SolidX Bitcoin Trust:
A Bitcoin Exchange Traded Product

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February 2017

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This White Paper is responsive to two issues that have been raised by SEC staff in conjunction with the approval proceedings of the SolidX Bitcoin Trust. These are: 1) the possible manipulation of bitcoin by market participants, and 2) the efficacy of the creation and redemption process at aligning share price and net asset value (NAV). We also discuss the role of insurance as a backstop to protect investors against bitcoin loss, and provide empirical evidence that demonstrates the diversification benefits of bitcoin as an asset class.

EXECUTIVE SUMMARY

The SEC is considering the approval of the SolidX Bitcoin Trust (SBT or the Trust) – an exchange traded product (ETP) that holds bitcoin. This White Paper provides an economic analysis of the possible manipulation of bitcoin, the benefits of continuous share creations and redemptions, the investor protection aspects of bitcoin insurance, and empirical data on key characteristics of bitcoin as an asset class that may be helpful to policymakers.

The main findings of the paper are:

- It is unlikely that the Trust will make manipulation of bitcoin more likely. By contrast, we conclude that it is likely to enhance liquidity and market efficiency.
- A continuous creation/redemption process, including with cash, enhances liquidity in the shares of the Trust, which in turn enhances price efficiency. The longer settlement cycles associated with other commodity-based ETPs, such as, for example, copper (three days) are designed to accommodate the physical delivery of the underlying commodity, a design element that is unnecessary for a digital asset like bitcoin.
- The risk that a bad actor may steal bitcoin by obtaining access to the Trust's private keys is mitigated by the availability of insurance that protects against such losses.
- The diversifying nature of bitcoin expands the "efficient frontier" available to investors. This enables investors to construct portfolios that either reduce the level of risk for a given level of return, or increase returns at the same level of risk, or both. That is, investors could possibly increase expected returns without taking more risk, or allowing them to meaningfully reduce risk without reducing expected returns.
- The Trust would enable ordinary investors to have relatively unconstrained access to an asset class that had previously been available only to investors willing and able to make direct investments in bitcoin.

1. Introduction to the Proposed SolidX Bitcoin Trust

The SolidX Bitcoin Trust falls under the broad asset class category that includes commodity-based ETPs. Investors find exposure to commodities attractive because they utilize investment strategies that provide expanded risk and reward opportunities.[1] The most important investor benefit associated with commodity-based ETPs like the SBT is the ability to expand investment opportunities through enhanced portfolio diversification.

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[1] See Gorton and Rouwenhorst (2006) for an analysis of the role that commodity futures play as diversifiers.

Although bitcoin has been referred to as a type of digital currency, the CFTC recently ruled that bitcoin and other virtual currencies are distinct from "real" currencies and should be treated as commodities.[2] Based on this regulatory classification, I evaluate the benefits of providing investors with indirect access to bitcoin through an ETP.

Since many of the same factors the SEC has considered when granting approval of other commodity-based ETPs apply to a bitcoin ETP, this White Paper compares bitcoin to other commodities, specifically precious metals like gold, silver, copper, platinum, and palladium.

2. Digital Assets and Financial Innovation

Financial innovation designed to provide retail investors with access to alternative investment strategies and asset classes is one of the factors that has spurred the development of commodity-based ETPs.[3] From an economic standpoint, innovative financial markets enhance investors' abilities to move funds into alternative asset classes and manage risk. Duffie and Rahi [1995] argue that financial innovators respond to incentives to bring new offerings to market for which there are no close substitutes, and which may be used to hedge risks. Given the dramatic increase in the price of bitcoin, as seen below in Figure 1, and its rather high volatility, this observation is particularly relevant.

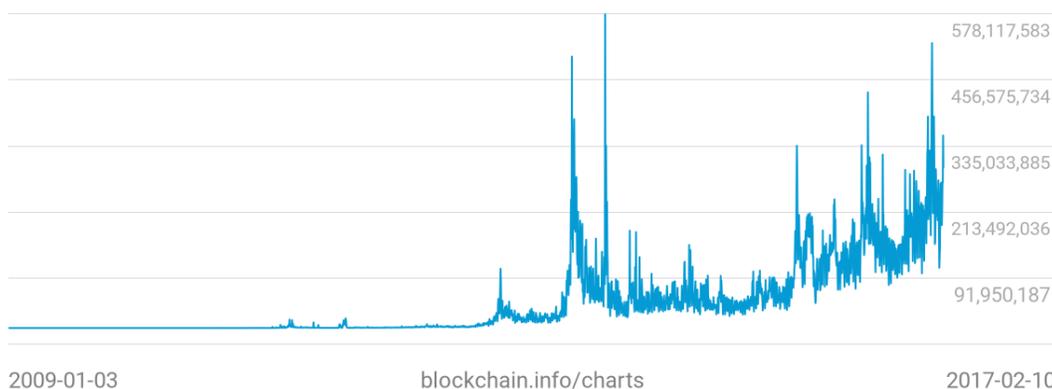**Figure 1. Bitcoin price history from January 3, 2009 to February 10, 2017.** Source: blockchain.info/charts

Figure 2 illustrates the associated transaction volume in USD over the same time period. One can see that the volatility in the price of bitcoin correlates with trading activity.

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[2] Coinflip Inc., Dkt. No. 15-29 (C.F.T.C. Sept 17, 2015).

[3] See Tufano [2003] and Merton [1992].

Figure 2. Bitcoin transaction value history from January 3, 2009 to February 10, 2017.
Source: blockchain.info/charts

3. The Potential Manipulation of Bitcoin Prices

The manipulation of asset prices typically takes one of two forms: (1) the dissemination of false or misleading information and (2) the attainment of a dominant market share, which would then enable that entity to possibly manipulate prices by controlling the available supply of the commodity.

3.1 Dissemination of False or Misleading Information

In the case of bitcoin, it should be difficult to disseminate false or misleading information because the aggregate supply is determined by a transparent and straightforward algorithm. New bitcoin are produced by "miners" that compete to verify bitcoin transactions. As of January 31, 2017, there were approximately 16.1 million bitcoin in circulation.[4] The aggregate supply of bitcoin is capped at 21 million bitcoin.

Since bitcoin is a digital asset that functions as a medium of exchange, all of the relevant information needed to price bitcoin is publically available. For example, unlike traditional securities, there are no important periodic information events, such as earnings announcements. Since there is no "inside" information to exploit, bitcoin valuations are based on publicly available information, providing a relatively high degree of information transparency.

3.2 Manipulation through the Attainment of a Dominant Share

Due to the innovative nature of the blockchain concept, the bitcoin industry is subject to a high degree of uncertainty regarding growth. The SBT S-1 describes a number of these risks associated with the growth of the asset class. As a general rule, these are risks that investors consider when pricing bitcoin, but would not be considered factors that would make bitcoin more

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[4] See https://blockchain.info/charts/total-bitcoin.

susceptible to manipulation than other commodities. Examples of bitcoin-specific risks that investors would need to consider include: 1) a decline in the adoption of bitcoin could cause price declines; 2) sales of newly minted bitcoin could create downward price pressure; 3) the loss or destruction of private keys may be irreversible;[5] 4) an entity that gains more than 50% control of the transaction confirmation process could manipulate transaction histories on the blockchain; 5) although bitcoin has a first-mover advantage, competition from other digital assets, such as Ethereum, or new blockchain innovations could diminish the desirability of bitcoin as a medium of exchange.

Commodity-based ETPs that provide exposure to precious metals (PMETPs) are conceptually similar to a bitcoin ETP because precious metals, such as gold, silver, copper, platinum, and palladium are often used as a type of currency. A key difference is that precious metals also have industrial uses that give them independent value aside from their role as currency, or as a store of value.[6]

One of the risks associated with bitcoin is the possibility that a single investor or a small group acting in collusion could own a dominant share of the available bitcoin. The SBT S-1 notes that it is possible, and in fact, reasonably likely, that a small group of early adopters hold a significant proportion of the bitcoin that has been mined. Since there is no registry showing which individuals or entities own bitcoin or the quantity owned, it is not possible to know how large individual positions are. This issue is not unique to bitcoin as there are no corresponding registries for precious metals.

There is, however, no compelling evidence to suggest that any single investor or group of investors successfully has acquired a dominant position in bitcoin. For example, certain individuals are known to have a significant cache of bitcoin, yet media estimates indicate that such holdings represent approximately just 1% of bitcoin currently in circulation.[7]

There are a number of factors that should ameliorate risks associated with possible manipulation due to a dominant market share.[8] These include:

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[5] For example, Mt. Gox was the target of multiple cyber-attacks between 2011 and 2014, eventually leading to the loss of US$460 million worth of bitcoin from the exchange and the company declaring bankruptcy in February 2014. See https://www.wired.com/2014/03/bitcoin-exchange/. Additionally, on August 2, 2016, Bitfinex was compromised and an estimated US$72 million worth of bitcoin were stolen from the bitcoin exchange through the theft of private keys that unlocked customer bitcoin wallets. The theft of the private keys granted the attackers authorized access to the bitcoin stored within the wallets hosted on the exchange and allowed the irreversible transfer of the bitcoin to third parties. See http://blog.bitfinex.com/announcements/security-breach/; http://fortune.com/2016/08/03/bitcoin-stolen-bitfinex-hack-hong-kong/.

[6] It is reasonable to assume that the spot price of precious metals would drop if they no longer had independent value in industrial applications but that the price would not collapse.

[7] See https://www.bloomberg.com/news/articles/2013-07-03/winklevoss-twins-confront-skeptics-to-sec-on-bitcoin-etp.

[8] Many of these factors were used as a basis for the approval of the JPM XF Physical Copper Trust and are equally relevant in the context of the SolidX Bitcoin Trust proposal. We either paraphrase or quote directly some of these observations from the Approval (See S.E.C Release No. 36-68440; File No. SR-NYSEArca-2012028, December 14, 2012).

- Bitcoin held by the SBT will remain available to investors because: 1) the Trust will not remove bitcoin from circulation, 2) shares are redeemable for bitcoin on every business day (as defined by NYSE Arca), and 3) redeeming authorized participants (APs) will receive the right to obtain bitcoin within one business day. The bitcoin received in exchange for redeemed shares could be sold in the OTC market for cash or sold on one of the many bitcoin exchanges.
- Given the structure of the SBT and the relative ease with which it is possible to take advantage of arbitrage opportunities, the quantity of bitcoin that will be held in the trust will not represent a meaningful percentage of the bitcoin currently available for transaction purposes.
- The introduction of a bitcoin ETP would be expected to increase the price of bitcoin in a manner analogous to increases in the spot prices of gold[9] and silver[10] following the introduction of gold and silver ETPs. This, however, is not a sign of price manipulation, but represents instead increased demand for bitcoin as well as a signal of the long-term viability of bitcoin as a digital asset.
- The SBT may actually reduce the potential for fraud or manipulation of bitcoin because: 1) the Trust has entered into RVP/DVP arrangements with multiple exchanges, which are intended to create a more liquid supply of bitcoin than would be available if creation and redemptions were only permitted in a single location; 2) the Trust and transactions in SBT shares would be transparent, with the Trust publishing information about its holdings and operations through its website; 3) the Trust would utilize a consistent, transparent, non-discretionary, rules-based, and fully disclosed protocol for redemptions; and 4) the Trust's net asset value (NAV) and intraday indicative values (IIVs) would be valued by a recognized independent valuation agent using the XBX index.
- The Commission has concluded in past commodity-based ETP approvals that the listing and trading of commodity-based ETP shares would facilitate transparency with respect to the ETP shares and diminish the risk of manipulation or unfair informational advantage. It would then be expected that the SBT's website disclosures, and creation and redemption activity, as well as the dissemination of quotations for and last-sale prices of transactions in the Shares and the IIV and NAV of the SBT, would be expected to help reduce the ability of market participants to manipulate the bitcoin market or the price of Trust shares.
- Although each bitcoin exchange has its own market price, it is expected that most bitcoin exchange market prices should be relatively consistent with the bitcoin exchange average. Since market participants can choose the bitcoin exchanges on which to buy and sell bitcoin, price differentials across bitcoin exchanges create incentives to eliminate cross-exchange arbitrage opportunities.
- By analogy to other Commission actions, it is reasonable to conclude that the listing and trading of the bitcoin ETP shares on NYSE Arca (and any other national securities exchange that trades the Shares pursuant to unlisted trading privileges) may serve to make the overall bitcoin market more transparent, particularly if OTC trading shifts to trading on exchanges.[11] The Commission also has noted that "although [an exchange]

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[9] See Baur [2013].

[10] See http://www.silverinstitute.org/site/silver-price/silver-price-history/2000-2010/.

[11] The blockchain tracks quantities traded but does not maintain a record of transaction prices.

currently provides for the listing and trading of shares of Commodity-Based trusts backed by physical gold, silver, platinum, and palladium, none of the commenters has identified any evidence that the trading of shares of these Commodity-Based trusts has led to manipulation of the gold, silver, platinum, or palladium markets."[12]

4. The Potential Manipulation of Bitcoin ETP Prices

This section considers the possible manipulation of SBT prices. It concludes that there are a number of institutional features of the bitcoin trading environment that should make share prices resilient to manipulation.

One of the key differences between bitcoin and other commodities is the lack of a liquid and transparent derivatives market. Although there have been nascent attempts to establish derivatives trading in bitcoin, at this time, bitcoin derivatives markets are not sufficiently liquid to be useful to APs and market makers who would like to use derivatives to hedge exposures.

Historically, derivative markets have been essential to the success of PMETPs. This is due, in no small part, to the absence of commodity exchanges that provide liquidity, price transparency, and an opportunity to buy and sell the physical commodity. By contrast, the bitcoin market has a number of active exchanges that report the valuation of each transaction and bid and ask prices on their websites.

A key issue is whether the pricing of commodity-based ETPs is efficient. Price efficiency can be achieved when there is a liquid market that accommodates price discovery. For physical commodities that are not traded on exchanges, the presence of a liquid derivatives market is a necessary condition. For digital assets like bitcoin, price discovery occurs on the OTC market and exchanges instead. For these assets, derivatives markets are not necessary because the OTC market and exchanges are close substitutes.

The ability to manipulate SBT prices is expected to be immaterial due to the market structure of bitcoin trading. The following factors are important aspects of the trading environment that tend to mitigate manipulation risk:

- The NAV and IIVs are based on the XBX index, which is determined by an independent third party valuation agent. The XBX is based on a proprietary algorithm. Although the exact methodology is not disclosed, the XBX index level is a weighted-average of prices across a number of exchanges. It recognizes that prices can deviate across exchanges and uses an algorithm that is designed to find a representative market price. The weighting methodology has several key features that mitigate manipulation risk: 1) lower trading volume reduces the weight an exchange is given in the average, 2) the weight of an exchange is reduced the more a price deviates from the average, and 3) weights are reduced for stale prices.
- Since the SEC does not regulate bitcoin exchanges, Reg NMS does not apply. Accordingly, there are no requirements to trade at the national best bid and offer prices.

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[12] See page 65 of S.E.C Release No. 36-68440; File No. SR-NYSEArca-2012028, December 14, 2012.

Since each exchange is an independent entity, a liquidity event on one exchange does not necessarily propagate across other exchanges. This makes prices more resilient to liquidity shocks but also slows down the transmission of fundamental information. In the context of a cost-benefit analysis, it also makes it harder to artificially manipulate prices enough to have a material effect of the XBX index.

- Concerted efforts to manipulate bitcoin prices enough to affect the level of the XBX would require a significant capital investment on each exchange in the index because: 1) one needs to trade in each exchange in sufficient volume to change price and 2) the XBX is designed to down-weight outlier prices. The capital requirements that would be required to manipulate prices may deter such behavior.

- Compared to equity markets, trading on bitcoin exchanges is relatively slow. Although the 24-hour nature of the market lends itself to algorithmic trading, there is no co-location on exchange servers and the number of available order types is relatively small. For example, the most liquid bitcoin exchange, Bitfinex, only has ten order types.[13] This means that cross-market arbitrage generally is available to all market participants at the same time.

- Given the degree of fragmentation across bitcoin exchanges, the relatively slow transaction speeds (compared to equity markets) and the capital necessary to maintain a significant presence on each one, the likelihood of spoofing is low.

- Manipulation of the open and close prices is not a significant risk because the market is open continuously and the XBX index is calculated on a continuous basis. The daily NAV that is used to calculate the price of creation and redemption baskets is fixed at 4:00 PM Eastern Standard Time. In-kind creation and redemption orders must be placed by 4:00 PM Eastern Standard Time and cash creation and redemption orders must be placed by 3:00 PM Eastern Standard Time so that the Trust can purchase the requisite number of bitcoin.

- Bitcoin are quoted with 8 decimals. This mitigates incentives to move prices a penny up or penny down because the potential gains from moving prices at the eighth decimal point are immaterial.

- Over the long term, this additional transparency could enhance efficiency in the market for bitcoin. In addition, the listing and delisting criteria for the Trust Shares are expected to help to maintain a minimum level of liquidity and therefore minimize the potential for manipulation of the share prices.

5. The Benefits of the Proposed Create and Redeem Process

A bitcoin ETP would trade at a price determined on an exchange by market participants. There is no guarantee that arbitrage trading on the exchange is sufficient to eliminate the possible spread between share price and the value of the underlying bitcoin held by the SBT. The SBT is designed to ameliorate this risk through the creation and redemption process. Specifically, a set of broker-dealers, called Authorized Participants (APs), are allowed to create or redeem new shares in exchange for the cash value of a "basket" of 1,000 bitcoin (or the delivery of 1,000 bitcoin) called a "Creation Unit." The Trust shares may be redeemed by either cash or "in kind"

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[13] The Bitfinex order types are as follows: limit orders, market orders, stop orders, trailing stop order, fill or kill order, one cancels other order, post only order, and a hidden order, plus two algorithmic orders–an iceberg (a partially hidden order) and a time-weighted average price order. See https://www.bitfinex.com/features.

exchanges of creation units for the underlying bitcoin. If non-AP investors wish to liquidate their positions they must sell on a secondary market or redeem through an AP acting as an agent on their behalf.

The creation/redemption process provides the AP with an opportunity to arbitrage the spread between share price and NAV by exchanging the cash value of the underpriced bitcoin for the overpriced shares or vice versa. For example, if the ETP share price exceeds a contemporaneous estimate of the NAV, an AP could deliver the cash value of the NAV or purchase bitcoin in the stipulated quantity and deliver them in exchange for a creation unit, which can then be broken up and sold as individual shares on an exchange. This simultaneously reduces the available liquidity of bitcoin and increases the supply of ETP shares. If ETP share price is less than a contemporaneous estimate of the NAV, an AP will redeem shares and either take the corresponding cash value or sell the underlying bitcoin that are delivered in the creation basket. The process of creating and redeeming ETP shares places pressure on both the ETP shares and the underlying prices of bitcoin, which causes the ETP spread to converge towards zero. In the aggregate, arbitrage pressure results in price adjustments that ensure stability between the ETP's NAV and its current market price per share.

The SBT plans to offer "continuous" creations and redemptions. This distinguishes their proposal from other commodity-based ETPs, which tend to have longer settlement periods of three to seven days. Longer settlement periods are designed to facilitate the creation and redemption process by accommodating the practicalities of arranging for the storage and delivery of the underlying commodity in possibly different locations and different grades. Since exchanges provide immediate access to bitcoin, it is straightforward to accommodate a one-day settlement period.

Continuous cash and in-kind creation and redemption of shares increases the efficiency of the Trust because the exchange trading of bitcoin lowers the costs of creating and redeeming shares. This not only enhances liquidity on bitcoin exchanges but facilitates the arbitrage process and helps to keep the spread between SBT prices and its NAV small, thereby reducing the likelihood of bitcoin price manipulation.

Bitcoin Insurance as a Key Investor Protection

The Trust will maintain three levels of insurance through Crime, Excess Crime, and Excess Vault Risk Insurance coverage underwritten by various insurance carriers. The purpose of the insurance is to protect shareholders against loss or theft of the Trust's bitcoin. The insurance will cover loss of bitcoin by, among other things, theft, destruction, bitcoin in transit, computer fraud and other loss of the private keys that are necessary to access the bitcoin held by the Trust.

The Trust's insurance policies have a deductible of $500,000 and generally cover loss up to $125 million, with further insurance coverage arrangements available for coverage exceeding $125 million. Both the Trust and the Sponsor are insured parties under the insurance policies. Pursuant to the terms of the policies, each of the Trust and Sponsor has the ability to submit a claim in connection with the policies and to cancel the policies.

The insurance coverage offered by the Trust is a key investor protection feature that is particularly important given the absence of a traditional custodial infrastructure to secure the Trust's bitcoin holdings. The Trust's insurance coverage also is an important, market-based solution that substitutes for a true transfer agency function that simply does not exist in the underlying bitcoin market. Unlike other exchange-traded products, bitcoin-based ETPs cannot rely on custodial firms, CCPs, or transfer agents to perform essential custodial and recordkeeping functions that protect investors in other ETPs.

While investors in the Trust will expect to assume the market risk (i.e., bitcoin price fluctuations) associated with their investment, the Trust's insurance features will minimize investors' risks regarding the adequacy of the mechanisms and infrastructure used to secure the Trust's bitcoin holdings, an analysis that typically is not undertaken by investors in the U.S. securities markets. Bitcoin insurance therefore is important for investor protection, and is a key feature that enables the Trust to offer investors an opportunity to participate in the bitcoin market through an investment in securities while minimizing concerns or risks associated with the potential loss or theft of the Trust's bitcoin.

6. A Bitcoin ETP and the Benefits of Diversification

The basic economic rationale for the SBT is simple. Since the returns to bitcoin have been less than perfectly correlated with traditional assets, such as stocks and bonds, bitcoin exposure will provide enhanced opportunities to diversify the risk of traditional asset allocation strategies that only consider stocks and bonds.

If we begin with the premise that investors desire high absolute returns, it is tempting for investors to seek out asset managers that consistently provide superior performance relative to their peers. Academic studies have shown that asset flows do in fact follow performance and that this performance is, at least in part, related to managerial skill.[14]

One of the conceptually challenging aspects of performance measurement is the role that diversification plays in evaluating the trade-off between risk and return. For example, a naïve investor may prefer to only hold assets that have experienced the highest realized returns. The problem with this perspective is that it ignores risk. Since riskier assets are expected to earn higher returns, it should not be surprising to find periods when riskier securities actually earn higher returns. The concept of diversification is based on the idea that investors can improve their risk-return profile by investing in different asset classes rather than concentrating their exposure in a single one, such as equities. This should allow a diversified portfolio to outperform an undiversified portfolio over the long term.

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[14] See Chevalier and Ellison [1997], Fulkerson, Jordan, and Riley [2013], Ivković and Weisbenner [2009], and Sirri and Tufano [1998]. These studies document that good performance leads to high flows of new money while bad performance produces only low outflows. This behavior is often attributed to the presence of uninformed (unsophisticated) investors (Gruber [1996]), or to the expectation that fund firms will replace poorly performing fund managers or alter their investment strategy (Lynch and Musto [2003]). More recently, Golstein, Jiang, and Ng [2015] show that poor performance in corporate bond markets results in heighted flows.

Standard asset pricing models argue that investors only receive compensation for bearing exposure to systematic or market risk factors. Diversification plays a central role because when assets are imperfectly correlated, idiosyncratic negative shocks to some securities may be offset by idiosyncratic positive shocks to others. To the extent that these shocks are offsetting, investors should not be able to demand compensation for bearing risk that can be diversified away. In this sense, diversification forces an investor to focus on risks that following simple to implement investment strategies cannot eliminate.

7.1 Historical Risk-Return Tradeoffs Among Asset Classes

An effective way to evaluate the inherent riskiness of bitcoin as an asset class is to compare its historical performance to more traditional assets classes such as equities, fixed income as well as to other commodity-based investments. Table 1 provides a list of the ETPs used in this analysis. To do this, we present summary statistics that demonstrate risk-return performance across different asset classes over the time period beginning January 2014 and ending December 2016. The sample period represents the two-year period that includes the introduction of the XBX index on July 1, 2014. The six-month period from January 2014 through June 2014 precedes the XBX and we use back-calculated XBX to complete the time series.

7.1.1. Performance of Well-Diversified Equity-Based ETFs

Table 2 reports summary data based on daily returns over the period January 2014 through December 2016 for a number of equity exchange traded funds (ETFs). These ETFs were selected to represent a diverse set of underlying exposures to the broad market and to specific industry sectors like healthcare and technology. The average of the annualized mean daily returns across all equity-based ETFs is 0.24% with an average annualized standard deviation of 3.52%. Given the high degree of overlap in the underlying assets, all of the ETFs are highly correlated with each other. Rather than report the full correlation matrix, Table 1 reports the correlation coefficient for each ETF and the SPY. The average correlation coefficient across all ETFs is 0.847. All of the correlation coefficients are high – the lowest level of correlation is 0.700.

The relatively high correlation levels also are reflected in annualized mean returns that are very similar across the different equity-based ETFs. The largest difference in mean returns is between the technology sector ETF (XLV) and the energy sector ETF (XLE), which respectively have annualized mean returns of 0.60% and -0.15%.

By contrast, the correlation between equity-based ETFs and fixed income (AGG) and commodities (DJP) is much lower. Table 1 reports that the average correlation coefficient between the equity-based ETFs and AGG is -0.177. The negative correlation for equity-based ETFs and fixed income indicates that fixed income provides significant diversification benefits when used in conjunction with equity exposure.

The correlation between equity-based ETFs and commodities (DJP) is lower than equities but higher than fixed income. Table 1 indicates that the average correlation across all equity-based ETFs and DJP is 0.362.

We also report the performance of bitcoin as an asset class. The mean return over the sample period is 1.08% with a standard deviation 13.40%. This indicates that bitcoin's relatively high rates of return are associated with high standard deviations. Note that the correlation between equity-based ETFs and bitcoin (XBX) is -0.037. Although bitcoin has been a volatile asset class when held in isolation, the negative correlation for equity-based ETFs and bitcoin indicates that bitcoin also provides significant diversification benefits when used in conjunction with equity exposure.

7.1.2. Performance of Well-Diversified Fixed Income ETFs

Table 3 reports results for fixed income ETFs. The main takeaway is that realized returns and standard deviations are lower. The average of the annualized mean daily returns is 0.02% compared to 0.24% for equity-based ETFs, and the average annualized standard deviation is 0.94%, which is less than one-third of the comparable volatility for equity (*i.e.*, 0.94%/3.52% = 0.267 < 0.333).

The variation in correlation also is much wider. For example, the correlation coefficients for the fixed income ETFs with the SPY range from -0.388 for Treasuries to 0.665 for high yield corporates. As credit risk increases, fixed income portfolios become more highly correlated with each other. Table 2 reports that the average correlation coefficient between the various fixed income portfolios and AGG is 0.652.

The average correlation between fixed income ETFs and commodities (AGG) is 0.065; while the average correlation with respect to bitcoin (XBX) is -0.014. This suggests that exposure to both asset classes will help a fixed income investor achieve relatively large benefits from diversification.

7.1.3. Performance of Well-Diversified Commodity-Based ETPs

Table 4 reports results for commodity-based ETFs. It shows that the realized returns to commodity ETPs have been negative and riskier than either equity or fixed income ETFs over the sample period. The average of the annualized mean daily returns across all strategies is 0.60% with an average annualized standard deviation of 4.55%. Commodity-based ETPs display considerable cross-sectional variation in how strongly they correlate with equities, ranging from -0.184 for gold (GLD) to 0.339 for a broad-commodities index ETF (GSG). On average their correlation with the SPY, AGG, and DJP respectively are is 0.165, 0.028, and 0.653. Not surprisingly, commodity-based ETPs are positively correlated with each other. Similar to our findings for equity and fixed income ETFs, commodity-based ETPs tend to be negatively correlated with bitcoin (-0.190).

7.2 Modern Portfolio Theory and Diversification

The benefits associated with portfolio diversification are rooted in the normative implications derived from modern portfolio theory (MPT), which was developed by Markowitz [1952]. MPT posits that investors make portfolio allocations by considering the expected return and volatilities of all possible combinations of risky assets. Investors then identify the set of optimal portfolios

that maximize expected return for a given level of risk – a so-called efficient portfolio. The collection of all efficient portfolios is then defined as the "efficient set," or the "efficient frontier." An investor then selects an optimal portfolio from the efficient set based on his/her tolerance for risk. That is, the optimal investment choice is to select the efficient portfolio for an investor's preferred level of risk.

7.2.1 The efficient frontier with equity and fixed income ETFs

Figure 3 displays the set of efficient portfolios (the blue line) that can be achieved by investors that take positions in equity and fixed income ETFs (the green dots) reported in Tables 1 and 2. We assume that investors hold positions in equity and fixed income and can take short positions of up to 30% in any ETF. Allowing investors to short is designed to demonstrate how diversification benefits are enhanced when investors are not constrained to hold long-only positions.

The efficient frontier illustrates how equities tend to display higher returns and higher volatility, while fixed income investments tend to have lower returns and be less volatile. One can see that equity and fixed income ETFs tend to cluster close to each other.
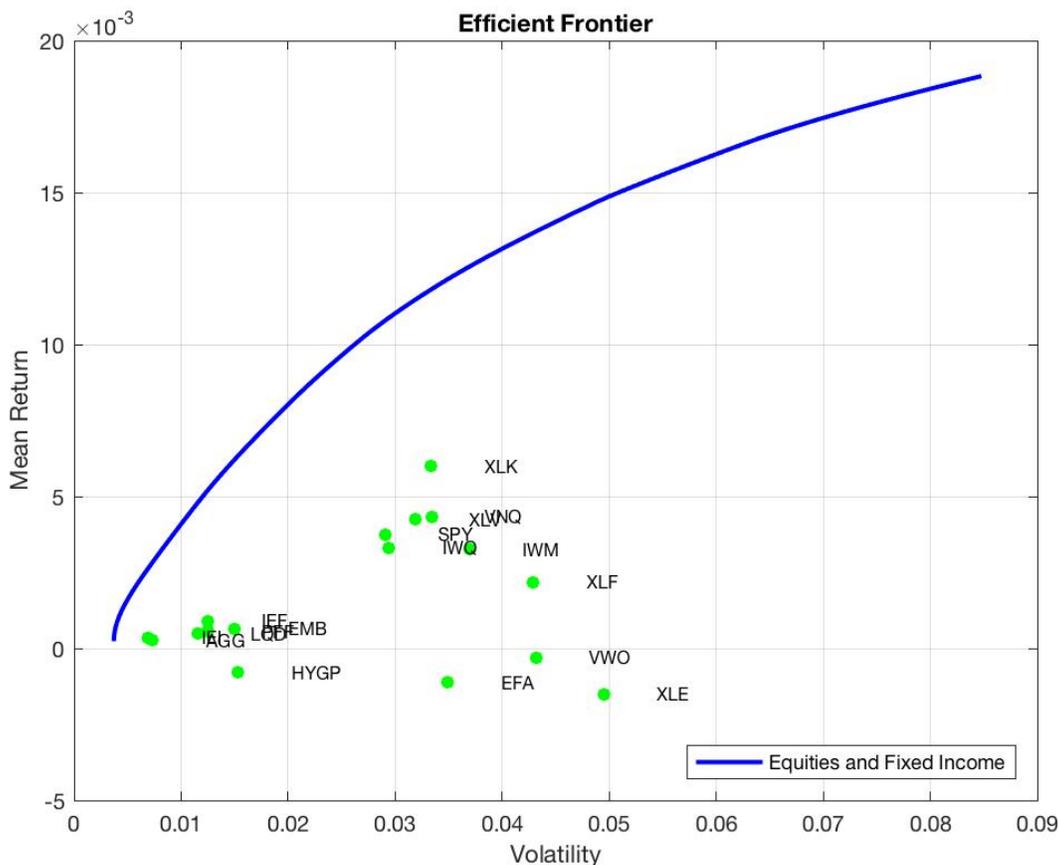
Figure 3. Efficient set based on equity and fixed income ETFs.

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### 7.2.2 The efficient frontier with equity, fixed income, and commodity ETFs

We now consider how the introduction of commodity-based ETPs affects the efficient set. Figure 4 shows that even when investors have access to equities and fixed income ETFs, the addition of commodity-based ETPs to the investment opportunity set reflects an economically significant expansion of the efficient frontier (the red line). The degree to which diversification enhances the investment opportunity set can be assessed by how far the efficient frontier moves in the direction of higher returns and lower risk – the northwest corner. Alternatively, Figure 4 shows that investors could meaningfully reduce risk without reducing expected return. The key takeaway is that exposure to commodities provides expanded investment opportunities relative to stocks and bonds.
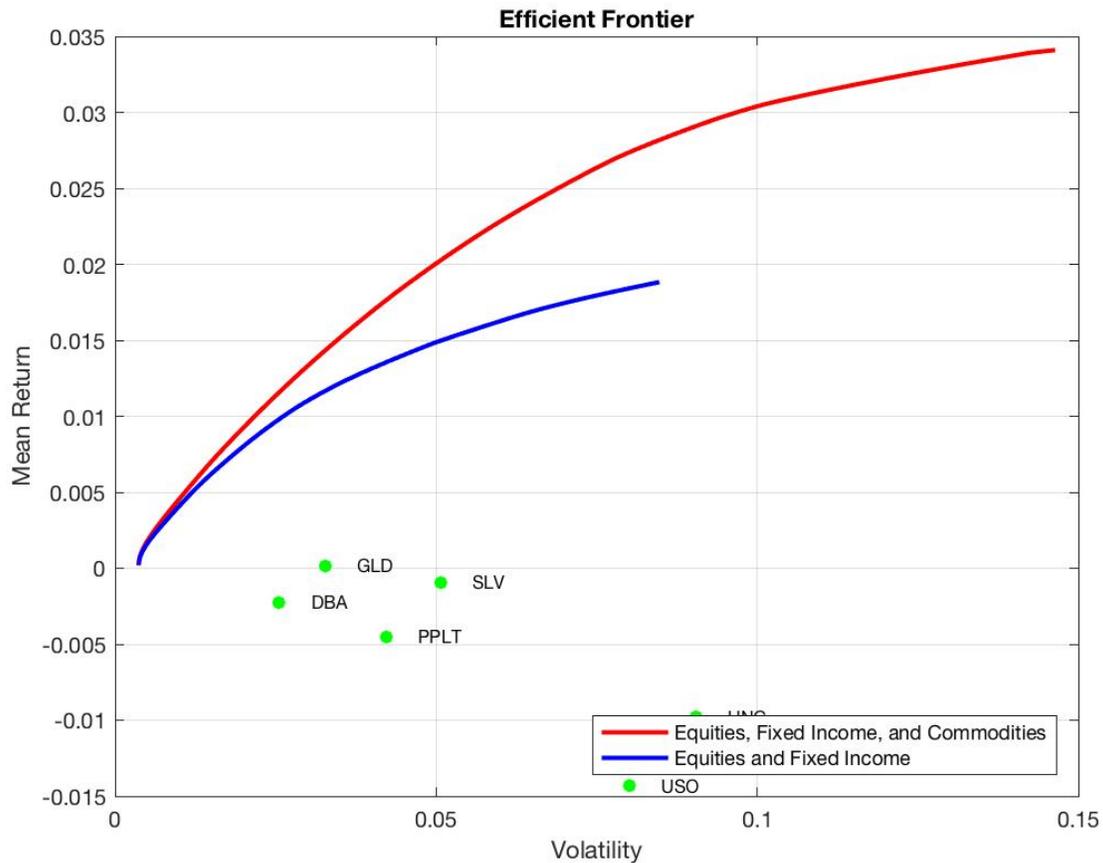
Figure 4. Efficient set based on equity, fixed income, and commodity ETFs.

7.2.3 The efficient frontier with equities, fixed income, commodities, and bitcoin

Figure 5 shows that the addition of bitcoin reflects an economically significant expansion of the efficient frontier (the magenta line). Once again, the key takeaway is that additional assets provide expanded investment opportunities. This indicates that bitcoin can be a valuable addition to investors' portfolios, even relative to other commodities like gold and silver that also represent other assets that have value as currencies.

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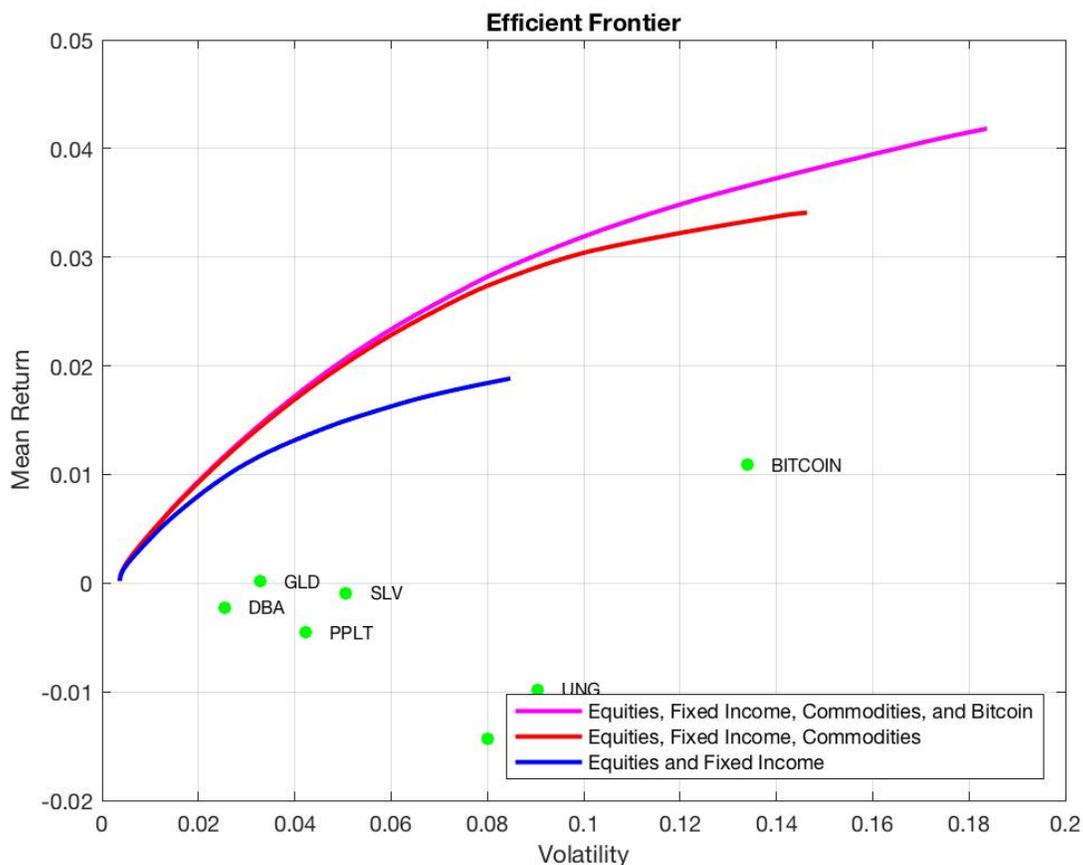
Figure 5. Efficient set based on long equity, fixed income, and liquid alternative mutual fund portfolios.

CONCLUSION

The SEC is considering the approval of the SolidX Bitcoin Trust. This White Paper provides an economic analysis of the possible manipulation of bitcoin, the benefits of continuous share creations and redemptions, the investor protection aspects of bitcoin insurance, and empirical data on key characteristics of bitcoin as an asset.

The main findings of the paper are: (1) the transparency that results from the blockchain and the algorithmic nature of new bitcoin creation makes bitcoin price manipulation no more likely than other commodities; 2) the SBT is expected to make the market for bitcoin more efficient; 3) market efficiency is further enhanced by the continuous creation/redemption process; 4) the use of bitcoin is a key investor protection that can be viewed as a substitute for the traditional transfer agency function associated with security-based exchange traded funds; and 5) as an asset class, bitcoin provides investors with expanded opportunities to reduce risk through diversification.

Policymakers engaged in determining whether to approve the SBT may want to use this study as input for their considerations.

References

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Table 1. List of the exchange traded funds used in the diversification analysis. The column headings are as follows: (1) the broad asset class, (2) the ticker symbol, (3) the name of the fund, and (4) a description of the underlying investment strategy. The list is sorted by assets under management within each asset class as of January 31, 2017. List is obtained from ETF.com.

ASSET CLASS (1)	TICKER (2)	FUND NAME (3)	DESCRIPTION (4)
Equities	SPY	SPDR S&P 500 ETF Trust	Equity: U.S. - Large Cap
Equities	EFA	iShares MSCI EAFE ETF	Equity: Developed Markets Ex-U.S. - Total Market
Equities	VWO	Vanguard FTSE Emerging Markets ETF	Equity: Emerging Markets - Total Market
Equities	VEA	Vanguard FTSE Developed Markets ETF	Equity: Developed Markets Ex-U.S. - Total Market
Equities	IWM	iShares Russell 2000 ETF	Equity: U.S. - Small Cap
Equities	IWD	iShares Russell 1000 Value ETF	Equity: U.S. - Large Cap Value
Equities	VNQ	Vanguard REIT Index Fund	Equity: U.S. Real Estate
Equities	IWF	iShares Russell 1000 Growth ETF	Equity: U.S. - Large Cap Growth
Equities	XLF	Financial Select Sector SPDR Fund	Equity: U.S. Financials
Equities	XLE	Energy Select Sector SPDR Fund	Equity: U.S. Energy
Equities	VYM	Vanguard High Dividend Yield Index Fund	Equity: U.S. - High Dividend Yield
Equities	VB	Vanguard Small-Cap Index Fund	Equity: U.S. - Small Cap
Equities	EWJ	iShares MSCI Japan ETF	Equity: Japan - Total Market
Equities	XLK	Technology Select Sector SPDR Fund	Equity: U.S. Technology
Equities	XLV	Health Care Select Sector SPDR Fund	Equity: U.S. Health Care
Bonds	AGG	iShares Core U.S. Aggregate Bond ETF	Fixed Income: U.S. - Broad Market Investment Grade
Bonds	BND	Vanguard Total Bond Market Index Fund	Fixed Income: U.S. - Broad Market Investment Grade
Bonds	LQD	iShares iBoxx $ Investment Grade Corporate Bond ETF	Fixed Income: U.S. - Corporate Investment Grade
Bonds	BSV	Vanguard Short-Term Bond Index Fund	Fixed Income: U.S. - Government/Credit Investment Grade Short-Term
Bonds	HYG	iShares iBoxx $ High Yield Corporate Bond ETF	Fixed Income: U.S. - Corporate High Yield
Bonds	PFF	iShares U.S. Preferred Stock ETF	Fixed Income: U.S. - Corporate Preferred Stock
Bonds	VCSH	Vanguard Short-Term Corporate Bond Index Fund	Fixed Income: U.S. - Corporate Investment Grade Short-Term
Bonds	BIV	Vanguard Intermediate Term Bond Index Fund	Fixed Income: U.S. - Government/Credit Investment Grade Intermediate
Bonds	VCIT	Vanguard Intermediate-Term Corporate Bond Index Fund	Fixed Income: U.S. - Corporate Investment Grade Intermediate
Bonds	BKLN	PowerShares Senior Loan Portfolio	Fixed Income: U.S. - Corporate High Yield Floating Rate
Bonds	EMB	iShares JP Morgan USD Emerging Markets Bond ETF	Fixed Income: Emerging Markets - Sovereign
Bonds	IEF	iShares 7-10 Year Treasury Bond ETF	Fixed Income: U.S. Government Treasury Intermediate
Bonds	IEI	iShares 3-7 Year Treasury Bond ETF	Fixed Income: U.S. Government Treasury Intermediate
Commodities	DJP	iPath Bloomberg Commodity Index Total Return ETN	Commodities: Broad Market
Commodities	DBA	PowerShares DB Agriculture Fund	Commodities: Agriculture
Commodities	USCI	United States Commodity Index Fund	Commodities: Broad Market
Commodities	PPLT	ETFS Physical Platinum Shares	Commodities: Precious Metals Platinum
Commodities	UNG	United States Natural Gas Fund LP	Commodities: Energy Natural Gas
Commodities	GLD	SPDR Gold Trust	Commodities: Precious Metals Gold
Commodities	SLV	iShares Silver Trust	Commodities: Precious Metals Silver
Commodities	USO	United States Oil Fund LP	Commodities: Energy Crude Oil
Commodities	DBC	PowerShares DB Commodity Index Tracking Fund	Commodities: Broad Market
Commodities	GSG	iShares S&P GSCI Commodity Indexed Trust	Commodities: Broad Market

Table 2. Summary statistics based on daily returns from equity-based ETFs and bitcoin. The reported statistics are the annualized mean daily return (Annualized Mean) and its associated annualized standard deviation (Annualized Std. Dev.). The next four columns are correlation coefficient between the indicated portfolio and the SPY (equity), AGG (bond), DJP (commodity) and the XBX index (bitcoin). Price data obtained from http://finance.yahoo.com/quote.

Ticker	Annualized Mean Ret.	Annualized Std. Dev.	Correlation with SPY	Correlation with AGG	Correlation with DJP	Correlation with bitcoin
SPY	0.38%	2.91%	1.000	-0.236	0.290	0.008
EFA	-0.11%	3.49%	0.829	-0.184	0.376	-0.027
VWO	-0.03%	4.31%	0.759	-0.084	0.438	-0.019
VEA	-0.08%	3.43%	0.837	-0.167	0.391	-0.037
IWM	0.33%	3.69%	0.857	-0.231	0.274	0.004
IWD	0.33%	2.94%	0.972	-0.236	0.364	0.009
VNQ	0.43%	3.34%	0.603	0.165	0.121	0.011
IWF	0.41%	2.99%	0.973	-0.211	0.225	0.002
XLF	0.22%	4.29%	0.755	-0.307	0.194	0.016
XLE	-0.15%	4.95%	0.708	-0.170	0.605	0.008
VYM	0.35%	2.73%	0.967	-0.191	0.326	0.008
VB	0.34%	3.36%	0.902	-0.218	0.319	-0.004
EWJ	0.14%	3.79%	0.713	-0.167	0.250	-0.062
XLK	0.60%	3.33%	0.923	-0.188	0.218	0.007
XLV	0.43%	3.19%	0.913	-0.227	0.203	0.020
XBX	1.08%	13.40%	0.008	-0.008	-0.021	1.000
Average	0.24%	3.52%	0.847	-0.177	0.306	-0.004
Median	0.33%	3.40%	0.847	-0.189	0.305	0.005

Table 3. Summary statistics based on daily returns for fixed income-based ETFs and bitcoin. The reported statistics are the annualized mean daily return (Annualized Mean) and its associated annualized standard deviation (Annualized Std. Dev.). The next four columns are correlation coefficient between the indicated portfolio and the SPY (equity), AGG (bond), DJP (commodity) and the XBX index (bitcoin). Price data obtained from http://finance.yahoo.com/quote.

Ticker	Annualized Mean Ret.	Annualized Std. Dev.	Correlation with SPY	Correlation with AGG	Correlation with DJP	Correlation with bitcoin
AGG	0.03%	0.73%	-0.236	1.000	-0.051	-0.008
BND	0.02%	0.74%	-0.258	0.950	-0.055	-0.025
LQD	0.05%	1.15%	-0.119	0.899	-0.021	-0.028
BSV	-0.01%	0.34%	-0.275	0.815	-0.039	-0.024
HYG	-0.08%	1.53%	0.665	0.020	0.387	-0.012
PFF	0.06%	1.25%	0.445	0.203	0.227	0.058
VCSH	0.00%	0.39%	-0.053	0.738	0.087	-0.030
BIV	0.03%	0.95%	-0.280	0.934	-0.079	-0.023
VCIT	0.06%	0.94%	-0.155	0.893	-0.008	-0.011
BKLN	-0.10%	0.75%	0.481	-0.087	0.287	-0.015
EMB	0.06%	1.50%	0.410	0.275	0.326	-0.048
IEF	0.09%	1.25%	-0.388	0.935	-0.129	-0.015
IEI	0.04%	0.69%	-0.349	0.905	-0.088	-0.002
bitcoin	1.08%	13.40%	0.008	-0.008	-0.021	1.000
Average	0.02%	0.94%	-0.009	0.652	0.065	-0.014
Median	0.03%	0.94%	-0.155	0.893	-0.021	-0.015

Table 4. Summary statistics based on daily returns for commodity-based ETFs and bitcoin. The reported statistics are the annualized mean daily return (Annualized Mean) and its associated annualized standard deviation (Annualized Std. Dev.). The next four columns are correlation coefficient between the indicated portfolio and the SPY (equity), AGG (bond), DJP (commodity) and the XBX index (bitcoin). Price data obtained from http://finance.yahoo.com/quote.

Ticker	Annualized Mean Ret.	Annualized Std. Dev.	Correlation with SPY	Correlation with AGG	Correlation with DJP	Correlation with bitcoin
GLD	0.02%	3.28%	-0.184	0.350	0.299	-0.015
SLV	-0.09%	5.07%	0.048	0.194	0.453	-0.022
USO	-1.43%	8.00%	0.334	-0.136	0.789	-0.016
DBC	-0.70%	3.49%	0.330	-0.092	0.938	-0.004
GSG	-1.03%	4.49%	0.339	-0.114	0.890	-0.013
DJP	-0.58%	3.25%	0.290	-0.051	1.000	-0.021
DBA	-0.22%	2.55%	0.149	-0.015	0.557	0.000
USCI	-0.49%	2.12%	0.249	-0.047	0.808	-0.015
PPLT	-0.45%	4.22%	0.103	0.182	0.401	0.006
UNG	-0.98%	9.04%	-0.011	0.008	0.398	-0.089
bitcoin	1.08%	13.40%	0.008	-0.008	-0.021	1.000
Average	-0.60%	4.55%	0.165	0.028	0.653	-0.019
Median	-0.54%	3.86%	0.199	-0.031	0.673	-0.015