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*This is an extract from the
Equity Gilt Study 2018*

Seeking value in crypto currencies

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Crypto currencies are a new form of ‘asset’ with no intrinsic value or promised stream of cash flows. As a result, Financial and Economic theory give no guidance for fundamental valuation or expected price behaviour. We attempt to parameterize a ceiling for the potential long-term fundamental value of crypto currencies (in total) based on our analyses of sources and factors of demand. Further, we use a combination of empirical and theoretical modelling of Bitcoin prices to generalise and forecast its price behaviour.

Our primary findings

- Based on our companion analysis, we estimate that long-term fundamental demand for and value of crypto currencies – as a class – is likely to come from low-trust sectors of the global economy.
- Using estimates of money demand for both transactions and wealth storage in these sectors, we estimate – with generous assumptions – that the ceiling for total crypto currency market capitalisation is between \$660bn and \$780bn. Importantly, these estimates represent an *upper bound for all crypto currencies*, not likely fundamental value and do not apply to any single crypto currency.
- For perspective, the upper bound is roughly equivalent to the peak sum of all crypto currencies’ market capitalisation in early January 2018.
- Using an empirical model of commodity inventory and price behaviour, we decompose weekly Bitcoin price movements into ‘supply’ and demand contributions, and find that since 2015 both inventory and demand behaviour have been speculative.
- We show that speculation in crypto currencies appears to be driven by developed economy purchasers and holders.
- Developing a theoretical model of speculative investment in crypto currencies that mimics the epidemiological literature, we show that crypto currency price behaviour is determined by the rate of new entrants (‘infections’) and the remaining ‘susceptible’ population.
- Survey evidence from developed economies suggests that crypto currency awareness now is nearly universal, that susceptibility to speculative investment is a small share of the population, and that former holders are developing ‘immunity’ to further investment.
- Combined with the results of our theoretical modelling, survey findings suggest that, unlike the peaks in Bitcoin prices in 2011 and 2013, the most recent peak may have been the ultimate top and that speculative interest could decrease from here.

The novelty and lack of intrinsic value or cash flows of crypto currencies make fundamental analysis difficult

Subject to caveats, we estimate a maximal upper bound for crypto currency market cap of \$780bn, and see signs that recent speculative buying may be nearing an end

Companion analysis suggests that long-term demand for and value of crypto currencies will come from low-trust environments

A generous definition of low-trust economies yields a total GDP of \$11tn

But accounting for likely government suppression of crypto currencies and internet penetration suggests only \$1.5tn of GDP transactions risk replacement with crypto currencies

What is Bitcoin's – or any crypto currency's – long-term value? And what caused Bitcoin's exponential price growth in 2017 (and collapse in 2018)? Fundamental analysis of crypto currencies is difficult due to their novelty, as well as lack of intrinsic value or cash flow generation. However, we attempt to establish an upper bound for the long-term fundamental value of total crypto currencies, based on our analysis of the underlying sources of demand; and model the price behaviour of Bitcoin to determine the factors that have led to its recent behaviour.

Subject to significant assumptions about long-term sources of demand based on our analysis in a companion piece and the existing state of crypto technology, our analysis suggests that the upper bound for the total value of all crypto currencies is between \$660bn and \$780bn, although the actual value likely is significantly lower. Further, we find that, since 2015, Bitcoin's price has been driven by speculative behaviour, rather than fundamental demand and supply for a commodity. In modelling speculative behaviour, we find that the supply of new entrants to the market is a key driver of price increases and that survey data suggest we may be near the end of that process.

Estimating long-term fundamental value

Our analysis of the determinants of fundamental demand for crypto currencies in *Chapter 3 – Crypto technology: A solution still seeking a problem* suggests that it is a mix of speculative (or potentially ideological) interest from developed markets and a desire for security or investment alternatives in low-trust environments. The former source of demand (as we show in our modelling below) likely will prove temporary, and only the latter likely will determine long-term use of and value for crypto currencies. Hence, our estimation of long-term value focuses on the monetary and store of value needs of low-trust sectors of the global economy: weak, underdeveloped states and global criminal enterprise.

Demand in low-trust, low-opportunity economies

Figure 1 lays out a calculation of the potential demand for currency in low-trust sectors of the global economy. The top portion of the table focuses on weak states with low trust and opportunities. Assuming, generously, that all of the countries in the bottom half of the Legatum Prosperity Index (LPI)¹ – shown to be key relative sources of interest in crypto currencies in *Chapter 3 – Crypto technology: A solution still seeking a problem* – are potentially at risk of complete adoption of crypto currencies, the total GDP of those economies is nearly \$11tn.

However, as we note in our companion chapter, governments are unlikely to allow their citizens to shift commerce wholly to alternative currencies as they risk loss of both seigniorage and tax revenue. Accordingly, we narrow the list of countries to those where the sovereign appears weakest, using the bottom third of the Fund for Peace's 'Fragile States Index'²; this brings the total GDP down to \$3.4tn. However, access to electricity and the internet – prerequisites for electronic payments with crypto currencies – are limited in these economies, so we further reduce by internet penetration rates, taking the total down to \$1.5tn. This is our upper-bound estimate of the size of the weak-state, low-trust economy that could adopt crypto currencies.

¹ The Legatum Prosperity Index is a measure of country-level social welfare produced by the Legatum Institute. It measures welfare based on 110 questions divided into eight categories (subindices): Economy, Entrepreneurship and Opportunity, Governance, Education, Health, Safety and Security, Personal Freedoms, and Social Capital, the last being a measure of the 'glue' of society, particularly trust in fellow citizens and institutions.

² The Fragile State Index is a quantitative measure of government control over sovereign territories that spans 178 sovereigns and is produced by the Fund for Peace.

We estimate money demand for that annual rate of transactions to be just \$323bn

But that is not the same as money demand. To estimate money demand in that portion of the global economy, we multiply the estimated \$1.5tn in GDP of the remaining countries by the average ratio of M1/GDP in those fragile, low-trust countries. That yields an estimated demand from these economies for crypto currencies of \$323bn. We view this as a likely upper bound, given that even weaker governments likely would be able to enforce at least some use of 'fiat' currency in their economies (at least for tax payments), and lack of payments infrastructure in these economies could force residents to keep a share of their preferred money balances in local currency.

FIGURE 1
Estimation of crypto currency value to low-trust economies

Potential low-trust crypto currency use and market capitalisation, USD, bns	
Weak states with low trust and opportunities	
Negative LPI countries' GDP	10,761
Share of which 'Fragile'	3,390
Share of which with internet (47%)	1,542
x Sample average M1/GDP (0.21)	323
Criminal enterprise	
3.6% of global GDP	2,854
x Global average M1/GDP (0.31)	889
x 25% wholesale share	222
Total low trust environments	545

Source: Haver Analytics, IMF, ITC, Legatum Prosperity Institute, OAS, RAND, The Fund for Peace, UNODC/World Bank, Barclays Research

Criminal enterprise, worth 3.6% of global GDP likely requires money demand of \$889bn

Demand in criminal enterprise

The lower half of Figure 1 adds in the potential crypto currency needs of global criminal enterprise under the same framework. The UN Office of Drugs and Crime and the World Bank jointly estimated that criminal enterprise generates annual proceeds of 3.6% of global GDP or, based on 2017 estimates, \$2.9tn. Assuming money demand for criminal enterprise is proportional to the global economy – the average ratio of M1/GDP globally – total money demand from criminal sectors would be \$889bn. However, there are indications that most 'retail' criminal transactions involve lower denomination bills.³ Given potential acceptance and safety issues, as well as processing times (for the current generation of crypto currencies), we assume that most retail transactions will continue to be dominated by small-denomination paper currency.⁴

But not all of that is likely to be through crypto currencies; we estimate \$222bn

Thus, crypto currency demand in criminal enterprise likely comes mainly from wholesalers. A RAND Corporation study appears to support this assumption, given its finding that the largest and increasing share of crypto currency transactions in the narcotics trade are wholesale.⁵ Both the RAND study and another by the Organization of

³ For instance, a Reason magazine study with the non-profit Lucy Parsons Labs' study of police seizures in Cook County, Illinois (Chicago) found that of 23,065 seizures of all types (including cars and other property) between 2012 and 2017, the median value was \$1,049, roughly 11,000 were for amounts less than \$1,000, and nearly 1,500 were for less than \$100; see 'Poor Neighborhoods Hit Hardest by Asset Forfeiture in Chicago, Data Shows,' C.J. Ciaramella, *Hit & Run Blog*, Reason, 13 June 2017. Most of the available data and analysis on crypto technologies comes from independent, specialty news services and blogs, hence some caveats are advised.

⁴ In any criminal transaction, one runs the risk of robbery, but that risk may be higher if one uses electronic means of payment such as crypto currency: if you pay cash in a 'retail' drug deal, the dealer can only rob you of the cash you are carrying; if paying by Bitcoin on a mobile, the dealer can force you to transfer your entire account value. See 'Bitcoin-Seeking Gangsters Hold Cryptocurrency Trader at Gunpoint in His Own Home,' J.P. Buntinx, *themerkle.com*, 29 January 2018.

⁵ 'Internet-facilitated drugs trade, an analysis of the size, scope and the role of the Netherlands,' Kristy Kruithof et alia, *RAND Corporation Research Reports*, 5 August 2016.

American States⁶ estimate that wholesale and trafficking account for about 20- 25% of drug revenues. Use of cash in the drug trade likely represents a safe upper bound for broader criminal usage as other studies have found it to have the highest usage of cash among criminal activities.⁷ Applying the higher wholesale share of narcotics revenue to the total money demand in criminal enterprise yields an estimated crypto currency demand of \$222bn.

Together, this implies an upper bound for transactional demand for crypto currencies of \$545bn

This provides an upper bound for total money demand in low-trust portions of the global economy – weak states and criminal enterprise – of \$545bn. Again, this likely significantly overstates actual demand based on our generous assumptions, but it provides a potential ceiling on non-sovereign crypto currency market capitalisation.

Demand as illicit store of value

Yet this may undercount illicit demand for a store of wealth

However, the above analysis may neglect potential demand for crypto currencies as an asset, or store of wealth, rather than a medium of exchange, from the same areas of the global economy. The money balance approach used in Figure 1 probably incorporates some asset demand. Roughly \$1.25tn of US \$100 bills are in circulation and about 65% are estimated to be held outside of the US.⁸ Given low levels of merchant acceptance of \$100 bills, it is assumed that most is used as a store of wealth. Indeed, there is evidence that demand for \$100 bills rises amid global economic turmoil – when transaction demand is falling – supporting the idea that it acts like an asset as well as a medium of exchange.⁹ An unknown but assumed large share likely is used in criminal activity or as a store of illicit wealth, as revealed by *single* seizures of \$207mn in a Mexican drug bust and \$650mn from Uday Hussein’s palace during the Iraq War.¹⁰

Collectively, high-denomination notes of reserve currencies circulating outside of issuer countries is about \$1.2tn

Figure 2 shows the total supply of high-denomination notes from the US, euro area, Switzerland, and the UK, circulating outside of their respective borders.¹¹ These countries’ high-denomination notes represent roughly 80% of the seizures of cash suspected in criminal activity.¹² We focus on currency circulating outside of issuing sovereigns’ domains for two reasons: 1) research suggests that most home-country large-denomination note use is legitimate;¹³ and 2) illicit wealth storage in home-country currency likely reflects home bias in asset preference and, hence, is less likely to be exchanged into crypto currencies, particularly if their volatility remains high.

⁶ ‘The economics of drug trafficking,’ *The drug problem in the Americas: Chapter 4*, Organization of American States.

⁷ For instance, the share of cash in drug transactions is estimated at 80%, whereas human trafficking is estimated at 50% and counterfeit goods at just 30%; see ‘Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes,’ Peter Sands, *M-RCBG Associate Working Paper Series, No. 52*, Harvard Kennedy School, February 2016.

⁸ Outstanding amount 2017 estimate of Federal Reserve Board of Governors; share abroad estimated in ‘Crisis and Calm: Demand for U.S. Currency at Home and Abroad from the Fall of the Berlin Wall to 2011,’ Ruth Judson, *International Finance Discussion Papers 1058*, Federal Reserve Board of Governors, November 2012.

⁹ See ‘Crisis and Calm: Demand for U.S. Currency at Home and Abroad from the Fall of the Berlin Wall to 2011,’ Ruth Judson, *International Finance Discussion Papers 1058*, Federal Reserve Board of Governors, November 2012.

¹⁰ ‘The \$207-million question in Mexico,’ Hector Tobar and Carlos Martinez, *Los Angeles Times*, 17 July 2007; and ‘Saddam seized \$1bn from central bank,’ Alex Spillius, *The Telegraph*, 7 May 2003.

¹¹ Total circulation of high-denomination notes data are available from the Bank of England, European Central Bank, Federal Reserve, and Swiss National Bank. Proportions circulating abroad are assumed to be 65% of \$100 notes, 50% of €500 and €100 notes, 70% of Sfr1,000 notes, and 50% of £50 notes, taken respectively from Judson; ‘Estimation of euro currency in circulation outside the euro area,’ *External Statistics Division*, ECB, 6 April 2017; ‘The use of large denomination banknotes in Switzerland,’ Katrin Assenmacher et alia, manuscript, Bundesbank, 24 March 2017; and ‘How has cash usage evolved in recent decades? What might drive demand in the future?’ *Quarterly Bulletin 2015 Q3*, Bank of England, 15 September 2015.

¹² See ‘Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes,’ Peter Sands, *M-RCBG Associate Working Paper Series, No. 52*, Harvard Kennedy School, February 2016.

¹³ Researchers assume that most \$100 bills in circulation within the US are not used in criminal enterprise; see ‘U.S. Consumers’ Holdings and Use of \$100 Bills,’ Claire Greene and Scott Schuh, *Research Data Reports No. 14-3*, Federal Reserve Bank of Boston, 25 November 2014.

FIGURE 2

Estimated potential value of crypto currencies as an asset

Potential crypto currency use as store of illicit wealth, USD, bns	
\$100 notes outside the US	813
€500 and €100 notes outside the euro area	315
Sfr1,000 notes outside of Switzerland	34
£50 notes outside of the UK	11
Total	1,173
Upper bound assumption, 20%	235
Lower bound assumption, 10%	117

Source: Bank of England, Bundesbank, European Central Bank, Federal Reserve, Swiss National Bank, Barclays Research

We suspect a significant portion of that may double count our estimates of transactional demand for crypto currencies

How much of the roughly \$1.2tn in high-denomination bills circulating outside issuing countries would be double counted under our estimation of the monetary needs of criminal enterprise is unknowable. However, two pieces of evidence suggest that the overlap could be substantial. First, 5- 10% of cash seizures suspected as criminal proceeds are in the currencies of the originating or destination countries (other than USD, EUR, GBP, or CHF).¹⁴ Second, high-denomination notes comprise a large share of the outstanding value of currencies of countries counted as 'low-trust' in Figure 1, suggesting that our low-trust environments' calculations already encompass a significant portion of wealth storage.¹⁵

We also see several reasons why the remainder may not be converted to crypto currencies

Furthermore, we are sceptical that a large share of any remainder would be converted into crypto currencies, for several reasons:

- *Preference for cash:* Despite the growth of crypto currencies – and evidence of their use in crime¹⁶ – average annual growth in demand for \$100 bills since the creation of Bitcoin in 2011 is 8.1%, almost double the growth of US nominal GDP, and it accelerated to 8.4% in 2017. Even more clearly, in many developing countries the black market exchange rate premium for \$100 bills over lower-denomination USD notes has been measured at 5- 10%, and in Ethiopia it has been measured as high as 20%, suggesting that cash is still king.¹⁷
- *Low criminal balance/transaction ratio in crypto currency:* Despite the surge in crypto currency usage and values in 2017, estimated holdings of criminal proceeds in crypto currency remain small in absolute value and even smaller relative to estimated criminal transactions. A recent study by the University of Sydney and University of Technology Sydney found that 'approximately one-quarter of bitcoin users and one-half of bitcoin transactions [approximately \$72bn per year] are associated with illegal activity.' But, the researchers found the same users collectively hold just \$8bn worth of Bitcoin.¹⁸ There is evidence that 'dark web' criminal activity on Bitcoin is shifting to Monero and Zcash to better mask transactions, but these two crypto currencies have total market capitalisations of just \$2.7bn and \$670mn, respectively.¹⁹

¹⁴ See 'Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes,' Peter Sands, *M-RCBG Associate Working Paper Series, No. 52*, Harvard Kennedy School, February 2016.

¹⁵ See 'Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes,' Peter Sands, *M-RCBG Associate Working Paper Series, No. 52*, Harvard Kennedy School, February 2016..

¹⁶ 'Internet-facilitated drugs trade, an analysis of the size, scope and the role of the Netherlands,' Kristy Kruihof et alia, *RAND Corporation Research Reports*, 5 August 2016.

¹⁷ See 'Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes,' Peter Sands, *M-RCBG Associate Working Paper Series, No. 52*, Harvard Kennedy School, February 2016..

¹⁸ 'Sex, Drugs, and Bitcoin: How Much Illegal Activity Is Financed Through Cryptocurrencies?' Sean Foley, Jonathan R. Karlsen, and Talis J. Putnins, *SSRN*, 15 January 2018.

¹⁹ See 'Monero, the drug dealer's cryptocurrency of choice, is on fire,' Andy Greenberg, *Wired*, 25 January 2017; and 'Criminal underworld is dropping bitcoin for other cryptocurrency,' *South China Morning Post*, 2 January 2018.

- *Transformation risks traceability:* Transforming large quantities of cash into crypto currencies requires transforming it into electronic debit-entry money, which is then exchanged for crypto currencies, typically via exchanges. Each of these steps creates a point of traceability by sovereign authorities. Bitcoin and other first-generation crypto currency transactions are themselves increasingly traceable, too.²⁰ While new crypto currencies with enhanced privacy masking and transaction mixing, such as Monero and Zcash, may solve that problem – though authorities and researchers are working on cracking their algorithms too – criminals still need to exchange criminal proceeds into these currencies, and exchanges increasingly are rejecting suspicious transactions under sovereign pressure.²¹
- *Risk:* Crypto currencies, to date, cannot be considered a safe store of value compared with cash. Crypto currencies have demonstrated extreme volatility since their inception. Bitcoin's 105% annualized daily volatility in the past year was small by comparison with Ripple's 286%, but was still more than 10 times typical exchange rate volatility. Further, theft of Bitcoin through hacking, scams and ransomware has surged.²²

Among other reasons, estimates of criminal crypto currency holdings to transactions suggest 10% or at most 20% of illicit wealth may be converted

This implies an upper bound market cap of between \$660bn and \$780bn

Importantly, those values are a generous upper bound, not an estimate of fair value

We use an empirical and numerical model in combination to capture crypto currency price dynamics

Based on our view that low-trust money demand likely already encompasses significant asset demand for crypto currencies and scepticism regarding the share of cash wealth that is likely to be converted into crypto currencies, we expect only 10- 20% of high-denomination cash wealth will be exchanged in the long run. The lower bound, 10%, is roughly in line with the ratio of estimated criminal Bitcoin holdings to transactions. Generously, we assume that the upper bound is double that share. As shown in Figure 2, these ranges imply long-term demand for crypto currencies as an asset of between \$117bn and \$235bn.

Together with our earlier estimates for potential transaction demand, this suggests that the upper bound for total crypto currency market capitalisation is between \$660bn and \$780bn. For perspective, the upper end of that range is roughly the peak market capitalisation of all crypto currencies in early January 2018.

Two important points are worth emphasising. First, these estimates are upper bounds based on generous assumptions, *not* fair values. Second, the upper bound is for crypto currencies *as a class*, not any particular crypto currency. As we note in *Chapter 3 – Crypto technology: A solution still seeking a problem*, we see a significant likelihood of diffusion of value across a number of crypto currencies, reducing the acceptance and network value of each, and thus potentially reducing further the fundamental market capitalisation value for all collectively.

Modelling Bitcoin price behaviour

With a ceiling for crypto currencies' potential fundamental long-term value in hand, we use two methods, one empirical and one numerical, to understand and forecast the price behaviour of crypto currencies. We start by testing whether Bitcoin's price and inventory behaviour fit an 'inventory supply' model of commodity behaviour or a model of speculative holdings. We then use those results in a theoretical model of speculative behaviour to determine price dynamics under speculative investment.

²⁰ 'Criminals Thought Bitcoin Was the Perfect Hiding Place, but They Thought Wrong,' Mike Orcut, *MIT Technology Review*, 11 September 2017.

²¹ 'Criminal underworld is dropping bitcoin for other cryptocurrency,' *South China Morning Post*, 2 January 2018.

²² See 'The Changing Nature of Cryptocrime,' Chainalysis, 18 January 2018.

Digital gold?

Survey and other evidence suggests that developed economy crypto currency demand is speculative

Our analysis in *Chapter 3 – Crypto technology: A solution still seeking a problem* suggests that, unlike in underdeveloped countries, where demand for crypto currencies appears driven by lack of trust and opportunities for wealth storage, speculation is the main driver of demand in advanced economies. Survey evidence appears to strongly support our analysis. Consistent with speculation being a clear motive for holding, despite a Japanese law exempting purchases made in crypto currencies from VAT, only 34% of surveyed owners used Bitcoin for purchases, while 54% held it as a long-term investment and 42% as a short-term investment.²³ A late 2017 survey of US Bitcoin holders undertaken by Lendedu found that just 8% owned it for purchases or payments, while 41% saw it as ‘world changing’ and 22% viewed it as a long-term investment.²⁴ The perceived value of crypto currencies by advanced economy investors and whether or not they see crypto currencies as commodities, like gold, or as speculative instruments likely will determine their price dynamics.

We use an empirical model of commodities to test if Bitcoin holders act like it is a commodity or speculative investment

To investigate, we model Bitcoin’s past price behaviour as a commodity to determine if ‘inventory’ holders act as suppliers or speculators, and then develop a theoretical model of speculative behaviour of future price dynamics. Our analysis suggests that while inventory acted as supply in the past, since 2015 it has acted more like speculation. Modelling future behaviour based on speculation suggests that bubbles can have multiple peaks and continue until the supply of new entrants dwindles, as may already be occurring.

Bitcoin holdings can be thought of as ‘inventories’ in a commodity model

The supply of Bitcoins, like mineral commodities, is created by ‘mining’, albeit virtually. Because the mining process is algorithmically constrained, supply cannot adjust to demand shocks, just like mineral commodity mining in the short run. But, also like physical commodities, existing Bitcoins can be held in inventory to meet short-run demand shocks. The behaviour of inventory holders amid demand shocks thus determines Bitcoin price dynamics. In the commodity literature, there are two theories of the behaviour of inventory holders.

Commodity inventories typically act as supply: moving opposite to price

One view is that they act as suppliers, basing their expectation of future demand on current prices relative to a notion of fundamental value. This means that when prices are high, inventory holders release supply to meet demand in expectation of lower future prices; when prices are low they reverse course and accumulate inventories in expectation of higher future prices. Under this view, inventory ‘supply’ moves opposite to prices.

Unless holders are speculating, then holdings move with prices

Another possibility is that inventory holders speculate, or accumulate or release inventories based on their expectation of future prices. If suppliers extrapolate from recent price dynamics, this type of forward-looking expectation can exacerbate price moves in both directions. As prices rise, inventory holders accumulate more in expectation of higher future prices; as prices fall, they shed inventories to avoid selling at expected lower future prices.

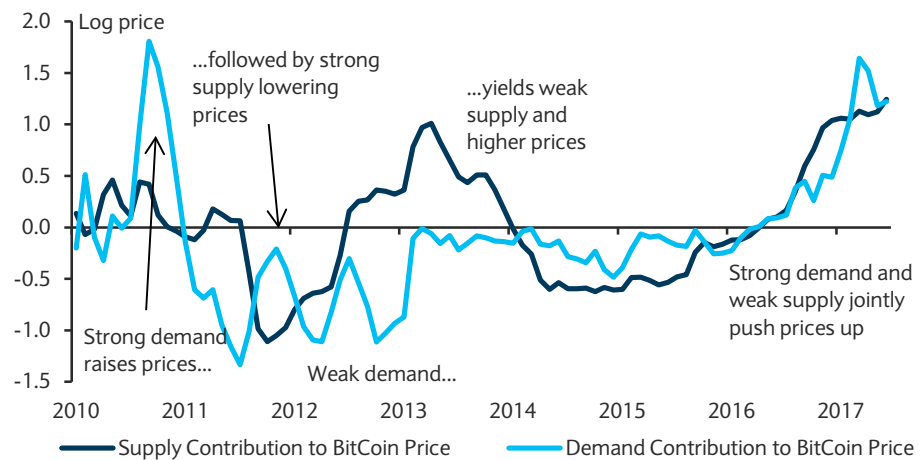
We use a VAR model and weekly Bitcoin prices to estimate the contributions to prices from ‘supply’ and demand

We use a VAR model, a standard approach to study commodity prices, to econometrically examine which of the two inventory behaviours better describes Bitcoin price formation. For this purpose, we need both the price and quantity of Bitcoin supplied. In lieu of inventory data, which is not available, we use Bitcoin transactions as a measure of effective release. We then estimate the model with two lags on monthly data, though similar results are obtained with weekly data. Supply shocks cause transactions and prices to move in opposite directions, while demand shocks push them both in the same direction. We then decompose the deviations from a linear trend into contributions from these two shocks.

²³ See ‘Survey Says 88% of Japanese Have Heard of Bitcoin’, Kevin Helms, *Bitcoin.com*, 19 November 2017.

²⁴ See ‘Survey: Bitcoin buyers prefer investing in it over using it as a payment method,’ Jon Martindale, *Digital Trends*, 17 November 2017.

FIGURE 3
Decomposition of Bitcoin price dynamics into supply and demand shocks



Source: Blockchain.info, Barclays Research

Our analysis suggests that early behaviour was commodity like, but that since 2015, behaviour has been consistent with speculation

Using our findings, we model speculative investment behaviour similar to propagation of an infectious disease

The theoretical model of asset demand assumes a fundamental value, but still exhibits speculative behaviour when that value is unknown

The results of our econometric analysis are shown in Figure 3. The light blue line is the contribution of demand to Bitcoin’s price, while the dark blue line is the contribution of inventory supplied. Up until 2015, it seems relatively clear that strong demand pushed prices up and was followed by a release of inventories that pushed prices down. Similarly, weak demand yielding falling prices was followed by a supply shock, which pushed them up again. However, since 2015, both supply and demand appear to be pushing prices simultaneously in the *same* direction, suggesting inventory behaviour has become speculative.

Or an ‘infectious disease’?

Taking this a step further, we developed a theoretical model of an asset price with a pool of speculative investors and compared it with actual Bitcoin price behaviour to see what it might imply for the future dynamics. The model has clear parallels with compartmental models of the spread of an infectious disease in epidemiology. Like the infection analogy, the population divides into three groups: ‘susceptible’ individuals who are vulnerable but not yet infected; ‘infected’ individuals; and those who are ‘immune’. Also like infection, transmission – especially to those with ‘fear of missing out’ – is by word-of-mouth, via blogs, news reports and personal anecdotes.

The model assumes a theoretical asset with an unknown long-term fundamental value held by a small, initial share of the population (the ‘infected’). The rest of the population is divided into those who are ‘susceptible’ to speculation in the new asset and those who are ‘immune’. Even with an assumed fundamental value, it is possible for frothy price behaviour to develop. Moreover, the asset’s bubble can exhibit multiple peaks and reach surprising heights. However, once full adoption is approached, the price decline is sustained and rapid.

The characteristics of our theoretical model are as follows:

- The crypto currency is assumed by all agents to have a long-term fundamental value, but the value is unknown, as is the time until it is reached.
- Initially, only 0.1% of the population holds the asset and is the source of supply. Their willingness to supply (sell) the asset is positively related to past selling (persistence), inversely related to expected future prices (speculative inventory behaviour) and subject to randomly generated shocks.

- New entrants (buyers) are not existing holders and are drawn from the portion of the total population that is susceptible to the ‘fear of missing out’ speculation. We assume this is 25% based on survey evidence.²⁵ Their decision to buy the asset is a positive function of previous buyers (persistence), expected future prices (speculation), and randomly generated shocks.
- Some portion of the population is immune and will never buy the asset.
- Expected future prices of both holders and new buyers are a weighted average of the extrapolated exponential trend in recent prices and the most recent price. The weight on the former decreases with time and the weight on the latter increases as it is assumed that prices get closer to the long-term fundamental value as time passes.
- Prices are a function of the ratio of new entrants (buyers) to exits (sellers).

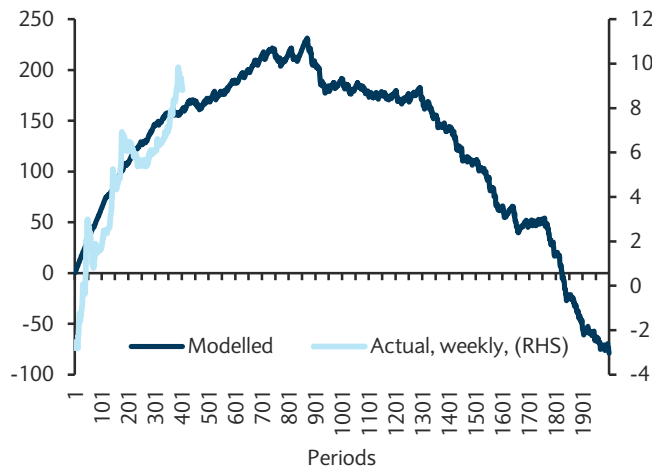
Prices rise rapidly with expectations as new entrants – or ‘infected victims’ – join, but eventually plateau as awareness – or immunity – expands through the population

Figure 4 plots the simulated results of the model (dark line) versus the actual price history of Bitcoin, both in logarithms. While actual Bitcoin prices have been more volatile, a similar pattern is apparent. As new entrants buy the stimulated asset, its price rises, inducing expectations of further price rises that cause more new entrants and reluctance of existing holders to sell. Word of mouth spreads and creates more new entrants (or ‘infections’). As more of the population become asset holders, the share of the population available to become new buyers – the potential ‘host’ population – falls, while the share of the population that are potential sellers (‘recoveries’) increases. Eventually, this leads to a plateauing of prices, and progressively, as random shocks to the larger supply population push up the ratio of sellers to buyers (Figure 5), prices begin to fall. That induces speculative selling pressure as price declines are projected forward exponentially. Analogously, this occurs with infectious diseases when the immunity threshold is reached; ie, the point at which a sufficient portion of the population becomes immune such that there are no more secondary infections.

The height of the bubble is randomly generated by shocks, but its peak is driven by the exhaustion of new buyers

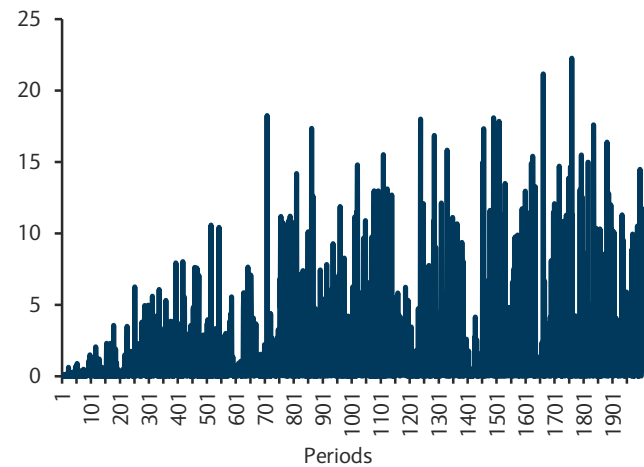
The modelling exercise suggests that even if crypto currencies do have fundamental value, they are subject to extreme bubble formation as the population adjusts to their introduction. The height of bubble prices is driven by the pattern of random shocks to entrants and exits, but the conditions that lead to its peak and subsequent decline are clearly apparent: the exhaustion of new buyers.

FIGURE 4
Simulated vs actual Bitcoin prices, log scale



Source: Bloomberg, Barclays Research

FIGURE 5
Ratio of sellers to buyers through time



Source: Barclays Research

²⁵ See survey data in later section; we use the highest estimate of population share that has invested in Bitcoin among various surveys (South Korea), but lower values yield similar results.

Once exits begin to exceed new buyers, prices begin to fall inexorably

Surveys of Bitcoin awareness suggest that a peak is near: as much as 90% of developed economy residents now are familiar with it, and holding rates are half to a third of peak levels, indicating increasing 'immunity'

Unlike past peaks in Bitcoin prices, the survey evidence, based on our modelling, suggests that the speculative bubble in crypto currencies may have passed its peak

Applying this model to speculative behaviour in crypto currencies, it suggests that once a large enough share of the population susceptible to speculation becomes aware of and holders of crypto currencies, upward pressure on prices stalls. To the extent that holders' attraction to Bitcoin was speculative – as our empirical analysis of historical prices suggests – those holders then become sellers, initiating an accelerating downward spiral. The crucial variables determining when the turn from rising to falling prices occurs, according to our modelling, are the share of the population that are aware of Bitcoin and the share that are willing to invest (or susceptible to 'infection').

Is speculation near its end?

What survey evidence we have suggests that this process may be at or near its end, as awareness is nearly universal in developed economies and the share of the population susceptible to speculative investment in most developed economies appears small. A late 2017 survey conducted in South Korea, one of the top centres of Bitcoin trading, found that 90% of Koreans were aware of Bitcoin, and, while 26% had purchased Bitcoin at some point, only 8% were then holders.²⁶ A November 2017 survey of 10,000 Japanese showed 88% awareness of Bitcoin, but only 4.7% had ever held Bitcoin and only 2.7% were current holders.²⁷ A late 2016 survey by the Bank of Canada marked Canadians' awareness of Bitcoin at 64%, but ownership at just 2.9%; while a smaller November 2017 survey of Americans placed awareness at 75% and ownership or willingness to own at 10%.²⁸ Yet these awareness rates likely are out of date; more up-to-date surveys from the UK illustrate that Bitcoin's December 2017 price spike caused a surge in awareness. A D-CYFOR survey in November 2017 found that 80% of UK residents were aware of Bitcoin, but by January 2018, a survey by the same firm pegged awareness at 91%.²⁹

Past peaks in Bitcoin in 2011, early 2013 and late 2013 were followed by collapses in price of 93%, 70% and 86%, respectively, before recovering and advancing to new highs. But in each of those cases, awareness was relatively low and the potential for new entrants consequently was high. The above survey evidence suggests this is no longer the case: 1) most potential 'hosts' (Bitcoin investors) in developed economies already are aware of Bitcoin (have been exposed to the 'virus'); 2) only a small share of developed populations are susceptible to speculation ('infection'); and 3) the falling ratio of current to prior holders suggests a rising 'recovered' share of the population. As a result, we believe the speculative froth phase of crypto currency investment – and perhaps peak prices – may have passed.

²⁶ See 'Surveys Show South Korea Ahead of Japan and US in Bitcoin Awareness,' Kevin Helms, *Bitcoin.com*, 7 December 2017.

²⁷ See 'Survey Says 88% of Japanese Have Heard of Bitcoin', Kevin Helms, *Bitcoin.com*, 19 November 2017.

²⁸ See 'Bitcoin Awareness and Usage in Canada,' Christopher S. Henry & Kim P. Huynh & Gradon Nicholls, *Staff Working Papers* 17-56, Bank of Canada, November 12, 2017; and Ditto Cryptocurrency Public Knowledge Report November 2017

²⁹ See 'Nearly a third of people think bitcoin will collapse in the next six months,' Courtney Goldsmith, City A.M., 14 November 2017; and 'More than half of people say bitcoin will drop or collapse in six months,' Courtney Goldsmith, City A.M., 26 January 2018.

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