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Abstract: This paper analyses the effects of economic policy uncertainty (hereafter, EPU) on the relationship between Bitcoin and traditional financial markets during the period 27/04/2015 to 25/10/2018, represented by five stock market indices namely the NASDAQ100, S&P500, Euronext100, FTSE100 and NIKKEI225. EPU is measured in terms of economic policy, monetary policy, financial regulation, taxation policy, and the news-based policy uncertainty index for the U.S., U.K., Europe and Japan. By applying a variety of statistical techniques (multivariate EWMA models, Spearman's rho, the Diebold & Yilmaz (2012) spill-over index, GAS models with conditional multivariate Student–t distribution and time–varying scales and correlations, BVAR models with the Litterman/ Minnesota priors and nonlinear impulse responses with local projections accounting for different regimes in uncertainty) we estimate interdependence between traditional financial and Bitcoin markets and their reaction to the selected policy shocks. Our findings indicate the investment attractiveness of bitcoin as a hedging tool against shocks in uncertainty in the USA economic policy.

The results are significant and potentially useful to researchers, practitioners, and Bitcoin market participants to better understand the nature of Bitcoin and facilitate better portfolio and risk-management decisions.

Key words: Bitcoin, financial market, interdependence, policy uncertainty, dynamic copula, BVAR.

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1. Introduction

There appears to be a significant surge in uncertainty following major economic and political shocks. The substantial negative impact of economic policy uncertainty (hereafter, EPU) on macro-economic conditions is well documented. For instance, Baker et al. (2016), Caldara et al. (2016), and Henzel & Rengel (2017) among others document that an increase in economic uncertainty negatively impacts aggregate investment, industrial production and employment rate. Junttila & Vataja (2018) demonstrate the importance of accounting for EPU in any forecasting of real economic activity.

In terms of impact on financial markets, Baker et al. (2016) show that EPU causes an increase in stock-market turbulence, while Chiang (2019) documents that stock returns are negatively correlated with EPU innovation. Antonakakis et al. (2013), Arouri et al. (2016), Kang & Ratti (2014) demonstrate that EPU causes a decrease in stock prices. Similarly, Gozgor et al (2016), Joets et al. (2016), Van Robays (2016) and Bakas & Triantafyllou (2018) investigate the impact of uncertainty shocks on commodity markets. Bilgin et al. (2018) document that rising EPU contributes to increases in the prices of gold.

Recently, crypto-currency markets and volatility therein has attracted significant attention from researchers and policy-makers alike. There exists substantial literature that examines the relationship between traditional financial markets and the rather contemporary Bitcoin markets. For instance, Corbet et al. (2018a) analyse the inter-dependence between crypto prices with other financial assets such as gold, bonds and stocks and find that crypto-currencies are rather independent of movements in prices of traditional financial assets, giving them a 'diversification' quality. In a similar spirit, Corbet et al. (2018b) document the relative isolation of cryptocurrencies from other financial and economic assets. Matkovskyy (2019) shows that drops in Bitcoin markets cause an increase in their volatility.

A recent event that is widely believed to have an impact on the interdependence between Bitcoin and traditional markets is the launch of the Bitcoin futures in December 2017. Studies in this area find that the launch of futures not only caused an increase in Bitcoin market efficiency, but also increased contagion effects from financial to Bitcoin markets, both in terms of correlation and co-skewness of market returns (Matkovskyy & Jalan, 2019). This might indicate higher integration of Bitcoin markets into traditional financial systems. (Köchling et al. 2018).

The interest in investigating the impact of EPU on Bitcoin markets is fairly recent. Bouri et al. (2016) using the US VIX, and a GARCH-based framework, find that Bitcoin volatility is negatively related to U.S. economic policy uncertainty. Bouri et al. (2017) examine the relationship between uncertainty, measured as the first principal component of the VIXs of 14 developed and developing equity markets and Bitcoin, and find that Bitcoin does act as a hedge against uncertainty. Demir et al. (2018) demonstrate that the EPU has predictive power on Bitcoin returns and that Bitcoin acts as a potential hedging tool against economic uncertainty. Panagiotidis et al. (2018) show that the EPU indexes in China, the European Union, and the USA negatively affects Bitcoin returns. Wu et al. (2019) document that Bitcoin is more responsive to EPU shocks than gold. Gozgor et al. (2019) show that trade policy uncertainty significantly and negatively affects the Bitcoin returns during 2010–11 and 2017–18.

Even when the impact of EPU has been documented with reference to both traditional financial markets and Bitcoin markets individually, there is no paper till date that investigates its impact on the interdependence of these markets. We believe that this link poses an important research question, primarily for two reasons: (1) Increased inter-dependence between traditional and crypto-currency markets post-launch of Bitcoin futures, and (2) To facilitate better understanding of the role and nature of the Bitcoin in the larger investment landscape.

We bridge this gap by investigating the impact of economic policy uncertainty on the relationship between cryptocurrency and traditional financial markets, using five stock market indices namely the NASDAQ100, S&P500, Euronext100, FTSE100 and NIKKEI225. Interdependence is analysed along two dimensions - return and volatility. EPU is measured in terms of economic policy, monetary policy, financial regulation, taxation policy, and the news-based policy uncertainty index for the U.S., U.K., Europe and Japan.

To address this question, we apply a variety of statistical techniques to estimate the interdependence between financial and Bitcoin markets and how this relationship is affected by economic policy shocks. As the first step, we use multivariate EWMA models for the covariance matrix to study the volatility of returns across selected markets. The dynamics of volatility correlation between Bitcoin and traditional financial markets is derived by means of Spearman's rho. Volatility spill-overs between two types of the markets are measured using the Diebold & Yilmaz (2012) spill-over index.

The evolution of return interdependence between Bitcoin and traditional markets is derived by means of time-varying parameter copula models, i.e., GAS models with conditional multivariate Student–t distribution and time–varying scales and correlations (Creal et al. 2011, 2013). The interdependence measures obtained are further used in Bayesian Vector Autoregression (BVAR) models with the Litterman/ Minnesota priors and local projection to quantify the responses of the Bitcoin and traditional financial markets as well their interdependence, to different economic policy shocks.

The data set covers the daily close prices of the Bitcoin in Euro, US Dollar, Great Britain Pound, and the Japanese Yen in centralized Bitcoin markets of GDAX, Bitmap and

BTCBOX and closing prices of the traditional financial market indices, namely the NASDAQ100, S&P500, Euronext100, FTSE100 and Nikkei225, over the period 27/04/2015 to 25/10/2018.

The monthly economic policy uncertainty data comes from Baker et al. (2016) and www.policyuncertainty.com. These sources present uncertainty data in terms of the economic policies of EU, the UK and the U.S. They further decompose EPU into monetary policy, taxes and financial regulation. Data for EPU in Japan comes from Arbatli et al. (2017).

Our study makes the following contributions to literature. We examine the relationship between Bitcoin and traditional financial markets both in terms of volatility and returns, in the context of economic policy uncertainty. Our results indicate that volatility-correlation between Bitcoin and traditional financial markets is higher than interdependence in terms of returns. Also, this volatility-correlation does not remain stable over time and actually increased post-launch of Bitcoin futures. The Diebold-Yilmaz (2012) spill over index shows increased interconnectedness of the Bitcoin and financial markets after the launch of Bitcoin futures. This is consistent with and extends the findings of Matkovskyy & Jalan (2019).

Our impulse response function results support the findings of Corbet et al. (2017) who document volatility spillovers from US monetary policy announcements to cryptocurrencies with the exception of some small-cap cryptocurrencies. Our results, however, are in contrast with Vidal-Tomás and Ibañez (2018) who find that Bitcoin returns are not affected by monetary policy news. Our results also highlight the asymmetric effects of economic uncertainty shocks in the selected markets, which is in line with Bilgin et al. (2018).

We find evidence that interdependence between traditional financial markets and Bitcoin decreases due to economic uncertainty shocks. Our results clearly indicate a significant relationship between EPU and volatility in Bitcoin markets. Specifically, we find that uncertainty shocks in USA economic policies are associated with a decrease in volatility in the analysed Bitcoin markets. Also, an increase in Japanese economic uncertainty causes a reduction in volatility of the JPY Bitcoin market.

While Koutmos (2018) and Katsiampa et al. (2019) document that volatility can be transmitted from Bitcoin to other cryptocurrencies, the direct implication of our results is that economic policy shocks can affect other cryptocurrencies through the Bitcoin market as their medium.

In general, Bitcoin is a potential hedging tool against uncertainty in the USA economic policy.

The remainder of this paper is organized as follows. Section 2 describes the data and methodology. Section 3 presents the empirical evidence and provides economic interpretations. Section 4 concludes the findings. Appendix contains supplementary graphs and tables.

2. Data and Methodology

The data set covers the daily close prices of the Bitcoin in Euro, U.S. Dollar, Great Britain Pound, and the Japanese Yen in centralized Bitcoin markets of GDAX, Bitmap and BTCBOX and closing prices of the 'traditional' financial market indices, namely the NASDAQ, S&P500, Euronext100, FTSE100 and Nikkei225 over the period 27/04/2015 to 25/10/2018. Daily percentage returns are computed as the difference of the natural logarithms of the daily price indices, multiplied by 100.

The monthly economic policy uncertainty data comes from Baker et al. (2016) and www.policyuncertainty.com. These sources present uncertainty data in terms of the economic policies of EU and the U.S. They further decompose EPU into that resulting from monetary policy, trade policy and financial regulation. Data for EPU in Japan comes from Arbatli et al. (2017).

We build multivariate EWMA models for the covariance matrix to demonstrate the volatility of returns across different markets. Among the many desirable properties EWMA has over traditional GARCH modelling is the greater weight it assigns to more recent observations. The EWMA model was first proposed in Riskmetrics (1996), where variances and covariances are as in the IGARCH-type models.

In general, this model is of the form $\hat{\Sigma}_t = \lambda\hat{\Sigma}_{t-1} + (1-\lambda)\hat{a}_{t-1}\hat{a}'_{t-1}$, where $\hat{a}_t$ are residual from fitted ARMA-GARCH models, and λ ($0<\lambda<1$) is the persistence parameter, which is estimated to be 0.97 for daily observations (0.96 according to Riskmetrics, 1996).

Because correlation is not linear and variance is not constant, Spearman's rho is applied to test the stability of correlation over time between selected market-pairs.

Diebold & Yilmaz (2012) spillover index is based on a generalized vector autoregressive framework where forecast-error variance decompositions are invariant to the variable ordering. This index captures the contribution of the other variables to the FEVD of the self-variable and is computed as the contribution of the diagonal elements of the FEVD to the total sum of the matrix.

The evolution of interdependence between the Bitcoin and traditional markets is derived by means of time-varying parameter copula models, i.e., GAS models with conditional multivariate Student–t distribution and time–varying scales and correlations (Creal et al. 2011, 2013; Harvey 2013). We believe that these models are best suited to the purpose at hand for the following reasons. *First,* they allow for time-varying parameters in copulas. *Second,* they exploit the complete density structure of the data, rather than merely means and higher moments.

In a GAS model, parameters are updated over time by applying the scaled score of the likelihood function. In general, the evolution in the time-varying parameter vector θ_t can be presented as follows (see Creal et al. 2011 and Creal et al. 2013 for technical details):

$$\theta_{t+1} = \kappa + As_t + B\theta_t, \qquad (1)$$

where κ, A and B are matrices that contains coefficients (κ and A control for the level and the persistence of the mean reverting process for θ_t), s_t is a vector proportional to the score of $y_t|y_{1:t-1} \sim p(y_t;\theta_t)$, where $y_{1:t-1} \equiv (y_1', \dots, y_{t-1}')$ and $\theta_t \in \Theta \subseteq \Re^J$ and is defined as

$$s_t \equiv S_t(\theta_t)\nabla_t(y_t, \theta_t), \qquad (2)$$

where S_t is a $J \times J$ positive defined scaling matrix known at time *t*, $\nabla_t(y_t, \theta_t)$ is the score of $y_t|y_{1:t-1} \sim p(y_t;\theta_t)$ estimated in the following manner:

$$\nabla_t(y_t, \theta_t) \equiv \frac{\partial \log p(y_t, \theta_t)}{\partial \theta_t}. \qquad (3)$$

Therefore, the updated equation for θ_t is defined by:

$$\theta_t \equiv \Lambda(\tilde{\theta}_t) \qquad (4)$$

$$\tilde{\theta}_t \equiv \kappa + A\tilde{s}_t + B\tilde{\theta}_{t-1}, \qquad (5)$$

where $\tilde{s}_t \equiv \tilde{S}_t(\tilde{\theta}_t)\tilde{\nabla}_t(y_t, \tilde{\theta}_t)$. Jacobian matrix estimated at $\tilde{\theta}_t$ is $\mathcal{J}(\tilde{\theta}_t) \equiv \frac{\partial \Lambda(\tilde{\theta}_t)}{\partial \tilde{\theta}_t}$.

Matrices κ, A and B are gathered into ξ, which is estimated by means of maximum likelihood (ML) approach:

$$\tilde{\xi} \equiv \arg\max_{\xi} \mathcal{L}(\xi; y_{1:T}), \qquad (6)$$

where $\mathcal{L}(\xi; y_{1:T}) \equiv \log p(y_1;\theta_1) + \sum_{t=2}^{T} \log p(y_t;\theta_t)$, $\theta_1 \equiv (I-B)^{-1}\kappa$, and $\theta_t \equiv \theta(y_{1:t-1}, \xi)$.

The interdependence values so obtained are further used in the Bayesian Vector Autoregression (BVAR) model to quantify the responses of interdependence between the Bitcoin and traditional financial markets to economic and policy shocks. A BVAR model with the Litterman/Minnesota priors is used to deal with over-parameterization of VAR models (Litterman, 1986; Doan, Litterman, and Sims, 1984; Sims and Zha, 1998). Based on these models, generalized impulse response functions, IRFs, are derived.

We also compute nonlinear impulse responses with local projections by Jordà (2005). Reactions of Bitcoin markets to shocks are analysed in two different regimes, i.e., a high and low uncertainty in policy. The two regimes - high uncertainty (regime 1) and low uncertainty (regime 0) are identified by a smooth transition function as in Auerbach and Gorodnichenko (2012). Reaction is calculated to standard deviation shock. Finally, the time series is decomposed via the Hodrick-Prescott filter (Auerbach & Gorodnichenko, 2013). Nonlinear impulse responses are computed following Ahmed and Cassou (2016).

3. Empirical results

3.1. Correlations between Bitcoin and traditional financial markets

For estimation we use the dataset of the closing prices of Bitcoin denominated in four currencies - Euro, U.S. Dollar, Great Britain Pound, and the Japanese Yen and closing prices of mainstream financial markets, represented by five equity market indices namely the NASDAQ, S&P500, Euronext100, FTSE100 and Nikkei225. Based on this dataset, we estimate two types of correlation among the selected bitcoin and traditional financial markets.

Correlations in volatility are derived from multivariate EWMA models for the covariance matrix. The dynamics of volatility-correlation between Bitcoin and traditional financial markets is derived by means of Spearman's rho. Interdependence in terms of returns is estimated by means of a Student-t GAS model with time-varying conditional mean and scale parameters (estimated by maximum likelihood). The Diebold & Yilmaz (2012) spillover index is calculated as a ratio of weighted volatilities/covariances based on the transition covariance matrix to show volatility spillovers between traditional financial and Bitcoin markets.

Graphs A1 in Appendix 1 indicate that Bitcoin markets demonstrate higher volatility, notably towards the end of 2017 and beginning of 2018. We attribute this heightened volatility to the launch of Bitcoin futures which allowed investors to short-sell Bitcoin (Matkovskyy & Jalan, 2019). It is also in line with Corbet et al. (2018c) who document increased spot volatility following the appearance of futures contracts. For the traditional financial markets, we observe some clusters of volatility in the beginning of 2018 for the U.S. (NASDAQ 100 and S&P500), and between 2016 and 2017 for the Euronext100, FTSE100 and NIKKEI225.

Volatility correlation over time between Bitcoin and traditional financial markets is presented in Fig. A2-A5 in Appendix 2. Overall, one notices that volatility correlation does not remain stable over time for the selected markets. Analysing with respect to the timing of launch of Bitcoin futures, one finds that volatility correlation increased post-launch of futures.

The Diebold-Yilmaz (2012) spillover index measures the contribution of spillovers of volatility shocks across the selected markets to the total forecast error variance. The estimates reflect an increase in interconnectedness of Bitcoin and financial markets after the launch of Bitcoin futures, especially for the Bitcoin markets and NASDAQ100 and Nikkei225. It is in line with the findings of Matkovskyy & Jalan (2019) who document that the contagion effect increased after the launch of Bitcoin futures and during bearish times (see Tables A1-A2 in Appendix). Interestingly, the spillover effect between FTSE100 and GBP Bitcoin market did not increase, implying that these markets are rather isolated from the rest.

Interdependence between Bitcoin and traditional financial markets in terms of returns is less significant (see Fig. A6-A10). In general, it is summarised in Table A3 in Appendix. The estimates show that Bitcoin USD and GBP markets have negative correlation with the NASDAQ and Nikkei markets that gives them a rather 'diversification' quality, while the Bitcoin JPY market is positively correlated with traditional financial markets.

3.2. Effects of economic policy uncertainty shocks on volatility and correlation

The calculated interdependence measurements (volatility and interdependence in returns) are used in the Bayesian Vector Autoregressions (BVAR) models with the Litterman/Minnesota priors to quantify the responses of the Bitcoin and traditional financial markets as well their interdependence to different economic policy shocks.

We calculated generalized IRFs and accumulative generalized IRFs to avoid issues with variable ordering. Table A4 in Appendix summarizes the effects of shocks in economic policy on the selected markets.

We *a priori* expected that shocks in policies mainly cause an increase in volatility of the respective market to which they relate. Even when we find this to be true for the traditional financial markets, Bitcoin markets reveal a rather different trend. We find that shocks in the USA economic policy that lead to an increase in uncertainty cause a decrease in volatility in Bitcoin markets. US news-based policy uncertainty index confirms this correlation. Also, an increase in Japanese economic uncertainty causes a reduction in volatility of the JPY Bitcoin market.

These results point out to the 'hedging' quality of Bitcoin markets, making them rather insulated from the negative effects of policy uncertainty.

There exists substantial literature on the effects of monetary policy on stock prices. For example, Lobo (2000) shows that monetary policy rates negatively affect stock prices and hence stock returns. Jensen & Johnson (1995) show that stock returns following discount rate decreases are higher and less volatile than returns following rate increases. Koutmos (1999) documents that stock prices incorporate bad news faster than good news. For Bitcoin markets we find that monetary policy shocks actually end up increasing volatility. Overall, our results contradict those of Vidal-Tomás and Ibañez (2018) who document that Bitcoin remains unaffected by monetary policy news.

We find that while shocks in the U.S. tax policy increase volatility in Bitcoin markets, they also tend to exacerbate the volatility-interdependence between financial and Bitcoin markets.

Calculations of nonlinear impulse responses with local projections for the high and low uncertainty in policy regimes reveal that in times of high uncertainty volatility increases more in response to shocks in economic policy uncertainty while during low uncertainty in economic policy volatility decreases more to shocks.

We *a priori* expect changes in tax policy to affect the interdependence in volatility between financial and Bitcoin markets. Taxes on capital gains made on sale of investments affect the perceived net return on investment by prospective and current investors. Therefore, a change in tax regime or uncertainty therein is expected to create opportunities for tax arbitrage between traditional and cryptocurrency markets. This opportunity becomes more stark given the fact that unlike traditional financial securities such as stocks, bonds and commodities, both purchase and sale of Bitcoin is rather opaque. The same opacity in transactions makes it easier to avoid/ evade taxes on sale of Bitcoin.

We attribute our results of greater volatility-interdependence between financial and Bitcoin markets following tax uncertainty to the same phenomenon (see Table A5).

Next, we attempt to investigate the impact of economic policy uncertainty on the interdependence of returns in traditional financial and Bitcoin markets in U.S., Europe and Japan. As before, uncertainty is measured along four dimensions – economic policy, monetary policy, financial regulation and tax policy

Interdependence in terms of returns decreases mainly due to shocks in the US economic policies (Table 3). Connectedness of Euronext100, FTSE100, Nikkei225 and Bitcoin markets (especially the GBP Bitcoin market) also decreases due to shocks in European, UK and Japanese economic policy uncertainty. These results are similar to the ones obtained from the Diebold-Yilmaz (2012) spillover index. Therefore, it highlights that these pairs of the markets have hedging characteristics against each other. Shocks to USA taxes cause an increase in interdependence in returns.

4. Conclusion

In this study we analyse the effects of financial regulation and economic, monetary and taxation policies of the U.S., U.K., Europe and Japan, on the relationship between Bitcoin markets, denominated in USD, GBP, Euro and JPY and traditional financial markets. Five stock market indices are chosen for this purpose - NASDAQ100, S&P500, Euronext100, FTSE100 and NIKKEI225 that represent important traditional financial markets in their respective geographies. We apply multivariate EWMA models, Spearman's rho, dynamic copula models (Student-t GAS models with time-varying conditional mean and scale parameters), the Diebold & Yilmaz (2012) spillover index and BVAR models and local projection to estimate interdependence between financial and Bitcoin markets and its reaction to economic policy shocks.

In general, the results extend the findings of Demir et al. (2018), Panagiotidis et al. (2018), Gozgor et al. (2019), Wu et al. (2019) with the analysis of reaction of interdependence of the traditional financial markets and bitcoin markets to policy uncertainty shocks. Results indicate that volatility-correlation between Bitcoin and traditional financial markets is higher than interdependence in terms of returns. Moreover, this volatility-correlation does not remain stable over time and ends up increasing post-launch of Bitcoin futures in December 2017. The Diebold-Yilmaz (2012) spill over index shows increased interconnectedness of the Bitcoin and financial markets after the launch of Bitcoin futures that is consistent with and extends the findings of Matkovskyy & Jalan (2019).

Impulse response function results support Corbet's et al. (2017) study, that shows volatility spillovers from US monetary policy announcements to cryptocurrencies with the exception of some small-cap cryptocurrencies. However, our results are in contrast with Vidal-Tomás and Ibañez (2018) who find that Bitcoin return is not affected by monetary policy news. Our results also show the asymmetric effects of economic uncertainty shocks in the selected markets that is in line with Bilgin et al. (2018).

We also find evidence that interdependence between traditional financial markets and Bitcoin decreases due to economic uncertainty shocks. However, our results clearly indicate a significant relationship between EPU and volatility in Bitcoin markets. Specifically, we find that uncertainty shocks in USA economic policies are associated with a decrease in volatility in the analysed Bitcoin markets. Also, an increase in Japanese economic uncertainty causes a reduction in volatility of the JPY Bitcoin market.

Koutmos (2018) shows that Bitcoin is the dominant contributor of return and volatility spillovers and that interdependencies among cryptocurrencies has risen. Katsiampa et al. (2019) show that find evidence of bi-directional shock transmission effects between Bitcoin and both Ether and Litecoin. Therefore, economic policy shocks through Bitcoin can be transmitted to other cryptocurrencies.

Bitcoin (especially the GBP Bitcoin market) is a potential hedging tool against economic uncertainty in the USA monetary policy, USA taxes, UK and Japan economic policy. We leave the investigation of the main causes of this phenomenon to future research.

We believe that our findings are significant and potentially useful to researchers, practitioners, and Bitcoin market participants, both for understanding the hedging quality of cryptocurrencies and in making better risk-management decisions in terms of portfolio optimization due to the fact that uncertainty is an important factor driving investor behaviour in financial markets.

It would be interesting to extend the findings of this paper by focusing on other cryptocurrencies (e.g., ETH, LTC, etc.) to investigate whether the Bitcoin indeed acts as a medium for transmission of economic policy shocks to other cryptocurrencies. We leave that to future research.

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