in the world, cryptocurrencies offer access and transparency that is rather unprecedented. Because the cryptocurrency is governed by the code set forth by the community, it represents a degree of direct voting such that all informed users of the network have a say in the direction of the entity.

This does not, however, mean that cryptocurrencies are immune from attack or manipulation. One of the main goals of these cryptocurrencies is that when sufficiently decentralized, the probability of a harmful breach or downfall of the system itself becomes less and less likely. The importance of the network effect here cannot be understated. As a network grows, the number of nodes that need to agree upon a change (whether good or bad) becomes higher to achieve a simple majority. If any faction indeed decides that the majority network is not suiting their needs or has a vulnerability that they do not want to support, they can choose to go on and use or build their own network, but those who want to keep on going with the existing network may choose to without losing their way of life per se. This, using the concept of forking a repository (going in two different directions, diverging from this point) allows people to use and get exactly what they want, or more specifically more features of what they want. On the other hand, when a country has an internal civil war, bad leadership, or other internal conflicts that divide a nation and throw the economy or banking mechanisms into turmoil, the path to self-sufficiency is not so clean.

Game Theory

A classical game theory approach applies very neatly to participation within a cryptocurrency network. In a regular fiat currency set up with a central bank, there are many costs for the government to ensure that the monetary system is working, from setting up physical reserves, to spending leadership time on policy, etc. However, a robber may still choose rob a bank because it is the best expected payout for them to rob a bank and take on the potential consequences. We hope that jail, time, fines, bad reputation, and other punishments are enough to deter most people from rationally deciding to rob a bank. What mechanisms come into play in cryptocurrency, you might ask?

The Grocery Clerk Model

Well, networks pay rewards to miners for mining - the distribution of these rewards comes with each "block" of transactions that is processed, that is - a batch of transactions (much like a shift or day's worth of entries in a grocery store's system, database, or cash registers). When a mining computer come up with a correct cryptographic solution for that batch of transactions, it tacks on the new batch of correctly processed transactions to the new ledger,

essentially tacking on the block to the end of the chain, hence the term blockchain. As it does so, it includes its own wallet with a transaction to pay out the predetermined reward for solving the puzzle first, kind of like a student submitting a name and ID for a poetry contest, such that when he/she wins, she can receive the reward. Everyone that is watching (in this case, computer nodes on the network) is constantly keeping track of the full history of transactions, and will receive the update with the new batch of transactions. When these other computers pull from the network, they will see the new updated solution and start solving the next block of solutions. Just like the grocery store, the clerks call the next customers up in line, and keep processing. Occasionally, there may be problems with two people solving the problem within a very, very short time of each other, such that the later computer did not know that it was already solved - much like instant replay of the finish-line, the network can go ahead and check which one was first to accurately determine the winner, and resolve any conflict within the network of what is the current batch.

Which brings us back to game theory. In a real-world model, a clerk is incentivized not to steal from the register, or not give customers (or friends) freebies if everything is tracked, and that the missing bagel at the coffeeshop would cost the clerk some pay, or that the risk of being caught stealing leading to a potential loss of job or jail-time is a high enough deterrent.

In cryptocurrencies with proper protocols, the computer nodes also have disincentives to cheat - if the network is sufficiently quick enough to catch erroneous (whether purposeful or not) transactions and blocks, it will quickly dismiss the false chain and not propagate it. If the false chain is not propagated, then the proof of whatever transactions (such as paying oneself a bunch!) will not appear on the network, such that if an actor tried to pull the double spend, the other accepting nodes processing a future transaction from ill-gotten money would never see this transaction that provided the funds in the first place, and thus not allow the second spending opportunity to ever occur, and the bad actor will not be able to cash out even briefly achieved false transactions.

Further, when network protocols make the processing of the network sufficiently difficult (resource intensive), it would cost a bad actor more than the expected payout of a very unlikely chance of obtaining and successfully spending fraudulent transactions, thus disincentivizing nodes from not doing their job. If a machine is not doing the correct work, it has no shot of properly earning the reward, and thus the initial set-up costs, running electricity costs, and other opportunity costs of participating make it not worthwhile to try and cheat the

system. Conversely, the reward for mining must be high enough to meet the breakeven costs. Thus, many miners are based in countries with subsidized electricity (such as Mongolia/Inner China), or even college students in electricity-included dorms. In a classic expected payoff situation, someone with the capability of being a bad actor in the system should have a better incentive to make money in some other fashion, even if it means mining another coin.

Pseudonymity & Implications on Illicit Activity

A lot of the preconception surrounding cryptocurrencies is that it is only used by criminals and individuals attempting to conduct subversive or illicit activities. However, many cryptocurrencies, like bitcoin, are not truly anonymous. Because of the public nature of the blockchain and code, one can view a feed of all past transactions - thus, if one can tie an individual to a wallet ID (much like a username on social media - a unique address where all incoming/outgoing transactions/messages/information is sent), then any party looking to track down illicit activity can find all transactions involving that wallet.

In the case of withdrawal to (or purchase from) fiat currencies, most exchanges require KYC (Know Your Customer) and AML (Anti-Money Laundering) procedures, such as providing Social Security Numbers, bank account numbers, photo ID, proof of residency, etc. Even in the case of bitcoin ATMs, stringent security and individual information is logged prior to access to any funds. As a result, the privacy costs for someone truly looking to avoid detection would actually be much more conspicuous than using a cash-only operation. We will further examine this within this paper.

Distributed ledgers are just a fancy term for public accessible, shared, decentralized databases. This also means that sensitive information, such as amount of money in wallets, prices paid for recent transactions, and purchase points is actually very easy to track on publicly open databases once people and entities are associated with wallets. For example, if you knew that my address was "abcdefg0123456789" , you could see that I spent .XX bitcoin at this wallet address, which belongs to my dentist, .xx bitcoin at the university wallet (knowing how much I pay for tuition, the list goes on and on.

Thus, bitcoin is not the solution that most savvy fraudsters are now using. Instead, they rely on private coins that have security measures in place that block out amounts in transactions to outside parties, or other mechanisms that shroud the true value and parties involved in a transaction.

This kind of open access and automated capture of all business activity is unprecedented in terms of data collection, as an incredible amount and proportion of human activity is not captured by country-wide metrics and existing institutions. Many Cryptocurrency ATMs are reporting incredible amounts of transactions from individuals who do not have a bank account. Particularly in areas where the cost of carrying cash is high (such as the need for a security guard at a restaurant in a rough neighborhood), cryptocurrencies and other digital options provide a true value-add. Leaving a paper-trail may someday become a blockchain-trail.

Why middlemen provide value

At first, the thought of middlemen in a cryptocurrency world seems antithetical - that centralized platforms and ways of accessing cryptocurrency somewhat defeat the value of a cryptocurrency system that holds its own trust, rather than relying on the trust of a third party.

However, one only needs a quick look at a place like Localbitcoins.com to understand the implications of low liquidity.

One of the biggest problems that cryptocurrencies can potentially address is the underbanking of many underserved populations. For most of us, we're fortunate enough to have access to great credit card rewards, airline miles, banking bonuses, free payment services and apps like Venmo, and convenient transactions with Stripe, Square, and PayPal. Merchants may wince about 2.9% and 35 cent processing fees and credit card fees, but we're lucky that we're not amongst the population that utilizes the regressive-fee structures of wire transfers, payday loans, and other predatory financial practices that eat off value from the poorest of the poor.

Localbitcoins offers a glimpse into the value of access to additional markets: for those looking to purchase bitcoins online by sending money to an online bank account, the spread for online transactions is not particularly high - in fact, there sometimes can be overlapping orders between the bid and the ask, which means that the highest bid is greater than the lowest ask; however, this method of purchase leads itself to counterparty risk - will the other side follow through with the agreed upon amount of bitcoin or dollars? Thus, even if it's an apparent arbitrage violation, the time and effort necessary to contact both parties and pair them is often not worthwhile unless done in a systematic way, and that's what exchange platforms can offer. Exchanges provide an orderbook, by which people can list more of these offers than just one-off OTC offers, such that people can pluck off the best bids and asks off a list, and the third party exchange holds the coins on the platform to ensure the transaction

occurs smoothly, creating a liquid market.

While this seems contradictory to one of the key goals of cryptocurrencies - to prevent the need to trust the second party or an institutional third party (like the site itself) to ensure the transaction goes through, it sure does beat trying to message a random individual you've never met to meet at a parking lot or library to transact.

Essentially, LocalBitcoins acts as a Craigslist, and it is up to the users to communicate and agree upon the transaction. If people prefer to transact in person and meet up to exchange their cryptocurrency for cold hard cash (or vice versa) and reduce the risk of the other party failling to hold up their end of the bargain, users pay a dear price. Furthermore, those who do not have access to any online banking solutions are forced to use this route rather than the online route, as they cannot deposit online funds for a reputable fiat to crypto exchange (where we're back the the underbanking problem) or send directly to a remote individual on LocalBitcoins. As of writing, the current local spread between the bid and ask in Chicago is nearly $ 1000 on bitcoin, or between a 10-12% difference between the two spot prices. This is natural for an illiquid market; let's say I post a price very close to the current market price available on an online exchange, if I don't have some measures in place to remove my order after a certain amount of time, or if the price of a coin moves significantly, I expose myself to some volatility risk between the time I propose the offer and when someone else sees the offer and decides whether or not to take it.

The is where large exchanges also come into play - as a marker for such OTC transactions. If a popular exchange has a cryptocurrency that is trading for X dollars, and sufficient participants in a second market also have access to the first, the price will be fairly anchored to the large exchange price by the law of one price to prevent any arbitrage conditions. Otherwise, ther would be a persistant arbitrage available for all users. Thus, users on other platforms like LocalBitcoins refer to the price on their preferred online fiat-to-crypto exchange of their country (such as Coinbase here in the US) before they make an offer, such that they don't accidentally put a too high bid or a too low ask versus current online prices. This is a really unique illustration of the value of shopping around. Because every bitcoin is non-fungible, that is - each coin is the same good, just like one dollar bill with a certain serial number is the same in value as another dollar bill with a different serial number, any online/offline retailer is able to offer the same good, and thus people can shop around based on their own preferences and utility functions for the optimal purchase experience.

While the large bid-ask spread for bitcoin on LocalBitcoins may be significant, most true cryptocurrency exchanges have bid-ask spreads at one penny, the smallest possible difference without overlap in the orderbooks - on occasion, there's some slippage that occurs when a few orders are bought up, leading to a momentary few dollar gap that is quickly closed by

algorithmic traders that can place orders between the current bid-asks. The same goes for crypto to crypto exchange pairs as well.

In order to build trust in the counterparty, exchanges require users to deposit or purchase funds before posting an offer. Unless one is using margin trading, an individual cannot overextend themselves to offer up more than he/she owns. The exchange works in that individuals deposit USD or cryptocurrencies into their account in order to trade, much like a user would fund an options account, before they can list any positions they are willing to take with said account values.

Thus, illiquid markets such as LocalBitcoins have many shortcomings, from trust to large bid ask spreads. For those who are transacting large quantities (known as "whales"), OTC desks at places like Bitfinex (a Hong Kong based exchange) or at a trading firm like Cumberland/DRW offer the path of least slippage (loss of price when buying/selling on a thin orderbook). However, if we are interested the retail investor looking to buy or sell small amounts of cryptocurrencies, exchanges are the best place to understand the entry of individuals into the world of crypto.

2 Literature Review

Cryptocurrencies have gained a lot of mainstream attention over the last few years, and likewise, the amount of literature has grown a lot since I first began this thesis in September. Like most people, I initially was very interested in some sort of valuation on cryptocurrencies, trying to uncover if the price appreciations were simply apparitions, or actually something systemic demand and supply forces that drove prices upwards. Many of the measurements were very imprecise, as the price of a cryptocurrency can be attributed to many elements, not just some simple intrinsic value cost. Most of the research that has been done on the valuations of cryptocurrencies has mostly focused on some imperfect measure of network values, but few also took the approach at how people actually access this market: through exchanges. The practical situation is that if someone has zero cryptocurrency today, what must they do to get some? For most people, mining and directly working with the cryptocurrency is not quite user friendly, and startup costs for actually owning computer equipment to mine/acquire cryptocurrencies are prohibitively high for most market participants. Thus, purchasing cryptocurrencies on exchanges is the easiest route to go, and is the most fascinating route to uncover what goes into the purchase.

Jean Tirole's Nobel-prize winning work on participants in dual-sided marketplaces neatly ties together the practical implications of game theory, market power, and imperfect information within decision makers within these marketplaces.
In many ways, his work is incredibly extensible to the electronic financial markets. Ernkvist (2015) explored the growth and innovation of digital exchanges, and how they helped shape the regulatory environments in the fields they pioneered, manifesting their market-power into long-lasting effects on the capital markets.

Meanwhile, Aitkena et al. (2017) studied how the fragmentation traditional markets amongst many exchanges and liquidity providers. Especially in today's stage of cryptocurrency adoption, more liquidity options will allow for more options for more efficient markets, lower spreads, and better user experiences for consumers.

In a classic Industrial Organization model, cryptocurrencies provide a glimpse of primary and secondary markets for a large offering of different products. The primary markets are the creators and miners that produce and uphold the transaction networks that cryptocurrencies and blockchain technologies are used for. Many compare cryptocurrencies as commodities because of their fungibility, that is - one unit of a specific coin purchased on one exchange

is the same in functionality as another individual unit of the same coin purchased on another - much like a bushel of soybeans is treated the same as another bushel. Miners and technological investment, either through investment of time, computing power, or intellectual property, create some sort of commoditized product in the forms of tokens or coins. These miners and coders decide what coins and projects is most profitable to pursue, trying to profit maximize given their endowment of resources, and picking the coins and projects. These tokens and coins may either be exchanged directly for goods and services provided, or taken to exchanges, OTC trading desks, or 'darkpools' - anonymous asset liquidity options that do not publish a price on the market, rather taking market price for large orders that would affect market prices if the coins were traded on exchanges with thin orderbooks. Thus, either the miner/creator or someone that has transacted with a miner/mining pool will bring the token to the marketplace. Thus, traditional centralized cryptocurrency exchanges act

as a secondary market that allow users buy to and sell the different coins they may have, and cryptocurrency projects with tokens/coins to be listed on the exchange such that they can be traded. Thus, these exchanges act as the gatekeeper for the entrance and exit of the cryptocurrency markets. How they decide to provide liquidity and ease of access to each cryptocurrency effectively controls the potential for these coins to actually get into the hands of potential users, developers, evangelists, or other supporters of a system.

Gina Pieters has done some very fascinating work on apparent violations of Law of One Price, arriving at the conclusion that various market frictions, from identification costs, cause differences in prices across markets.

Price communication between exchanges was also something that was studied early on, but sadly the exchanges in question are no longer around - Mt. Gox was one of the most famous cryptocurrency exchange failures and scandals, with its shutdown costing many people their bitcoin [link]. An in-depth look at the manipulation that occurred on Mt. Gox can be found here.
These kinds of massive losses raise concerns about trusting a centralized entity to hold one's cryptocurrencies, but today's cryptocurrency market has many more platforms that are under microscopes for every action they perform, making it a little bit less of a Wild West than even a few years ago.

A couple papers have also discussed the impact of liquidity on efficiency of cryptocurrency markets, as well as leverage effects (the phenomenon of negative correlation between asset

return and change in volatility over time). However, all of these effects have been studied from the perspective of the value of individual coins, or an individual investor.

There's even been work to try and fit cryptocurrencies into traditional CAPM models and see if it is an "asset class" that provides a level of diversification from other assets, making it an attractive addition to diversified portfolios.

However, little has been done to analyze the decisions behind exchanges themselves. By looking at this space from an exchange perspective, we can recognize the factors that influence exchange decision-making, which in turn influence which coins get exposure and prominence and potentially a great chance of appreciation in value.

Just to illustrate the market power exchanges wield, one only has to look at price discrimination in fee structures offer to consumers. Cryptocurrency exchanges can price discriminate in many ways. For example, Coinbase charges different fees for using its friendly Coinbase interface vs. its own trading platform GDAX. Using different payment options, from debit/credit card, to bank wire transfer, to other cryptocurrencies, can also lead to different fees and prices for levels of convenience. However, at the end of the day, the consumer simple pays a price to receive an identical good (some fraction or amount of a cryptocurrency), so they will choose the exchanges that provide the best liquidity and access for optimal prices for the coins they want to buy or sell. Thus, exchanges must compete to provide the optimal offerings and experiences to reduce spreads and become effective, usable markets.

Exchanges may even offer different fee structures for limit order makers (cheaper or free free to encourage a fuller orderbook and higher liquidity) and price takers (who deplete orderbook depth and thus liquidity), similar to other trading markets. Some exchanges also provide liquidity rebates, by which they return rebates back to high volume traders based on how much they trade within given timeframes. Thus, we will examine exchanges to try and better understand the entrance to this growing market.

3 A Description of Exchanges

Characterizing Exchanges

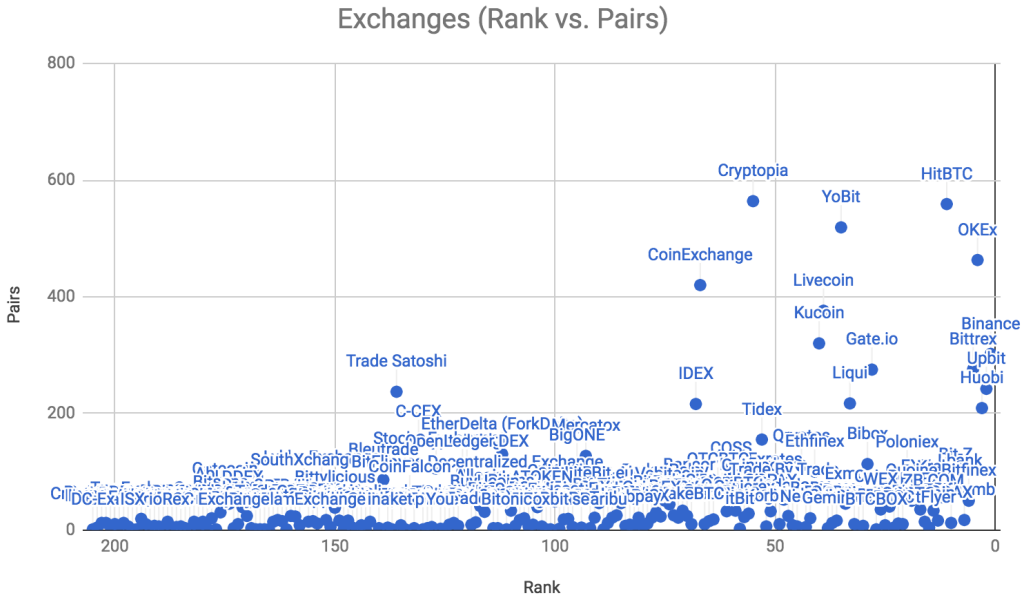
We can first characterize exchanges as risk-averse entities looking to reduce the likelihood of negative outcomes, both present and future, due to each additional decision they make, be it adding a new user, a new cryptocurrency, a new fee policy, etc. If exchanges are bound by geographic-based legislation, they must operate within the guidelines and restrictions of their locale, or face risk of punishment. Because the space is still in its infancy, many current day laws have no provisions on how cryptocurrencies should be handled, so exchanges may also self-police or set industry standards and help cooperate with official entities to reduce the risk of punishment in future periods or reflexive legislation that may become law after something goes awry. Thus, they may operate with some constraints on growth practices.

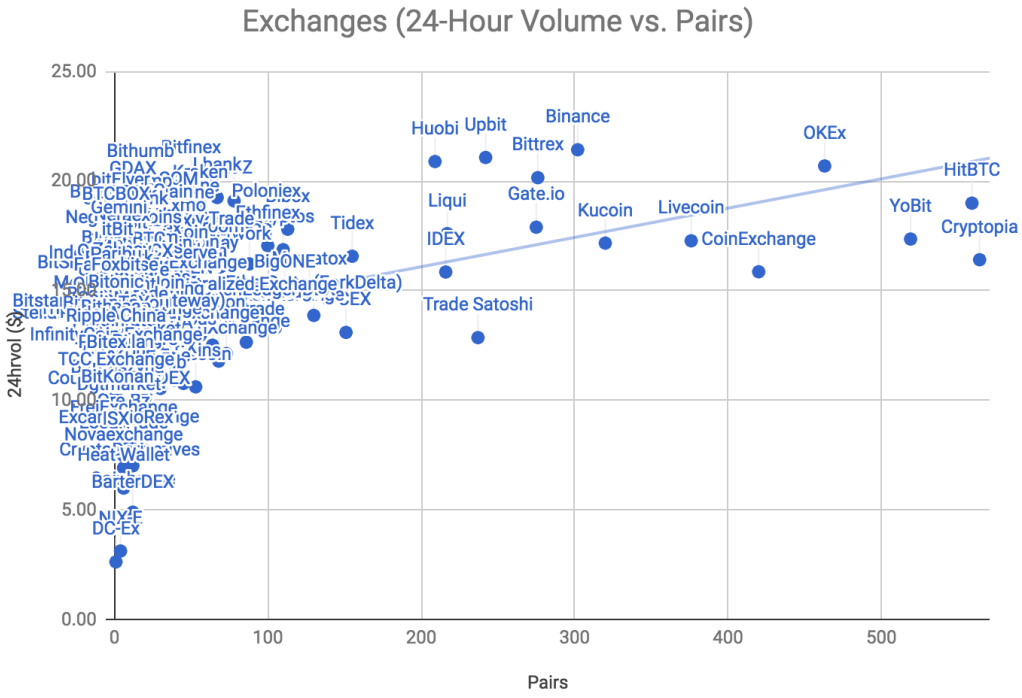
A Look at Exchanges

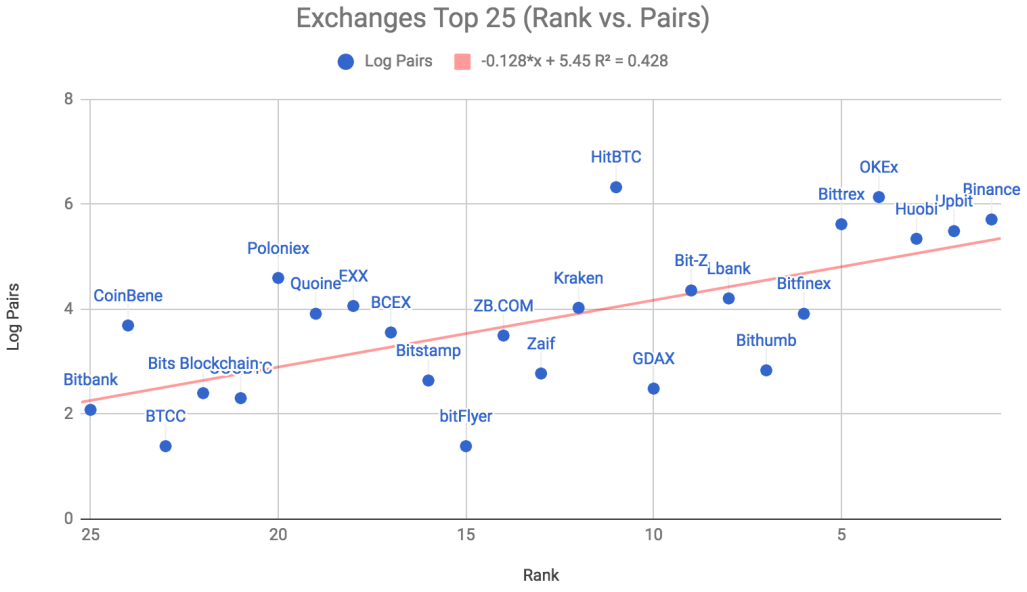
We first gathered data on the transaction volume and number of trading pairs of the 206 recognized cryptocurrency exchanges on CoinMarketCap. This list included household names, as well as ones with no popularity at all. Running regressions on volume ranking, volume itself, and the trading pairs, it was very apparent that there was some sort of relationship between number of pairs and rank, but perhaps a nonlinear one. It was particularly interesting to note that only 15 exchanges had north of 200 pairs, 25 had above 100, and the rest were scattered about in number of pairs and relatively lower size. This was particularly surprising, given the 1500+ unique cryptocurrencies that are recognized on these exchanges collectively, with more and more cryptocurrency token projects coming out each and every day. There was a clear group of large exchanges with more pairs, so we took the log of both variables, and as we whittled down the pool of exchanges to the top 100, top 50, and top 25 respectively, the correlation became strong and stronger between log(rank) and log(pairs). This in particular suggested that getting beyond some initial size, exchanges then had more and more incentive to add exponentially more pairs in a pursuit for the largest marketshare. Comparing rank and log(pairs) on an exchange, we actually get a fairly high correlation of 0.428! Thus, for the top exchanges, rank is fairly well correlated with just having more pairs. Trade Satoshi was the only exception amongst the large group of exchanges which had more than 100 pairs and while being outside the top 100 in total volume (136th). We find a temporal issue: do we know that the size of exchanges led to the size of these exchanges? Or did they first become profitable exchanges and thus have the funds to hire more developers and build out more trading pairs, compounding their growth.

Pairs are a variable that serve as a proxy for many things, from an indicator of liquidity (supply side), technical ability to integrate so many coins,

With network theory, more pairs means exponentially more sequences individuals can travel between coins, such that individuals can have more trade options that are valuable. *Ceteris paribus*, having more options will always be more valuable for the end user. So why don't exchanges just list everything?







An early assumption was that the cost of introducing an additional currency on a platform is fairly trivial, but if having more pairs does in fact have some correlation with more volume and thus more profits, why haven't exchanges try to list more coins? In the above figure, only

15 exchanges have more than 200 pairs listed. With over 1500 cryptocurrencies recognized on CoinMarketCap, and even more soon to ICO, it seems surprising that more pairs aren't typically offered on most of these exchanges.

Costs of Adding Coins

At first, we assumed that the costs of adding additional coins to an exchange were fairly trivial, but in listing a new coin on the platform, developers need to system works and how to set up secure wallets such that they could safely account for any coins in the network. Any time the underlying network undergoes changes, the exchange may need some maintenance time to get up to speed with any such updates so as to not have any issues with account management. Thus, we can characterize these costs as some immediate fixed/sunk developer time cost, as well as variable costs for maintenance that comes with having a coin listed. In addition, non-technical support staff will be needed to assuage any concerns that pop up.

We then can write the marginal revenue and costs for adding each additional coin.

$$MR = ListingFees(Unknown) + ExpectedChangeinVolumeXExchangeFeeRate \quad (1)$$

$$MC = CoinOnboardingTechLabor + ExpectedAdditionalNeedforSupportLabor \quad (2)$$

In the following sections, we will discuss what goes in to these equations, and how an exchange can differ in its offerings and features.

A Venture Model - Quality Matters

Marginal Revenue

Unfortunately, listing fees are largely unknown for most exchanges. Rumors suggest that listing fees for some of the fairly popular exchanges are all north of 30 bitcoin, which at this current time of writing, is around $ 270,000. In some recent news, it was leaked that Ripple (XRP) tried to buy its way to listings on major exchanges, with Ripple offering even a $ 1 million cash payment to be listed on Coinbase. It was also willing to lend Coinbase $ 100 million in Ripple token, which could be paid back in either USD (which would allow Coinbase to profit if Ripple's token went up) or Ripple.

This is not uncommon; a report in early April 2018 suggested that exchanges were charging anywhere from $ 1 million to $ 3 million for many coin listings, with the hind end of the range mainly pertaining to coins with poor liquidity. A project with little recognition may hold a lot of notional value in its token but need a way to sell them in a market, and so if no exchanges have this token at all, then it is willing to pay a liquidity premium quite directly to the exchange itself - the provider of liquidity. Thus, exchanges too then have an incentive to approach new coins and be the first exchanges to list a coin, to pick up that liquidity premium and receive a larger listing fee. Meanwhile, a highly coveted coin may then not require any listing fee if exchanges have enough users that wish to trade with it.

Furthermore, for a team that recently raised capital of their token, creating markets allows them a way to slowly offer them for sale to raise working capital for the project. Depending on the exchange and the quality of the token, the exchange may be willing to take the listing fee for offering the token on their exchange, helping the development team diversify and divest from their token at OTC prices without flooding the open market with tokens, and have no upfront cost. In traditional equity markets, getting listed on Nasdaq costs anywhere from $ 42,000 to $ 155,000 annually, so these million dollar one-time costs don't seem all that extreme, especially with volumes for most coins already at a level comparable to those of big name equities despite market's lack of maturity. For a project, such an expense could also be an opportunity to advertise towards thousands of users. Investors doing their due diligence will do some research on the project, causing the listing to act as an incentive for users to learn about their technology.

Expected Income Effects

While the listing fees are simply upfront, the listing of a new coin or trading pair also has an impact on the expected trading volume on an exchange. Trading volume is a function of both the value of the coins being traded times the number of coins being traded. With more

possible combinations of trades, adding a pair should in theory only bring additional total volume to an exchange.

Virtually any coin can be traded to from another coin within two trades: from some coin to bitcoin or ethereum, and then from bitcoin and ethereum back out to the other coin. However, these two trades do not have to happen on the same exchange. In the case of a start-coin-to-end-coin path where each of the two coins is on a different exchange, this means that an exchange that brings liquidity to the market by offering both coins on one exchange makes it possible for an individual to obtain the coin in one transaction rather than two, would simply turn a one-transaction trade in the purview of their platform (plus a transaction trade on another exchange) into a one-transaction trade denominated in a new currency. Because exchange income comes from the multiplication of exchange volume X exchange fees, providing these strictly-better paths in terms of user experience to move from one coin to another should certainly provide more volume to the exchange and an even stronger relative market share with the transaction eliminated on another exchange. Further, with most fees being crypto-denominated as anywhere from 0-0.25% of each transaction, it is imperative that the coins that are being traded are not at risk of becoming worthless instantly, as exchanges can quickly stockpile large quantities of these tokens. Thus, being the first exchange to list a growing coin provides the greatest opportunity to capture the largest expected increase in income, which yet again suggests that exchanges have incentives to act with a venture model, as they literally often get paid in the token for providing the liquidity, access, and support. GDAX's "Digital Asset Framework" paper outlines some of the criteria they use in order to decide whether or not a coin is worthy of being listed on the exchange, and it too mirrors an investment criteria checklist: open financial systems that are accessible and decentralized, with progress on a a secure open-source product with a significant, focused market impact, with a strong team of leaders, developers, business and operational staff, the list goes on and on. In this paper, GDAX also mentions its preference for coins that have a fairly distributed trading volume across the exchanges that currently list it; thus, GDAX will not be the early stage coin-lister, but rather wait until the coin already has sufficient liquidity in other markets. Meanwhile, other exchanges may choose to be more risk-tolerant, and take on coins with less liquidity and capturing rent as the provider of access of a potentially-appreciating "asset" .

Reinforcing Network Effects

The total crypto wealth of users on an exchange is equal to the sum of all the deposits of all the coins. Thus, if the coins have a higher expected value of outcomes, the wealth of the users is higher. Because most exchanges operate on a fixed percentage cut of each transaction,

there's mainly two ways for them to make more money: get more transactions, or get more valuable transactions.
Consequently, as the market grows, their revenues grow, all else constant. However, when people receive an income shock positively when one of their coins goes up, they become more likely to sell to another coin and diversify to more holdings, thus creating demand for more transactions of a more valuable coin. Further, if the markets did well in a previous period, individual users on exchanges will often desire to tell their friends about their successes, leading to further referrals and more transactions into the network. As markets grow in maturity, trading volume will continue to grow, meaning that exchanges will grab a larger fraction of the coins within the system. For example, if there were 100 bitcoin on an exchange, and the 100 bitcoin had a velocity of 4 trades per coin within the period, and the fee on the exchange was 0.25% , then the exchange would wind up with 1 bitcoin, reducing the available amount of bitcoin in the system to be 99 bitcoin. Thus, if the exchange does not immediately liquidate its accumulations of coins, the exchanges can also contribute to the reduction of supply on these coins, leading to further increases in potential equilibrium prices. For a less popular coin that an exchange is the only market for, the exchange could see a higher average velocity of trades per coin, meaning that the exchange could wind up on a larger position of this coin.

This is assuming that exchanges have positive fees for most of their trades. On some exchanges, we actually even see negative fees for makers to ensure more full orderbooks in hopes of encouraging increased liquidity. However, these exchanges are likely the early-stage listers that offer coins with more volatile coins that users are willing to pay a premium on taker transactions to close arbitrage conditions when makers have locked in their set limit orders around old prices.
In short, exchanges have a significant amount of power in influencing the liquidity of each cryptocurrency, and can leverage its position of power and knowledge to select an optimized portfolio of coins to be available on the exchange.

The Changing Landscape

The cost of onboarding each coin will vary on the difficulty of integrating with each new coin's network and technology, but this cost may become much more standardized as more blockchains are built off as offshoots of existing projects. Some tokens, such as ERC-20 compatible tokens (ERC stands for Ethereum Requests for Comments that come in response to Ethereum Improvement Proposals - proposed amendments to how the Ethereum blockchain works), are compatible with other popular blockchain networks like ethereum, such that

they can be sent and transacted using existing systems. As a result, the exchange costs to implement additional ERC-20 tokens start to come down with economies of scale.
This question will change as ERC compatibility becomes more and more prevalent, leading to most coins having similar onboardings, making the support of an additional coin more trivial in cost and effort for exchanges.

User Onboarding Costs and Frictions

If a coin attracts new users to a platform, we must consider the user onboarding costs that occur due to a popular coin's listing. This will require multiple types of administrative and support costs.

KYC and AML

The onboarding costs of a new customer to a cryptocurrency exchange are nonsignificant when there's a strict adherence to know your customer (KYC) and anti-money laundering (AML) laws. The concepts of KYC and AML are often lumped into one in the purview of exchanges, as both revolve around the problem of identity. With cryptocurrencies, the industry has to fight the perception of shady, crime-riddled dark warlords, and with regulators watching this space, many exchanges proactively offer many KYC and AML measures to increase security and trust on the platform. Potentially letting in a bad actor with stolen funds or creating a conduit for tainted money could be potentially disastrous for a legally registered entity in a country looking to crack down and make an example out of any infractors. However, there are many technological implementations of KYC/AML measures, such as email confirmation, two-factor authentication, SMS text verification, captchas, IP address validation/country restriction, etc., that provide some level of account security and fraud protection.
As a fiat onramp for consumers, an exchange is under even more scrutiny than a platform that only accepts crypto deposits, as it needs to educate the new consumer about the risks of buying into cryptocurrencies. Consequently, different exchanges may require a more rigorous background check before allowing any user onto the platform. Many exchanges ask for the uploading of a photo ID, a selfie of oneself holding the ID, Social Security Numbers and/or other forms of citizenship identification. For many seeking privacy, these exchanges ask for enough data that make it prohibitive for some to use. Different exchanges may feature lower KYC/AML measures at the risk of potential federal scrutiny if they wish to grow at a faster rate at least at the start. However, once exchanges become larger, the cost of a potential audit or shutdown becomes higher, making it more and more imperative to implement more stringent KYC and AML rules.

For some exchanges, that means retroactively adding in tiered verification systems, in which users can unlock additional features/benefits such as increased withdrawal limits if they provide additional forms of identification. Not only do these measures increase the effort required to create an account, but the exchanges themselves must spend more time and labor in processing these materials and verifying the identity of every signup. Consequently, some exchanges closed new registrations for periods of time and removed referral programs/incentives to invite friends and family to join to quell the rush. With this backlog, some users reported waiting weeks and months before getting approved. Thus, the exchanges themselves can control some measures to affect the short-term signup rate.
Update: Even LocalBitcoins, as a listing page rather than an exchange, has begun asking its users for additional identification as well. [link]

More Entrance Costs & **Corresponding Revenue Sources**
Though verification plays a key role in the onboarding process, there are many more frictions. As we alluded to in the LocalBitcoins example, there also seems to be a premium for having bank access, particularly online banking access. With only 51% of US Adults banking online [cite], it is no surprise that adding funds to a cryptocurrency account becomes a more difficult task.
Ease of use and convenience factors are often created by the exchanges and platforms themselves. Furthermore, sign-ups could be (and have in the past) temporarily held up for external reasons outside of one'??s application: everything from scheduled server and website maintenance to complete signup moratoriums during periods of high demand can occur.
Coinbase, one of the largest US-based platforms, is a unique case of this, as it also owns GDAX, its own exchange. Coinbase acts as the retail front-page, the modernly-designed, checkout process like paying for an Amazon order. However, that convenience comes at a fee: as a taker of the spot market price, a user will pay at least 1.49% , with a minimum fee of $ 0.99. Furthermore, this fee does not allow for instant payout in bitcoin - rather the current price is locked in, and the bitcoin will be credited to your account within 7 days. Because the current ACH (Automated Clearing House) systems take 3-5 business days to verify that you truly have the amount stated in your bank account before transferring amounts to other banks digitally, you're stuck with zero liquidity for at least a week, if not more during high demand times. Coinbase states that if you want instant transactions, pay with a credit/debit card and take on a 3.99% fee.
Thus, Coinbase is protecting itself from a certain degree of volatility, and price differentiating between different elasticities of demand, with some consumers looking to buy cryptocurrencies to sell and trade with immediately, and others looking to just acquire an amount for

longer term. Furthermore, the price quoted on Coinbase actually comes from GDAX with up to a 50 basis point spread. GDAX, which is fairly easily accessed through the same login and account depositing structure as Coinbase, offers a much cheaper fee structure: for those who make limit orders on the exchange - that is they place orders that fill only once the price hits the specified price (falls to the limit for a buy, increases to the limit for a sell), the exchange is fee-free, and the filling of account balance from bank account is also free. For those who want to fill an order instantly, they pay a 0.25% taker fee for their market price order. If the orderbook is sufficiently thin, the transactor also loses some slippage because the order quantity is larger than the quantity on the books at the best available market price. Once again, the exchange is able to price discriminate between customers that are looking to fill orders instantly or can be a little more patient.

The only difference between buying on Coinbase and buying on GDAX is that, all else equal, if a user wanted to sign up today and purchase cryptocurrency, they would not be able to buy instantly at the market price, but rather, they would have to wait for the expected seven days before they could place an order and thus not be able to lock in a price despite having the intention to purchase. In a bearish market, that might not be a bad thing, but the fear of missing out (FOMO) in a bullish price run forced many users to eat the 1.49% fee to lock in todays price, fearing that the price in a week would be much higher than the fees saved. For the new user unaware of all the possible pricing options, odds are they will settle for the default options and not even hear of the GDAX option until maybe a future transaction. Thus, Coinbase as an entity has price differentiated between different types of users, creating their own sources of market frictions for entry.

Transfer Costs & Exit Friction

Once one enters into the world of cryptocurrency by purchasing a certain amount or fraction of a coin, he or she may choose to remove it from the exchange and/or transfer it to a separate wallet, or address to keep the balance in. Different exchanges place different transfer fees and daily/weekly withdrawal limits. Firstly, transfer fees vary from coin to coin and from exchange to exchange - for some, the only cost is the cost of a network transaction, so the cheaper and more expedient the underlying network or technology a token has, the easier it is to move out for the exchange on behalf of the user. For other exchanges, they may batch transactions or send them with less urgency, and thus save on transaction fees to a level where they can offer free withdrawals, such as Coinbase. For others, they may institute more frictions, such as minimum amounts to withdraw, or set fixed fees per transaction rather than a percentage amount to encourage a lower frequency of withdrawals. The variation in fees may make it more likely for certain coins to be withdrawn, all else being equal. That

for most coins on most exchanges, withdrawals are not free provides a nonzero friction and some level of complication that makes it more likely that capital flows in free-free than to flow out. Consequently, positive income shocks tend to be preserved on the exchange level ecosystem. We will explore this further in regards to diversification between coins, but an initial hypothesis is that given a boost in wealth, if there are some walls that make it difficult to move this wealth into something else, the individual may choose to move some of the gains into other coins listed on the platform. In regards to such "walls" , many exchanges have specific limits on withdrawals; depending on if the coin has fiat pairs or not, it may choose to denominate that limit typically in USD or Euro, or in bitcoin. For example, Binance, a crypto-to-crypto exchange, has a withdrawal limit of 2 bitcoins worth per day (50 for verified users), whereas Coinbase (with the fiat onramp) has a $ 10,000 weekly limit.
This distinction is crucial, as the latter is fixed in fiat terms while the former is variable - thus, if one's portfolio appreciated tremendously in value, and someone wanted to move it off the one exchange and diversify to more exchanges and other assets/coins offered on other platforms, the fiat limit increases friction in the case of withdrawal after appreciation in value.
However, in the event of a significant crash or run, the fiat limit would stay stable, whereas the crypto-denominated limit would shrink, making it more and more difficult to move much currency. Thus, both types of limits have their potential drawbacks, and different users can pick the exchanges that best serve their portfolio size & risk tolerance, or more specifically, their willingness to sacrifice some degree of liquidity.

It's important to note that an exchange can change these policies at any time and make a significant impact on the market. In the case of Bittrex, a Seattle-based exchange, after a purported breach of user login information, withdrawal limits on unverified accounts created after August 2017 were brought all the way to 0, trapping some users in if they aren't able to provide full identification, and various other limits if individuals did not set up two-factor authentication or other measures that double as security and anti-fraud measures. [link] For a user on a centralized exchange, all rules are always subject to change, even if they've never changed before.

User Support & Education Costs

In today's hyperconnected social media age, any disgruntled user may become a PR nightmare. As a result, anyone with huge reach could detract from future users, thus making customer support particularly crucial for exchanges. Because exchanges are perhaps the only human contact point for the tech-dominated space, the exchange will often be forced

to deal with all sorts of questions and complaints, even if they have nothing to do with the exchange itself. Whether it is building out frequently asked question repositories, to support staff across various methods of communication, and geographies, much effort must be put in to ensure that users are comfortable armed with the knowledge they need to make their financial decisions. The exchange becomes a source and point of education, whether they like it or not.
User demand is ultimately the final decider in whether a coin is worth listing; if an exchange lists a coin but no transactions happen, it's just like an unsold item at a store, simply hogging valuable shelf space. The opportunity cost of introducing a pair to this space must equal the marginal revenue brought in from bringing in this marginal cryptocurrency.

However, not all coins are created equal. Every time a new coin pair is opened up, an exchange is able to attract new users that perhaps hold that coin and would like to trade with it, and thus be able to use that coins underlying network to transfer it into the exchange account. For some networks that are less user friendly, it may be difficult to send and receive coins, which leads to support tickets on the exchange at no fault of the exchange, leading to different marginal costs for the additional listing. Thus the exchange has the incentive to choose better/more friendly-to-use coin networks that require less potential education and support first. This leads to the notion that exchanges do in fact have an incentive to vet and choose their offerings wisely, only letting on coins that could bring significant capital inflows onto the exchange. The exchange is a marketplace, the products are the coins, and so the exchange wants to offer products that get customers in the door early and frequently. They thus become somewhat of a venture capital firm with incentives to pick the best teams with the most traction, progress, stage of usability, or acceptance to maximize in expectation likelihood of appreciation in value. Conversely, any coin that creates controversy, concern, or confusion leads to increased support costs, making them less desirable.

We then take a look at how the number of listings, the diversification of volume sources, and the rank and volume of exchanges are correlated, to better understand how exchanges' decisions to list more coins affects their potential for growth.

4 Data

Looking at exchanges as a whole, can we predict the rank of an exchange based on the HHI of the coins that are listed on an exchange? How important is diversification of coin

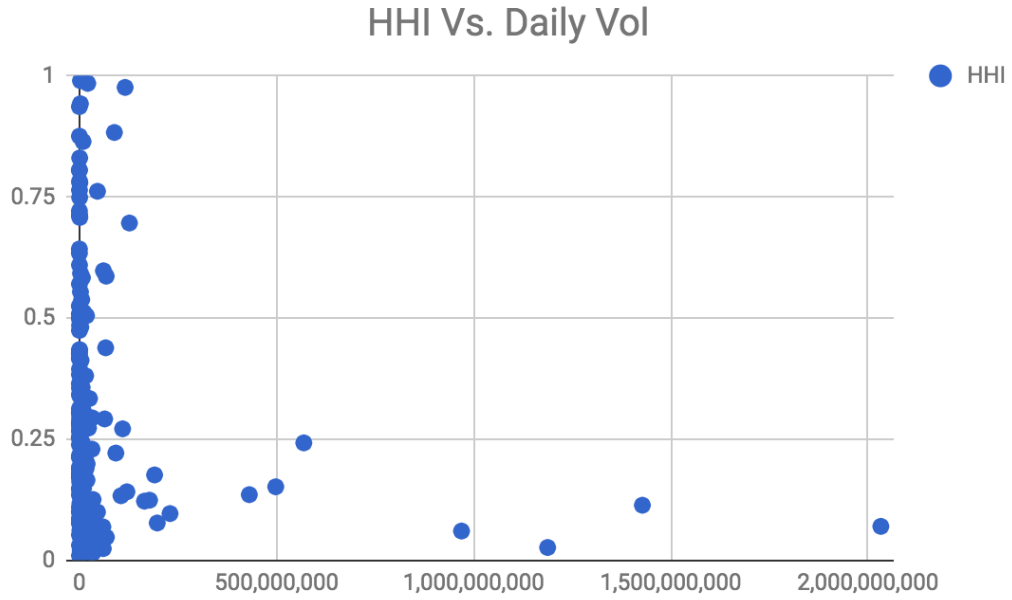
popularity within an exchange? The Herfindahl-Hirschman Index is often used as a measure of market concentration, and in our case, we will use it to see how strongly dominated various exchanges' transactional volumes are dominated by individual pairs. When HHI is low, the total of the sum of squared weightings of each coin's volume on an exchange is low, which means that many coins are available and the exchange is a nicely balanced market with flows going from one coin to another.

The HHI is a unique proxy as well for reliance on the underlying value of any currency, as exchanges are paid as a fraction of the coin that is traded, and thus they at least momentarily hold on to the coins the receive; the ones they sell out of, they get out, whereas the ones they hold on to, will also go up in value because some of the circulating supply is drawn out, and as the coin's supply changes hands more often, the exchange winds up with a larger and larger slice of the pie, assuming no instant liquidation.

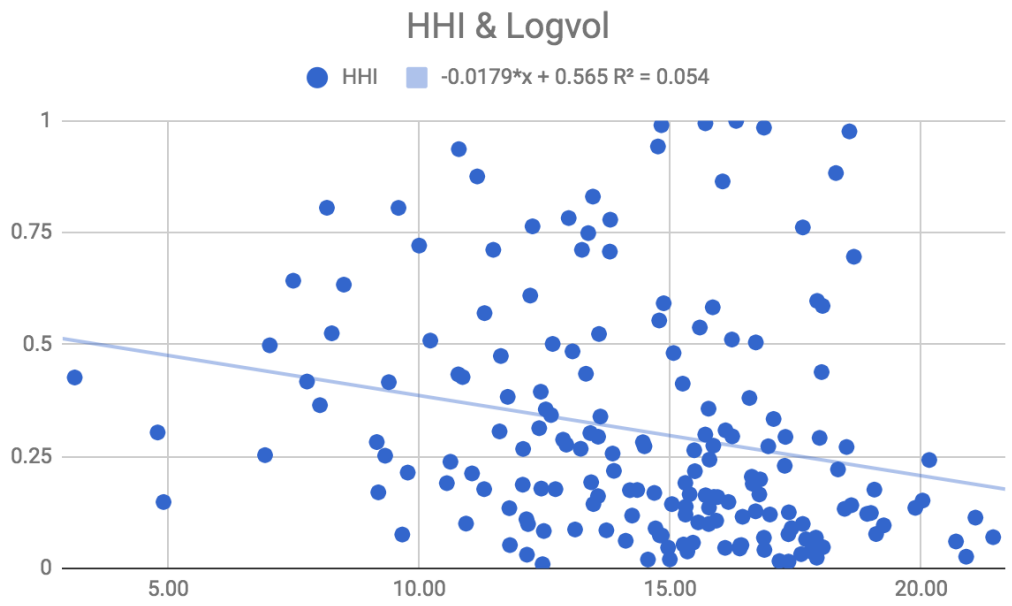
In our data (Appendix: Table 1), we find that an exchange's HHI has a positive correlation with rank (lower rank), and strongly with number of pairs: as an exchange has more pairs, it should have a higher potential for diversification in source of volume, leading to a lower (better HHI).

Graph 1: HHI Vs. Daily Vol

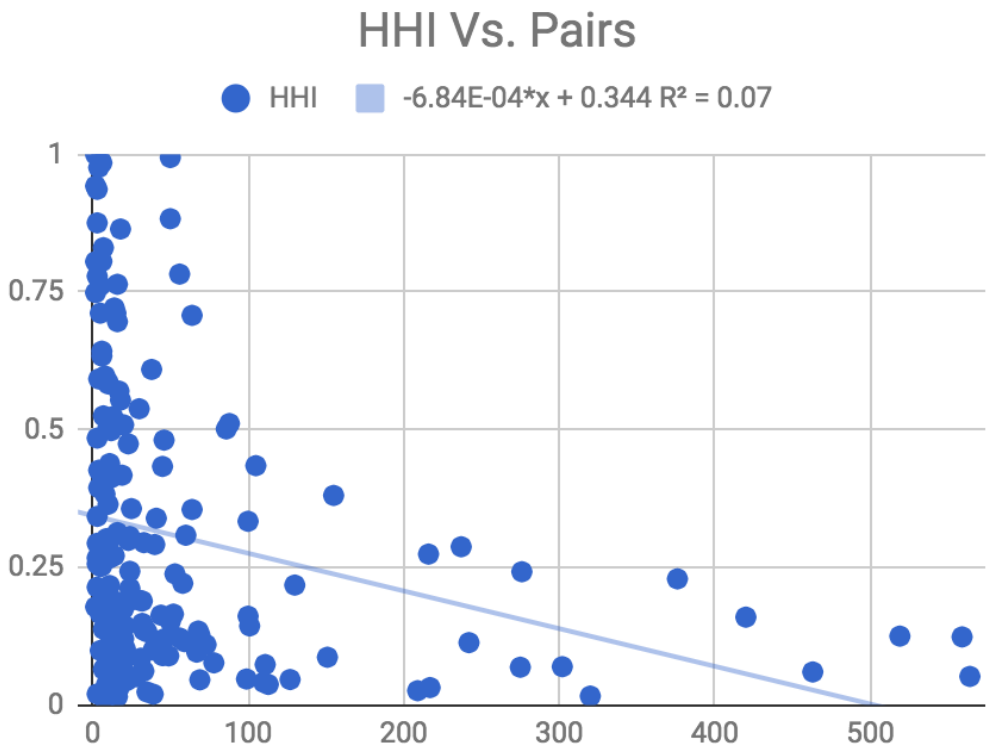
We see that only a handful of exchanges are much larger than the mass majority, and all of them have relatively low HHI scores below 0.25.



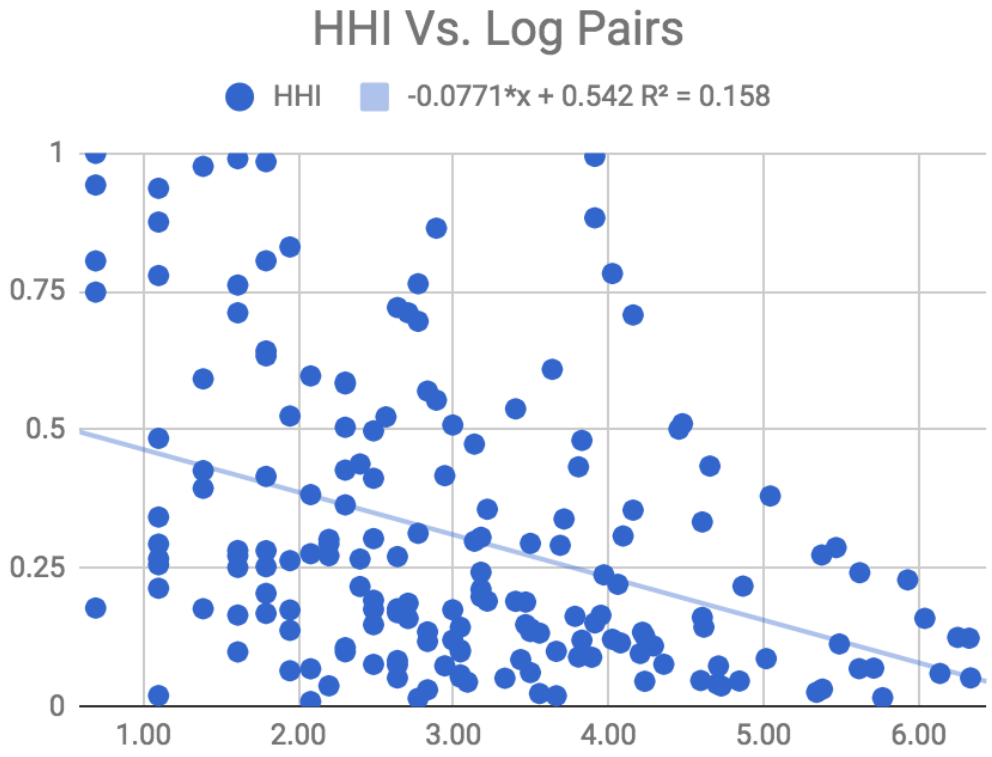
Graph 2: HHI vs. Ln(Daily Vol)
We find a very weak negative correlation between HHI and the natural log of daily volume.



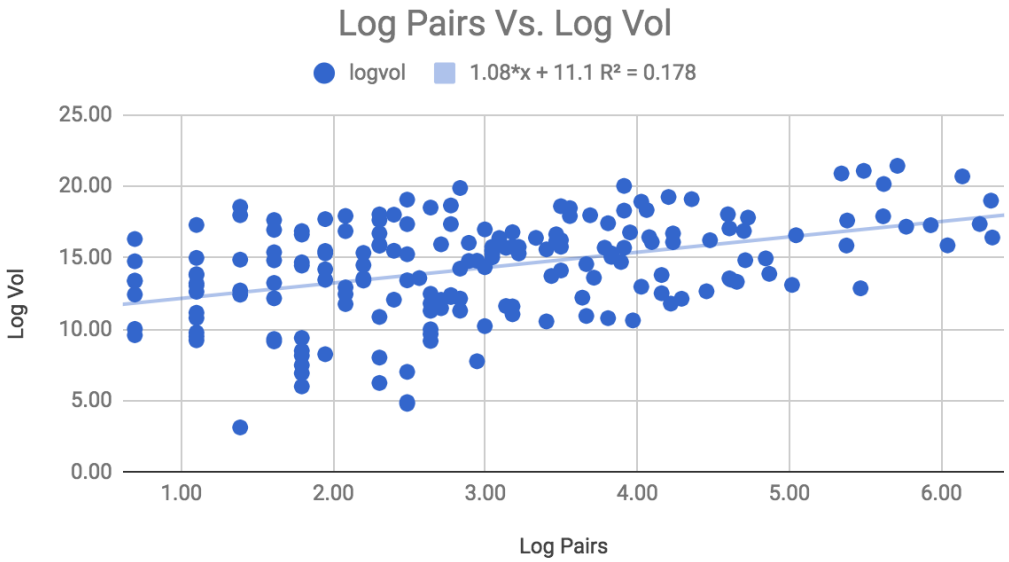
Graph 3: HHI vs. Trading Pairs
We find a slightly negative correlation between number of pairs and HHI, as expected, as a lower HHI is possible from more coin offerings.



Graph 4: HHI vs. Log Pairs Taking the natural log of number of pairs, and comparing to HHI, we get a stronger correlation.



Graph 5: Log Pairs Vs. Log Volume Finally, we compare the log number of pairs on an exchanges versus their log volume, and see a more significant correlation, but still not a very strong linear correlation.



Thus, placing arbitrary, empty, and unattractive markets on a platform doesn't do the trick, either. One must list relevant pairs that actually help add to the liquidity for the platform's users.

5 Model

Given an exchange with a portfolio of coins available for purchase, what does the addition of the marginal coin do to the volume?

With our $MR = MC$ condition from earlier, we know that

$$LHS = ListingFees + Expected\Delta VolumeX ExchangeFeeRate \tag{3}$$

$$RHS = CoinOnboarding + VariableCostofSupport \tag{4}$$

Thus, for a low fee exchange, in order for the equation to still hold, we expect a larger amount of volume to compensate to keep the equation constant. This does not seem out of the ordinary, with the potential for more people drawn by the cheaper transaction costs, but it may not be as simple as we have made it in this model. With listing fees likely higher for exchanges that already are larger, we can create an indicator variable for exchanges who are in the top 5, 10, 25, 50, and 100 in volume rank, and use these indicators as an expectation of listing prestige. If an exchange is not able to accurately estimate the expected change in volume, they may have to act in a risk-averse manner and assess an uncertainty discount for the variability in expected revenue from listing a coin, thus concluding that a coin is not profitable to list when in reality it may be.

Despite the most popular exchanges having much higher volume, the regression indicator variables of being within higher ranks didn't produce many significant results, and thus we removed many of them.

Adding new coins both attracts users of the coin to start using the exchange, as well as encourages exchange users to diversify their holdings into this new coin as well, leading to a more balanced portfolio amongst its users, and a more diversified revenue stream in terms of transaction fees.

We then construct a linear model to predict the 24 hour volume of an exchange based on these parameters.

We begin with a null hypothesis that an exchange's HHI has no correlation with log volume.

OLS Regression Results

Dep. Variable:	Rank	R-squared:	0.536
Model:	OLS	Adj. R-squared:	0.534
Method:	Least Squares	F-statistic:	205.8
Date:	Sat, 21 Apr 2018	Prob (F-statistic):	1.62e-31
Time:	15:06:25	Log-Likelihood:	-1030.9
No. Observations:	179	AIC:	2064.
Df Residuals:	178	BIC:	2067.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
HHI	206.1843	14.372	14.346	0.000	177.823	234.546

Omnibus:	11.215	Durbin-Watson:	0.994
Prob(Omnibus):	0.004	Jarque-Bera (JB):	11.480
Skew:	-0.573	Prob(JB):	0.00321
Kurtosis:	3.477	Cond. No.	1.00

In running a univariate regression, we see that HHI is significantly related to log daily volume, but the R-squared statistic of 0.536 could be improved. However, this result would suggest that an increase in HHI, or a platform with less diverse offerings, would have a higher log volume, which seems counterintuitive, and not particularly specific. There may be some interaction terms and other things that we must consider.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                 logvol   R-squared:                       0.941
Model:                            OLS   Adj. R-squared:                  0.939
Method:                 Least Squares   F-statistic:                     556.8
Date:                Sat, 21 Apr 2018   Prob (F-statistic):          5.06e-105
Time:                        23:13:57   Log-Likelihood:                -483.19
No. Observations:                 179   AIC:                             976.4
Df Residuals:                     174   BIC:                             992.3
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
HHI            8.6497      0.858     10.077      0.000       6.956      10.344
Log Pairs      2.4892      0.139     17.905      0.000       2.215       2.764
Top 25         0.2834      1.056      0.268      0.789      -1.800       2.367
Top 50         1.5238      0.915      1.665      0.098      -0.283       3.331
Top 100        5.2292      0.662      7.896      0.000       3.922       6.536
==============================================================================
Omnibus:                        2.353   Durbin-Watson:                   1.547
Prob(Omnibus):                  0.308   Jarque-Bera (JB):                2.011
Skew:                           0.141   Prob(JB):                        0.366
Kurtosis:                       2.564   Cond. No.                         15.8
==============================================================================

..    .
```

We then added log pairs to the regression, which turned out to be strongly significant as well. To adjust for the tiering that we saw in terms of a handful of top exchanges separating from the pack, we also added indicator variables for being an exchange in the top 25, top 50, and top 100 out of the list of 180 exchanges we had data on. Only the top 100 indicator was significant, which makes sense as there is some overlap in this implementation of indicators (a top 25 exchange is also a top 50 exchange, etc.).

OLS Regression Results

Dep. Variable:	logvol	R-squared:	0.955
Model:	OLS	Adj. R-squared:	0.954
Method:	Least Squares	F-statistic:	742.0
Date:	Sun, 22 Apr 2018	Prob (F-statistic):	2.66e-115
Time:	20:44:11	Log-Likelihood:	-458.82
No. Observations:	179	AIC:	927.6
Df Residuals:	174	BIC:	943.6
Df Model:	5		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
HHI	17.1467	1.371	12.505	0.000	14.440	19.853
Log Pairs	3.0747	0.145	21.227	0.000	2.789	3.361
HHI X Log Pairs	-4.5971	0.622	-7.386	0.000	-5.826	-3.369
Top 50	1.2873	0.655	1.967	0.051	-0.004	2.579
Top 100	4.6236	0.583	7.926	0.000	3.472	5.775

Omnibus:	0.261	Durbin-Watson:	1.521
Prob(Omnibus):	0.878	Jarque-Bera (JB):	0.416
Skew:	-0.045	Prob(JB):	0.812
Kurtosis:	2.782	Cond. No.	21.7

After adding an interaction term for HHI and log pairs (as we saw in the initial scatterplots, HHI and log pairs were negatively correlated), we start to get a better sense of what is going on. Exhibiting specialization in specific coins (having a higher HHI) is positive for volume, as is having more pairs (a higher number for log pairs), but having a high HHI despite having lots of pairs is a strong negative relationship with log volume. Thus, exchanges have incentives to list only the amount of pairs it can ensure actual volume in, and should not necessarily do so until the demand for the existing pairs are fairly diversified.

As for the coefficients, we used HHI on a scale from 0 to 1, rather than the often used scale of 0 to 10,000, so despite the larger HHI coefficient than the Log Pairs, an incremental change in HHI might only be 0.01, whereas adding a few coin pairs might move log pairs much more. The Top 25 indicator was also removed, which made the Top 50 indicator variable much closer, but not quite statistically significant, with a p-level of 0.051.

OLS Regression Results

Dep. Variable:	logvol	R-squared:	0.957
Model:	OLS	Adj. R-squared:	0.955
Method:	Least Squares	F-statistic:	635.1
Date:	Sun, 22 Apr 2018	Prob (F-statistic):	5.23e-115
Time:	20:55:56	Log-Likelihood:	-456.05
No. Observations:	179	AIC:	924.1
Df Residuals:	173	BIC:	943.2
Df Model:	6		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
HHI	18.0903	1.413	12.803	0.000	15.301	20.879
Log Pairs	2.8137	0.182	15.499	0.000	2.455	3.172
HHI X Log Pairs	-4.1054	0.650	-6.319	0.000	-5.388	-2.823
HHI X Top 100	-4.3146	1.849	-2.334	0.021	-7.963	-0.666
Top 50	1.3099	0.646	2.027	0.044	0.034	2.586
Top 100	6.0279	0.833	7.237	0.000	4.384	7.672

Omnibus:	0.024	Durbin-Watson:	1.544
Prob(Omnibus):	0.988	Jarque-Bera (JB):	0.121
Skew:	-0.018	Prob(JB):	0.941
Kurtosis:	2.878	Cond. No.	30.1

Finally, we add in another interaction term for HHI and the indicator variable of being in the top 100, to account for different types of strategies of exchanges - does a small exchange outside the top 100 have a reason to treat HHI differently? Our -4.3146 coefficient for this interaction term demonstrates that for exchanges within the top 100, having a higher HHI (less diversified) is a penalty on expected log volume compared to a smaller exchange outside the top 100 with the same HHI.
With this addition, the top 50 indicator also becomes statistically significant, and thus we arrive at 6 explanatory variables that give us a pretty nice R-squared value of 0.957 in explaining log daily volume of exchanges.

After this regression, we find that as expected, HHI has an inverse correlation with number of pairs: as an exchange has more pairs, it has a greater degree of possible concentration distribution, which directly leads to a lower HHI score. HHI is also significantly correlated with rank, such that an increase in HHI (less diversified platform) has a higher number rank (lower size). Looking at the scatterplots in these figures, we certainly see that only a handful of exchanges even are able to list this many pairs. Knowing that HHI has interactions with pairs and rank, we added two interaction variables, HHI $*$ Log Pairs, and HHI $*$ Top 100 Indicator, both of which were significantly negative. Thus, we find a really interesting conclusion: that HHI itself has a positive correlation with volume. When an exchange is

starting out, it is very small and has few pairs, so being concentrated (having a high HHI) allows it to gain more volume and thus marketshare.
However, once an exchange gets larger and moves up in the rankings, it has incentives to offer more coin pairs and more liquidity in each pair. On average, once an exchange has 29 pairs (e^ [(18.0903-4.3146)/4.1054]), a reduction in HHI is necessary to boost volume.

For an exchange with a high HHI, if it tries to flood its market with lots of new pairs that gather no volume, then the negative term of HHI X Log Pairs will mostly cancel out any benefits in positive volume growth from the addition of the pairs, as the effects with HHI constant would be 2.8137 $*$ Log Pairs - 4.1054 HHI X Log Pairs. In fact, if an exchange's HHI is above 0.685, it would be expected that the addition of pairs would actually reduce expected volume, which is can be explained by the paralysis of choice - much like at a restaurant with too many options at a menu, individuals may actually take more time to choose and thus make fewer transactions in a given timeframe.
This also suggests that as HHI drops, it becomes easier to add more volume, displaying some sort of exponential network effect here; the more diversified an exchange already is in its source of volume, the more it can grow in volume and its future offerings.

This makes a whole lot of intuitive sense, as exchanges that flood the user with too many options that go unused fail to reduce HHI and shouldn't receive extra volume if it fails to change user behavior in coins traded. The new, unused trading pairs simply clutter the user interface.

Given an average exchange fee rate, number of pairs, and an exchange's current status, we can utilize this regression to predict the expected change in volume based on adding a new coin. We can simply predict the effective difference in HHI due to the addition of the new pair (is it a popular, in-demand coin?) and the change to the log of pairs, and then we should be able to calculate an expected boost in volume and consequently revenue of the exchange. In order to reduce HHI, the addition of the new pair needs to mainly draw volume away from the most popular trading pair, rather than cannibalize the volume of other small pairs. This way, the addition of the new coin needs to actually add volume and liquidity to the exchange, rather than just rerouting the same trades from other non-frequently-traveled network nodes. Drying up the volume flow through these other paths would create other routes of illiquidity that would counteract the benefits of the new trading pair.

The Rapid Growth of Binance

One of the most interesting cases is the growth of Binance, now one of the largest exchanges in the world. If this space is dominated by network effects, how could a new entry into the market perform well, let alone reach the # 1 rank in daily volume in less than 10 months of existence? Binance has over 300 trading pairs listed on its exchange from 118 new coin listings, and has found ways to build out customer support for 10 languages and integration with Google Translate for all of its options. Launched on July 14th, 2017, Binance grew from an exchange based in China (pre-ban), survived a few organizational adjustments, and built a transaction matching engine that handles a throughput of 1.4 million transactions per second, it has been able to provide a fairly simple but powerful interface to many cryptocurrency traders. Thus, the exchange found a way to invest upfront in the cost side of the marginal revenue/marginal cost equation, such that it could continue to add more support for new coins.

On December 19th, Binance passed 2 million active users, and just 9 days later on December 28th, Binance hit the 3 million mark, thus picking up over 100,000 traders per day over the holiday season. By January 10th, 2018, Binance had reached 5 million active users. Some news outlets claimed that the founder Changpeng Zhao (also known as CZ) told reporters that the exchange at one point was onboarding 240,000 users in an hour. As of March 2018, the exchange had 7.9 million users. After just 9 months of operation, the exchange features 122 total coins across over 300 currency pairs. It has been able to parlay its quick success into further growth. Binance has even built out their own coin-tracking encyclopedia resource where they have recognized over 841 coins, compared to the 122 already listed, so there could still be plenty more room to grow. No other exchange has been so diligent in adding additional pairs and liquidity to markets, encouraging users to further diversify and utilize more crypto tools for liquidity and access.

6 Conclusion

We have reason to believe that the listing costs for additional pairs is not insignificant, or else more exchanges would be able to quickly list thousands of coins. We did not take into consideration that the number of pairs may come from a different structure of coins. Much like the hub and spoke model of airline routes, cryptocurrency exchanges feature "hub coins" that receive most of the traffic, and all other less popular "destinations" have pairs with these popular coins, rather than unique pairs for every combination of coins.
Today, bitcoin and ethereum are the two most trusted coins, with USD Tether and maybe an exchange's own coin being the 4 possible pairs. As more trustworthy stablecoins and exchanges' own coins are introduced, there will be more hubs and possible combinations of pairs with little need for additional infrastructure costs and changes for the exchanges. For decentralized exchanges, any combination may be possible, as no central entity decides which coins can be hub coins. Will the opening of more "trade routes" and liquidity provide a positive boost to prices or remove the likelihood of crazy short term gains by opening up supply flows of coins.
A future approach would be to take the Lancaster Model approach to breakdown what percentage of a token's current trading price is simply a function of its current liquidity/access due to exchange listings, and if future listings could be a catalyst for price appreciation. We could also run the same regression on the HHI and exchange reliance of different cryptocurrencies, and see if coins do better when they are listed and traded significantly in more exchanges, which would show the same network effects of growth in coin popularity and notional value, but this would have to be done in conjunction with looking at specific announcements of listings of coins by exchanges, and looking at the change in price before and after such announcements.

This research is based on today's current snapshot of the cryptocurrency world. It is very likely that several key factors will evolve within this space that could affect the proportion and demographic of individuals who use centralized exchanges, the go-to-route to purchase and hold cryptocurrencies today.

Decentralized vs. Centralized
A big debate currently being discussed in the cryptocurrency world is the use of centralized and decentralized exchanges. While many are drawn to cryptocurrencies for their promise of a system that is independent and trustless - that it does not need to be backed by a central government to hold value, others are drawn to cryptocurrencies for speculation or belief in

the early-stage applications that the blockchain technology can bring to every day industries. Some may distrust large financial institutions, yet centralized exchanges themselves are also financial institutions. From a blockchain purist perspective, centralized exchanges are points of off-chain transactions, which have two key implications: for scaling, it takes some of the workload off of the underlying blockchain network, at the sacrifice of some degree of security in reduced decentralization (creating a centralized point of attack that currently controls a significant portion of the market). However, with cryptocurrency still growing, centralized exchanges provide a familiar pathway towards entering the market. Thus, while some people prefer to hold their coins themselves and take on the carry costs as well, others may prefer to hold them on an exchange.

Hedging Their Horses

For some centralized exchanges like Binance, they are able and willing to list decentralized exchange tokens, such that if people desire to move towards the decentralized exchanges, they still at least see increased transaction volume to acquire the tokens of potential competitors. If decentralized exchanges become incredibly popular and their tokens become more valuable, the centralized exchanges can also protect against their relative weakening by capturing value from the increased volume for decentralized exchange coins. For other projects that may be in direct conflict of interest with an exchange, it may not make sense to list that coin at any cost.

Offline Vs. Online

Keeping cryptocurrencies in online or offline forms are often broken down into cold wallets and hot wallets. For example, some individuals choose to keep their cryptocurrencies in hardware not connected to any external networks (also known as cold storage) such as a Ledger or Trezor Wallet - these amount to USBs that make it easy to store cryptocurrencies offline and reduce the risk of exposing a private key or allowing an online hacker to obtain one's funds through a third party.

However, this opens up to individual security problems, like leaving one such USB device on a desk, or losing it, or worse yet, any passwords or recovery phrases/codes that allow one to gain reentry into the device. Some people also write down their passwords the old-fashioned way, or save them on an online password protector, but yet again are subject to the same trust issues that such methods will not be compromised. Thus, if an individual prefers to allow the exchange to the work of security and privacy for them, they may be willing to pay in the form of the counterparty risk from using an exchange.

Despite the low-to-no fees, added privacy, and removing the middleman risk and friction,

decentralized exchanges often still lack of liquidity and usership. However, these exchanges are becoming more and more popular as they become easier and easier for less-technical users to learn and utilize, and more users recognize the risks of relying on centralized platforms. A hybrid option of exchanges giving users the ability to easily trade from offline wallets may be an attractive option to role out for those who value their own custody of coins. For institutional traders, they conversely are starting to demand custodial services from the exchanges themselves, such that the values of their portfolio are secured with the exchange itself, rather than sitting on USB sticks on the office premises.

ICOs vs. IPOs

In the cryptocurrency market, there are ICOs - initial coin offerings, rather than IPOs (Initial Public Offering). Most of the time, ICOs happen on individual websites for each project, but in the case of Binance, Binance also offered a few ICOs through their launchpad program. Similar to a YCombinator or other start-up incubator programs, the brand of being an endorsed ICO receives the validation of an established entity. As more exchanges take their brand to help endorse the growth of new projects, exchanges could grow in scope to provide more than a marketplace, changing how people view investing or purchasing coins on these sites. For project leaders and stakeholders, there is definitely an incentive to bring a project onto more reputable exchanges that truly provide additional access and liquidity to the coin, which would mean that as we get more data, different exchanges may have more information about how good they are at identifying talent for their programs.

Exchange Native Tokens

A phenomenon that we've started to see is exchanges issuing their own utility token that allows its users to receive a discount on trades, encouraging further usage of the exchange. Coins like KuCoin Shares, Binance Coin, as well as protocol coins with exchanges (Stellar, 0x) could provide exchanges a way to self-fund or pre-fund development of more support and infrastructure to spur future growth without issuing a raise that could be construed as a security.

Pump & Dumps, And Other Risks, Schemes, or Market Manipulation

The idea that people, like prop traders, just want something to speculate on, and if it can be as cheap as the lowest decimal possible on the platform, it can literally only go up from there. A bitcoin is divisible down to 8 decimal places - one such unit is called a satoshi. Small exchanges with little volume are vulnerable and ripe for manipulation, such that they lose credibility. As people start to recognize the risks of poorly run centralized exchanges, there may be an increased number of attacks on exchanges. This concept of "honeypots" -

potentially high financial rewards for attacking poorly protected exchanges - may lead to a significant degree of consolidation within this space, forcing more users to concentration to a few trusted platforms.

Short Term Growth Strategies

Exchanges could also apply a variety of short term growth strategies, such as temporarily lowering transactions fees to attract new users, or sign up promotions that give users a bonus credit when they deposit a certain amount. A potential future project would be to look at the percentage of fraudulent or faked volume, particularly on exchanges with fee free transactions, which is typically used to encourage the filling of order books, if an exchange wants to appear more attractive or popular than it actually is.

Further Research

Exchanges do not close - cryptocurrencies do not have a strict 6.5 hour trading window as the New York Stock Exchange does, so mathematically, volatility is linear with respect to time, which makes sense as to why cryptocurrencies have the potential to be more volatile. The barrier to entry for a novice coder to set up a simple trading bot that runs all day is quite low, making it easier than ever to have participants in the market at any time of day. As more traders come from algorithms written by amateurs rather than large investment firms, the cryptocurrency market could provide some very interesting data in regards to efficiency of markets due to technological implementation and increased degrees of information share. Data within this space is much easier to grab than most financial-related industries, so being able to track the delistment of coins, the ordering that coins appear on exchanges, as well as many structures of token sales and exchanges, we can look at so many different economic situations. As governments, hacks, and other interventions provide very clear dates that change significant variables, we can create many difference in difference models for virtually any situation. With cryptocurrencies at the intersection of finance, tech, network theory, game theory, and behavioral science, we can utilize this industry to analyze so many of the questions we have about how the world works.

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APIs

https://cryptocompare.com/api/
https://coinmarketcap.com/all/views/all/

Code

https://github.com/calchulus/cryptothesis

8 Appendix

Omitting the 26 exchanges for which we could not calculate an HHI, we were left with 180 in our regressions.

Trade Satoshi is the only exchange with more than 200 pairs that isn't in the top 100 in exchange rank, but with an HHI of 0.287448813, it's also outside the top 100 in volume source diversity.

Table 1: (Exchanges)

Exchange	logvol	HHI	24hrvol	Pairs	Log Pairs	Top 5	Top 15	Top 25	Top 50	Top 100	Rank
Binance	21.43	0.06969	2,032,882,118	302	5.71	1	1	1	1	1	1
Upbit	21.08	0.11338	1,427,987,238	242	5.49	1	1	1	1	1	2
Huobi	20.90	0.02606	1,187,672,148	209	5.34	1	1	1	1	1	3
OKEx	20.69	0.06008	969,256,793	463	6.14	1	1	1	1	1	4
Bittrex	20.16	0.24211	569,190,028	276	5.62	1	1	1	1	1	5
Bitfinex	20.03	0.15147	498,035,114	50	3.91	0	1	1	1	1	6
Bithumb	19.88	0.13517	430,965,556	17	2.83	0	1	1	1	1	7
Lbank	19.25	0.09611	229,814,401	67	4.20	0	1	1	1	1	8
Bit-Z	19.10	0.07671	197,429,553	78	4.36	0	1	1	1	1	9
GDAX	19.07	0.17590	190,703,797	12	2.48	0	1	1	1	1	10
HitBTC	19.00	0.12377	177,920,383	559	6.33	0	1	1	1	1	11
Kraken	18.92	0.12179	165,038,073	56	4.03	0	1	1	1	1	12
Zaif	18.66	0.69616	126,845,461	16	2.77	0	1	1	1	1	13
ZB.COM	18.61	0.14109	120,472,864	33	3.50	0	1	1	1	1	14
bitFlyer	18.57	0.97615	115,972,653	4	1.39	0	1	1	1	1	15
Bitstamp	18.51	0.27113	109,567,406	14	2.64	0	0	1	1	1	16
BCEX	18.47	0.13297	105,433,702	35	3.56	0	0	1	1	1	17
EXX	18.34	0.22108	92,382,923	58	4.06	0	0	1	1	1	18
Quoine	18.30	0.88309	88,661,118	50	3.91	0	0	1	1	1	19
Poloniex	18.04	0.04728	68,373,157	99	4.60	0	0	1	1	1	20

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OOOBTC	18.03	0.58633	67,921,696	10	2.30	0	0	1	1	1	21
Bits Blockchain	18.01	0.43847	66,628,785	11	2.40	0	0	1	1	1	22
BTCC	17.98		64,320,400	4	1.39	0	0	1	1	1	23
CoinBene	17.97	0.29151	64,033,307	40	3.69	0	0	1	1	1	24
Bitbank	17.93	0.59750	60,985,650	8	2.08	0	0	1	1	1	25
WEX	17.92	0.02382	60,527,545	35	3.56	0	0	0	1	1	26
BTCBOX	17.90		59,524,800	1		0	0	0	1	1	27
Gate.io	17.90	0.06870	59,474,900	275	5.62	0	0	0	1	1	28
Bibox	17.81	0.03749	54,276,288	113	4.73	0	0	0	1	1	29
CoinsBank	17.70	0.06495	48,864,812	7	1.95	0	0	0	1	1	30
Simex	17.64	0.76166	45,843,730	5	1.61	0	0	0	1	1	31
Coinone	17.64	0.09926	45,771,884	10	2.30	0	0	0	1	1	32
Liqui	17.61	0.03176	44,299,766	217	5.38	0	0	0	1	1	33
Exmo	17.42	0.08977	36,612,311	45	3.81	0	0	0	1	1	34
YoBit	17.36	0.12516	34,667,656	519	6.25	0	0	0	1	1	35
IDAX	17.36	0.01518	34,471,050	16	2.77	0	0	0	1	1	36
TOPBTC	17.35	0.07642	34,413,802	12	2.48	0	0	0	1	1	37
Gemini	17.29	0.29375	32,427,315	3	1.10	0	0	0	1	1	38
Livecoin	17.28	0.22915	31,963,374	376	5.93	0	0	0	1	1	39
Kucoin	17.17	0.01629	28,770,143	320	5.77	0	0	0	1	1	40
Ethfinex	17.06	0.33370	25,608,736	100	4.61	0	0	0	1	1	41
B2BX	16.99	0.12036	23,808,548	20	3.00	0	0	0	1	1	42

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Neraex	16.95	0.27269	23,041,167	5	1.61	0	0	0	1	1	43
Qryptos	16.87	0.04129	21,314,402	110	4.70	0	0	0	1	1	44
Negocie Coins	16.87	0.98452	21,149,094	6	1.79	0	0	0	1	1	45
Bitinka	16.87	0.06849	21,116,013	8	2.08	0	0	0	1	1	46
Indodax	16.79	0.19872	19,583,392	24	3.18	0	0	0	1	1	47
Trade By Trade	16.77	0.16517	19,273,762	52	3.95	0	0	0	1	1	48
Coinhub	16.70	0.50475	17,970,709	10	2.30	0	0	0	1	1	49
Exrates	16.70	0.12750	17,898,902	69	4.23	0	0	0	1	1	50
GOPAX	16.64	0.18900	16,892,366	32	3.47	0	0	0	0	1	51
Korbit	16.62	0.20471	16,581,276	6	1.79	0	0	0	0	1	52
Tidex	16.58	0.38064	15,818,454	155	5.04	0	0	0	0	1	53
Coinroom	16.44	0.11527	13,806,445	59	4.08	0	0	0	0	1	54
Cryptopia	16.42	0.05198	13,491,105	564	6.34	0	0	0	0	1	55
xBTCe	16.39	0.05143	13,162,465	28	3.33	0	0	0	0	1	56
Omicrex	16.38	0.04445	13,053,189	22	3.09	0	0	0	0	1	57
itBit	16.31	0.99960	12,146,511	2	0.69	0	0	0	0	1	58
Coinnest	16.23	0.29498	11,234,540	33	3.50	0	0	0	0	1	59
COSS	16.23	0.51122	11,161,221	88	4.48	0	0	0	0	1	60
Sistemkoin	16.16	0.14828	10,415,710	32	3.47	0	0	0	0	1	61
Bancor Network	16.10	0.30837	9,833,803	60	4.09	0	0	0	0	1	62
OTCBTC	16.09	0.04585	9,750,173	69	4.23	0	0	0	0	1	63
Iquant	16.04	0.86442	9,277,525	18	2.89	0	0	0	0	1	64

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Octaex	15.94	0.15930	8,388,368	15	2.71	0	0	0	0	1	65
BtcTrade.im	15.92	0.10659	8,164,609	10	2.30	0	0	0	0	1	66
CoinExchange	15.87	0.15960	7,796,055	420	6.04	0	0	0	0	1	67
IDEX	15.86	0.27410	7,707,310	216	5.38	0	0	0	0	1	68
LakeBTC	15.85	0.58320	7,617,325	10	2.30	0	0	0	0	1	69
CEX.IO	15.78	0.24289	7,137,469	24	3.18	0	0	0	0	1	70
RightBTC	15.77	0.13581	7,068,887	33	3.50	0	0	0	0	1	71
C2CX	15.77	0.09902	7,028,318	21	3.04	0	0	0	0	1	72
Fatbtc	15.76	0.35671	7,004,936	25	3.22	0	0	0	0	1	73
Vebitcoin	15.70	0.16324	6,607,591	44	3.78	0	0	0	0	1	74
Radar Relay	15.70	0.99422	6,581,416	50	3.91	0	0	0	0	1	75
BuyBitcoin	15.70	0.29896	6,564,669	23	3.14	0	0	0	0	1	76
BitBay	15.59	0.53805	5,888,021	30	3.40	0	0	0	0	1	77
ChaoEX	15.56	0.10268	5,708,969	21	3.04	0	0	0	0	1	78
BTC Markets	15.49	0.21707	5,337,244	11	2.40	0	0	0	0	1	79
MBAex	15.48	0.26386	5,270,800	7	1.95	0	0	0	0	1	80
Ovis	15.45	0.05736	5,139,658	21	3.04	0	0	0	0	1	81
Zebpay	15.39	0.16551	4,807,089	5	1.61	0	0	0	0	1	82
Koineks	15.34	0.03773	4,596,258	9	2.20	0	0	0	0	1	83
QuadrigaCX	15.31	0.13791	4,451,646	7	1.95	0	0	0	0	1	84
BTC-Alpha	15.30	0.12012	4,429,019	46	3.83	0	0	0	0	1	85
BX Thailand	15.30	0.19080	4,415,496	25	3.22	0	0	0	0	1	86

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QBTC	15.27	0.05330	4,262,397	21	3.04	0	0	0	0	1	87
Independent Reserve	15.25	0.41262	4,189,203	12	2.48	0	0	0	0	1	88
Paribu	15.18		3,895,940	1		0	0	0	0	1	89
LiteBit.eu	15.07	0.48108	3,490,678	46	3.83	0	0	0	0	1	90
OEX	15.03	0.14352	3,377,039	21	3.04	0	0	0	0	1	91
BTCTurk	14.99	0.02014	3,239,818	3	1.10	0	0	0	0	1	92
Mercatox	14.96	0.04637	3,131,093	127	4.84	0	0	0	0	1	93
Luno	14.87	0.59222	2,867,370	4	1.39	0	0	0	0	1	94
BigONE	14.83	0.07357	2,760,192	111	4.71	0	0	0	0	1	95
Coinfloor	14.82	0.99003	2,739,468	5	1.61	0	0	0	0	1	96
Koinex	14.79	0.07381	2,652,204	19	2.94	0	0	0	0	1	97
BitShares Asset Exchange	14.78	0.55380	2,623,715	18	2.89	0	0	0	0	1	98
BL3P	14.76	0.94245	2,558,892	2	0.69	0	0	0	0	1	99
Coinrail	14.71	0.08934	2,437,676	49	3.89	0	0	0	0	1	100
Fargobase	14.70		2,432,700	1		0	0	0	0	0	101
Foxbit	14.68		2,381,420	1		0	0	0	0	0	102
Unocoin	14.68	0.16851	2,378,668	6	1.79	0	0	0	0	0	103
LATOKEN	14.56	0.01977	2,095,664	39	3.66	0	0	0	0	0	104
Bitso	14.49	0.27277	1,955,193	9	2.20	0	0	0	0	0	105
Coinsquare	14.46	0.28179	1,895,547	6	1.79	0	0	0	0	0	106
DSX	14.34	0.17508	1,692,509	20	3.00	0	0	0	0	0	107

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CoinEx	14.24	0.11791	1,529,057	17	2.83	0	0	0	0	0	108
Cryptonex	14.20	0.17469	1,463,270	7	1.95	0	0	0	0	0	109
Bitbns	14.11	0.06166	1,345,477	33	3.50	0	0	0	0	0	110
Bitonic	13.90		1,083,710	1		0	0	0	0	0	111
EtherDelta (ForkDelta)	13.88	0.21785	1,063,785	130	4.87	0	0	0	0	0	112
Mercado Bitcoin	13.85	0.25647	1,036,324	3	1.10	0	0	0	0	0	113
OkCoin Intl.	13.80	0.77888	988,569	3	1.10	0	0	0	0	0	114
Waves Decentralized Exchange	13.80	0.70763	980,896	64	4.16	0	0	0	0	0	115
BuyUcoin	13.73	0.08505	915,181	31	3.43	0	0	0	0	0	116
Allcoin	13.61	0.33915	812,526	41	3.71	0	0	0	0	0	117
The Rock Trading	13.58	0.52358	790,426	13	2.56	0	0	0	0	0	118
Tidebit	13.56	0.29411	776,630	9	2.20	0	0	0	0	0	119
OpenLedger DEX	13.56	0.16133	774,853	100	4.61	0	0	0	0	0	120
CryptoBridge	13.47	0.14373	707,506	101	4.62	0	0	0	0	0	121
ACX	13.46	0.83050	699,913	7	1.95	0	0	0	0	0	122
Gatehub	13.42	0.19234	675,909	12	2.48	0	0	0	0	0	123
Nanex	13.41	0.30223	665,143	9	2.20	0	0	0	0	0	124
Koinim	13.41		665,043	2	0.69	0	0	0	0	0	125
BitcoinTrade	13.37	0.74892	637,948	2	0.69	0	0	0	0	0	126
Stocks.Exchange	13.32	0.43470	609,129	105	4.65	0	0	0	0	0	127

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BitMarket	13.24	0.71158	562,876	5	1.61	0	0	0	0	0	128
RippleFox	13.22	0.26717	548,630	3	1.10	0	0	0	0	0	129
CoinMate	13.15		516,016	1		0	0	0	0	0	130
C-CEX	13.10	0.08686	490,772	151	5.02	0	0	0	0	0	131
Bitstamp (Ripple Gateway)	13.05	0.48476	466,441	3	1.10	0	0	0	0	0	132
CoinFalcon	12.98	0.78254	432,132	56	4.03	0	0	0	0	0	133
BitcoinToYou	12.95		420,312	1		0	0	0	0	0	134
Altcoin Trader	12.93	0.27636	412,236	8	2.08	0	0	0	0	0	135
Trade Satoshi	12.87	0.28745	386,611	237	5.47	0	0	0	0	0	136
Bithesap	12.78		356,766	1		0	0	0	0	0	137
Tripe Dice Exchange	12.71	0.17699	331,884	4	1.39	0	0	0	0	0	138
Bleutrade	12.66	0.50138	313,950	86	4.45	0	0	0	0	0	139
OasisDEX	12.62	0.34261	303,632	3	1.10	0	0	0	0	0	140
BitFlip	12.52	0.35510	273,738	64	4.16	0	0	0	0	0	141
Stellar Decentralized Exchange	12.48	0.08345	263,252	14	2.64	0	0	0	0	0	142
AidosMarket	12.46		258,494	1		0	0	0	0	0	143
Stellarport	12.46	0.00933	256,935	8	2.08	0	0	0	0	0	144
CoinCorner	12.43	0.17825	250,354	2	0.69	0	0	0	0	0	145
Rfinex	12.42	0.39457	247,728	4	1.39	0	0	0	0	0	146
Kuna	12.39	0.31321	240,092	16	2.77	0	0	0	0	0	147

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Ripple China	12.34		229,624	1		0	0	0	0	0	148
Mr. Exchange	12.26	0.76404	210,343	16	2.77	0	0	0	0	0	149
Bittylicious	12.21	0.60941	200,915	38	3.64	0	0	0	0	0	150
Coinrate	12.17	0.09897	192,261	5	1.61	0	0	0	0	0	151
Token Store	12.14	0.03053	188,114	17	2.83	0	0	0	0	0	152
Lykke Exchange	12.13	0.10971	186,185	73	4.29	0	0	0	0	0	153
Buda	12.07	0.26678	174,319	11	2.40	0	0	0	0	0	154
BTC Trade UA	12.06	0.18691	172,970	15	2.71	0	0	0	0	0	155
Coinut	11.81	0.05201	134,028	14	2.64	0	0	0	0	0	156
SouthXchange	11.79	0.13446	132,485	68	4.22	0	0	0	0	0	157
CryptoMarket	11.76	0.38315	128,230	8	2.08	0	0	0	0	0	158
Braziliex	11.62	0.47436	111,851	23	3.14	0	0	0	0	0	159
TDAX	11.60	0.30596	109,023	24	3.18	0	0	0	0	0	160
InfinityCoin Exchange	11.51		99,791	1		0	0	0	0	0	161
Paradex	11.47	0.71160	96,220	15	2.71	0	0	0	0	0	162
Bitlish	11.30	0.57018	80,815	17	2.83	0	0	0	0	0	163
TradeOgre	11.29	0.17697	80,220	14	2.64	0	0	0	0	0	164
Nocks	11.20		73,340	1		0	0	0	0	0	165
ezBtc	11.18		71,372	1		0	0	0	0	0	166
Paymium	11.17		70,927	1		0	0	0	0	0	167
Bitex.la	11.17		70,617	1		0	0	0	0	0	168

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Bit2C	11.15	0.87553	69,875	3	1.10	0	0	0	0	0	169
Crex24	11.05	0.21208	62,992	24	3.18	0	0	0	0	0	170
DDEX	10.93	0.10001	55,897	39	3.66	0	0	0	0	0	171
cfinex	10.86	0.42740	52,200	10	2.30	0	0	0	0	0	172
CRXzone	10.79	0.93649	48,443	3	1.10	0	0	0	0	0	173
Abucoins	10.78	0.43331	47,917	45	3.81	0	0	0	0	0	174
Gatecoin	10.62	0.23816	40,972	53	3.97	0	0	0	0	0	175
Bitsane	10.55	0.19036	38,140	30	3.40	0	0	0	0	0	176
TCC Exchange	10.37		31,991	1		0	0	0	0	0	177
Cryptohub	10.22	0.50885	27,441	20	3.00	0	0	0	0	0	178
Bitmaszyna	10.02		22,566	2	0.69	0	0	0	0	0	179
Coinbe	10.00	0.72108	21,959	14	2.64	0	0	0	0	0	180
OKCoin.cn	9.77	0.21399	17,498	3	1.10	0	0	0	0	0	181
Cryptomate	9.66	0.07558	15,697	14	2.64	0	0	0	0	0	182
BitKonan	9.59	0.80533	14,554	2	0.69	0	0	0	0	0	183
Counterparty DEX	9.50		13,353	3	1.10	0	0	0	0	0	184
Cryptox	9.39	0.41594	12,001	6	1.79	0	0	0	0	0	185
Stronghold	9.32	0.25165	11,158	5	1.61	0	0	0	0	0	186
Dgtmarket	9.23		10,191	3	1.10	0	0	0	0	0	187
Bisq	9.18	0.16981	9,740	14	2.64	0	0	0	0	0	188
Coinlink	9.15	0.28215	9,442	5	1.61	0	0	0	0	0	189
Ore.Bz	8.50	0.63379	4,899	6	1.79	0	0	0	0	0	190

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RuDEX	8.26	0.52511	3,852	7	1.95	0	0	0	0	0	191
FreiExchange	8.16	0.80553	3,497	6	1.79	0	0	0	0	0	192
Coingi	8.02	0.36458	3,045	10	2.30	0	0	0	0	0	193
Tux Exchange	7.76	0.41736	2,352	19	2.94	0	0	0	0	0	194
ExcambrioRex	7.74		2,294	1		0	0	0	0	0	195
ISX	7.67		2,146	1		0	0	0	0	0	196
LocalTrade	7.49	0.64260	1,789	6	1.79	0	0	0	0	0	197
C-Patex	7.02	0.49829	1,121	12	2.48	0	0	0	0	0	198
Novaexchange	6.93	0.25293	1,020	6	1.79	0	0	0	0	0	199
CryptoDerivatives	6.24		515	10	2.30	0	0	0	0	0	200
Heat Wallet	6.00		405	6	1.79	0	0	0	0	0	201
Coinhouse	4.91	0.14815	135	12	2.48	0	0	0	0	0	202
BarterDEX	4.79	0.30362	120	12	2.48	0	0	0	0	0	203
NIX-E	3.14	0.42643	23	4	1.39	0	0	0	0	0	204
DC-Ex	2.64		14	1		0	0	0	0	0	205
Averages	14.07	0.3062	51,188,247.79	48.65							