The Cryptocurrency Participation Puzzle

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The Elephant in the Room - Data

- *"Should I buy any crypto?"*

  Yes - Data (high risk adjusted return and low correlation)

- *Non*-Participation

  - 76% US individuals not invest in the cryptocurrency!

- *Then why people do not invest – Puzzle?*

The Elephant in the Room – Model

- *"Should I buy any crypto?"*

  No - Model (negative returns)

- Standard economic model:
  Discounted Cash Flows

$$P_t = \sum_{j=1}^{\infty} E\left[\frac{D_{t+j}}{(1+r_{t\to t+j})}\right]$$

There aren't any dividend, and *can't* be any by design

  - Price should be zero, price should always have been zero

- Asset pricing models imply negative return if P>0 - Bubble!

Zero-weights Implied Beliefs Reasonable?

- What crypto allocation should you have *if you think Bitcoin might be a bubble with negative returns?*
- Anecdotally, median crypto pessimist has a weight of zero or non- participation.
- Under Bayesian portfolio theory, are zero weights implied pessimistic beliefs reasonable?
  - Mehra & Prescott (1985) Equity Premium Puzzle:

  High risk premium implied high risk aversion reasonable?

Results

- Zero weights surprisingly hard to generate with pessimistic priors

- With ten years of prior data (modest strong prior), need hugely pessimistic belief about mean returns to never buy crypto:

  -10.6% per month for BTC

  -19.6% per month for EW crypto

- Most priors that never buy should desire to *short*

Results

- Absolute weights small but non-trivial (1-5%), smooth, often positive
- Benefits exceed international diversification, SMB for many priors
  - Huge costs needed to deter investment

    (~21% BTC; 39% EW)
- Zero weights most easily produced by highly "dogmatic" beliefs (fifty years of prior data) that crypto earns slightly negative returns – slow bursting or soft-landing bubble (why bubble can hold for 20 years – another puzzle?).

Data

- Daily cryptocurrency prices from CoinGecko from May 2013 to February 2022, including dead coins
- Screens to eliminate errors without winsorizing
  - Exclude coins with less than $100m mkt cap over previous week
  - Drop negative prices and market capitalizations
  - Drop if return and mkt cap change seem incongruous (>2x diff)
  - Drop if previous market cap appears stale (no change, |R|>2%)
  - Drop if previous turnover <0.1% or >200%
- No look-ahead bias, nearly all screens use stale data
- Portfolio returns insensitive to winsorizing coin-level returns
- Mkt-RF, SMB, HML, UMD, MSCI World Ex-US

Data

Sample means of 11% and 20% *per month* for BTC and EW Crypto

Panel A: Descriptive Statistics

	BTC-RF	ew100-rf	vw100-rf	mkt-rf	smb	hml	umd	MSCI-rf
count	106	106	106	106	106	106	106	106
mean	0.110	0.201	0.113	0.011	0.000	-0.002	0.001	0.002
std	0.494	1.020	0.532	0.041	0.026	0.034	0.037	0.041
min	-0.382	-0.462	-0.407	-0.134	-0.059	-0.139	-0.124	-0.147
25%	-0.091	-0.145	-0.112	-0.009	-0.020	-0.020	-0.021	-0.021
50%	0.035	0.039	0.029	0.014	0.003	-0.005	0.004	0.007
75%	0.234	0.214	0.211	0.032	0.018	0.014	0.022	0.029
max	4.493	9.582	4.735	0.137	0.071	0.127	0.100	0.152
SR	0.224	0.198	0.214	0.279	-0.007	-0.052	0.039	0.061
skew	6.719	7.601	6.425	-0.358	0.215	0.268	-0.287	-0.150
kurtosis	56.924	66.139	52.367	1.722	-0.329	3.344	0.970	2.051

Data

Standard deviations are ~12x market and ~25x market respectively

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25%	-0.091	-0.145	-0.112	-0.009	-0.020	-0.020	-0.021	-0.021
50%	0.035	0.039	0.029	0.014	0.003	-0.005	0.004	0.007
75%	0.234	0.214	0.211	0.032	0.018	0.014	0.022	0.029
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Methodology

- Standard Bayesian Portfolio Theory Pastor (2000), Tu and Zhou (2010)
- Investors start with the value-weighted market portfolio, consider adding weights in either BTC, EW Crypto, VW Crypto
- Have access to leverage, solving for tangency portfolio and desired amount of leverage
  - Relative risk aversion of 3 (only needed for leverage, certainty equivalent of returns, not tangency weights)
  - Roughly well calibrated about volatility, correlations with equity market (assumed zero), but differ in beliefs about mean
  - Assume investors saw ten years' of data before crypto began, Bayesian updating as new data comes in
  - Quadratic utility, one-period model

Baseline Pessimism Needed for Non-Partic

- Main result – what level of pessimism is needed to justify not taking a positive weight in crypto
  - 1) at that point specifically?
  - 2) never buy up to that point?
- At each point, only a single prior corresponds to zero weight
  - All others either long or short
- For "never buying", this includes weights that are either zero or negative (but zero for some earlier dates).
  - Required prior mean thus ratchets down over time

Baseline Pessimism Needed for Non-Partic

Even after 8 months (positive realized returns), non-investment needs large pessimism

Panel A: Snapshot Non-Investment

	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
Btc-rf	-0.047	-0.042	-0.047	-0.055	-0.085	-0.076	-0.085	-0.098	-0.104	-0.103
ew-rf	-0.095	-0.091	-0.093	-0.102	-0.171	-0.161	-0.163	-0.173	-0.195	-0.192
vw-rf	-0.049	-0.045	-0.049	-0.056	-0.091	-0.081	-0.086	-0.098	-0.109	-0.107

Panel B: Cumulative Non-Investment

	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
Btc-rf	-0.05	-0.05	-0.05	-0.055	-0.085	-0.085	-0.09	-0.098	-0.106	-0.106
ew-rf	-0.097	-0.097	-0.097	-0.102	-0.171	-0.175	-0.175	-0.175	-0.196	-0.196
vw-rf	-0.052	-0.052	-0.052	-0.056	-0.091	-0.091	-0.091	-0.098	-0.110	-0.110

Baseline Pessimism Needed for Non-Partic

Big jump occurs in 2017, after high realized returns that year

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Baseline Pessimism Needed for Non-Partic

End-of-sample cutoffs are *extremely* pessistic…

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Baseline Pessimism Needed for Non-Partic

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…and fairly similar to the numbers needed for *never* buying (-74% per year for BTC, -92% per year for EW Crypto)

Panel A: Snapshot Non-Investment

	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
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vw-rf	-0.052	-0.052	-0.052	-0.056	-0.091	-0.091	-0.091	-0.098	-0.110	-0.110

Baseline Pessimism Needed for Non-Partic

General pattern – VW crypto part way between BTC and EW, but closer to BTC (mostly not reported in the paper)

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	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
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Short Selling and Non-Participation

- With ten-years of prior data, short sales constraints not the primary justification for non-participation, except for extremely pessimistic investors (o.w. should buy).

- Bitcoin could be shorted via futures on CME and CBOE in December 2017 - Could be shorted on Bitfinex for whole sample

- Equal-weighted portfolio harder to say
  - Some can be shorted, other smaller ones, less so.
- Even if desired weights are short, how big are they?

- If too small, then round to zero.

Desired Weights

- Even if desired weights are short, how big are they?
  - Investors may round tiny weights to zero (rationally or not)
- Solve for desired weights at each point in time
  - Monthly mean priors { 2, 1, 0, -1, -2, -5, -10, -20, diffuse}
- Weights on average are:
  1. Small
  2. Non-trivial
  3. Frequently positive
  4. Smooth

Optimal Weights

Panel A: Bitcoin

Prior	Average	Lowest	Highest	Final	Fraction of positive	First Date Weight is Positive
Flat	0.160	-0.042	0.637	0.121	0.991	2013-06
2	0.059	0.025	0.073	0.070	1.000	all above
1	0.052	0.015	0.067	0.064	1.000	all above
0	0.045	0.004	0.061	0.059	1.000	all above
-1	0.038	-0.006	0.055	0.053	0.953	2013-10
-2	0.030	-0.016	0.049	0.047	0.943	2013-11
-5	0.009	-0.046	0.032	0.030	0.642	2016-06
-10	-0.026	-0.096	0.003	0.002	0.104	2021-02
-20	-0.096	-0.198	-0.054	-0.055	0.000	all below

1. Weights are small

Average weights for BTC are range from 5.9% for mildly optimistic to -9.6% at extremely pessimistic

Optimal Weights

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1. Weights are small

Extreme weights aren't massively bigger – lowest weight is -19.8%, highest is 7.3%

Optimal Weights

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1. Weights are small

First driver: Existence of 10 year priors stops wild fluctuations

Much more extreme weights for diffuse priors

Optimal Weights

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Panel B: Equal-weighted Cryptocurrency

Prior	Average	Lowest	Highest	Final	Fraction of positive	First Date Weight is Positive
Flat	0.075	-0.010	0.296	0.053	0.991	2013-6
2	0.024	0.007	0.031	0.029	1.000	all above
1	0.023	0.005	0.029	0.027	1.000	all above
0	0.021	0.003	0.027	0.026	1.000	all above
-1	0.019	0.000	0.026	0.025	1.000	all above
-2	0.018	-0.002	0.024	0.023	0.943	2013-11
-5	0.013	-0.010	0.020	0.019	0.943	2013-11
-10	0.004	-0.022	0.013	0.012	0.632	2016-06
-20	-0.013	-0.046	-0.001	-0.001	0.000	all below

1. Weights are small

Second driver: Investors well calibrated about volatility

Weights for EW crypto considerably smaller (due to higher volatility)

Optimal Weights

Panel A: Bitcoin

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Flat	0.160	-0.042	0.637	0.121	0.991	2013-06
2	0.059	0.025	0.073	0.070	1.000	all above
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0	0.045	0.004	0.061	0.059	1.000	all above
-1	0.038	-0.006	0.055	0.053	0.953	2013-10
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1	0.023	0.005	0.029	0.027	1.000	all above
0	0.021	0.003	0.027	0.026	1.000	all above
-1	0.019	0.000	0.026	0.025	1.000	all above
-2	0.018	-0.002	0.024	0.023	0.943	2013-11
-5	0.013	-0.010	0.020	0.019	0.943	2013-11
-10	0.004	-0.022	0.013	0.012	0.632	2016-06
-20	-0.013	-0.046	-0.001	-0.001	0.000	all below

2. Weights are frequently positive

Many positive months across a range of priors

Optimal Weights

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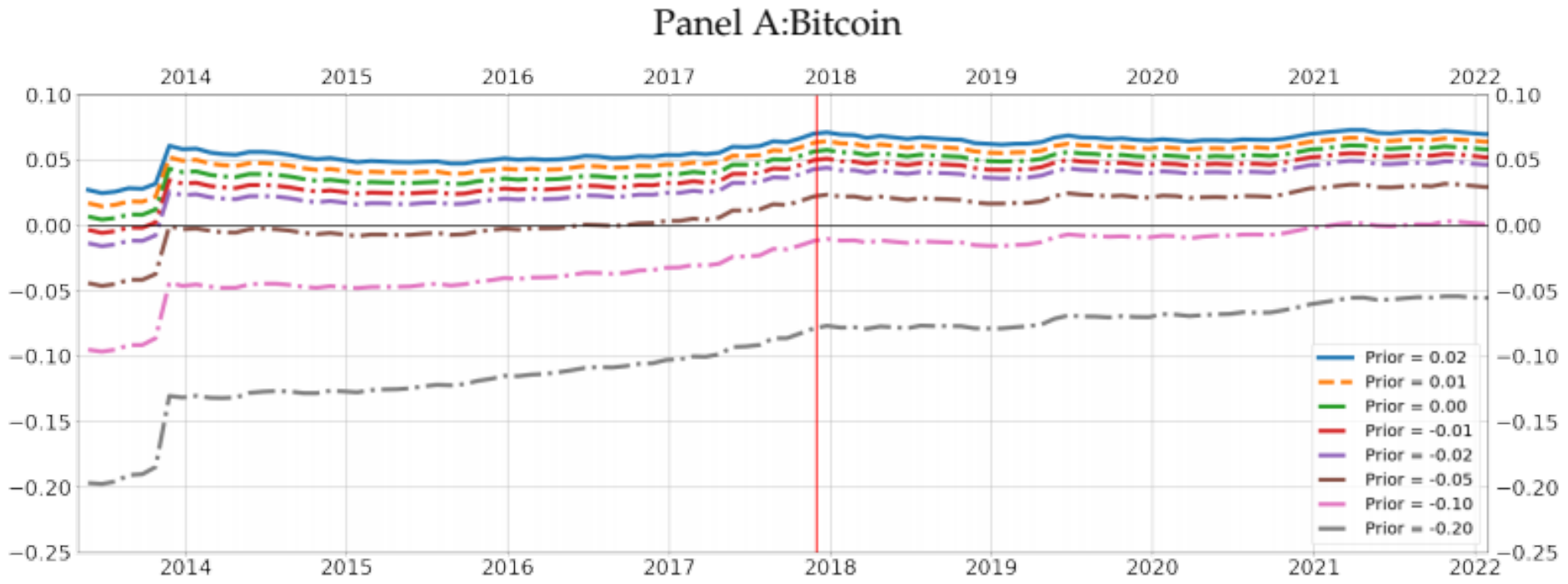
Many positive months across a range of priors;
Mild pessimists switched quite early



Optimal Weights

Panel A: Bitcoin

Prior	Fraction above 0.5%	Fraction above 1%	Fraction above 2%	Fraction above 5%
Flat	1.000	0.991	0.991	0.981
2	1.000	1.000	1.000	0.830
1	1.000	1.000	0.953	0.566
0	0.991	0.953	0.943	0.481
-1	0.953	0.943	0.943	0.170
-2	1.000	0.991	0.792	0.000
-5	0.764	0.604	0.462	0.000
-10	0.849	0.679	0.481	0.057
-20	1.000	1.000	1.000	1.000

Panel B: Equal-weighted Cryptocurrency

Prior	Fraction above 0.5%	Fraction above 1%	Fraction above 2%	Fraction above 5%
Flat	0.991	0.981	0.953	0.943
2	1.000	0.943	0.943	0.000
1	0.991	0.943	0.642	0.000
0	0.943	0.943	0.566	0.000
-1	0.943	0.943	0.547	0.000
-2	0.943	0.943	0.528	0.000
-5	1.000	0.566	0.000	0.000
-10	0.604	0.368	0.047	0.000
-20	0.679	0.472	0.283	0.000

3. Weights are non-trivial

Desired bitcoin weights mostly between 1 - 5%

Optimal Weights

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Prior	Fraction above 0.5%	Fraction above 1%	Fraction above 2%	Fraction above 5%
Flat	1.000	0.991	0.991	0.981
2	1.000	1.000	1.000	0.830
1	1.000	1.000	0.953	0.566
0	0.991	0.953	0.943	0.481
-1	0.953	0.943	0.943	0.170
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-2	0.943	0.943	0.528	0.000
-5	1.000	0.566	0.000	0.000
-10	0.604	0.368	0.047	0.000
-20	0.679	0.472	0.283	0.000

3. Weights are non-trivial

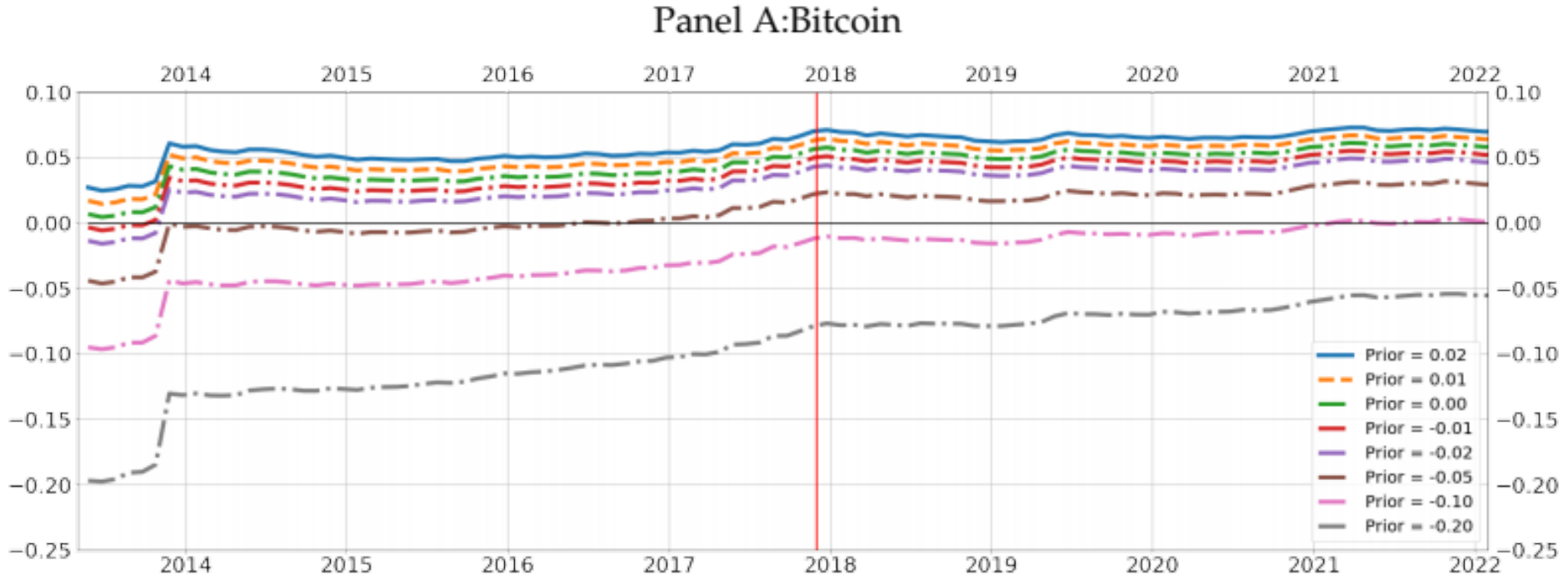
Desired EW crypto weights mostly between 1 – 2%

Optimal Weights

4. Weights are smooth

Ten-year priors smooth out effect of new data

While returns are volatile, this is priced in already, and posterior means only update slowly



Desired Weights

- Weights on average are:

1. Small
   - Investors not likely to blow up from crypto exposure
2. Frequently positive
   - Non-participation not easily explained by short sales constraints, except for extremely pessimistic investors
3. Non-trivial
   - Non-participation not easily explained by trivial weights just being rounded to zero
4. Smooth
   - Answers not hugely sensitive to additional data

Size of Benefit from Crypto

- How large are the benefits of investing in crypto, given beliefs?
- Ex-ante: What did the investor perceive at the time, given their prior beliefs
  - No requirement that the beliefs were correct, or that they ever got these benefits ex-post
- Compute Certainty Equivalent of Returns (CER) for market only
- Compare to CER of Crypto + Mkt, given beliefs at the time
- Difference is the ex-ante benefit of crypto investment.

Ex-Ante Perceived Benefits

Panel A: Bitcoin		Panel B: Equal-weighted Cryptocurrency	
Prior	End of Sample	Prior	End of Sample
Flat	0.680	Flat	0.553
2	0.229	2	0.161
1	0.193	1	0.146
0	0.161	0	0.131
-1	0.130	-1	0.117
-2	0.103	-2	0.105
-5	0.041	-5	0.071
-10	0.000	-10	0.030
-20	0.142	-20	0.000

Mild pessimists to optimists predict CER gains of 10-20 b.p. per month

Benefits relative to other portfolios

- 10 b.p. CER gain (for -2% prior) is decent and about 1% per year - Comes from only 2-5% of total portfolio!
- For priors above -2%, Crypto gains comparable or bigger than international diversification (10 b.p. per month)
- Compare the CER gains of crypto to international diversification as a baseline comparison (10 b.p. per month)
- Larger than SMB gains for nearly all priors, but smaller than HML and UMD for nearly all priors

Costs and Non-Participation

- Can different types of costs reverse this conclusion?
  - Ambiguity aversion, storage, trading costs, theft/loss
- Monthly cost levied on absolute weight in crypto position
  - Even ambiguity aversion likely isn't high if you only invest $1
- Assumed symmetric between long and short positions

Costs and Non-Participation

- The required costs are so large (~21% BTC, 39% EW)!
- Because weights are generally small, and costs are levied as a function of weights
- CER gains may seem small, but these apply to the whole portfolio

Ex-Post Benefits of Crypto

- What were the ex-post benefits of crypto investment?
- Evaluated on a distributional basis
  - Compare CER gain of ex-post mkt+crypto with ex-post mkt only
- Short positions generally likely to be bad ex-post, but also possible to be unhappy if long heavily (from volatility)
- Can also combine ex-ante and ex-post together
  - Were you long on average up to that point?
  - Are you long now?
  - Do you perceive a positive ex-post CER gain?

Ex-Post Benefits of Crypto

Ex-post CER gains positive for priors above -3.4% for BTC, -5.9% for EW

Panel A: Bitcoin

Prior	End of Sample
Flat	0.199
2	0.405
1	0.344
0	0.278
-1	0.205
-2	0.127
-5	-0.148
-10	-0.727
-20	-2.353
Max Gain	0.654
Optimal Prior	0.112
Positive CER, max	0.251
Positive CER, min	-0.034

Panel B: Equal-weighted Cryptocurrency

Prior	End of Sample
Flat	0.410
2	0.370
1	0.259
0	0.227
-1	0.194
-2	0.158
-5	0.042
-10	-0.182
-20	-0.747
Max Gain	0.558
Optimal Prior	0.205
Positive CER, max	0.467
Positive CER, min	-0.059

Ex-Post Benefits of Crypto

Negative for more pessimistic priors

Panel A: Bitcoin

Prior	End of Sample
Flat	0.199
2	0.405
1	0.344
0	0.278
-1	0.205
-2	0.127
-5	-0.148
-10	-0.727
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Panel B: Equal-weighted Cryptocurrency

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-20	-0.747
Max Gain	0.558
Optimal Prior	0.205
Positive CER, max	0.467
Positive CER, min	-0.059

Ex-Post Benefits of Crypto

Need to be extremely optimistic before ex-post CERs are negative

Panel A: Bitcoin

Prior	End of Sample
Flat	0.199
2	0.405
1	0.344
0	0.278
-1	0.205
-2	0.127
-5	-0.148
-10	-0.727
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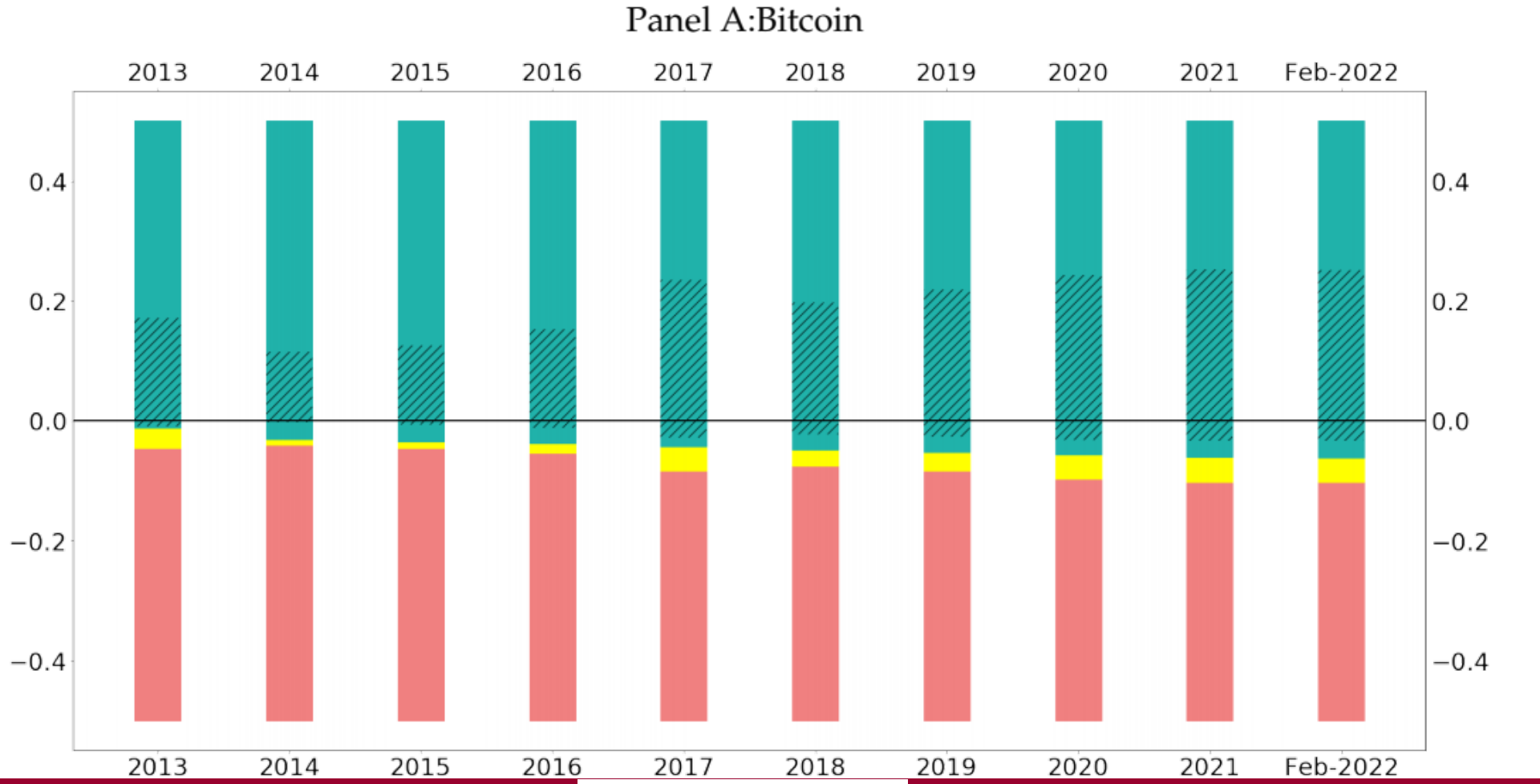
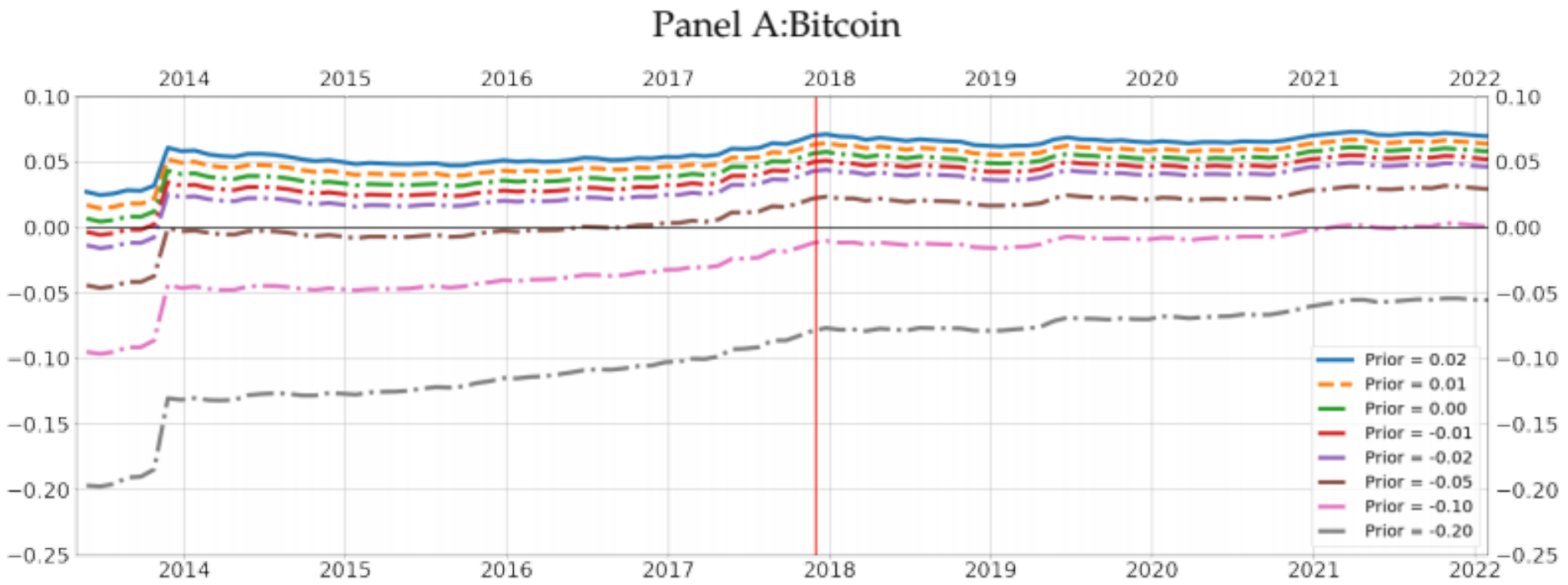
Max Gain	0.558
Optimal Prior	0.205
Positive CER, max	0.467
Positive CER, min	-0.059

Combining Ex-Ante and Ex-Post

Green - investor **long** on average up to that point & **long** at that point
Yellow (Red) - **short** on average & **long (short)** at that point
Shaded regions - investor was ex-post happy

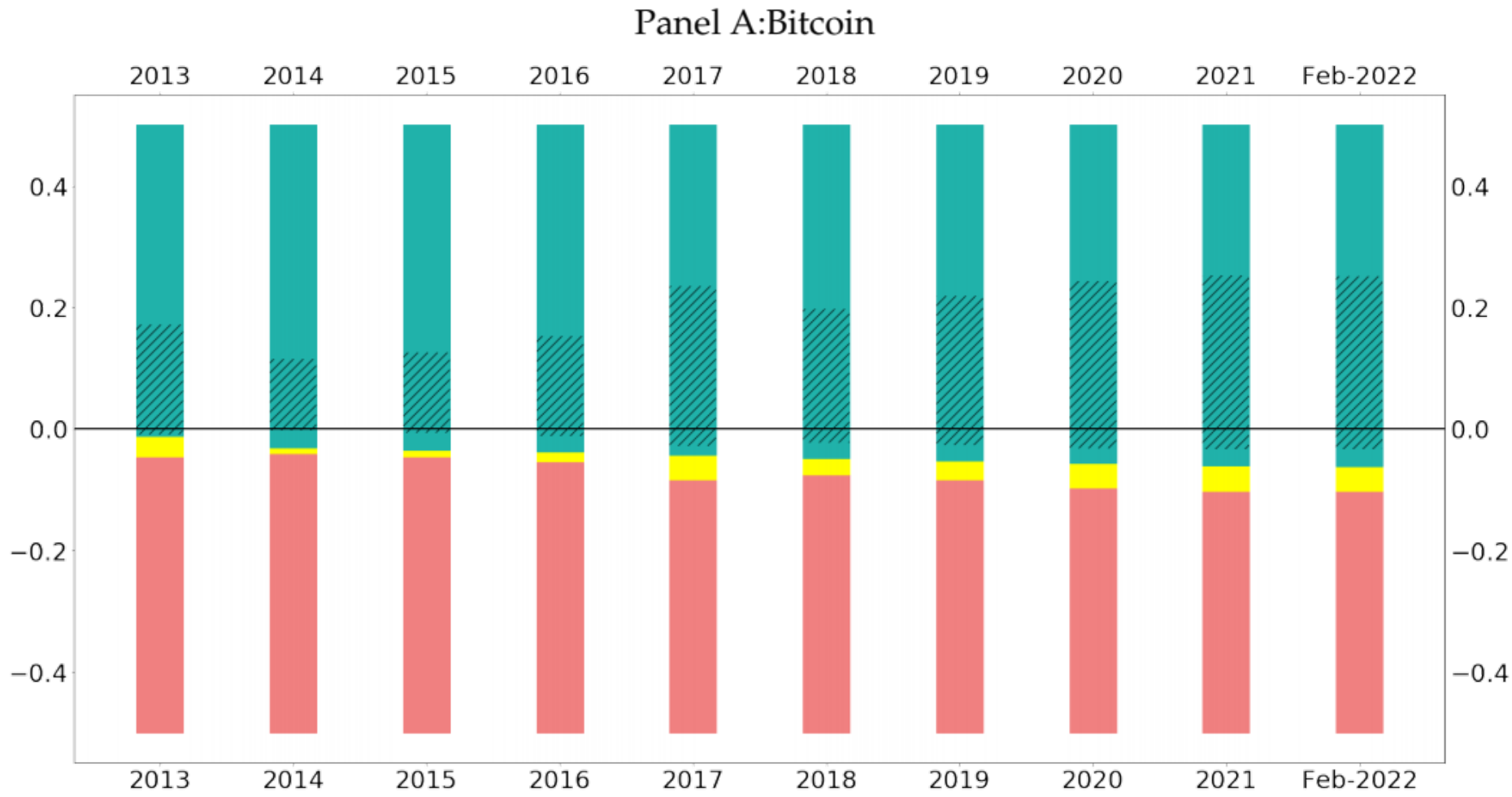


Optimal Weights



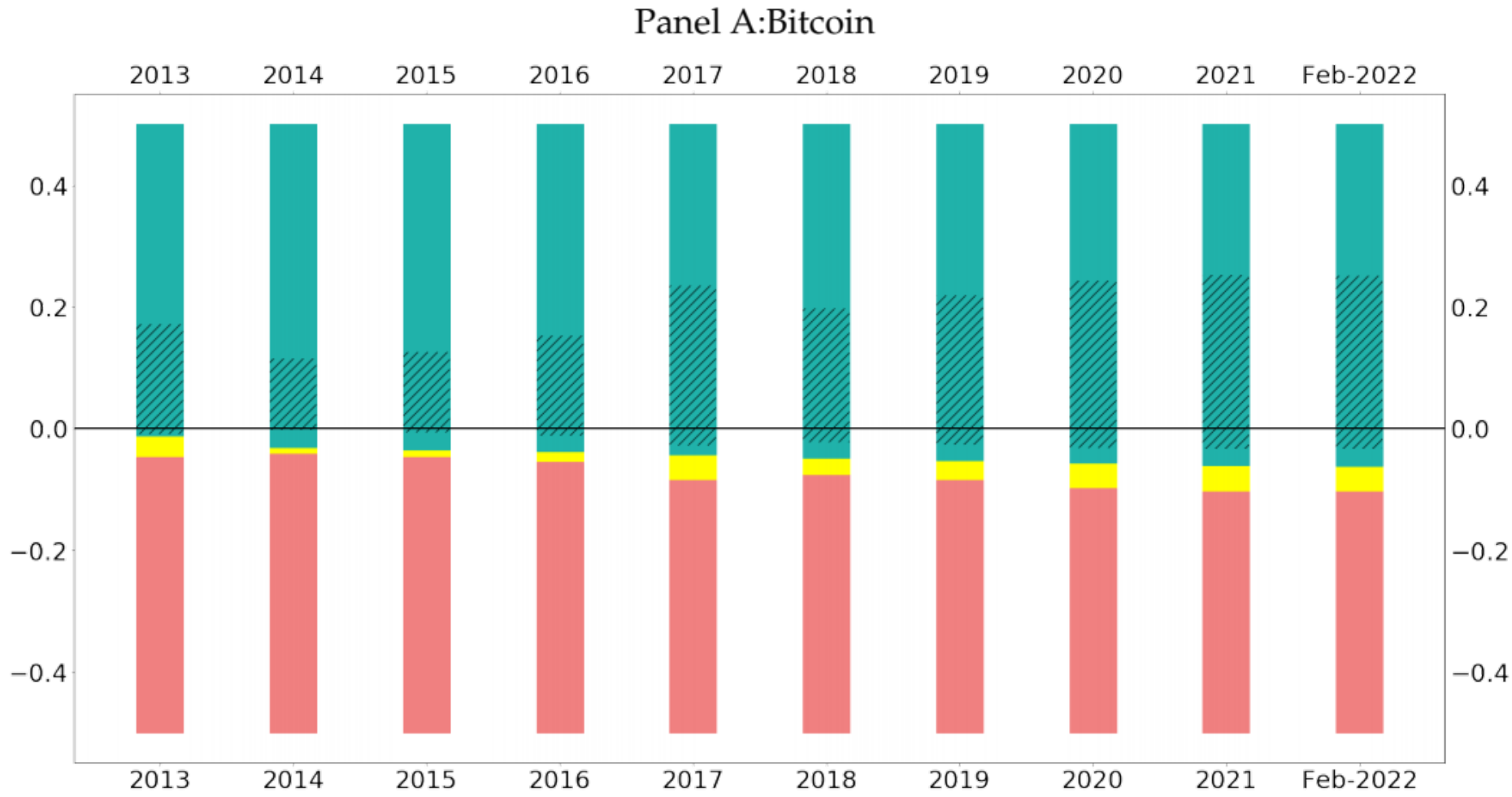
Combining Ex-Ante and Ex-Post

Nobody who was on average short was happy ex-post



Combining Ex-Ante and Ex-Post

Some who ended up long on average still not happy ex-post, due to switching too late



Extensions

Changing strength of priors, has largest effect on cutoff priors
Also leads to much more consistent weights
Equivalent to believing strongly crypto is a slowly deflating bubble.

Panel A: Strength of Prior Beliefs

Prior strength(Years)	3	5	10	30	50
BTC	-0.341	-0.206	-0.106	-0.038	-0.024
EWCrypto	-0.629	-0.382	-0.196	-0.072	-0.046

Extensions

Belief in positive correlations also has a sizable effect on reducing cutoff priors

Panel C: Different Priors about Correlations

Corr	0 (baseline)	0.1	0.2	0.3
BTC	-0.106	-0.091	-0.078	-0.065
EWCrypto	-0.196	-0.163	-0.137	-0.111

Extensions

No effect from starting with different equity portfolios (since all are assumed uncorrelated with crypto, which is roughly right)

Panel B: Different Baseline Assets

	Market Only	3 Factors	4 Factors	4 Factors + MSCI
BTC	-0.106	-0.106	-0.106	-0.106
EWCrypto	-0.196	-0.199	-0.202	-0.199

Extensions

- Higher volatility doesn't change cutoff priors, but shrinks weights towards zero
  - Reduces ex-ante CERs at all priors, ambiguous effect ex-post
- Multi-period beliefs complicate matters, but probably can still form single-period versions with conditional beliefs
- Crash risk, make buying less desirable, but make shorting *more* desirable
- High kurtosis -> ambiguity aversion, shrink trades to zero?
- Not exhaustive, just illustrative using standard tools

Towards a Theory of Bitcoin

- If discounted cash flows doesn't explain bitcoin, what does?

- Four rough theories (not original to me)
  1. Bitcoin is a substitute for gold, and may replace it
  2. Bitcoin is a substitute for fiat, and may replace it
  3. Bitcoin is a substitute for both fiat and gold, because something like gold will also replace fiat
  4. Orthogonal to the above, bitcoin may replace central bank reserves or corporate liquidity accounts

Towards a Theory of Bitcoin

- Bitcoin as a gold substitute is quite compelling
  - Personal disaster hedge if you need to flee the country
  - Disaster in one country, not global disaster

- Many of the same critiques apply to gold as to bitcoin
  - Is it a bubble? Will it burst? Could people switch to a substitute
  - What do all the bars actually do?
  - Possibility of reverse causality on wedding rings
  - Fixed supply likely more important
  - Jewelry as a narrative, similar to drug dealer demand

Conclusion

- Skepticism about cryptocurrency is a license for avoiding trade, but not an unlimited license
- Zero weight pessimism surprisingly hard to justify
  - Many investors should probably have some small weight in crypto, across a wide range of priors
- Prior belief that price to converge to zero or negative return prior - provides some advice on trading; but why price seems not converging to zero - develop positive theories of what's going on!

Optimal Weights

Panel A: Bitcoin

Prior	Average	Lowest	Highest	Final	Fraction of positive	First Date Weight is Positive
Flat	0.160	-0.042	0.637	0.121	0.991	2013-06
2	0.059	0.025	0.073	0.070	1.000	all above
1	0.052	0.015	0.067	0.064	1.000	all above
0	0.045	0.004	0.061	0.059	1.000	all above
-1	0.038	-0.006	0.055	0.053	0.953	2013-10
-2	0.030	-0.016	0.049	0.047	0.943	2013-11
-5	0.009	-0.046	0.032	0.030	0.642	2016-06
-10	-0.026	-0.096	0.003	0.002	0.104	2021-02
-20	-0.096	-0.198	-0.054	-0.055	0.000	all below

Panel B: Equal-weighted Cryptocurrency

Prior	Average	Lowest	Highest	Final	Fraction of positive	First Date Weight is Positive
Flat	0.075	-0.010	0.296	0.053	0.991	2013-6
2	0.024	0.007	0.031	0.029	1.000	all above
1	0.023	0.005	0.029	0.027	1.000	all above
0	0.021	0.003	0.027	0.026	1.000	all above
-1	0.019	0.000	0.026	0.025	1.000	all above
-2	0.018	-0.002	0.024	0.023	0.943	2013-11
-5	0.013	-0.010	0.020	0.019	0.943	2013-11
-10	0.004	-0.022	0.013	0.012	0.632	2016-06
-20	-0.013	-0.046	-0.001	-0.001	0.000	all below

2. Weights are frequently positive

Weights that are *on average* zero come from switching from short to long

Still many months that are positive, away from zero

Optimal Weights

Panel A: Bitcoin

Prior	Average	Lowest	Highest	Final	Fraction of positive	First Date Weight is Positive
Flat	0.160	-0.042	0.637	0.121	0.991	2013-06
2	0.059	0.025	0.073	0.070	1.000	all above
1	0.052	0.015	0.067	0.064	1.000	all above
0	0.045	0.004	0.061	0.059	1.000	all above
-1	0.038	-0.006	0.055	0.053	0.953	2013-10
-2	0.030	-0.016	0.049	0.047	0.943	2013-11
-5	0.009	-0.046	0.032	0.030	0.642	2016-06
-10	-0.026	-0.096	0.003	0.002	0.104	2021-02
-20	-0.096	-0.198	-0.054	-0.055	0.000	all below

Panel B: Equal-weighted Cryptocurrency

Prior	Average	Lowest	Highest	Final	Fraction of positive	First Date Weight is Positive
Flat	0.075	-0.010	0.296	0.053	0.991	2013-6
2	0.024	0.007	0.031	0.029	1.000	all above
1	0.023	0.005	0.029	0.027	1.000	all above
0	0.021	0.003	0.027	0.026	1.000	all above
-1	0.019	0.000	0.026	0.025	1.000	all above
-2	0.018	-0.002	0.024	0.023	0.943	2013-11
-5	0.013	-0.010	0.020	0.019	0.943	2013-11
-10	0.004	-0.022	0.013	0.012	0.632	2016-06
-20	-0.013	-0.046	-0.001	-0.001	0.000	all below

2. Weights are frequently positive

Mild pessimists switched quite early

Ex-Ante Perceived Benefits

Panel A: Bitcoin		Panel B: Equal-weighted Cryptocurrency	
Prior	End of Sample	Prior	End of Sample
Flat	0.680	Flat	0.553
2	0.229	2	0.161
1	0.193	1	0.146
0	0.161	0	0.131
-1	0.130	-1	0.117
-2	0.103	-2	0.105
-5	0.041	-5	0.071
-10	0.000	-10	0.030
-20	0.142	-20	0.000

Extreme BTC pessimists *also* predict large ex-ante gains

Ex-Ante Perceived Benefits

Panel A: Bitcoin		Panel B: Equal-weighted Cryptocurrency	
Prior	End of Sample	Prior	End of Sample
Flat	0.680	Flat	0.553
2	0.229	2	0.161
1	0.193	1	0.146
0	0.161	0	0.131
-1	0.130	-1	0.117
-2	0.103	-2	0.105
-5	0.041	-5	0.071
-10	0.000	-10	0.030
-20	0.142	-20	0.000

Priors close to zero weights predict zero CER gains

Crypto Ex-Ante CER gains versus other por

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BTC	
BTC prior 0.020 Gain	2.195
BTC prior 0.010 Gain	1.85
BTC prior 0.000 Gain	1.541
BTC prior -0.010 Gain	1.243
BTC prior -0.020 Gain	0.983
BTC prior -0.050 Gain	0.393
BTC prior -0.100 Gain	0.001
BTC prior -0.200 Gain	1.361
BTC flat prior Gain	6.507

EW	
EW prior 0.020 Gain	1.545
EW prior 0.010 Gain	1.401
EW prior 0.000 Gain	1.253
EW prior -0.010 Gain	1.124
EW prior -0.020 Gain	1.004
EW prior -0.050 Gain	0.681
EW prior -0.100 Gain	0.286
EW prior -0.200 Gain	0.002
EW flat prior Gain	5.289

Times(except MSCI)	
MSCI Gain(percentage)	0.104
SMB Gain	0.138
HML Gain	3.973
UMD Gain	4.397
SMB+HML Gain	4.371
SMB+HML+UMD Gain	11.744
SMB+HML+MSCI Gain	6.031
SMB+HML+UMD+MSCI Gain	12.917

Larger than SMB gains for nearly all priors, but smaller than HML and UMD for nearly all priors

Costs and Non-Participation

10% per year costs don't deter *any* priors from investing at *any* point in time

Panel A:Bitcoin

Percentage Cost/Time	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
10 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
10 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
15 (min)	-2.90	-2.90	-2.90	-2.90	nan	nan	nan	nan	nan	nan
15 (max)	-2.40	-2.40	-2.40	-2.40	nan	nan	nan	nan	nan	nan
20 (min)	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	nan	nan	nan
20 (max)	-1.50	-1.50	-1.50	-1.50	-3.60	-3.60	-3.60	nan	nan	nan
30 (min)	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50
30 (max)	0.30	0.30	0.30	0.30	-1.20	-1.20	-1.20	-1.20	-1.40	-1.40
50 (min)	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90
50 (max)	3.80	3.80	3.80	3.80	3.70	3.70	3.70	3.70	3.70	3.70
Lowest Preventing cost	13.3	13.3	13.3	13.3	19.4	19.4	19.4	20.1	21.3	21.3
Corresponding Prior	-2.6	-2.6	-2.6	-2.6	-3.7	-3.7	-3.7	-3.8	-4.0	-4.0

Costs and Non-Participation

20% per year costs don't deter *any* priors from investing by the end of the sample

Panel A:Bitcoin

Percentage Cost/Time	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
10 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
10 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
15 (min)	-2.90	-2.90	-2.90	-2.90	nan	nan	nan	nan	nan	nan
15 (max)	-2.40	-2.40	-2.40	-2.40	nan	nan	nan	nan	nan	nan
20 (min)	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	nan	nan	nan
20 (max)	-1.50	-1.50	-1.50	-1.50	-3.60	-3.60	-3.60	nan	nan	nan
30 (min)	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50
30 (max)	0.30	0.30	0.30	0.30	-1.20	-1.20	-1.20	-1.20	-1.40	-1.40
50 (min)	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90
50 (max)	3.80	3.80	3.80	3.80	3.70	3.70	3.70	3.70	3.70	3.70
Lowest Preventing cost	13.3	13.3	13.3	13.3	19.4	19.4	19.4	20.1	21.3	21.3
Corresponding Prior	-2.6	-2.6	-2.6	-2.6	-3.7	-3.7	-3.7	-3.8	-4.0	-4.0

Costs and Non-Participation

21.3% per year is the lowest cost needed to deter any investors by the end of the sample

Panel A:Bitcoin

Percentage Cost/Time	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
10 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
10 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
15 (min)	-2.90	-2.90	-2.90	-2.90	nan	nan	nan	nan	nan	nan
15 (max)	-2.40	-2.40	-2.40	-2.40	nan	nan	nan	nan	nan	nan
20 (min)	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	nan	nan	nan
20 (max)	-1.50	-1.50	-1.50	-1.50	-3.60	-3.60	-3.60	nan	nan	nan
30 (min)	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50
30 (max)	0.30	0.30	0.30	0.30	-1.20	-1.20	-1.20	-1.20	-1.40	-1.40
50 (min)	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90
50 (max)	3.80	3.80	3.80	3.80	3.70	3.70	3.70	3.70	3.70	3.70
Lowest Preventing cost	13.3	13.3	13.3	13.3	19.4	19.4	19.4	20.1	21.3	21.3
Corresponding Prior	-2.6	-2.6	-2.6	-2.6	-3.7	-3.7	-3.7	-3.8	-4.0	-4.0

Costs and Non-Participation

30% costs deter a range of mildly pessimistic priors

50% costs deter a wide range of priors

Panel A:Bitcoin

Percentage Cost/Time	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
10 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
10 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
15 (min)	-2.90	-2.90	-2.90	-2.90	nan	nan	nan	nan	nan	nan
15 (max)	-2.40	-2.40	-2.40	-2.40	nan	nan	nan	nan	nan	nan
20 (min)	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	-3.80	nan	nan	nan
20 (max)	-1.50	-1.50	-1.50	-1.50	-3.60	-3.60	-3.60	nan	nan	nan
30 (min)	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50	-5.50
30 (max)	0.30	0.30	0.30	0.30	-1.20	-1.20	-1.20	-1.20	-1.40	-1.40
50 (min)	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90	-8.90
50 (max)	3.80	3.80	3.80	3.80	3.70	3.70	3.70	3.70	3.70	3.70
Lowest Preventing cost	13.3	13.3	13.3	13.3	19.4	19.4	19.4	20.1	21.3	21.3
Corresponding Prior	-2.6	-2.6	-2.6	-2.6	-3.7	-3.7	-3.7	-3.8	-4.0	-4.0

Costs and Non-Participation

Results even stronger for EW Crypto – 38.9% is the smallest cost to deter any investors

Panel B: Equal-Weighted Cryptocurrency

Percentage Cost/Time	2013	2014	2015	2016	2017	2018	2019	2020	2021	End of Sample
10 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
10 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
15 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
15 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
20 (min)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
20 (max)	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
30 (min)	-6.1	-6.1	-6.1	-6.1	nan	nan	nan	nan	nan	nan
30 (max)	-4.5	-4.5	-4.5	-4.5	nan	nan	nan	nan	nan	nan
50 (min)	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
50 (max)	-0.9	-0.9	-0.9	-0.9	-4.7	-4.8	-4.8	-4.8	-4.8	-4.8
Lowest Preventing cost	25.2	25.2	25.2	25.2	38.5	38.9	38.9	38.9	38.9	38.9
Corresponding Prior	-5.3	-5.3	-5.3	-5.3	-7.5	-7.6	-7.6	-7.6	-7.6	-7.6

Combining Ex-Ante and Ex-Post

Similar patterns for EW crypto, but larger range who were happy ex-post