CENTRE FOR FINANCIAL REGULATION AND INNOVATION

White Paper

Central Banks and Cryptocurrencies

Daniel Broby[1]* | **Samuel Baker** [2]†

[1]Strathclyde Business School, Glasgow, Scotland

[2]National Bank of Rwanda

Correspondence
Daniel Broby, Department of Accounting and Finance, Stenhouse Wing, 199 Catherderal Street, Glasgow G4 0QU
Email: daniel.broby@strath.ac.uk

Funding information
This research was undertaken as part of a project to develop a digital wallet for the National Bank of Rwanda.

This paper set outs the challenges that Central Banks face from the increasing use of cryptocurrencies as a medium of exchange and money transmission. Traditionally, Central Banks control the money supply. They have not, however, devised a way to control the issuance of cryptocurrencies. Such digital tokens are a cross border phenomena, typically created by the private sector. Their immutable nature and lack of regulatory oversight has seen them increasingly being used to replace fiat money. This is important because Central Banks are responsible for both monitoring the money supply and maintaining their ability to control it. We categorize how Central Banks can react to this phenomenon through moral suasion, interpretation, regulation, licenses and prohibition. We suggest that one way for Central Banks to maintain their oversight of the money in circulation is to develop a cryptocurrency wallet that can hold secure balances centrally. We further suggest that these could be tied to a sovereign issued cryptocurrency.

KEYWORDS
Fintech, Central Bank, Cryptocurrency, Digital wallets, Capital flight, Rwanda.

Abbreviations: ECB - European Central Bank.

* Director, Centre for Financial Regulation and Innovation
† Economist, National Bank of Rwanda

1 | INTRODUCTION

A cryptocurrency is a digital or virtual currency that is stored on the internet. It uses cryptography to avoid the risk of double spending its digital tokens. Programing code is used to create these tokens and establish the process of transmitting their value. In this form, transactions can also take place over the internet. Public cryptocurrencies differ from fiat currency/money in as much as they are not issued by Central Banks. Fabio Panetta, deputy governor of the Bank of Italy, speaking on Central Bank's and digital currencies in June 2018, argued that argued that the European Union can save upto Euro 76 bn by adopting such digital currencies. Bank (2016) investigated this issue and concluded that Central Banks should issue such digital money to 1) augment their ability to understand economies, 2) reduce systemic risks and, 3) facilitate effective transmission of monetary policy. This paper therefore investigates the issues that this creates in respect of oversight and the control of currency issuance.

Public cryptocurrencies use blockchain technology and distributed ledger technology. They are different from digital money as they can be transfered multiple times to different parties, thereby making them a medium of exchange rather than simply payment. These were described by Nakamoto (2008) when Bitcoin was first proposed as a solution for the double spending problem. They allow users to make secure payments and store money without the need to use their name or go to a bank. Usually, electronic representations of money, such as bank deposits, are exchanged via centralized infrastructure, where a trusted intermediary clears and settles transactions. No such centralized infrastructure or intermediaries exist with cryptocurrencies. This requires that central banks have to address this problem if they want to keep control of the money supply.

The role and disruptive nature of cryptocurrencies have been commented on by the US Federal Reserve. It observed that they have the capacity for "faster, more secure and more efficient payment system". The European Central Bank, meanwhile, investigated their impact on monetary policy and price stability. The implication of this use case are clear, namely that such digital currency might replace paper money at some point in time. This has yet to happen but private cryptocurrencies have gained acceptance, trading outside of the remit of a Central Bank. As such, little progress has been made on establishing a central bank offering.

The European Central Bank identified four potential risks associated with cryptocurrencies as relates to Central Banks, namely (1) price stability, (2) financial stability, (3) payment system stability (4) and their current lack of regulation and reputation. Another downside identified by them is that it is currently impossible to track cryptocurrency transfers or purchases. The rise of cryptocurrencies therefore pose challenges to Central Banks, the institutions that manage national currency, sovereign money supply beyond a country's borders and interest rates. In this respect, Schilling and Uhlig (2018) investigated the evolution of Bitcoin prices and the consequence on monetary policy using an endowment economy model. As such, the conclusion of this paper is that their rise also raises challenges for the commercial banks which Central Banks oversee. This is relevant because the latter are at risk of being disintermediated by the new technology related to cryptocurrencies.

In this paper, we investigate how Central Banks might address the challenges and effectively deal with the emergence of cryptocurrencies in an optimal way. Discussions on cryptocurrencies tend to feature debates on Central Bank issued cryptocurrencies as well the technology on which they are based, but this paper will primarily focus on privately issued cryptocurrencies and provide a discussion on how Central Banks can best deal with them. The very way that money is defined is being re-visited. Traditionally, money supply is divided into narrow money (M0 and M1), which includes notes and coins in circulation and cash equivalents and broader money (M2, M3 and M4), which widens the net to include other types of near money deposits.

2 | FEATURES OF CRYPTOCURRENCIES

Cryptocurrencies are often confused with electronic money, which is also digitally created and stored electronically. However, cryptocurrencies are different from e-money and other traditional money. Traditional (fiat) money is denominated in a specific currency issued by a sovereign state and has legal tender status in that jurisdiction. Bolt and Oordt (2016) developed a model to explain the exchange rate of a virtual currency to a fiat currency. Their model demonstrated that the cross rate will likely become less sensitive to the impact of speculative behaviour the more widespread its use. As such, concern that cryptocurrencies are a poor store of value will hopefully abate with time.

Cryptocurrencies are not legal tender and are not linked to any specific currency. Electronic money is usually expressed in the same currency as money of Central Banks or commercial banks and can be exchanged at par value for them or be redeemed in cash. In contrast however, cryptocurrencies are not issued by any central institution, are sovereign controlled and cannot be exchanged at par value for any given currency. In some jurisdictions however, cryptocurrencies may meet conceptual definitions of electronic money, but they do not meet the legal definition of electronic money. For e-money, the value stored and value transferred must be denominated in a sovereign currency however private cryptocurrencies are not tied to any sovereign currency and are usually denominated in own units of value .

A casual assessment of cryptocurrencies may regard them as assets, because of their similarity to commodities such as oil or gold. They have their own value, which is usually determined by demand and supply. Different from commodities however, cryptocurrencies have no intrinsic value, because they draw value from the belief that they might be exchanged for other goods or services, or a certain amount of sovereign currency, at a later point in time. Cryptocurrencies are also not a liability of any institution or any individual and are not supported by a known authority. Their creation is usually determined by a computer protocol and anyone with the skills and access to that protocol can create units of them. Strathclyde University has created its own cryptocurrency for research purposes that has no intrinsic value. In this respect, there is therefore no single entity responsible for the total supply of cryptocurrencies which makes them different from electronic money.

The other distinction of cryptocurrencies is the ability to effect peer-to-peer transfer of value. Cash has a payer to payee exchange that is made in the absence of a trusted intermediary. Transactions in e-money, however, are exchanged in centralized infrastructures that allow third parties, trusted entities that act as intermediaries, to clear and settle transactions. It is however important to note that the peer-to-peer exchange is supported by the distributed ledger technology on which all cryptocurrencies are based and therefore it is not a specific feature of cryptocurrencies. The point, for Central Bank, is that this medium of exchange is different.

Relative to other payment methods, cryptocurrencies based on distributed ledger technology have the prospect of providing lower transaction fees for users. This is specifically attractive in areas (such as trade finance) where lower transaction fees can help in cross border payments. We argue this feature should be embraced by Central Banks as it is Pareto Optimal. Additionally, the facilitation of payments systems within cryptocurrency schemes does not require the use of intermediaries and this might help to substantially reduce processing costs. Another major difference and positive for Central Banks is that the clearing and settlement of transactions in cryptocurrencies is faster and efficient than it is in traditional systems.

Although payment systems are faster and more efficient in cryptocurrency schemes, it is important to note that there are innovations in tradional payments besides digital currencies. These aim at addressing the rising demand for smooth payment processes. A case in point is the Real Time Gross Settlement (RTGS) systems in the wholesale financial markets which allow for faster payment and settlement of large-value payments. Retail payments, systems are also being improved to be faster.

Since cryptocurrencies are not controlled by any single entity or attached to any specific currency, they allow for an open network a global scope. This is important since it does not allow the distinction of users because of location, helping to transfer value among users across different borders. Other cryptocurrencies based on the distributed ledger technology support transactions without prior disclosure of personal details or any any payment credentials that may be sensitive. This however is not a key feature of distributed ledgers.

We suggest that the issue of pseudonymity has to be addressed head on. The use of cryptocurrencies to avoid settlement through banks and disclosure to authorities is motivated by the need to bypass laws and regulation. National regulators have to work with Central Banks in this respect. In this respect, combined with their global reach, digital currency schemes are potentially vulnerable to illicit use. However, there are many legitimate reasons why users may prefer to use anonymous payment methods (e.g. when the payee is not trusted to protect the information disclosed which could arise, for example, in person-to-person online sales where the parties have no previous interaction).

3 | THE CHALLENGES

The growing usage of cryptocurrencies in global markets has attracted the attention of the international media. Bitcoin, the largest cryptocurrency at one point has a cross rate yo the US dollar that meant that its value surpassed that of Gold as an asset . The immutable nature of the blockchain that underpins them is encouraging central bankers to consider the possibility that cryptocurrencies would need to be included in reserves, as clearly they are a store of value. That said, Central Banks need to thin through the implications of anonymity and how far regulators should let that go.

Whilst cryptocurrencies have the potential to facilitate various retail transactions in e-commerce, there are other mediums that compete with them. That said, the lure of person to person payments and cross boarder transactions makes the challenge one that is worthwhile for Central Banks to investigate. They have the promise of making transactions less expensive, faster and more straightforward for users including merchants and consumers. Kahn, Rivadeneyra, and Wong (2018) suggested that for a central bank should issue a digital currency that the tradeoffs between centralized and decentralized payments systems had to be made. These tradeoffs depend on technology, the transmission of monetary policy, any risks to privacy from cyber attacks, and financial stability impact.

The development of cryptocurrencies has largely been led by technology companies in the private sector, challenging banks and operating outside the control of Central Banks. The motivations for these entities to develop cryptocurrencies also vary. They can be grouped into two, commercial and not-for-profit intentions. Where commercial motives are the main driver, the entities may be motivated by profits from cryptocurrencies through issuing units of cryptocurrencies for capital gain using Initial Coin Offerings, the revenue driver being transaction fees from payment intermediation.

Through sale of items or services, some cryptocurrencies are used to generate revenues. However, others have been developed for non-profit motives which may include the possible utility achieved by experimenting with the new innovations for its own sake. Ideological incentives have also been linked to the need create and use different methods to the existing financial infrastructure, or the motivation to facilitate financial inclusion. This in turn has led to a boom in Initial Coin Offerings. In this respect, the increasing interest in crypto-currencies has led a number of opportunists to jump on the bandwagon, thereby tainting their image.

There are now numerous schemes raising money for what they claim will be the next digital currency or cryptocurrency-backed service. The first fundraising iterations sold coins to investors at a fixed price and fixed valuation. More recently, innovative new forms of fundraising have emerged, including what are called hybrid Initial Coin Offerings, reverse Dutch auctions, Vickrey auctions, and proportional refunds. These are unregulated fund raising operations and it is

these that raise concerns. They do not enjoy financial oversight in the same way that securities do. As there are no protections in place, Ponzi schemes and similar could well develop. It is only a matter of time before some "investors" get burned.

4 | IMPLICATIONS OF CRYPTOCURRENCIES FOR CENTRAL BANKS

The main objectives of many central banks around the world are to maintain price stability and ensure a sound financial system. In doing so, central banks therefore have a responsibility of ensuring financial stability, issuing currency, both physical and electronic and maintain a smooth payments system. The evolution of cryptocurrencies that are supported by the distributed ledger technology therefore pose challenges for central banks and other public authorities in their conduct of policy and supervision.

In their second context, as regulators of the financial sector, Central Banks are often tasked with consumer protection. More than often, Central Banks design policies that help cushion consumers from any risks that may arise from the financial system. With cryptocurrencies however, this could be a challenge. In cryptocurrency trading, it is hardly possible to determine the future values or prices of the cryptocurrencies mainly because they are not driven by fundamentals but by speculation.

The value of many cryptocurrencies depend on the perception of users about how much they will be worth tomorrow. Since they are often expressed in their own units of value and are not backed by any known credible entity and are not tied to any sovereign currency are not a liability of any individual or institution, they lack intrinsic value. As such, it is impossible to guarantee consumer protection for people trading in these schemes. Any changes in the expectations of people, on what they perceive the value of cryptocurrencies to be, can create greater volatility and risk of loss in the value of cryptocurrency units than is usually observed in the value of sovereign currencies in foreign exchange markets.

The other risk to consumer protection that cryptocurrencies pose is the risk of fraud. Since cryptocurrencies are supported by the distributed ledger technology, they are mostly anonymous and this could enable fraudsters to operate without any oversight, which could as a result lead to consumer fraud. Cryptocurrencies are also stored in digital wallets, which use cryptography, that need specific codes in order to be granted access to the units of value in the wallet. In instances where the codes are stolen or the wallets are hacked, consumers suffer from heavy losses.

The growth in the use and adoption of cryptocurrencies also poses a challenge to the conduct of monetary policy. This is because any significant increase in the use of cryptocurrencies will affect the demand of existing monetary aggregates which central banks use as tools for conducting monetary policy. Some Central Banks around the world use money supply to control inflation, as such the central bank has power on how much money they can supply into the economy and how much they can remove from the economy, if needed. However, Central Banks have no authority on the supply of cryptocurrencies, and if widely used, they could undermine the effect of monetary policy through this channel. It is for this reason that we recommend Central Banks develop their own digital wallets. This will allow them to oversea the flow of digital assets.

Today, the use of private digital currencies is limited so the systemic risks are low. That said, it is likely that significant growth in the adoption of cryptocurrencies will have an effect on the implementation of monetary policy, which as a result will change demand for bank reserves (for example, will lead to substituting the existing banking system for deposits and payments, towards digital currencies). This in turn will impact the economic and financial interconnection of those who use digital currencies and the consumers of sovereign currency. In case there is any large substitution while the interconnection is left weak, monetary policy will lose the ability to produce intended results and otherwise lose meaning.

Another aspect that need policy attention is that cryptocurrencies can also be used to facilitate illegal activity. For example, Silk Road, a bitcoin-enabled, dark-web marketplace that was closed in 2013, operated as a clearinghouse for, among other things, illicit drugs. Cryptocurrencies have already been used to circumvent exchange and capital controls in some countries such as China and Venezuela . The increasing use of cryptocurrencies could therefore provide a platform for capital flight in countries under political or economic uncertainty. We believe this would exacerbate the challenges of maintaining domestic financial stability.

As cryptocurrencies are increasingly gaining significance, the risks and opportunities they pose has created the need for discussion on how well to regulate them. It is however important to note that these are new developments and existing regulation was not adopted to fit cryptocurrencies. New regulatory approaches should therefore be discussed and developed.

Regulating cryptocurrencies poses some challenges. First, this area is less understood and Central Banks are not well positioned to regulate them since there is lack of knowledge on how to well adopt suitable regulatory frameworks. Second, there is an ongoing debate whether cryptocurrencies should be treated as assets or currencies. Cryptocurrencies requires a different approach to regulation and some argue this in turn would require a different regulatory agency. If treated as currency for example, then Central Banks would be in charge of regulating them, if defined as assets on the other hand, then capital markets regulatory agencies would be in charge. Table 1 below compares the different ways in which currencies are treated by Central Banks.

TABLE 1 Comparison of characteristics of cryptocurrencies, traditional currencies and assets

Feature	Bitcoin	Traditional currency (USD)	Traditional asset (Commodity)
Intrinsic value	None	None	yes
Legal tender	No	Yes	N/A
Used as unit of account	No	Yes	Yes
Monopoly/decentralized	Decentalized	Monopoly	Decentralized
Supply rule	Computer program	Rule-based	Opportunity cost (for mining)
Supply source	**Private**	**Private Permissioned**	**Public**

A challenge for the regulation of cryptocurrencies is that they do not belong to any sovereign entity. Cryptocurrencies are online and borderless, they lack an indefinable issuer or a backing sovereign institution. This therefore pose significant challenges for regulators who attempt designing regulatory frameworks for cryptocurrencies. It is however important to note that although cryptocurrencies lack an indefinable issuer, there are identifiable third parties that could be regulated. Bitcoin exchanges are a case in point and could be easily regulated.

Such systems that lack the often complex layers that exists in traditional banking systems may be helpful in spending up transactions at low costs, they are also convenient since users do not have to endure delays caused by long processes in clearing and settling transactions. On the other hand however, such systems threaten law enforcement because they can harbor and support illegal activity, threaten efforts in compliance with AML/CFT obligations which are applied in traditional methods of payment and intermediation. The fact that cryptocurrencies can be exchanged for real money poses risks of money laundering and terrorist financing.

5 | APPROACHES TO REGULATION

In this section, we discuss the possible regulatory approaches, identified by the Bank of International Settlements, that Central Banks can take towards cryptocurrencies. There is not much literature on this. What exists is either pro banning or pro central bank issuance. In respect of the former, Hendrickson, Hogan, and Luther (2016) investigated whether governments should ban Bitcoin. They endogenized the matching process and showed that banning will be difficult if economic actors prefer bitcoin.

The Bank of International Settlements suggests different sets of approaches to regulating cryptocurrencies. Some of the approaches have been tried but the majority haven't. Clearly, there should be differences in approach between developed and developing countries but the broad tenants are the same. The broad categories include:

- ***Information/moral suasion***: Widely used in calling out cryptocurrencies as fraudulent and dangerous. This type of approach is often used in respect of the first cryptocurrency, Bitcoin. However, the increasing use of cryptocurrencies has demonstrated that such an approach is ineffective.

- ***Interpretation of existing regulations***: Broader regulation has proven ineffective, by the nature of cryptocurrencies and the existing regulatory setting. Cryptocurrencies have characteristics of both currencies and assets. As such, it is therefore difficult for authorities to use existing regulations to regulate cryptocurrencies since, the mandate to regulate currencies lies with the central bank, but the central bank has no mandate to regulate assets. Using these approaches would therefore need that authorities define cryptocurrencies and tie them into one category, so that they fall under one specific regulatory framework. Given the nature and the continued evolution of cryptocurrencies, this is practically difficult.

- ***Regulation of specific entities***: Under this approach, authorities may decide to adopt a set of regulations for entities/intermediaries that enable the interaction between cryptocurrencies and traditional currency or traditional payment instruments. The entities include exchanges, merchant acceptance facilities and digital wallet applications. Since these entities act as intermediaries that link cryptocurrencies to fiat currency, regulating them would ensure that any risks posed by cryptocurrencies are controlled.

- ***Licenses***: Although cryptocurrencies are borderless, third party entities like the Bitcoin exchange are licensed to operate within specific country jurisdictions. As such, targeting these intermediaries is more effective than regulation that specifically targets cryptocurrencies.

- ***Prohibition***: Authorities could also seek to ban the use of cryptocurrencies in their respective jurisdictions. This would mean a ban on any cryptocurrency-based financial activities, as well as cryptocurrency exchanges or acceptance by retailers. Prohibition could be imposed in various ways, including, banning all retail cryptocurrency transactions, ban on cryptocurrency acceptance by retailers, a ban on cryptocurrency-based financial instruments, a ban on cryptocurrency exchangers, and a ban on cryptocurrency transactions between banks.
The Appendix gives some examples of each of these approaches. It is important to note that cryptocurrencies are a financial innovation that bears risks as well as opportunities. The technology on which they are based has the ability to transform financial services for better. Banning cryptocurrencies would therefore be discouraging innovation that may prove to be useful in future. Meanwhile, we suggest risks, like money laundering, can be mitigated by a requirement for entities to conduct record keeping, reporting and implement anti money laundering (AML) approaches. Most countries including Singapore, Sweden and the US have adopted this approach to minimise risks posed by cryptocurrencies. Consumer protection would also be maintained through this approach. Authorities may require all third party entities to establish measures that offer customers payment guarantee and redeem-ability.

Our key recommendation is that Central Banks, particularly in Developing countries where the control of the money supply is more difficult, develop digital wallets through which cryptocurrency transactions can pass. This will

enable a better oversight of money supply and money movements. It will also facilitate greater taxation and exchange control options. In this respect, our view is supported by Chapman et al. (2017) who investigated whether a distributed wholesale payment systems is practical and concluded that centralized systems may be superior.

Despite the opportunities cryptocurrencies possess, some the risks may be greater in some countries than others. Specifically, in developing countries where technology penetration is very low and with many information asymmetries, legalizing cryptocurrencies may be dangerous. As such, we argue that such countries have a more pro-active role in oversight of cryptocurrency movements. Technology itself might have a role to play in regulation of cryptocurrencies. Malinova and Park (2017) suggested, for example, that Blockchain in financial markets provide new ways to manage transparency.

In most developing countries, the increasing use of cryptocurrencies has mainly been a result of speculation. Since cryptocurrencies have recently enjoyed high valuations, individuals are mostly using them to speculate with expectations for high future returns. This is a dangerous situation since it creates vulnerabilities to the financial system. As many people draw out money to invest in cryptocurrencies, traditional banks would likely to lose money (in form of fiat currency). With the volatile nature of cryptocurrencies, any loss in value would lead to a crisis where individuals as well as the financial system lose money. This would also have a negative effect of exchange rates and inflation.

In such countries, the cost of information is very high and less people understand the complexities of cryptocurrencies, which exposes them to a risk of fraud because it would be challenging for them to determine which cryptocurrency schemes are genuine or not. As such, any announcement by authorities to legalize cryptocurrencies would be taken as greenlight for individuals to engage in this speculation.

In countries where the risks are greater than the benefits posed by cryptocurrencies, banning them is often seen as the best way forward. We however argue that control is better, hence the concept of a digital wallet. Where a ban is imposed, we recommend it just be for a limited period of time and subject to periodic change after authorities have reviewed the new developments and considered all other available options. As such, we argue that taking official decisions on cryptocurrencies be conducted in a similar manner Central Banks review interest rates and announce their decisions after every period. Decisions of cryptocurrencies should be reviewed periodically to monitor changes within this area. We suggest this approach because technology is always evolving, and although cryptocurrencies may be a threat to these countries, it may become very useful in future.

6 | CONCLUSION

As more and more people take to the use of cryptocurrencies, and as they gain significance in global markets, they are becoming an issue for policy makers who are concerned about the risks they pose to monetary policy, financial stability and consumer protection. The question of whether Central Banks should issue their own cryptocurrencies is now being investigated. This is largely in the context of response to innovation but other advantages like efficiency and ease of money transfer should also be taken into account.

Cryptocurrencies are also are becoming significant in the world economy. Although they were initially seen as irrelevant or too small to cause concern, changing circumstances demand that authorities introduce ways to ensure that they are regulated and the risks they pose are controlled. They impact the very way money is viewed and is controlled by Central Banks. As such, this paper investigates the regulatory strategy that Central Banks can employ to address their use.

We argue that the best possible approaches are either regulating specific entities such as cryptocurrency exchange, periodic prohibition (subject to change when developments change) and/or the digital wallet. Prohibition would be more

acceptable in developing countries where these trends are only starting to emerge and where the level of technology and access to information is still very low. In developed countries on the other hand, authorities should not impose a burdensome some regulatory framework as this in turn creates the risk of destroying innovation and all the benefits associated with cryptocurrencies.

Despite any approach however, we suggest that Central Banks join the efforts to explore cryptocurrencies further especially the underlying technology-DLT, to ensure that they build the necessary capacity to deal with these growing trends. We suggest that in order to better understand cryptocurrencies and how to best approach them, Central Banks across the world should experiment with their own cryptocurrencies and digital wallets. Indeed, research shows that with central bank digital currencies, monetary policy would still continue to operate more as it does now, by varying central bank's money's price or quantity. There is also evidence that monetary policy transmission with central bank digital currencies may even strengthen for a given change in policy instruments .

In conclusion, we suggested three main areas of focus for Central Banks (1) establishing a protocol to oversee cryptocurrency transactions and balances, and (2) establishing a regulatory regime and (3) designing a central wallet and possible sovereign cryptocurrency

REFERENCES

Bank, FirstRand. (2016). The Advent of Crypto Banking: A New Paradigm for Central and Commercial Banking.

Chapman, James, Rodney Garratt, Scott Hendry, Andrew McCormack, and Wade McMahon. 2017. "Project Jasper: are distributed wholesale payment systems feasible yet?" Financial System.

Hendrickson, Joshua R, Thomas L Hogan, and William J Luther. 2016. "The political economy of bitcoin." Economic Inquiry 54 (2): 925–939.

Kahn, Charles, Francisco Rivadeneyra, and Tsz-Nga Wong. (2018). "E-money and Payments Policy."

Mills, D. (2006). Alternative central bank policies for liquidity provisions in a model of payments. Journal of Monetary Economics, 53:1593-1611.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system.

Schilling, Linda, and Harald Uhlig. (2018). Some Simple Bitcoin Economics. Technical report. National Bureau of Economic Research.

Timmers, P. (1998). Business models for electronic markets. Electronic markets„ 8(2), pp.3-8.

Option Moral suasion based on information:
Actions Instead of interfering directly with the development of cryptocurrencies, Central Banks could use moral suasion towards users and investors in order to highlight the relevant risks.
Examples- Public warnings - Investor/buyer information - Research paper Most countries have issued these types of warnings, research or information notes.

Option Regulation of public proof cryptocurrencies entities:
Actions Central Banks could adopt a set of regulations for entities/intermediaries that enable the interaction between cryptocurrencies and traditional currency or traditional payment instruments such as exchanges, merchant acceptance facilities and digital wallet applications which enable users to store and transact in their units of cryptocurrency - Regulation of digital currency administrators, record-keeping, reporting, AML/TF.
Examples United States. - Regulation of digital currency exchangers record-keeping, reporting, prudential measures, AML/TF. Examples: United States, France, Canada, Singapore, Sweden. - Consumer protection measures, payment guarantee, redeemability etc.

Option Interpretation of existing regulations: Authorities may assess whether existing regulatory arrangements might be applied to cryptocurrencies and intermediaries. - Application of regulation on interpretation of existing framework
Examples Example: United States.

Option Broader regulation money transfer and digital transfer licenses:
Actions Authorities may seek to adopt a broader approach to regulation, such that regulatory obligations that apply to traditional payment methods and intermediaries also apply to cryptocurrency schemes and intermediaries. For example, authorities may choose that AML/CTF requirements apply to cryptocurrency transactions and counterparties, or that the same consumer protection arrangements apply to cryptocurrency transactions as to other payment methods used by consumers.
Examples - Overall regulation - Dedicated regulation, covering all three aspects (consumer protection, prudential/organisational rules for stakeholders, and specific operating rules as payment systems).

Option Prohibition:
Actions Authorities could seek to ban the use of cryptocurrencies in their respective jurisdictions. This would mean a ban on any cryptocurrency-based financial activities, as well as cryptocurrency exchanges or acceptance by retailers.
Examples - Ban (or amount cap) on retail Bitcoin transactions. - Ban on cryptocurrency acceptance by retailers. - Ban on cryptocurrency-based financial instruments. Examples: China, Belgium. - Ban on cryptocurrency exchangers. - Ban on Bitcoin transactions between banks. Examples: China, Mexico.