Bitcoin and the Kimchi premium

Abstract

Between 2013 and 2018 Bitcoin were in Korea on average 3.2% more expensive than in the United States, a fact commonly referred to as the Kimchi premium. We argue that frictions within the microstructure of the bitcoin network as well as capital controls imposed by the Korean government limit the ability of arbitrageurs to take advantage of persistent price differences. We find that the Bitcoin premia are positively related confirmation times in the blockchain and to bitcoin volatility in line with the idea that the delay and the associated price risk during the transaction period make trades less attractive for risk averse arbitrageurs and hence allow prices to diverge. A cross country comparison shows that bitcoin tend to trade at higher prices in countries with lower financial freedom.

Keywords: Bitcoin, Limits to Arbitrage, Crypto-Currencies, Fintech

Extended Abstract: preliminary and incomplete

1 Introduction

In Korea Bitcoin frequently trade at a higher price than in other markets, a phenomenon referred to as the Kimchi premium. Between September 2013 and February 2018 the average Kimchi premium was 3.2% but it reached levels as high as 54.48%. Figure 1 shows a time series plot as well as a histogram of the Kimchi premium in this time period. In friction-less financial markets such a price difference could not persist as it would be immediately arbitraged away. Traders could buy bitcoin in another market, say the US, then transfer them to a Korean Bitcoin exchange, sell them for Korean Won, and convert the Won to US-dollars for an instant profit. However, institutional frictions prevent arbitrageurs to keep bitcoin prices in Korea aligned with the rest of the world. In this paper we analyze two main frictions that can contribute to a potential misalignment of Bitcoin prices across major markets: capital controls and frictions emanating from the microstructure of the bitcoin network

An arbitrageur faces two main sources of risk when executing the trade described above. First, the transfer of bitcoin from a foreign exchange to a Korean exchange takes time during which the price of bitcoin can change dramatically. Since bitcoin can usually not be shorted the premium cannot be locked in; bitcoin at a Korean exchange can only be sold once the transfer is complete. Because bitcoin can be much more volatile than many transitional assets, price risk (even for the short time of the transfer) can pose a significant deterrent for arbitrageurs. Second, time varying transaction costs can erode potential arbitrage profits. Demand for transactions fluctuates over the day and over time. As fees to be included increase, profits from arbitrage decrease allowing the price difference between bitcoin in Korea and the rest of the world to increase.

Korean capital controls limit the amount of money that can be sent abroad or at least complicate the transfer of funds and thus create a friction for one part of the arbitrage trade. in the aftermath of the global financial crisis and the European sovereign debt crisis Korea introduced capital controls that create administrative burden and additional time delay when sending money abroad as it is needed to complete the arbitrage trade. Even government regulations

regarding the interpretation of capital controls and the legal status of bitcoin vary over time.

Preliminary results indicate that the Kimchi premium is significantly positively related to bitcoin volatility, supporting our idea that price risk for traders limits arbitrage activity. The Kimchi premium is also positively related to the median confirmation time in the block chain, supporting the idea that longer transaction times create more uncertainty for arbitrageurs allowing prices to diverge. In ongoing research we are collecting data on transaction fees and news events, and are refining our measures of bitcoin volatility to use them as explanatory factors for the Kimchi premium. We will also examine other crypto-currencies to see if a Kimchi premium exists as well and how it is correlated with the Bitcoin Kimchi premium.

While our paper primarily focuses on Korea, divergent bitcoin prices also exist in other countries. Figure 2 plots the median bitcoin premium from March 2017 to the end of February 2018 as a function of financial freedom for a selected list of countries. To obtain the premia we use bitcoin transaction prices from bitcoincharts.com, foreign exchange data from the Federal Reserve Bank of St. Louis (where available) and OANDA otherwise. To measure financial freedom we average the to index components 'Investment freedom' and 'Financial Freedom' as published on a country level by the Heritage Foundation. As a stylized fact we observe higher premia in financially more restrictive countries which is consistent with our view that financial restrictions in Korea are one contributing factor to the Kimchi premium.

Our work is related to a broad literature of limits of arbitrage.[1] There are various constraints and limitations known in the literature to impede arbitrage trading. Among such constraints[2], the following four factors are the most relevant to the bitcoin price difference: (i) risk (or the price volatility in our case), (ii) the international trading frictions, (iii) short-sale constraints, and (iv) opportunity cost (holding costs). For the first and the second factors, we find that the Kimchi premium has a significant positive relation with the bitcoin price volatility and the capital control index, as mentioned before.[3]

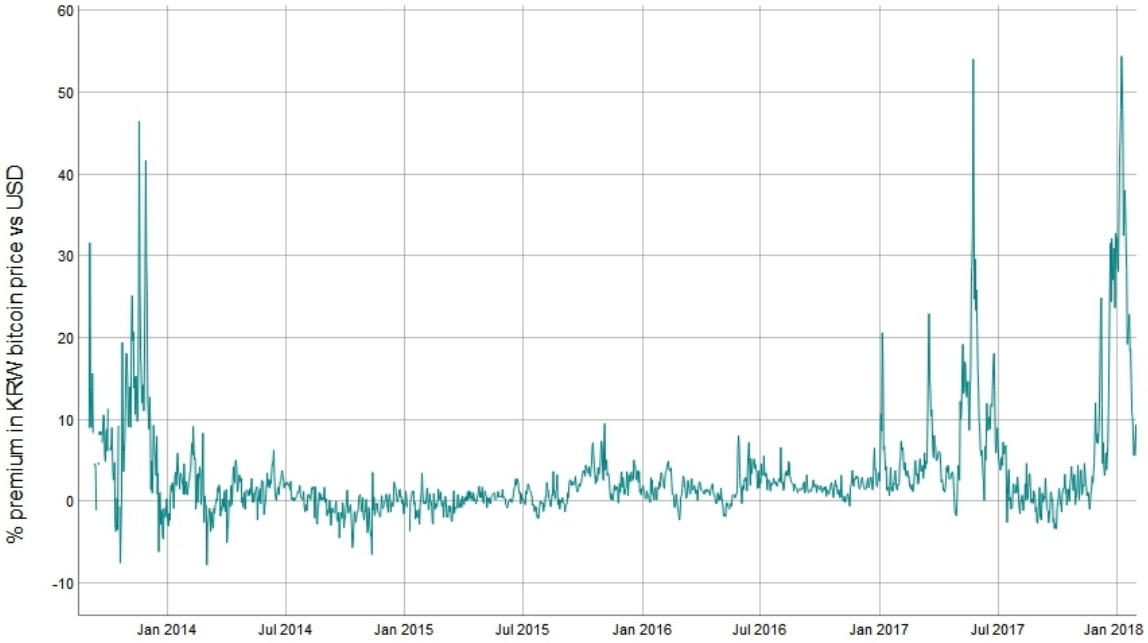
[1] See for example Gromb and Vayanos (2010) for a survey on limits arbitrage.

[2] The constraints include information asymmetry, short-sale constraints, leverage margin constraints, constraints on equity capital and so on.

[3] See, e.g., Edwards (1999) on the capital control

Figure 1. The Bitcoin Kimchi Premium: Bitcoins frequently trade at a higher price in Korea than in other markets. The premium for purchasing bitcoins with Korean Won (KRW) versus US Dollars (USD) is calculated: $(\text{KRWBTC}_{\text{price in USD}})/(\text{USDBTC}_{\text{price}}) - 1$, where the bitcoin price in USD is the mean price of all USD transactions on the Bitstamp exchange for that day. The bitcoin price in KRW is similarly defined from the Korbit exchange. Conversion from KRW to USD is done using the OANDA daily average rate.

a) The kimchi premium over time (top panel)



b) Distribution of the kimchi premium (bottom panel)

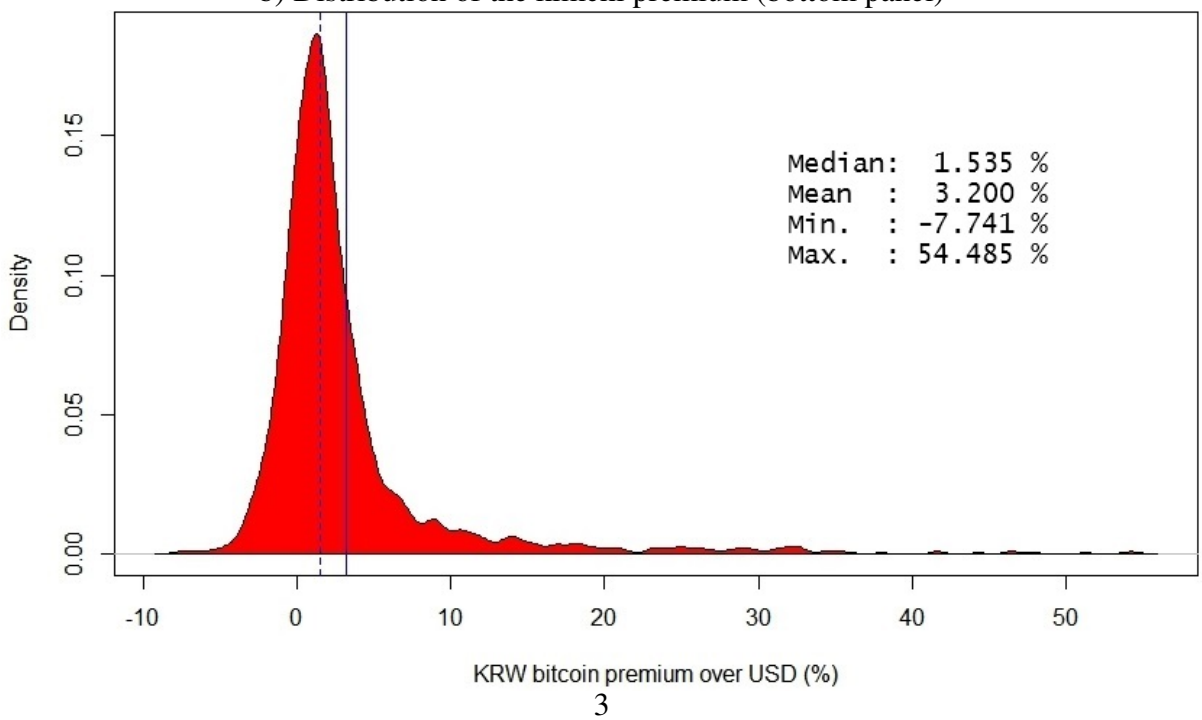
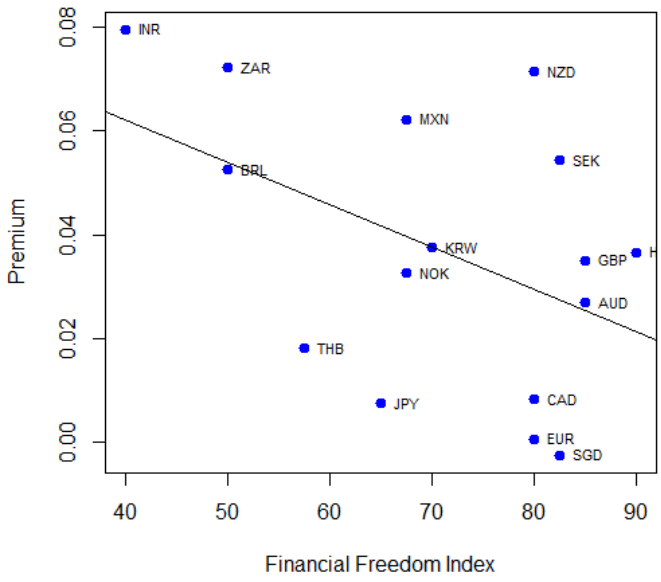


Figure 2. Bitcoin premia and Financial Freedom: The bitcoin premium is measured as the median percentage price difference to the USD price from March 2017 to the end of February 2018. Bitcoin transaction prices are from bitcoincharts.com, foreign exchange data from the Federal Reserve Bank of St. Louis (where available) and OANDA otherwise. To measure financial freedom we average the to index components 'Investment freedom' and 'Financial Freedom' as published on a country level by the Heritage Foundation.



For the third factor, there has been a large literature investigating the joint effect of short-sale restrictions and heterogeneous beliefs in the stock market (e.g., Miller (1997), Chen, Hong, and Stein (2002), Scheinkman and Xiong (2003), and Hong, Scheinkman, and Xiong (2006)). Under a short-sale constraint, the optimists are more likely to be marginal buyers and the stock price tend to reflect optimists' valuation more than that of pessimists. Based on this theoretical insight, Mei, Scheinkman, and Xiong (2009) investigate the price difference between the local A- and foreign B-share market in China. They show that A-share turnover had a significant and positive correlation with the A- and B-share price difference in the China market.[4] Consistent

[4]There are other papers to study the price difference between the Chinese A- and B- share prices (e.g., Chakravarty, Sarkar, and Wu (1998) and Chan, Menkveld, and Yang (2008)). For example, Chan, Menkveld, and Yang (2008) investigate how information asymmetry affects on equity prices. The information asymmetry in the Bitcoin market matters in the world wide level, but it is unlikely to have specific impact on the Bitcoin premium in the Korean market.

with this stream of research we also find a positive relationship between the Kimchi premium and the bitcoin trading volume in Korean exchanges.

Finally, the literature on the cross-listed stock price difference shows that the price deviations are positively related to holding costs that impede arbitrage (see, e.g., Pontiff (2006) and Gagnon and Karolyi (2010)). There are several proxies for holding costs such as idiosyncratic risk, stock's dividend yield, and the interest rate. We will explore this angle in future versions of the paper.

2 Institutional background

2.1 Bitcoin microstructure

The microstructure of bitcoin markets stands out in many ways from traditional markets. Bitcoin like many crypto-currencies are free of regulation that applies to many traditional monetary instruments and securities in financial markets. Therefore it is easy to move payments across borders that constitute soft or hard barriers to flows of capital in traditional markets. Overcoming capital control barriers creates a demand for bitcoin as individuals can circumvent government restrictions without much effort. This extra transnational value of Bitcoin can generate high demand in countries with capital controls such as Korea that can lead to prices above the world market price if not arbitraged away.

Bitcoin is very popular in Korea. As of February 1st, 2018, there are 16 cryptocurrency exchanges in South Korea. The five largest exchanges, in terms of trading volumes, are Upbit (#1), Bithumb (#7), Coinone (#14), Korbit (#18), and Coinnest (#21).[5] Korbit was the first Korean bitcoin exchange that opened in April, 2013. Then, Bithumb (January, 2014), Coinone (August 2014), Coinnest (July 2017) and Upbit (October, 2017) followed. Until Upbit started

[5]The number inside the parenthesis is the world ranking in trading volumes (all the cryptocurrencies) by Coinhills on February 1st, 2018 (see `https://www.coinhills.com/market/exchange/`)

an exclusive partnership with Bittrex (a major U.S. based exchange) on October 2017, Bithumb, Coinone, and Korbit had been the three major exchanges.[6]

Two frictions within the Bitcoin system can limit arbitrage activity. Transferring Bitcoin from one wallet to another requires a short period of time. Many exchanges require a certain number of confirmations to credit the Bitcoin to an account. A transaction with n confirmations means that this transaction has been included in a mined block and that there have been $n-1$ subsequent blocks mined in the blockchain. Time delay arises from the time it takes for a transaction to be included in a mined block and from the time it takes to mine the required number of subsequent blocks. The time to be included in a block can vary substantially. The average confirmation time reached 11,453 minutes (7.9 days) on January 22, 2018 and in the period of Feb 14 2017 to Feb 14 2018 the average confirmation time was above 2 hours 31% of the time.[7] The average time between successfully mined blocks is 10 minutes.

When trading on bitcoin exchanges another layer of delay arises. Most exchanges offer clients accounts similar to an account with a traditional stock broker. Trades are usually only possible between account holders at the same exchange and a trade is just recorded in the ledger of the exchange, not on the blockchain. The bitcoins transferred from the seller to the buyer are held in the name of the exchange on the blockchain before and after the trade; the exchange just records a change of ownership in its internal records. Account holders can request a transfer to a private walled out of the exchange account which will trigger a ledger entry on the blockchain. While there is no data available on processing times by exchanges, anecdotal evidence on several bitcoin forums shows that processing times can be substantial with traders waiting up to several days before exchanges transfer bitcoins from their exchange-account to a private wallet from which a transfer (to another exchange) can be initiated. In particular, 5-10 hours of processing time from a U.S. exchange to a Korean exchange is commonly reported by a major mass media in Korea. For example, Chosun Ilbo, a Korean newspaper, tested the arbitrage and reported a processing time of 9 hours from Coinbase to Bithum on December 26, 2017 when

[6]Among the top three, Korbit is the only one who provides a history of all the trades in unix-time

[7]source: `https://blockchain.info/`

the Kimchi premium was about 28%.[8]

Transaction fees are endogenously determined in the bitcoin network. When posting a transaction to the pool the originator can set a fee that he or she is willing to pay to the miner for the transaction to be included in the block. Miners can select transactions from the pool and keep the fee upon successfully mining a block. Transactions with higher fee have a higher probability to be included in a block. An arbitrageur thus faces a tradeoff between offering a high fee that will get the transaction processed faster and mitigate price risk and the cost of the higher fee which will directly reduce the arbitrageur's profit.

2.2 Capital Controls

On June 13 2010, in the aftermath of the global financial crisis and the European Sovereign debt crisis, Korea introduced capital controls that were revised several times since. The Korean foreign exchange transaction law has been very restrictive. According to the most recent law revision (valid since July 18th, 2017)[9], an individual can send money up to 3,000 USD per transfer and 20,000 USD between January 1st and December 31st through a financial institution. The total maximum is limited to 50,000 USD a year through different institutions.[10] There are several alternative ways to send cash abroad. First, one can use a Korean credit card when buying Bitcoin at an exchange in the U.S.. However, the maximum amount of purchases outside of Korea is limited to 10,000 USD per year. In addition, this transaction is considered as commodity purchase, which means the buyer should pay customs on buying Bitcoin. One can send US dollars to someone (e.g., relatives or friends in the U.S.) who can help arbitrage trading through Paypal. In this case, however, Paypal automatically reports this transaction to

[8]Chosun Ilbo (Daily Chosun) is the # 1 news paper company in South Korea in terms of the total number of daily printing. See the following news article by the Chosun Ilbo on January 4: `http://news.chosun.com/site/data/html_dir/2018/01/04/2018010400441.html`.

[9]See the government website on small foreign remitment: `http://www.mosf.go.kr/nw/nes/detailNesDtaView.do?searchBbsId1=&searchNttId1=MOSF_000000000009556&menuNo=4010100`.

[10]There are some exceptions. For example, the maximum per year is up to 100,000 USD for educational reasons such as tuition with proper evidence.

the US Internal Revenue Service (IRS) and the IRS normally considers this money inflow to the receiver as taxable income if the transfer amount is sufficiently large or the transfers occur on a regular basis. In addition, many Korean lawyers[11] say that in the current South Korean law it is not very clear if transferring Bitcoins between a Korean exchange and exchanges in other countries is considered as capital in- and out-flow or commodity export/import. This legal interpretation issue might pose an additional risk since the government might investigate transfer activities ex-post and accuse market participants of violation of the law depending on how they interpret the law.

3 Data Sources and Model Variables

We describe the data sources and the variables used for our OLS regression analysis. A summary of the variables can be found in Table 1. Our primary variable of interest is the kimchi premium (KRW Bitcoin premium over USD). We also look at the EUR Bitcoin premium over USD for comparison. We define the premium as

$$Premium = \frac{\text{KRW/BTC price} \times \text{USD/KRW exchange rate} - \text{USD/BTC price}}{\text{USD/BTC price}} \tag{1}$$

For the daily USDBTC, KRWBTC, and EURBTC prices we look at all transactions on specific Bitcoin exchanges (data accessed via `https://bitcoincharts.com/`). Exchanges were selected due to data availability, length of trading history, and both current and historical market share. USDBTC data is from Bitstamp. Bitstamp has offices in Luxembourg, London, and Berkeley. They are currently the 3rd largest exchange for USDBTC trades by volume and have the longest trading history of the current major players. In the early days of bitcoin trading the USDBTC leader was Mt. Gox which famously went bankrupt following a security breach. The dataset contains 20,251,411 total trades with the first trade occurring on 2011-09-13. The total notational value (at the time of each trade) is USD 34.4b. KRWBTC data is from Korbit.

[11] See, e.g., `http://hongbyun.tistory.com/22`.

Korbit was South Koreas first bitcoin exchange and is currently third by volume for KRWBTC. The dataset contains 4,932,571 total trades with the first trade occurring on 2013-09-03. The total notational value (at the time of each trade) is KRW 13.6t. EURBTC data is from Kraken. Kraken is currently the largest exchange for EURBTC by volume, with more than half the total volume. The dataset contains 15,762,932 trades with the first trade occuring at 2014-01-08. The total notational value (at the time of each trade) is EUR 16.2b.

The USDBTC daily price we utilize for analysis is the mean price of all USD transactions on the Bitstamp exchange for that day. The KRWBTC and EURBTC daily prices are similarly defined using Korbit and Kraken exchanges respectively. To convert the KRWBTC and EURBTC prices to USD for comparison we utilize data from OANDA (`https://www.oanda.com/`). The daily prices utilized are the average price (not the close) over the 24-hour period (UTC time standard) aggregated from multiple exchanges. This is necessary for our purposes as the bitcoin markets operate 24/7.

We estimate short and long term volatility for Bitcoin prices using market data over one day and 20 days, respectively. For the short term volatility we define volatility as the sum of 10 minute squared returns over one day. Microstructure noise can arise from spreads between bid and ask prices and from shifts in transaction prices die to the random execution of large trades at the beginning or the end of the 10 minute interval. We use two measures to mitigate potential biases doe to microstructure noise. First, we compute daily volatility for a given exchange as the average of two volatility measures, based on 10 minute returns shifting the tome interval by 5 minutes. Second, we define volatility as the median volatility over several exchanges.[12] Similarly we compute long term volatility for a given exchange as the sum of squared 12 hour returns over a period of 20 days. We then define long term volatility as the median volatility over several exchanges.

The Bitcoin blockchain median confirmation time data is from `https://blockchain.`

[12]Data availability differs per time period as data is not available for all exchanges at all times. We include data from the following exchanges: bitfinex, bitstamp, BTCC, btc-e, coinbase, Gemini, hitbtc, itbit, kraken, OK-Coin, Poloniex as available on bitcoinchain.com.

info/. This is the median time in minutes for a Bitcoin transaction to be accepted into a mined block and added to the public ledger (note: only includes transactions with miner fees). For days with missing data (of which there are none in the most recent 2 years) we interpolate by using the prior day's value. The maximum gap in the data set was 1 day. Results were unchanged when using straight-line smoothing or removing those days completely from analysis.

For the KRWBTC and EURBTC volumes we look at the daily total number of exchange transactions (in thousands) on Korbit and Kraken respectively. This approach was taken rather than volume in bitcoins due to the wildly differing Bitcoin prices at the start versus the end of the sample period. Alternative measures considered included daily local currency total valuation and daily USD total valuation. For the KRWUSD and EURUSD foreign exchange volatilities we use the standard deviation of 1-day logarithmic returns in the daily average KRWUSD and EURUSD exchanges from OANDA, over the most recent 20 days.

4 Preliminary Findings

To analyze the kimchi-premium we regress daily observations of the relative price difference for bitcoin in Korea and the US on several factors poxing for potential frictions inhibiting the arbitrage. All bitcoin for fiat currency transaction times are converted to UTC time standard. At the moment all analysis is done at the daily level. Days with missing trading data are excluded. All results were robust to testing on a sample with price smoothing over missing days (where the price path on missing days was assumed to follow the geometric mean return path connecting the two known days).

Regression results are shown in Table 2. These initial results lend support to the view that bitcoin price risk is a significant component to the kimchi premium size. In periods of high volatility, the cost of waiting for blockchain confirmations could be very significant and deter arbitrageurs. Models (1) and (2) both document a positive relation between the kimchi premium and short and long term volatility. Model (3) shows short term volatility is more important in

Table 1. Analysis Variables

Variable Name	Variable Definition
Kimchi premium (KRW premium over USD)	Calculated as $(\text{KRWBTC}_{\text{price in USD}})/(\text{USDBTC}_{\text{price}}) - 1$, where the bitcoin price in USD is the mean price of all USD transactions on the Bitstamp exchange for that day. The bitcoin price in KRW is similarly defined with data from the Korbit exchange. Conversion from KRW to USD is done using the OANDA daily average rate.
EUR premium over USD	The absolute value of $(\text{EURBTC}_{\text{price in USD}})/(\text{USDBTC}_{\text{price}}) - 1$, where the bitcoin price in USD is the mean price of all USD transactions on the Bitstamp exchange for that day. The bitcoin price in EUR is similarly defined from the Kraken exchange. Conversion from EUR to USD is done using the OANDA daily average rate.
Bitcoin short-term volatility	The sum of 10 minute USDBTC squared returns over one day. We define short-term volatility as the median volatility over several exchanges: bitfinex, bitstamp, BTCC, btc-e, coinbase, Gemini, hitbtc, itbit, kraken, OK-Coin, Poloniex.
Bitcoin long-term volatility	The sum of squared 12 hour USDBTC returns over a period of 20 days. We define long-term volatility as the median volatility over several exchanges: bitfinex, bitstamp, BTCC, btc-e, coinbase, Gemini, hitbtc, itbit, kraken, OK-Coin, Poloniex.
Blockchain median confirmation time	The median time (in minutes) for a Bitcoin transaction to be accepted into a mined block and added to the public ledger (note: only includes transactions with miner fees). Source: *blockchain.info*. To interpolate missing days, the most recent known value is used (max gap in data set is 1 day).
KRWBTC volume	The daily total number of KRW and BTC exchange transactions on the Korbit exchange. Measured in thousands.
KRWUSD volatility	The standard deviation of 1-day logarithmic returns in the daily average KRWUSD exchange rate from OANDA, over the most recent 20 days.
EURBTC volume	The daily total number of EUR and BTC exchange transactions on the Kraken exchange. Measured in thousands.
EURUSD volatility	The standard deviation of 1-day logarithmic returns in the daily average EURUSD exchange rate from OANDA, over the most recent 20 days.

line with the stylized fact that bitcoin volatility varies a lot over time and the idea that arbitrage activity is short term in nature. Model (4) documents that higher median confirmation times on the block chain are associated with higher bitcoin premia. An arbitrageur could potentially jump the queue get her transaction processed faster by offering a higher transaction fee to miners, yet such a higher transaction fee would also cause a direct reduction in arbitrage profits and hence allow for a larger premium.

In model (5) we add bitcoin volume data and find that it is positively associated with the Kimchi premium while the confirmation time becomes insignificant. Several potential explanations are consistent with this finding. Increased trading volume could increase the demand for concurrent or future transactions in the blockchain and hence both explanatory variables could be driven by the same underlying factor. Higher trading volume at the exchanges could lead to increased processing times for deposits or withdrawals (see section **??**) of bitcoin in exchanges and hence increase the turnaround time for an arbitrage trade. The positive association of volume and premium is also consistent with the findings of Mei, Scheinkman, and Xiong (2009) who show that A-share turnover had a significant and positive correlation with the A- and B-share price difference in China. In model (6) we find that a higher FX volatility is associated with a lower Kimchi premium. Despite a larger coefficient the economic significance of the FX-vola is much lower as it is orders of magnitude smaller than the bitcoin volatility.

To separate the effect of frictions emanating from within the bitcoin network from Korea specific factors like the capital controls we perform a similar analysis for the European market. Figure 3 plots the relative price difference of bitcoin in the EURO market relative to the USD market. Price differences are substantial, yet the divergence of bitcoin prices are smaller then in the Korean market and fairly symmetric in its distribution (average 0.27%, minimum -4.37%, maximum 4.07%). In our regression analysis for the European market we explain the absolute value of the premium as we are are primarily interested in explaining the cause of price divergences.[13] Regression results for the EUR premium can be seen in Table 3.

[13] In the Korean case regression results are very similar for explaining the absolute premium since the premium is positive almost for the entire sample.

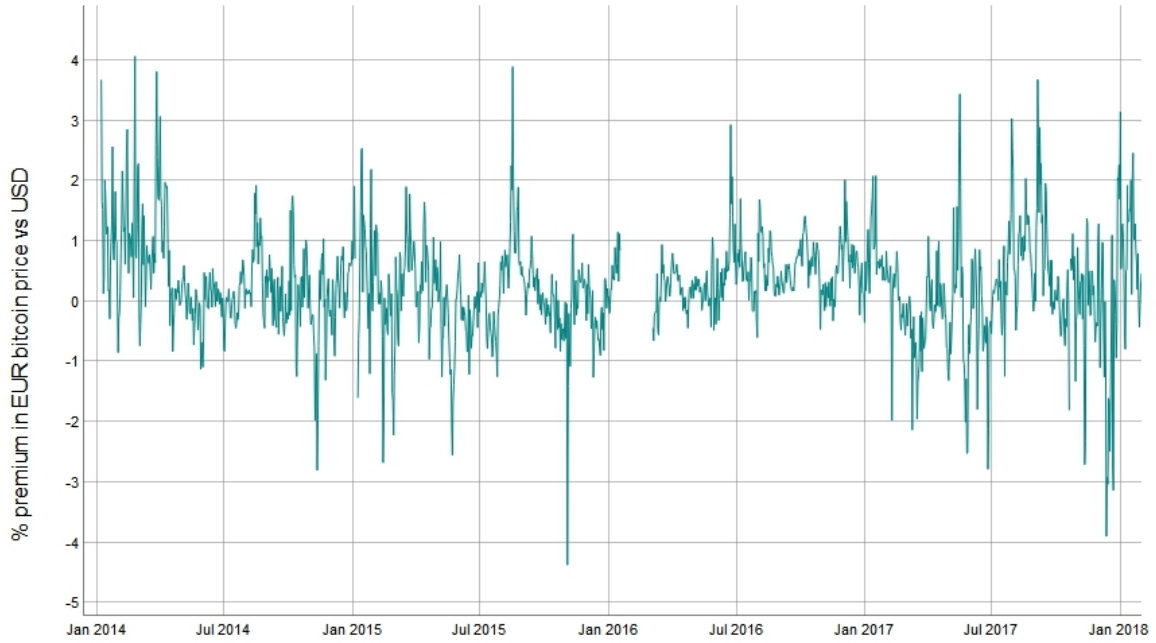
Both, the coefficients for the short term and long term volatility have the same sign but are ten times smaller than in the case of the Korean market. These findings are consistent with an interpretation that bitcoin price divergences are in part driven by microstructure effects within the bitcoin network and that increased volatility makes arbitrage more risky and hence allows prices to diverge more. Yet the smaller amount of frictions in the European market facilitates arbitrage and hence price divergence is much smaller. Increased volume in European Bitcoin markets seems to be associated with smaller divergence but the effect is of small economic significance.

Table 2: Regression results for the KRW Bitcoin premium over USD. Daily time series regressions: the dependent variable is the premium for purchasing bitcoins with Korean Won (KRW) versus US Dollars (USD) and is calculated: $(\text{KRWBTC}_{\text{price in USD}})/(\text{USDBTC}_{\text{price}}) - 1$, where the bitcoin price in USD is the mean price of all USD transactions on the Bitstamp exchange for that day. The bitcoin price in KRW is similarly defined with data from the Korbit exchange. Conversion from KRW to USD is done using the OANDA daily average rate. The independent variables are defined as in Table 1.

	Dependent variable:						
	KRW Bitcoin Premium over USD						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bitcoin short-term volatility	0.0450 ***		0.0455 ***	0.0432 ***	0.0310 ***	0.0300 ***	0.0325 ***
	(0.0023)		(0.0028)	(0.0023)	(0.0024)	(0.0024)	(0.0028)
Bitcoin long-term volatility		0.0328 ***	−0.0013				−0.0064 *
		(0.0033)	(0.0037)				(0.0036)
Blockchain median confirmation time				0.0030 ***	0.0003	0.0004	0.0004
				(0.0005)	(0.0005)	(0.0005)	(0.0005)
KRWBTC volume (thousands of transactions)					0.0033 ***	0.0031 ***	0.0031 ***
					(0.0003)	(0.0003)	(0.0003)
KRWUSD volatility						−4.0039 ***	−4.4785 ***
						(1.2668)	(1.2930)
(Intercept)	0.0010	0.0071 **	0.0016	−0.0256 ***	−0.0020	0.0113 *	0.0164 **
	(0.0022)	(0.0030)	(0.0028)	(0.0047)	(0.0049)	(0.0064)	(0.0070)
Observations	1,626	1,626	1,626	1,626	1,626	1,626	1,626
R^2	0.1903	0.0574	0.1904	0.2104	0.2781	0.2825	0.2840
Adjusted R^2	0.1898	0.0568	0.1894	0.2094	0.2768	0.2808	0.2818
Note:							*p<0.1; **p<0.05; ***p<0.01

Figure 3. The Bitcoin EUR Premium: Bitcoins sometimes trade at a higher price even between relatively frictionless markets (here EUR vs. USD) The premium for purchasing bitcoins with Euros (EUR) versus US Dollars (USD) is calculated: $(\text{KRWBTC}_{\text{price in USD}})/(\text{USDBTC}_{\text{price}}) - 1$, where the bitcoin price in USD is the mean price of all USD transactions on the Bitstamp exchange for that day. The bitcoin price in EUR is similarly defined from the Kraken exchange. Conversion from EUR to USD is done using the OANDA daily average rate.

a) The EUR premium over time (top panel)



b) Distribution of the EUR premium (bottom panel)

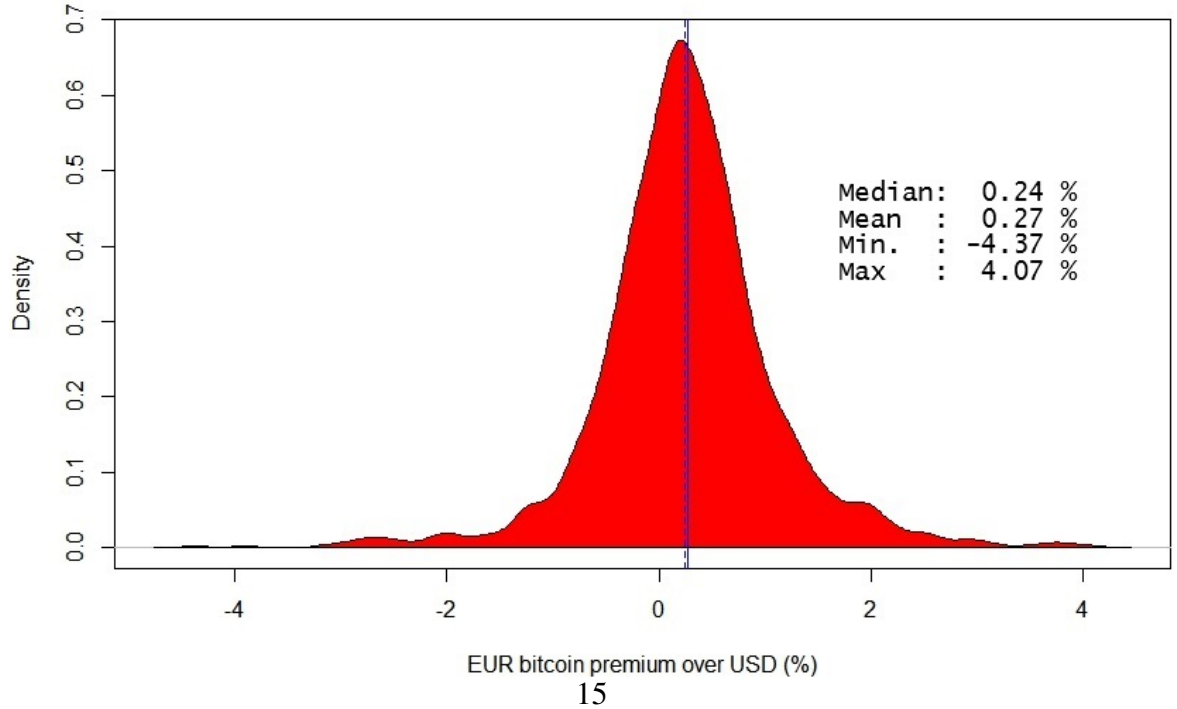


Table 3: Regression results for the EUR Bitcoin premium over USD. Daily time series regressions: the dependent variable is the absolute value of the premium for purchasing bitcoins with Euro (EUR) versus US Dollars (USD) and is calculated: $(\text{EURBTC}_{\text{price in USD}})/(\text{USDBTC}_{\text{price}}) - 1$, where the bitcoin price in USD is the mean price of all USD transactions on the Bitstamp exchange for that day. The bitcoin price in EUR is similarly defined with data from the Kraken exchange. Conversion from EUR to USD is done using the OANDA daily average rate. The independent variables are defined as in Table 1.

	Dependent variable:						
	EUR Bitcoin premium over USD						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bitcoin short-term volatility	0.0049 ***		0.0050 ***	0.0050 ***	0.0061 ***	0.0061 ***	0.0061 ***
	(0.0003)		(0.0003)	(0.0003)	(0.0004)	(0.0004)	(0.0004)
Bitcoin long-term volatility		0.0034 ***	−0.0002				0.00001
		(0.0004)	(0.0004)				(0.0004)
Blockchain median confirmation time				−0.0001	0.00002	0.00002	0.00002
				(0.00005)	(0.00005)	(0.00005)	(0.00005)
EURBTC volume (thousands of transactions)					−0.0001 ***	−0.0001 ***	−0.0001 ***
					(0.00001)	(0.00001)	(0.00001)
EURUSD volatility						−0.0780	−0.0781
						(0.1174)	(0.1175)
(Intercept)	0.0030 ***	0.0037 ***	0.0031 ***	0.0035 ***	0.0027 ***	0.0030 ***	0.0030 ***
	(0.0002)	(0.0003)	(0.0003)	(0.0005)	(0.0005)	(0.0006)	(0.0007)
Observations	1,460	1,460	1,460	1,460	1,460	1,460	1,460
R^2	0.1786	0.0505	0.1787	0.1796	0.1900	0.1903	0.1903
Adjusted R^2	0.1780	0.0498	0.1776	0.1785	0.1884	0.1880	0.1875
Note:							*p<0.1; **p<0.05; ***p<0.01

References

Chakravarty, Sugato, Asani Sarkar, and Lifan Wu, 1998, Information asymmetry, market segmentation and the pricing of cross-listed shares: theory and evidence from Chinese A and B shares, *Journal of International Financial Markets, Institutions and Money* 8, 325–356.

Chan, Kalok, Albert J Menkveld, and Zhishu Yang, 2008, Information asymmetry and asset prices: Evidence from the China foreign share discount, *The Journal of Finance* 63, 159–196.

Chen, Joseph, Harrison Hong, and Jeremy Stein, 2002, Breadth of ownership and stock returns, *Journal of Financial Economics* 66, 171–205.

Edwards, Sebastian, 1999, How effective are capital controls?, *Journal of Economic Perspectives* 13, 65–84.

Gagnon, Louis, and G Andrew Karolyi, 2010, Multi-market trading and arbitrage, *Journal of Financial Economics* 97, 53–80.

Gromb, Denis, and Dimitri Vayanos, 2010, Limits of arbitrage, *Annu. Rev. Financ. Econ.* 2, 251–275.

Hong, Harrison, Jose Scheinkman, and Wei Xiong, 2006, Asset Float and Speculative Bubbles, *Journal of Political Economy* 111, 1073–1117.

Mei, Jianping, Jose Scheinkman, and Wei Xiong, 2009, Speculative trading and stock prices: Evidence from Chinese AB share premia, *Annals of Economics and Finance* 10, 225–3255.

Miller, Edward, 1997, Risk, uncertainty and divergence of opinion, *The Journal of Finance* 32, 1151–1168.

Pontiff, Jeffrey, 2006, Costly arbitrage and the myth of idiosyncratic risk, *Journal of Accounting and Economics* 42, 35–52.

Scheinkman, Jose, and Wei Xiong, 2003, Overconfidence and speculative bubbles, *Journal of Political Economy* 111, 1183–1219.