

# What are the main drivers of the Bitcoin price?

## *Evidence from wavelet coherence analysis*

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# What is Bitcoin?

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# What is Bitcoin?

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- ▶ Digital currency
  - ▶ Crypto-currency verified by Bitcoin miners (to ensure uniqueness of each bitcoin)
  - ▶ Not directly connected to any state/government/central bank
  - ▶ Not directly regulated (supply of bitcoins is given by a stable formula)
  - ▶ Not backed by any physical asset (gold, silver, etc.)
  - ▶ Backed practically solely by trust (faith?)

# Why is Bitcoin worth examining?

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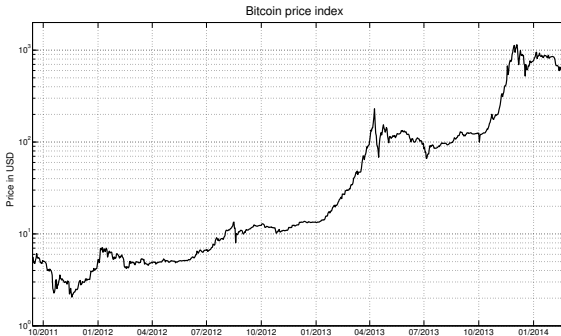
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# Why is Bitcoin worth examining?

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- ▶ Unprecedented data availability (compared to standard currencies)
- ▶ Unique financial asset
  - ▶ Practically purely speculative (at least it is believed so)
  - ▶ Short-selling almost impossible
  - ▶ Very shallow market
- ▶ Rich network structure



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## *BitCoin* meets *Google Trends* and *Wikipedia*: Quantifying the relationship between phenomena of the Internet era

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Digital currencies have emerged as a new fascinating phenomenon in the financial markets. Recent events on the most popular of the digital currencies – *BitCoin* – have risen crucial questions about behavior of its exchange rates and they offer a field to study dynamics of the market which consists practically only of speculative traders with no fundamentalists as there is no fundamental value to the currency. In the paper, we connect two phenomena of the latest years – digital currencies, namely *BitCoin*, and search queries on *Google Trends* and *Wikipedia* – and study their relationship. We show that not only are the search queries and the prices connected but there also exists a pronounced asymmetry between the effect of an increased interest in the currency while being above or below its trend value.

Introduction of the Internet has completely changed the way real economy works. By enabling practically all Internet users to interact at once and to exchange and share information almost cost-free, more efficient decisions on the markets are possible. Even though the interconnection between digital and real economies has hit several bumps such as the DotCom Bubble of the break of the millennium, the benefits are believed to have overcome the costs.

One of the fascinating phenomena of the Internet era is an emergence of digital currencies such as *BitCoin*, *LiteCoin*, *NameCoin*, *PPCoin*, *Ripple* and *Ven* to name the most popular ones. A digital currency can be defined as an alternative currency which is exclusively electronic and thus has no physical form. It is also not issued by any

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# Main motivation

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- ▶ Analyze the behavior of Bitcoin prices with no prejudice or expectations
- ▶ Use a model-free approach
- ▶ Compare various possible drivers of the prices

# Economics & transaction drivers

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- ▶ Money supply
- ▶ Money demand, i.e. use in transactions
- ▶ Price level
- ▶ Trade transactions and trade volume

# Technical & interest drivers

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- ▶ Hashrate & difficulty
- ▶ General interest in the currency – Google and Wikipedia searches

# Safe haven & influence of China

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- ▶ Gold in CHF
- ▶ Financial stress index
- ▶ Chinese prices and volume

A wavelet  $\psi_{u,s}(t)$  is a real-valued square integrable function defined as

$$\psi_{u,s}(t) = \frac{\psi\left(\frac{t-u}{s}\right)}{\sqrt{s}} \quad (1)$$

with scale  $s$  and location  $u$  at time  $t$ . A continuous wavelet transform  $W_x(u, s)$  is obtained via a projection of a wavelet  $\psi(\cdot)$  on the examined series  $x(t)$  so that

$$W_x(u, s) = \int_{-\infty}^{+\infty} \frac{x(t)\psi^*\left(\frac{t-u}{s}\right) dt}{\sqrt{s}} \quad (2)$$

where  $\psi^*(\cdot)$  is a complex conjugate of  $\psi(\cdot)$ . The original series can be reconstructed from the continuous wavelet transforms for given frequencies so that there is no information loss. From a wide range of wavelets, we opt for the Morlet wavelet which provides a good balance between time and frequency localization.

The continuous wavelet framework can be generalized for a bivariate case to study relationship between two series in time and across scales. A continuous wavelet transform is then generalized into cross wavelet transform as

$$W_{xy}(u, s) = W_x(u, s)W_y^*(u, s) \quad (3)$$

where  $W_x(u, s)$  and  $W_y(u, s)$  are continuous wavelet transforms of series  $x(t)$  and  $y(t)$ , respectively. As the cross wavelet transform is in general complex, cross wavelet power  $|W_{xy}(u, s)|$  is usually used as a measure of co-movement between the two series. Cross wavelet power uncovers regions in the time-frequency space where the series have common high power and it can be thus understood as a covariance localized in the time-frequency space. However, as for the standard covariance, the explanation power of  $|W_{xy}(u, s)|$  is limited as it is not bounded.

# Wavelet coherence

To tackle this weakness, the wavelet coherence is introduced as

$$R_{xy}^2(u, s) = \frac{|S(\frac{1}{s}W_{xy}(u, s))|^2}{S(\frac{1}{s}|W_x(u, s)|^2)S(\frac{1}{s}|W_y(u, s)|^2)}, \quad (4)$$

where  $S$  is a smoothing operator. The squared wavelet coherence ranges between 0 and 1 and it is usually interpreted as a squared correlation localized in time and frequency. Due to the above mentioned complexness of the used wavelets and in turn the use of the squared coherence rather than coherence itself, the information about a direction of the relationship is lost. For this purpose, a phase difference is introduced as

$$\varphi_{xy}(u, s) = \tan^{-1} \left( \frac{\Im [S(\frac{1}{s}W_{xy}(u, s))]}{\Re [S(\frac{1}{s}W_{xy}(u, s))]} \right), \quad (5)$$

where  $\Im$  and  $\Re$  represent an imaginary and a real part operator, respectively. Graphically, the phase difference is represented by an arrow. If the arrow points to the right (left), the series are positively (negatively) correlated, i.e. they are in the in-phase or the anti-phase, respectively, and if the arrow points down (up), the first series leads the other by  $\frac{\pi}{2}$  (vice versa). The relationship is usually a combination of the two, i.e. if the arrow points to north-east, the series are positively correlated and the second series leads the first one.



# Example of wavelet coherence

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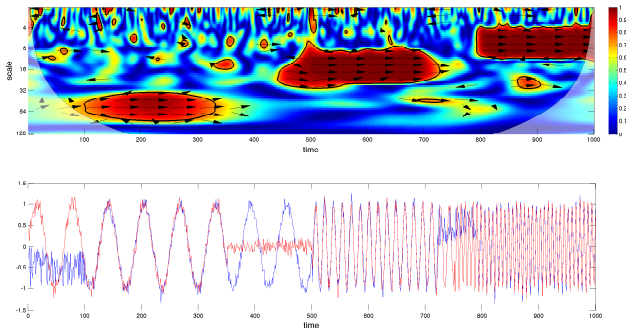
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**Example of wavelet coherence.** Two series with changing sinusoid components with different frequencies. There is no lead or lag relationship between the two (arrows pointing to the right).

# Example of wavelet phase

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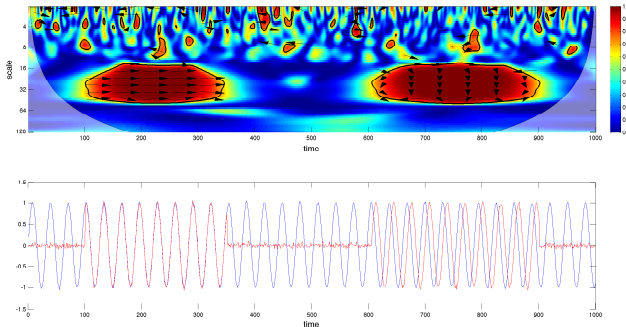
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**Example of wavelet phase.** Similar to the previous picture but now, the blue series leads the red one which is represented by a downward pointing arrow.

- ▶ Bitcoin price index (BPI) from coindesk.com is used.
- ▶ BPI starts from 14.9.2011 and we cover the series up to 28.2.2014.
- ▶ Blockchain.info provides total number of bitcoins in circulation, number of transactions (excluding exchange transactions), estimated output volume, trade vs. transaction volume ratio, hash rate and difficulty.
- ▶ Google Trends and Wikipedia series are obtained from trends.google.com and stats.grok.se, respectively.
- ▶ Financial stress index (FSI) is obtained from clevelandfed.org and gold price from gold.org.
- ▶ Exchange volumes and exchange rates with CNY are retrieved from bitcoincharts.com.

# Fundamental drivers

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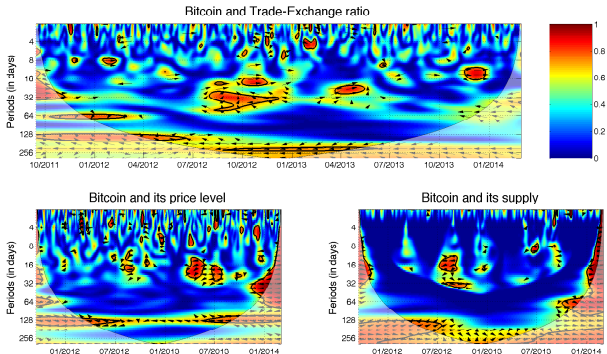
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**Fundamental drivers.** Wavelet coherence is represented by colored contour for which it holds that the hotter the color the higher the local correlation in the time-frequency space (with time on the x-axis and scale on the y-axis). Matching of colors and correlation levels are represented by the scale on the right hand side of the upper graph. Regions with significant correlations tested against the red noise are contrasted by a thick black curve. Cone of influence separating the regions with reliable and less reliable estimates is represented by bright and pale colors, respectively. Phase (lag-lead) relationships are shown by the arrows – positive correlation is represented by an arrow pointing to the right, negative correlation with one to the left, leadership of the first variable is shown by a downwards pointing arrow and if it lags, the relationship is represented by an upward pointing arrow. The last two relationships hold for the in-phase relationship (positive correlation) and for the anti-phase (negative correlation), it holds vice versa. Now specifically for the fundamental drivers. Bitcoin price is negatively correlated to the Trade-Exchange ratio (*top*) in the long-term for the whole analyzed period and there is no evident leader in the relationship. The Bitcoin price level is negatively correlation with the Bitcoin price in the long-term for the whole analyzed period as well (*bottom left*) with no evident leader. Between relatively calm period between 05/2013-09/2013, the price level leads the prices in the medium term. Supply of bitcoins is positively correlated with the price in the long-term (*bottom right*) with no evident leader.

# Currency mining and trade usage

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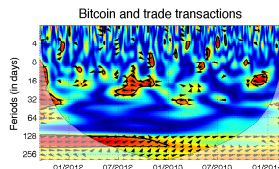
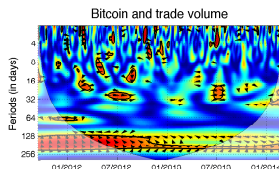
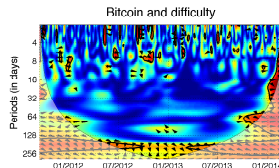
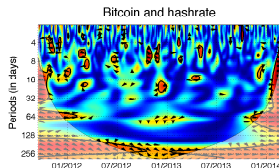
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**Currency mining and trade usage.** Both hash rate (*top left*) and difficulty (*top right*) are positively correlated with the Bitcoin price in the long-term. The price leads both relationships as the phase arrow points to south-east in most cases and the interconnection remains quite stable in time. The trade volume (*bottom left*) is again connected to the Bitcoin price mainly in the long-term. However, the relationship is not much stable in time. Up to 10/2012, we observe negative correlation between the two and the price is the leader. The relationship then becomes less significant and the leader position is not evident anymore. For the trade transactions (*bottom right*), the relationship is positive in the long-term and the transactions are leading the Bitcoin prices. However, the relationship becomes weaker in time and it is not statistically significant from 01/2013.

# Search engines and safe haven value

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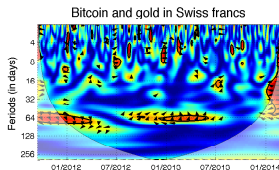
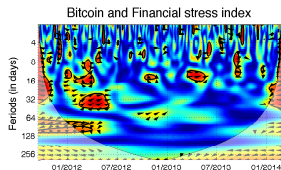
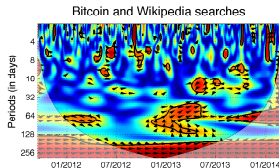
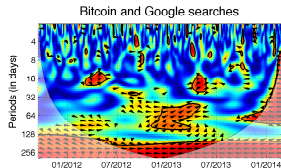
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**Search engines and safe haven value.** Searches on both engines (*top*) are positively correlated with the Bitcoin price in the long run. For both, we observe that the relationship somewhat changes in time. In the first third of the analyzed period, the relationship is lead by the prices whereas in the last third of the period, the search queries lead the prices. Unfortunately, the most interesting dynamics remains hidden in the cone of influence and it is thus not too reliable. Apart from the long run, there are several significant episodes at the lower scales with varying phase direction hinting that the relationship between search queries and prices depends on the price behavior. Moving to the safe haven region, we find no strong and lasting relationship between the Bitcoin price and either the Financial stress index (*bottom left*) or gold price (*bottom right*). The significant regions at medium scales for gold are rather connected to the dynamics of the Swiss franc exchange rate.

# Influence of Chinese market

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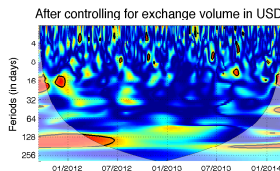
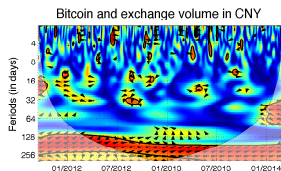
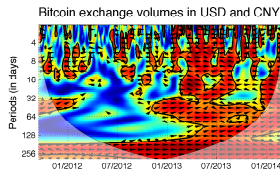
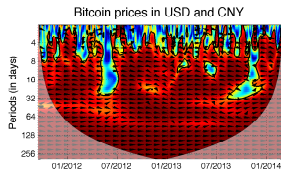
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**Influence of Chinese market.** Bitcoin prices in USD and CNY (*top left*) move together at almost all scales and during the whole examined period. There is no evident leader in the relationship, even though the USD market seems to slightly lead the CNY one at lower scales. However, at the lowest scales (the highest frequencies), the correlations vanish. For the exchange volumes (*top right*), the two markets are strongly positively correlated at high scales. However, for the lower scales, the correlations are significant only from the beginning of 2013 onwards. There is again no dominant leader in the relationship. The CNY exchange volume then leads the USD prices in the long run (*bottom left*). However, when we control for the effect of the USD exchange volume (*top right*), we observe that the correlations vanish.

# Summary

- ▶ Even though Bitcoin is usually labeled as strongly speculative asset, we find that even fundamental factors – usage in trade, money supply and price – play a role in the long term.
- ▶ Increasing prices of bitcoins motivate users to become miners. However, this effect has been vanishing in time.
- ▶ Prices are driven by investors' interest in the currency, mostly in the long term.
- ▶ Bitcoin does not seem to be a safe haven.
- ▶ No clear influence going from Chinese to the US market is found. However, this might be due to the nature of the dataset.



# Time for questions.

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# Thank you.

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