

# Taxing Cryptocurrencies

*Katherine Baer, Ruud De Mooij, Shafik Hebous, Michael Keen*

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Poschingerstr. 5, 81679 Munich, Germany

Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email [office@cesifo.de](mailto:office@cesifo.de)

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# Taxing Cryptocurrencies

## Abstract

Policymakers are struggling to accommodate cryptocurrencies within tax systems not designed to handle them; this paper reviews the issues that arise. The greatest challenges are for implementation: crypto's quasi-anonymity is an inherent obstacle to third-party reporting. Design problems arise from cryptocurrencies' dual nature as investment assets and means of payment: more straightforward is a compelling case for corrective taxation of carbon-intensive mining. Ownership is highly concentrated at the top, but many crypto investors have only moderate incomes. The capital gains tax revenue at stake worldwide may be in the tens of billions of dollars, but the more profound risks may ultimately be for VAT/sales taxes.

JEL-Codes: E620, H250, H320.

Keywords: cryptocurrency, virtual assets, tax evasion, tax compliance, Bitcoin.

*Katherine Baer*  
*International Monetary Fund IMF*  
*Washington DC / USA*  
*kbaer@imf.org*

*Ruud De Mooij*  
*International Monetary Fund IMF*  
*Washington DC / USA*  
*rdemooij@imf.org*

*Shafik Hebous*  
*International Monetary Fund IMF*  
*Washington DC / USA*  
*shebous@imf.org*

*Michael Keen*  
*Tokyo College, University of Tokyo*  
*Tokyo / Japan*  
*michael.keen@mail.u-tokyo.ac*

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# 1 Introduction

The rise to a contentious prominence of crypto assets has been frenetic, and the pace of innovation involved remains dizzying. From zero in 2008, the market value of crypto assets peaked (so far) at around USD 3 trillion in November 2021 (Figure 1); and from Bitcoin, introduced in 2009, has now sprung several thousand other cryptocurrencies. On some estimates, perhaps 20 percent of the adult population in the US<sup>1</sup> and 10 percent of that in the UK<sup>2</sup> hold or have held some crypto assets. Use elsewhere is perhaps even more marked, including in some emerging and developing economies: the number of global users has been put at more than 400 million. These developments need to be kept in some perspective: that USD 3 trillion, for instance, was only around 3 percent of the global value of equities. But the power of developments in crypto assets to disrupt traditional ways of doing financial business, including the collection of tax—and their potential to do more—has been made clear.

To some, these developments presage a brave new world in which people are liberated from oversight by government and reliance on financial institutions, placing their trust instead in cryptographically-protected distributed ledgers, and transactions costs are ultimately greatly reduced. And, beyond this, crypto is the harbinger of wider innovation in the form of decentralized finance that will extend these benefits throughout the financial system. To others, these developments have made crypto markets a ‘Wild West’<sup>3</sup> in which criminal activities are facilitated and poorly informed investors exposed to massive price swings (the USD 3 trillion has now fallen to less than USD 1 trillion), bankruptcies, scams and frauds (epitomized by the demise of FTX—an exchange platform that also issued its own cryptocurrency—in November 2022). The deepest scam of all, to critics, is that all this is on the basis of assets whose creation creates significant environmental damage and in many cases have no intrinsic value. In response, advocates might point to the emergence of ‘green cryptocurrencies’, note that fiat currency also has no intrinsic value, argue that crypto has shown its potential superiority in speed and ease of transactions in the support provided to Ukraine and assert unknowable benefits from continued innovation.

Regulators face a daunting task in identifying and striking a balance between enabling innovation while securing financial stability and investor protection. For tax authorities, the first-order task is ultimately more mundane, if no easier and no less important: to encompass developments in the use of crypto assets into a well-functioning tax system. Though its importance will differ,

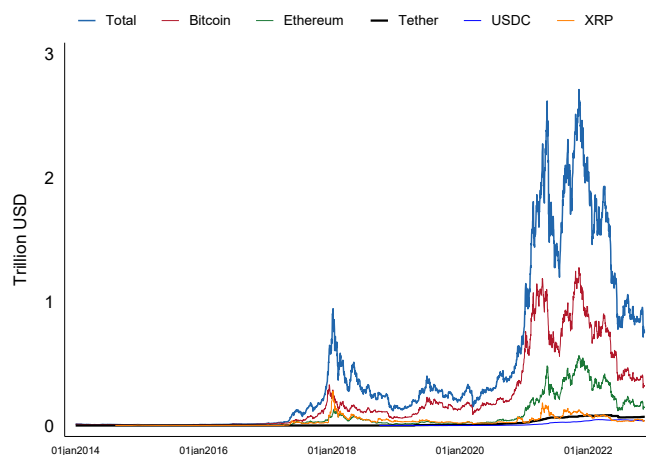
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<sup>1</sup>Figures for the U.S. are from surveys whose disinterestedness and quality are not always clear, and orders of magnitude vary widely: towards the low end, InsiderIntelligence (2022) puts at 13 percent the proportion of crypto holders at end 2022; at the high end, MotleyFool (2022) reports 56 percent as holding or having held crypto May 2022.

<sup>2</sup>HMRC (2022a).

<sup>3</sup>Gary Gensler, chair of the US Securities and Exchange Commission.

**Figure 1:** Market Capitalization of Cryptocurrencies (Aggregate and Selected Currencies)



Note: The chart shows the total market capitalization of all cryptocurrencies and of five selected ones. Data are from Coinmetrics. In 2014, Bitcoin comprised 95 percent of market capitalization of all cryptocurrencies. As of November 2022, Bitcoin (40 percent) and Ethereum (19.5 percent) are the top two cryptocurrencies in terms market capitalization, followed by Tether (7.4 percent). XRP is a cryptocurrency associated with a payment settlement system for financial institutions.

that task will remain whatever the future holds for crypto: whether crypto withers or blossoms, the tax system still needs to deal with it.

This paper aims to provide an overview of the issues that the emergence of and likely developments in crypto assets raise for tax design and implementation, with an eye to the implications for the taxation of the rich that is the focus of this issue. The aim is not to provide policy prescriptions, but to set the scene within which decisions must be made and highlight the issues they will need to address.

The challenge for tax policy and design—beyond that of coming to terms with what remains for many a complex and baffling set of instruments—is simply stated but fundamental: tax systems were not designed for a world in which assets could be traded, and transactions completed, in anything other than national currencies. Incorporating that possibility, however, is more than just a matter of expanding legal definitions (important though in some cases that is). The element of anonymity inherent in crypto assets raises issues of enforcement that have long been associated with the use of cash. Those in turn raises issues for the coherence in the taxation of capital income (viewing crypto assets as a form of property) and—less noted, but perhaps ultimately more significant—in the taxation of final sales under the VAT and similar taxes (viewing them as a form of currency). Questions also arise as to whether taxation might also have some corrective role to play, complementing regulatory interventions.

Among the most prominent tax concerns, however—and the rationale for a contribution on this topic in the present collection—is the presumption, or suspicion, that crypto assets provide a new and important way for the rich, criminal and other, to evade or avoid taxation. Certainly, crypto has made some people very rich, with, for example, 19 “crypto billionaires” making it to the Forbes List of April 2022.<sup>4</sup> Beyond that, while some of the notably rich visibly recoil from crypto,<sup>5</sup> a loosely defined sense that much wealth channeled into crypto escapes proper taxation appears to have become part of the wider mood of dissatisfaction around the taxation of the rich. The concern may have eased since the continuing crypto crash. Auer et al. (2022), for instance, suggest that 75 percent of users have lost money on their Bitcoin investments (which raises its own tax issues around the treatment of losses). How developments in crypto might and should affect the taxation of the rich are among the most important of the challenges they pose—though, as will be seen, to large extent inseparable from still deeper ones.

As well as the challenges there are also real opportunities for tax authorities in the innovations underlying crypto assets. The distributed ledger technology on which they rest, of which blockchain is the most important, is remarkably transparent in the information they contain on the history of transactions, which might ultimately prove valuable for tax administration; and the use of smart contracts (self-executing programs) within blockchains, for example, might in principle help secure chains of VAT compliance and enforce withholding. The focus here, however, is entirely on the tax challenges associated with crypto assets themselves.

In identifying and taking stock of these, there is relatively little analytical work or empirical evidence to draw on. Within the burgeoning literature on crypto, tax aspects have received relatively little attention. There are compendia on the tax treatment of crypto in various countries,<sup>6</sup> with a useful overview in OECD (2020). And while vast amounts of data are in principle available on transactions in cryptocurrencies, empirical analysis around a complex technology whose central purpose is to leave no tracks is inherently difficult. Experience is accumulating, surveys (doubtless of variable quality) are proliferating, and, importantly, harder evidence emerging from blockchain analytics. The reality, nonetheless, is that this is a technically difficult area in which policymakers need to act on severely limited information.

To set the scene, the paper first reviews key elements of crypto technologies (with some details and terminology of the mechanics in an appendix) the ways in which they are traded and used, and by whom. Section 3 takes up crypto-related issues of tax design. Section 4 focuses on the scope for

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<sup>4</sup>Forbes (2022). The richest was FTX founder Sam Bankman-Fried, with an estimated net worth at the time of USD 8.7 billion.

<sup>5</sup>Warren Buffett, most famously, said he would not pay USD 25 for all the Bitcoin in the world (CNBC, 2018).

<sup>6</sup>Such as PwC (2021).

tax evasion that cryptocurrencies offer, and Section 5 turns to the critical issue of tax enforcement. Section 6 concludes.

## 2 Context

This section provides background on the nature and use of the cryptocurrencies that are the main concern of the paper, and on their importance in the taxation of the rich.

### 2.1 The Nature of crypto assets

By ‘crypto asset’ is meant here<sup>7</sup> a “digital representation of value that relies on a cryptographically secured distributed ledger...to validate and secure transactions”. This produces, without any need for a central authority, a presumptively tamper-free record of transactions in that asset. Categorizing assets within this very wide class in terms of their function—key for their characterizations for tax purposes—is made difficult by both continued innovation and the multiple services that particular assets can provide. That said, one key tax-relevant dimension along which they vary is between their use for investment purposes and as a means of payment:

- At one extreme are ‘security tokens’, which are essentially digital representations of conventional financial or other assets. ‘Non-fungible tokens’ (NFTs), for example, are cryptographically protected representations of unique assets, such as works of art.<sup>8</sup>
- At the other are the central bank digital currencies (CBDCs), which are essentially fiat currency in digital form. Many national governments remain highly cautious on their adoption,<sup>9</sup> but— noting in particular the experiment now underway in China—the general expectation appears to be that, in time, the issuance of CBDCs will become widespread.

Conceptually, the appropriate tax treatment of each of these is straightforward. NFTs are naturally treated as investment assets (though issues of implementation much like those discussed below arise). CBDCs would simply be another form of fiat currency, and so naturally treated as that now is. Depending on their design, CBDCs might have other implications for the tax system: they might, for example, enable tracking of transactions in ways useful for tax administration, or even

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<sup>7</sup>Precise definitions and classifications in the crypto area vary. That which follows is from OECD (2022).

<sup>8</sup>Sothebys, one of the largest multinational art brokers, for instance, is reported to have sold USD 100 million of NFTs in 2021 (Bloomberg, 2021).

<sup>9</sup>A few, however, have already issued CBDCs (in the Bahamas and Nigeria, for example), though it seems with only modest impact.

the levying of some form of withholding.<sup>10</sup> That, however, is not the concern here. In what follows we set aside both these categories of cryptoasset.

The focus instead is on crypto assets that potentially serve both an investment and a settlement function, and are privately issued. We refer to these as ‘cryptocurrencies’.<sup>11</sup> They are also (for now at least) by far the most prevalent form of cryptoasset.<sup>12</sup> The essential mechanics of their operation are summarized in an appendix. Prominent examples include:

- *Stablecoins*, which are crypto assets that aim to maintain a stable value relative to some specified asset or pool of assets,<sup>13</sup> generally currency(ies), either through some degree of backing in the underlying asset or by algorithmic methods regulating supply. The most prominent are Tether and USDC, both linked to the US dollar.

The primary purpose of stablecoins is to serve as a means of payment, and they would be naturally treated as such for tax purposes if they were to achieve the intended stability with probability one. In practice, however, holders are exposed to significant valuation risk, epitomized by the collapse of Terra in May 2022.<sup>14</sup>

- Bitcoin, Ethereum, and similar assets that, while their supply may ultimately be limited (as with Bitcoin), have no intrinsic value. These are sometimes referred to as ‘unbacked tokens,’ or simply as ‘non-stablecoins.’ While Bitcoin, introduced in 2009, remains the best known and still has the largest share of the crypto market (Figure 1), there are now several thousand alternatives, taking somewhat different forms: Bitcoin operates by proof of work, for example, while Ethereum now works by proof of stake and can incorporate smart contracts; ‘privacy coins’ offer enhanced anonymity of various kinds; and some cryptocurrencies provide assurances on the greenness of the underlying mining process. Bitcoin is legal tender in (only) El Salvador and the Central African Republic.

It is this intermediate class of assets, and especially non-stable coins, that are the focus here.<sup>15</sup> It is these that raise the most challenging issues of tax design and implementation, combining as they do

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<sup>10</sup>See Sarfo (2022).

<sup>11</sup>Also sometimes referred to as ‘virtual currencies’. In the US, the IRS defines cryptocurrency as “a digital representation of value that functions as a medium of exchange, a unit of account, and/or a store of value.”

<sup>12</sup>Security tokens have a total market capitalization of around USD 19 billion, far less than the trillions in which cryptocurrencies are measured.

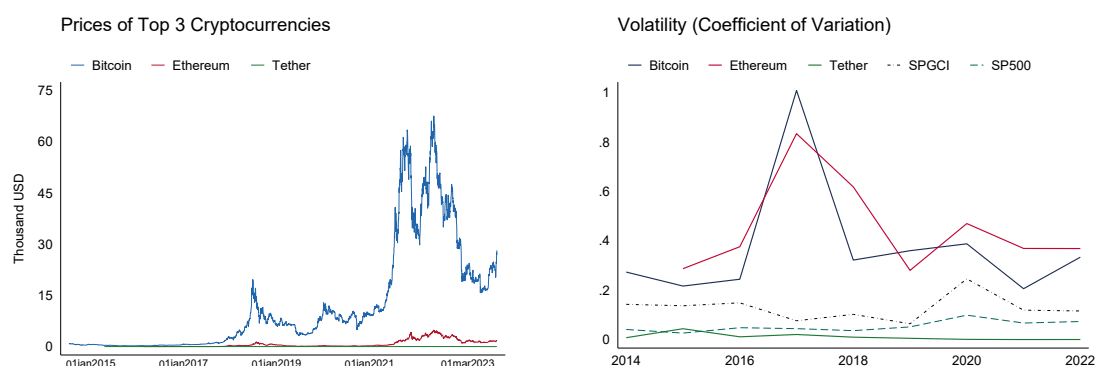
<sup>13</sup>This definition follows IMF (2023).

<sup>14</sup>Only 6 percent of the liabilities of Tether, for example, are backed by cash (IMF, 2023).

<sup>15</sup>A detailed account of tax issues around stablecoins is provided by Waerzeggers et al. (forthcoming). Other forms of crypto assets not considered here include, for example, Initial Coin Offerings, which are crypto assets issued to provide traditional finance, acquired by investors either for resale or to access services of the issuer.



**Figure 2: Prices and Volatility of Cryptocurrencies**



Note: The left panel shows the price of 1 unit of a cryptocurrency per US\$; Tether aims to maintain its value at 1US\$. The right panel shows the coefficient of variation of the three series of prices and, for reference, of the S&P GSCI (a composite index of commodity sector returns) and the S&P500 (stock market index). Underlying data are from Data are from Coinmetrics, S&P, and FRED.

elements of currency and investment asset.<sup>16</sup> They have been marked too by extensive/notorious price volatility (Figure 2), which creates its own complications in considering their proper tax treatment. The figure also shows that price variability is by no means zero for stablecoins.

The central feature of cryptocurrencies is that, like cash, their use or ownership does not intrinsically reveal the personal or business identity of those involved in a transaction. Holders exercise control through a private ‘key’ (or address), held in a ‘wallet,’ but transactions reveal (at most) only a public address from which it is encrypted, and from which it cannot be inferred. Private addresses are not, in case, inherently linked to identifiable beneficial owners; and a single user may have (very) many addresses. In this sense cryptocurrencies are generally ‘quasi-anonymous’. (As something of an outlier, Monero, which appears to be the leading privacy coin, is fully anonymous in that it conceals even the public addresses of those involved in a transaction). Indeed the creation of difficulty in identifying beneficial owners is one of the primary motivations for the development of crypto assets. It poses obvious problems for tax enforcement, as well as—perhaps more important, in the broader scheme of things—for countering crime, money laundering and the financing of terrorism.

A second important feature of cryptocurrencies is that, unlike cash, they are remarkably transparent in the sense that these and other details of all transactions on a particular coin are publicly available.<sup>17</sup> This has enabled the development of sophisticated techniques of cryptoanalytics to

<sup>16</sup>We do not examine the tax issues—or the considerable fiscal risks, emphasized by IMF (2023), that arise if cryptocurrency accepted as legal tender.

<sup>17</sup>See for instance <https://www.blockchain.com/explorer>

analyse patterns of activity and links between participants.

While it appears effectively impossible to recover private addresses from information provided in crypto transactions, the general view seems to be that with sufficient effort IP addresses can often be traced. Again, however, this conveys only limited clues on beneficial ownership, and can be concealed by use of VPN. Seizures are nonetheless made. In June 2022, for example, the US Department of Justice seized USD 2.3 million of Bitcoins that it assessed to have been paid in a ransomware attack, presumably—though, unsurprisingly, the FBI chose to leave this unclear—obtaining the private key by traditional investigative methods.<sup>18</sup> What several papers do show can be done with some confidence, as will be seen, is to cluster public addresses by the likely nature of their holders: to identify those likely held by exchanges for example, or those likely held by miners, those involved in ransomware attacks, or those likely having close connection with the darknet.

A third feature of cryptocurrencies that amplifies the difficulties posed by anonymity is their extra-territoriality: transactions reveal no information on the jurisdictional location of those transacting. The ease with which cryptocurrencies can be transacted across national borders immediately casts the tax issue as in part one of international cooperation and coordination, with an evident incentive to locate associated activities where tax (and/or regulatory burdens) are light: FTX, for example, was headquartered in the Bahamas.

## 2.2 Trading in and Using Cryptocurrencies

There are broadly three ways in which cryptocurrencies may be traded. One is directly peer-to-peer, without the involvement of any third party. The second is through decentralized exchanges,<sup>19</sup> whose purpose is to facilitate such peer-to-peer trades, with customers retaining custody of their private keys. The third is through centralized exchanges,<sup>20</sup> which generally hold their customers' private keys and make transactions on their behalf, charging a commission or fee for doing so. (In this case, as with FTX, the exchange may act much like a bank in trading the crypto it holds, making it potentially vulnerable to a run). Transactions in centralized exchanges may be “off the chain” in the sense that they are not recorded within the blockchain, the purpose being to avoid potentially sizable transactions costs<sup>21</sup> (by for instance, swapping private keys instead).

Cryptocurrencies are not yet widely used to purchase goods and services. Press reports suggest

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<sup>18</sup>Department of Justice (2022b) simply states that: “by reviewing the Bitcoin public ledger, law enforcement was able to track multiple transfers of Bitcoin [representing]...the proceeds of the victim’s ransom payment, [that] had been transferred to a specific address, for which the FBI has the private key.” Other seizures, to 2017, are listed in the Annex A of Foley et al. (2019).

<sup>19</sup>Such as Uniswap (v3) and dYdX.

<sup>20</sup>Such as Binance and Coinbase.

<sup>21</sup>For example, Bitcoin fees averaged USD 2.72 per transaction over the past three years; at a median value of Bitcoin transactions of USD 93.61, this implies a transaction fee of almost 3 percent. At times, the fee has reached USD 60.

that around 15,000 firms globally (400 of them in California) accept Bitcoin and in some cases other cryptocurrencies, including a few household names (such as Overstock.com, Sothebys, Whole Foods and Microsoft).<sup>22</sup> Information on the extent of actual usage is hard, though it clearly does happen: the crypto analytics firm Chainalysis (undated) reports puts such spending at around USD 15 million per day in early 2021, tiny relative to a daily total of retail sales in the U.S. of around USD 550 billion;<sup>23</sup> one survey suggests that in 2021 about 2 percent of Americans have used cryptocurrencies to make purchases or money transfers<sup>24</sup> and another, for HMRC (2022a) in the UK, reports about 4 percent of crypto owners as having received crypto for the provision of goods and services.<sup>25</sup> In El Salvador, where businesses have been required to accept Bitcoin since September 2021, only around 20 percent in fact do so, and only around 5 percent of all sales are in this form (Alvarez et al., 2022). Unfamiliarity, high transactions costs and volatility all impede the routine use of crypto to make purchases. Taxation, as will be seen, can also discourage the use of cryptocurrencies as means of payment. Were these obstacles to fall over time, however, the situation could clearly change; starting from a base of zero, even the low figures in El Salvador are not unimpressive.

The use of cryptocurrencies is not only—or even mainly—a matter for advanced economies. In an index of national penetration produced by Chainalysis,<sup>26</sup> the top four are Vietnam, the Philippines, Ukraine and India, and the only high income countries in the top twenty are the US (5<sup>th</sup>) and the UK (17<sup>th</sup>). Of the estimated 420 million users, more than one-third are in India, with the highest population shares in UAE (28 percent), Vietnam (26 percent) and the US (13 percent).<sup>27</sup> The reasons for high take up in emerging and developing countries is not clear. Both Alnasaa et al. (2022) and World Bank (2018) find strong positive correlation between the use of cryptocurrencies and indicators of corruption. Though that is suggestive of potential shadiness, more benign interpretations see the the use of crypto as a way to escape corrupt practices and governments that are untrustworthy in their political and/or economic behavior, and perhaps also as facilitating remittances often important in lower income countries.<sup>28</sup> In absolute terms, however, the US has the largest crypto market (reaching 16.5 percent of global crypto value).<sup>29</sup>

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<sup>22</sup>From [Fundera](#).

<sup>23</sup>Figure for aggregate retail from [Ycharts](#).

<sup>24</sup>See Box 2 in Board of Governors (2022). Strikingly, the use of cryptocurrencies for transactional purposes was most prevalent among low-income households and those without bank accounts or credit cards.

<sup>25</sup>See Table 8.3 in HMRC (2022a).

<sup>26</sup>See Chainalysis (2022b). This is a composite reflecting five types of cryptocurrency services and giving higher weight to countries with lower income per capita.

<sup>27</sup>According to [TripleA](#).

<sup>28</sup>That said, Alnasaa et al. (2022) find no significant relationship with remittances or domestic inflation rate when controlling for governance.

<sup>29</sup>The US is also the top crypto mining country (37.8 percent), followed by China (21 percent) and Kazakhstan (13.2

## 2.3 Cryptocurrencies, the Rich, and the Not-so Rich

There are those who have made (and lost) large fortunes from the development of crypto assets and markets. Forbes (2022) lists 19 ‘crypto billionaires’, a noted above, with four among its list of the world’s wealthiest 400 people in 2021 (though that was down from seven in 2019).<sup>30</sup> How much of their wealth is tied up in crypto assets, however—and so poses problems distinct from those already familiar in taxing the super-rich—is unclear. Harder evidence on those made rich by investing in cryptocurrencies comes from Hoopes et al. (2022), who identify all crypto sales in the universe of tax returns in the U.S. between 2013 and 2020, the limitation being that this reveals only those among the compliant who chose not to continually defer realization. They find 1,245 ‘crypto millionaires’<sup>31</sup> with evidence too that while “at least some low-income taxpayers [experienced] life-challenging levels of income via cryptocurrency investments” many of them were already wealthy.<sup>32</sup>

There are also those who, while deriving their wealth from other sources, are invested in crypto assets. One survey—conducted at the crypto peak in November 2021—suggests that about two-thirds of all Americans with net worth of more than USD 1 million hold some cryptocurrency; and of these, a striking two-thirds hold more than half their wealth in this form.<sup>33</sup> Another survey suggests that in early 2021 there may have been around 100,000 Americans holding more than USD 1 million in crypto assets.<sup>34</sup>

Holdings, moreover, appear to be extremely concentrated. The top 116 addresses, for example, own nearly 16 percent of all Bitcoins. The link between addresses and individuals, however, is not one-to-one: addresses are held by corporations and intermediaries; they may be jointly owned; and an individual may well hold more than one address.<sup>35</sup> Makarov and Schoar (2021) use algorithms that exploit trading patterns of Bitcoin addresses to distinguish between intermediaries and individual investors. They estimate that the largest 0.01 percent of individual holders (a total of 10,000) controlled around 5 million Bitcoins, or one quarter of the total outstanding. This is far larger than the comparable share of equity holdings (and it might even be more concentrated if some of these individuals control more than one address).

The apparent propensity of the wealthy to hold significant amounts of cryptocurrency, and the high concentration of holdings (which implies that many are sizable) means that real issues

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percent): [Cambridge Bitcoin Electricity Index](#).

<sup>30</sup>Forbes (2021).

<sup>31</sup>Meaning those with cumulative reported gains on cryptocurrency of USD 1 million or more over this period.

<sup>32</sup>Their average wage income was over USD 360,000.

<sup>33</sup>MotleyFool (2021).

<sup>34</sup>CBS (2021).

<sup>35</sup>[bitinfocharts.com](#)

of equity and perhaps revenue are at stake in securing their appropriate taxation for income, inheritance and wealth taxation—including, not least, the treatment of losses.

It is also important, however, to remember that it is by no means only the wealthy who hold crypto assets: in the US, survey evidence suggests that 30 percent of holders have annual income below USD 50,000;<sup>36</sup> Hoopes et al. (2022) find even greater prominence of those on lower incomes: over half have taxable income of less than USD 40,000. For the UK, HMRC (2022a) finds that 85 percent of crypto holders have income below £50,000.

### 3 Cryptocurrencies and Tax Design

This section considers the key questions of policy that arise in framing and assessing the tax treatment of cryptocurrencies, deferring until later the issues of administration with which they intersect. Following the chain of events through transactions in and the creation of cryptocurrency (Figure 3), issues arise in relation to both income taxation and VAT/sales taxes;<sup>37</sup> there may also be scope for purely corrective taxation. Countries' current practices in these areas are diverse, in many cases await clarification, and are generally in a state of flux.<sup>38</sup>

The natural principle to apply in approaching these design issues—externalities aside, for the moment—is that of neutrality: taxing cryptocurrencies in the same way as comparable traditional instruments. For miners, for example, there seems no reason to treat income from fees and the generation of new coins differently from other business income, unless some specific (dis)incentive is intended. Application of neutrality principles to the treatment of cryptocurrencies is made difficult, however, by their dual nature: as investment assets and as a medium of exchange.

#### 3.1 Income Taxation

Corresponding to these two functions, there are two main ways in which cryptocurrencies might be classified for income tax purposes: as property (like shares, or bonds) or as (foreign) currency. The implications of the difference will depend on domestic rules, but can be highly material. For instance, many countries exempt individuals' capital gains on foreign currencies (Cnossen and Jacobs, 2022). Classification as property usually gives rise to capital gains tax, although important detail on, for instance, any ring-fencing of losses, exempt amounts and variation of rates with holding periods will be critical. In the US, for example, the characterization of cryptocurrencies

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<sup>36</sup>Board of Governors (2022).

<sup>37</sup>There are of course implications for other taxes, including on wealth, gifts and inheritances, that for brevity we do not pursue here.

<sup>38</sup>For a systematic account, see OECD (2020).

as property means that capital gains are in principle reportable on all transactions, with lower than the ordinary income tax rate applying if held for more than one year; had they instead been characterized as currency, gains would be taxable as ordinary income but only on gains over USD 200. Similar difficulties arise elsewhere, with the treatment of cryptocurrencies as property requiring calculation of gain or loss on every transaction. The obligations this imposes on small users are potentially extremely burdensome, and a significant obstacle to the routine use of cryptocurrencies to acquire goods and services.<sup>39</sup>

There is perhaps a third possibility. Some have drawn analogies between the holding of cryptocurrencies and gambling, with the apparent implication that it should be taxed in the same way: see for instance Panetta (2023). This would have implications not only for income taxation but for VAT and sales tax (with acquisition being treated as a stake), which treat gambling in complex and diverse ways<sup>40</sup> The aptness of the analogy, however, is unclear: about half of respondents in HMRC (2022a) report holding cryptocurrency “just for fun,” but Hoopes et al. (2022) find that cryptosellers look much like everyone else in terms of their reported gambling income.

In practice, the most common approach appears to be to treat cryptocurrencies for income tax purposes as property and subject to the corresponding capital gains tax rules. That still leaves room for a wide variety of treatments. Several countries, including in Europe, Malaysia, and Singapore, either do not tax capital gains from financial assets or exempt gains after a rather short holding period.<sup>41</sup> Portugal, which has tried to position itself as crypto-friendly, has specifically exempted gains on crypto holdings, though this now applies only to holdings of over one year; El Salvador still has an outright exemption.<sup>42</sup>

One special case of note is that of India. There crypto assets are in a regulatory limbo: neither illegal nor, strictly speaking, legal. Nevertheless, the government has implemented a bespoke tax regime specifically aimed at taxing at 30 percent gains and/or income from trading in ‘virtual digital assets’ (VDAs), meaning cryptocurrencies, NFTs and similar tokens, and other assets that it may specify. This is accompanied by a one percent surcharge on the transfer of any VDA.<sup>43</sup>

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<sup>39</sup>See for instance Wiseman (2016), who suggests that users be entitled to self-select as investment or transactional users (or at least that a *de minimis* personal exemption be introduced). Waerzeggers et al. (forthcoming) highlight this difficulty for stablecoins in particular, given what is clearly their primary purpose of serving as a means of payment, and explore further the complications associated with the differences between the many types of stablecoin.

<sup>40</sup>See for example Clotfelter (2005).

<sup>41</sup>Auer and David (forthcoming) find that owners of cryptocurrencies increasingly tend to hold for longer periods.

<sup>42</sup>Where cryptocurrencies are brought into capital gains tax, the question—partly conceptual, but above all practical—also arises as to whether the exchange of crypto for other virtual assets should be deemed a realization of gains/losses or a step-up/down in the asset’s base for taxation later upon realization: see Avi-Yonah and Mohanad (2022).

<sup>43</sup>Above an annual threshold of around USD 600.

### 3.2 VAT and Sales Taxation

The use of cryptocurrencies should pose no great difficulty of principle for the core structure of these taxes, since—with barter transactions in mind—these are commonly couched in terms of supply being made not for legal tender but for ‘consideration,’ a term broad enough to encompass crypto assets. (Practical difficulties in applying this may well arise, however, some of them touched on later, from price volatility (which can place particular pressure on verifying precisely when transactions occur), scope for fraud, and incorporation into cross-border rules). To ensure that the acquisition of cryptocurrency for fiat money is not in itself subject to VAT, several countries (including Australia, Japan, and South Africa) provide an explicit VAT exemption;<sup>44</sup> in the EU, the Court of Justice held in 2015 that VAT should not be applied to such transactions.

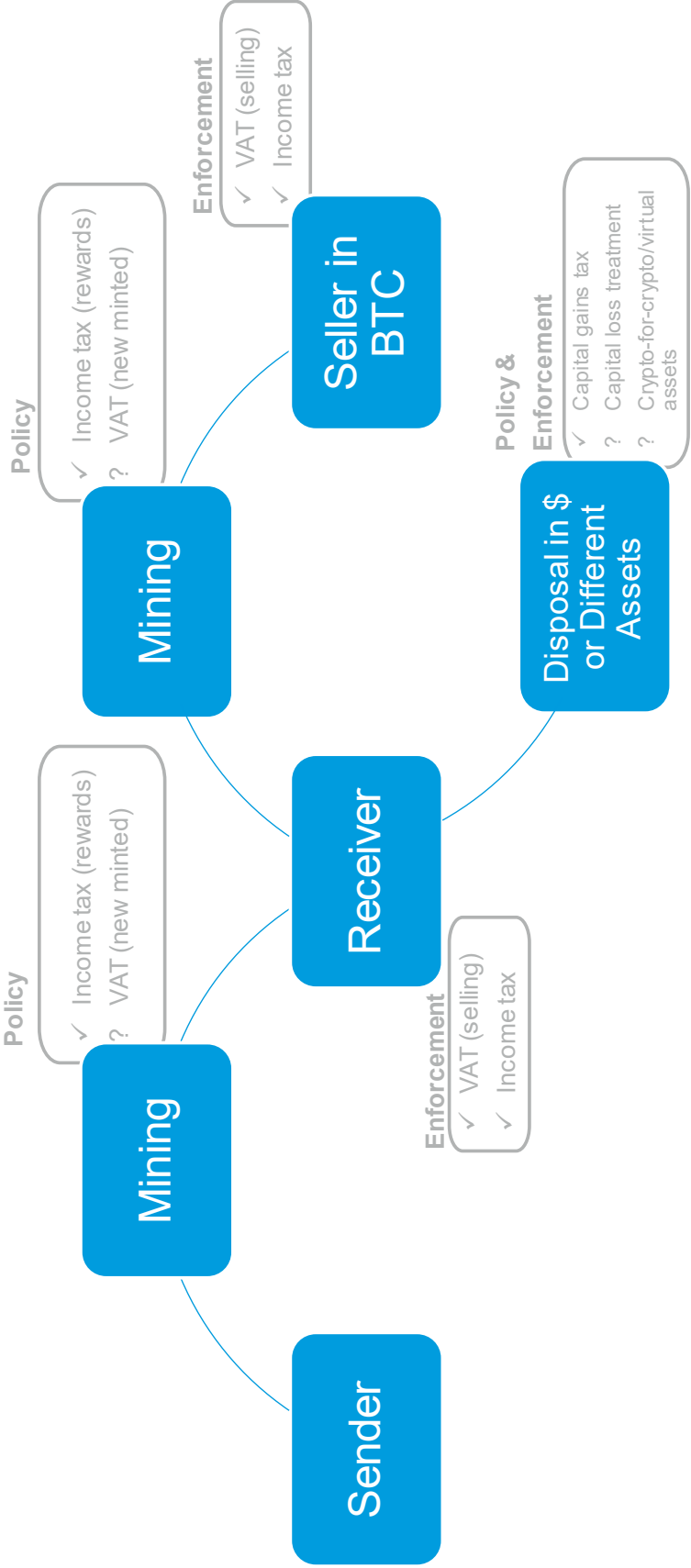
The VAT treatment of the fees and newly minted cryptocurrencies received by miners also requires a clear policy stance. In principle, there seems no reason why—again except by way of creating a deliberate (dis)incentive<sup>45</sup>—these should not be fully liable to VAT, with corresponding right to credit of VAT charged on inputs. While that is generally recognized as good practice, in practice many VATs exempt fees for financial services. This will result in over-taxation of business use of cryptocurrency (because of miners’ unrecovered input VAT ) and under-taxation of individual use.

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<sup>44</sup>OECD (2020).

<sup>45</sup>The question of whether to allow crediting of electricity costs is taken up below.

Figure 3: An Illustrative Chain of Events



Note: This diagram illustrates taxable events from the circulation of a cryptocurrency—taken here to be Bitcoin (BTC)—, highlighting their particular tax policy and administrative challenges. The sender, via miners, purchases a service from the receiver using BTC, and the receiver has the options to either dispose the BTC or purchase a service with the BTC. A “?” indicates a particular need for policy/legal clarity. Not explicitly depicted here is that these transactions can be peer-to-peer (P2P), or via decentralized or centralized exchange, which does not affect the policy treatment but affects tax enforcement capability (P2P being most difficult, followed by decentralized and finally centralized exchange).



### 3.3 Externalities

Several types of externality might be associated with the use of cryptocurrencies, and indeed these are reflected in the calls in many countries for their more effective regulation and, in some (including China, Egypt, Bolivia and Bangladesh), the outright prohibition of trading in or mining cryptocurrencies.<sup>46</sup> Beyond those externalities conventionally addressed through regulatory measures aimed at ensuring financial stability,<sup>47</sup> protecting consumers, and countering criminality, however, some may be associated directly with the use of cryptocurrencies themselves.

The analogy with gambling mentioned above, for example, points to possible problems of self-control of a kind that can rationalize corrective taxation. Extensive substitution of cryptocurrencies for national currencies ('cryptoization') might undermine the tools of macroeconomic management, significantly reducing the effectiveness of monetary policy or capital flow measures—with possible implications for the functioning of international monetary system. For both problems, the possibility arises of correction through some form of tax on transactions in cryptocurrencies, akin to the financial transactions taxes that have been adopted and even more often proposed for traditional instruments (including to reduce excessive price volatility),<sup>48</sup> of a kind that many also associate with cryptocurrencies. It might also be that, pending more effective regulation, using the tax system to discourage trading could in principle serve as a (very) second-best stop-gap device to counter risks to financial stability and dampen risks to poorly-informed investors. The one percent transfer tax in India might indeed be seen as a pioneering step addressed to these purposes. But whatever the conceptual merits of a crypto transactions tax might or not be—and there are counterarguments in the unknown benefits of fostering innovation in crypto—implementation is problematic, for reasons similar to those highlighted in Section 5: while national application to the subset of transactions through centralized domestic exchanges (and/or miners) may be feasible, this might simply drive transactions into peer-to-peer form or offshore. Similar arguments might nonetheless warrant less dramatic measures within existing structures, such as denying or limiting loss offsetting under the capital gains tax.

The most compelling case for feasible corrective taxation, however, is environmental. Proof-of-work consensus mechanisms (such as that behind Bitcoin) require considerable energy, as they rest on finding the solution to a complex mathematical problem by making an enormous number of guesses. The associated carbon emissions are cause for considerable concern: Hebous and Vernon

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<sup>46</sup>Mining seems, nevertheless, to have lingered in China at least into 2022.

<sup>47</sup>Tax design has a role here too, for instance in avoiding biases towards excessive debt finance (Keen, 2011).

<sup>48</sup>Whether they in fact do so is another matter cut, and likely to depend on market characteristics, such as thickness and the prevalence of institutional investors. For an overview of the issues around financial transactions taxes, see Matheson (2012).

(forthcoming), for instance, estimate that in 2021 Bitcoin and Ethereum used more electricity than did Bangladesh or Belgium, generating 0.28 percent of global greenhouse gas emissions.<sup>49</sup>

Awareness of this is now quite widespread, and reflected in the explicit marketing of some cryptocurrencies as ‘green.’ Voluntariness alone, however, is unlikely to provide a complete solution.<sup>50</sup> By the usual arguments, externalities from mining-related carbon emissions are best addressed within a general carbon tax, which would automatically internalize the costs of the energy-heavy proof-of-work verification mechanisms. In the absence of a carbon tax, however, there is a case for more targeted tax measures. In March, the Biden administration proposed a 30 percent tax on miners’ electricity use, though (for now at least) with no differentiation to reflect the carbon-intensity with which it is generated. Kazakhstan (an important location for mining) introduced a similar tax at the start of 2023, with a reduced rate for those using renewable sources.<sup>51</sup> Absent any additional tax of this kind, a less efficient but nonetheless meaningful measure might be to limit or deny income tax deductions for energy costs incurred in for their mining activities, and/or similarly that (if not VAT exempt) there be no credit for input VAT on energy costs.

## 4 Evasion and Revenue Potential

From their outset, a paramount concern with cryptocurrencies and crypto assets more generally has been the appeal of their anonymity properties in facilitating criminal activities. And there is no doubt that their criminal use is extensive, both in the large seizures that have been (the largest, in February 2022, being of Bitcoin valued at USD 3.6 billion)<sup>52</sup> and in the sizable (though short-lived) price responses to them. It is also suggestive of shadiness that has long surrounded crypto that there is a strong negative cross-country correlation between usage of Bitcoin and various indicators of institutional quality/control of corruption.<sup>53</sup> Specific areas of concern include both ‘traditional’ crimes—money laundering, trade in drugs and other illegal goods and services, financing of terrorism—and newer ones that draw on similar digital skills, including online frauds and ransomware attacks. Tax evasion is commonly included in this long list, but, perhaps

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<sup>49</sup>One might be tempted to argue further that, irrespective of any environment impact, the resources that these procedures use are in any case in effect a deadweight cost: the mathematical problem is of no substantive importance, and is required only to impose a cost that discourages the sending of dishonest messages. Abadi and Brunnermeier (2022) show, however, that some such costs are required if a consensus mechanism is to have desirable properties. Short of arguing that crypto in itself is inherently worthless, they thus have some value.

<sup>50</sup>In September 2022, Ethereum moved to a proof-of-stake mechanism that is far less damaging to the environment, but there are no signs that Bitcoin and others will abandon the proof-of-work consensus any time soon.

<sup>51</sup>By way of context, with shares of 35 and 18 percent respectively, the US and Kazakhstan account for more than half of all mining; Russia follows at 11 percent.

<sup>52</sup>This related to theft from Bitfinex, a cryptocurrency exchange: see Department of Justice (2022b).

<sup>53</sup>As found for instance in Alnasaa et al. (2022) and World Bank (2018).

unsurprisingly, often rather low down. And, indeed, it is easier to get at least some direct handle on the use of crypto for criminal activity in general than for tax evasion in particular. We consider each in turn.

## 4.1 Crime and Crypto

More is known about the use of crypto for what may be more serious crimes than its use for tax evasion. This is because the nature of the technology—with the entire history of transactions on a blockchain and public keys all public information—turns out to provide meaningful clues as to the extent of hard-core criminal activities.

With data on the universe of (over 600 million) transactions in blockchain from its inception in 2009 until April 2017, Foley et al. (2019) start by identifying addresses associated with seizures and trading on the darknet.<sup>54</sup> Building on this, they go further and estimate a wider population of those likely to be engaged in illegal activities, both by building clusters based on trades with those identified as ‘directly’ illegal and estimation based on their characteristics (such as the use of ‘tumbling’<sup>55</sup> and other measures of obfuscation). Their final estimate is that in 2017 around 25 percent of all Bitcoin users were engaged in criminal activity, accounting for around 23 (respectively, about 17)<sup>56</sup> percent of all transactions by number (by value), and holding around half of all Bitcoins. In dollar terms, this means transactions of USD 76 billion and Bitcoin holdings of USD 7 billion in 2017. These are large enough figures to conclude that “a significant component of [Bitcoin’s] value as a payment system derives from its use in facilitating illegal trade.”<sup>57</sup> Chainalysis, a specialist crypto analytics firm, arrives at much smaller numbers for the relative scale of illegal activities enabled by cryptocurrencies. For that same year of 2017, Chainalysis (2022a) estimates that ‘illicit addresses’ accounted for around 1.4 percent of all transactions, and received payments of around USD 4 billion. Makarov and Schoar (2021) arrive at a similarly modest figure, putting illegality and gambling at under 3 percent of the total.

These are very substantial differences. Makarov and Schoar (2021) attribute them largely to differences in the denominator, with their own estimate, unlike that of Foley et al. (2019), excluding exchange related and similar transactions, which they see as not being “economically meaningful transactions:” these account for about 80 percent of total volume. While this helps reconcile the figures, the implication would nonetheless be that these transactions are a sizable share of Bitcoin

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<sup>54</sup>For 2017, about 6 percent of all Bitcoin users are placed in this category, accounting for around one-third of all transactions.

<sup>55</sup>Tumbling involves mixing funds from different sources and sending on to distinct addresses; it is intended to make tracking harder.

<sup>56</sup>From inspection of their Figure 6B.

<sup>57</sup>Foley et al. (2019), p.1802.

transactions that relate to real activity.

There is though consensus that while crypto-enabled crime is growing rapidly in absolute volume and value, it is declining in relative terms.<sup>58</sup> It also seems to be agreed, albeit more asserted than demonstrated, that criminality continues to rely more heavily on traditional financing means, including cash.<sup>59</sup>

What is also clear is that cryptocurrencies continue to innovate towards increasing anonymity. Monero, for example, operates on the blockchain but has the feature that public keys, transaction details and other information are not publicly revealed. These are increasingly seen as the cryptocurrency of choice for serious crime. In response, in 2020, the IRS issued a request for proposals to enhance capacity to trace transactions on Monero and other privacy keys.

## 4.2 Evasion and Crypto

Since the proceeds of illegal activities are generally taxable, estimates of illegality of the kind above will encompass some degree of tax evasion. For the serious crimes that have been the primary focus of concern and investigation, however, tax evasion is likely a by-product rather than a primary motivation; indeed the purpose of the extensive money laundering in cryptocurrency is to make illegal gains appear legal, and even perhaps consequently subject to some tax.

From the tax perspective, however, three issues are more paramount. The first is the nature of the incentives to use crypto as a means of evading taxes on what are otherwise legal transactions: the provision of legal goods or services, for example, or payment of salaries. The second is the extent to which cryptocurrencies are, or might be, used to such an end. The third is the extent to which taxes related to the generation of or trading in crypto assets themselves—earnings from mining, for example, or gains on their sale—are properly paid. Little is firmly known about any of these.

On the first question, crypto technologies do not in themselves fundamentally alter the considerations shaping decisions on engaging in tax evasion. Their essence remains as set out in the literature that begins with Allingham and Sandmo (1972): balancing the tax saved in the event that evasion succeeds against the losses suffered in the event that it does not, with the likelihood of each depending on the probability of detection. In that canonical setting, the distinctive feature of crypto, arising from its anonymity, is naturally thought of as a particularly low probability of detection and hence particular appeal as a device for evasion. But there may be further considerations entering

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<sup>58</sup>This was true over the sample period of Foley et al. (2019) (and see also Tasca et al. (2022)); for the period since, Chainalysis (2022a) estimate that the amounts flowing to 'illicit' addresses have about tripled, to around USD 15 billion, but the share of transactions to have fallen by 90 percent.

<sup>59</sup>See for instance Europol (2021).

the evasion calculus.

One is that transactions costs will matter, both as to whether to evade at all and in selecting the means of doing so. In this respect, where the balance of advantage lies between crypto and, the obvious comparator, cash, is not a priori clear-cut (and may change over time). Crypto may, for example, offer some savings in transactions costs relative to cash,<sup>60</sup> for which existing channels can sometimes be more expensive; the estimated fee for a \$200 remittance, for instance, is 5.7 percent compared to 1.4 percent for a Bitcoin transaction (Beck et al., 2022). But its use and exploitation to enhance anonymity may require skills that costly to acquire. Over time, the latter obstacle to the use of crypto (leaving any regulatory restrictions aside) will surely decrease.

Another, more distinctive consideration, is the risk implied by the high price volatility of cryptocurrencies.<sup>61</sup> Differentially higher risk of fraud or theft in using cryptocurrencies would have similar effect. Akin to exchange rate risk, the primary consequence is likely to be to discourage the use of crypto for evasion purposes. Limiting it may lead risk-averse evaders to cash out more quickly than those holding for investment purposes, a trait that the studies cited above suggest is associated with criminal use of crypto.

There is almost no hard evidence, even anecdotal, on the second, quantitative question as to the extent of crypto-enabled tax evasion. In India, the authorities seized nearly USD one billion in evaded GST from local exchanges in May 2022.<sup>62</sup> And, in the UK, HMRC seized crypto assets and NFTs apparently intended to set up a VAT fraud.<sup>63</sup> It is interesting, and perhaps telling, that both stories relate not to income taxation but to the VAT. Having even less firm evidence on the possible extent of crypto-related evasion than for more traditional forms, we speculate further in the next section.

On the third question, there is some information on the converse of evasion: tax paid. For the U.S., the results of Hoopes et al. (2022) imply that around one percent of all returns in 2020 reported some sales of crypto. That is well below the 10-20 percent or so of American adults suggested by survey evidence to have held crypto around then; but of course some compliers may simply have chosen not to realize. There are also signs of at least some degree of compliance in the UK: a survey conducted for HMRC (2022a) reports that 45 percent of crypto owners thought they might be subject to capital gains tax, and 34 percent believed that they had a good understanding of the rules. It also reports that nearly 30 percent of owners had sought their guidance on the tax treatment of crypto—most, presumably, intending to comply rather than seeking clues on how to evade. While

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<sup>60</sup>IMF (2023) is skeptical on this, at least at present, except perhaps for some small cross-border payments of the kind in the example that follows.

<sup>61</sup>To a lesser degree, of course, for stablecoins.

<sup>62</sup>ITR (2022). Traders in cryptocurrencies are subject to 18 percent GST.

<sup>63</sup>See [Financial Times](#) and [Cointelegraph](#).

that might suggest fairly widespread but far from complete understanding, many holdings were so small that any gain would almost certainly be below the exempt amount.<sup>64</sup> Cluster analysis, however, identifies only one group ('A') as having tax-relevant gains (or losses)—within which,<sup>65</sup> 90 percent believe they have a good understanding of capital gains tax and 72 percent have seen HMRC guidance. Knowing one's tax obligations is not the same, of course, as intending to comply with them; and it is noticeable that those in Group A are also more likely to trade outside centralized exchanges, including peer-to-peer, in ways that are harder to monitor. More generally, it seems unlikely that those determined not to comply will respond to a survey on this topic. While there is thus some comfort in these results, it is far from complete.

Cong et al. (2022) look for signs of tax compliance by exploring the extent to which US-based crypto owners harvest tax losses around year end; that is, sell crypto and immediately repurchase so as to realize losses while leaving their holding unchanged—a transaction that would be hard to rationalize other than one of tax planning. (For traditional securities, such harvesting is restricted by disregarding repurchases within 60 days of the sale; as one of the gray areas in the precise details of the taxation of crypto, however, this restriction was not believed to apply to crypto.)<sup>66</sup> Using both proprietary data from 500 large retail traders and data from 34 exchanges,<sup>67</sup> Cong et al. (2022) find that such crypto transactions do occur and moreover increase following public statements by the IRS highlighting tax obligations on crypto transactions and its intention of targeted enforcement efforts. The conclusions to be drawn from this, however, are somewhat mixed: while there is a degree of compliance, the impact of policy statements by the IRS suggests that, whether willful or the product of ignorance, there is, or at least has been, a consequential element of non-compliance.

### 4.3 Revenue Potential

All this leaves little sense as to the amount of revenue at stake, whether for collection or evasion. Perhaps coming closest to this goal is the work by Thiemann (2021). Using data on Bitcoin transactions provided by Chainalysis, linked probabilistically to country of user (by information on web traffic flows to platforms and other clues such as time difference) this arrives at estimates of accrued and realized capital gains by EU residents. While information on capital gains tax actually paid on these transactions is unavailable, this enables rough estimation of the tax due in

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<sup>64</sup>At the time, £12,500. In principle, they might also have gains on other assets.

<sup>65</sup>Figures that follow are from HMRC (2022a) (Table 8). Of those in Group A (marked by higher incomes and much more frequent trading), 64 percent were estimated to have a taxable gain on crypto alone; in the other three groups, that figure is no more than one percent.

<sup>66</sup>The administration has now made clear its intention to ensure that it will.

<sup>67</sup>The latter may be more compelling since, as the authors note, their willingness to provide data may suggest that traders intend to be broadly compliant.

principle—which in turn can be thought of as an upper bound on the amount of tax evaded. And that amount is put at EUR 850-900 million in 2020. It is hard to scale this relative to revenues from the taxation of personal capital gains tax in the EU, which many countries do not report. But, for example, Thiemann (2021) suggests that this is about 0.3 percent of total property tax revenue in the EU; and it compares to capital gains tax revenue in the UK alone (not included in the sample) of about EUR 12 billion.<sup>68</sup>

Beyond this, so great is the ignorance in this area that even the crudest back-of-envelope calculations may be helpful. In this spirit, one approach is to treat cryptocurrencies as an investment asset, and apply some assumed rates of return and of taxation. Suppose, for instance, a total crypto market capitalization of USD 1 trillion<sup>69</sup> (which, for scaling, might be compared, with well-known estimates that global “hidden wealth” is around USD 7 trillion).<sup>70</sup> Assuming a rate of return of 5 percent—having in mind returns closer to normal than in the past—and a tax rate of 20 percent (brushing aside the complexities and diversity of national tax regimes), the implied total tax due is USD 10 billion. Taking instead the peak market valuation (in November 2021) of USD 2.6 trillion, this becomes an annual USD 26 billion.

These may all seem small numbers in the global context\* even that latter, for instance, is only around one percent of worldwide revenue from the corporate income tax (CIT). However, while an assumed return of 5 percent may approximate some kind of steady state for cryptocurrencies, there is little sign of an approach to such normalcy, and, to the contrary, the past has been characterized by remarkable volatility. Looking back at the past 2 years can illustrate how much revenue has been at stake. Market capitalization of crypto assets in 2021 went from USD 752 to USD 2,368 billion; in 2022, it dropped to USD 836 billion. These numbers are close approximations of the accrued capital gain/loss (the volume of Bitcoins, for instance, rose by only 2 percent and these newly minted Bitcoins would be subject to income tax too). Again assuming a tax rate of 20 percent, the tax revenue from an accrual-based capital gains tax would thus have been a hefty USD 323 billion in 2021, or around 12 percent of global CIT revenue. If one third of these gains were realized, revenue would still be around USD 100 billion. In 2022, on the other hand, if losses had been fully offset against other incomes, the reduction in tax revenue loss would have been of a similar magnitude—although loss offset could also be restricted by ring fencing crypto assets for tax purposes.

Given the high concentration of holdings noted above, the potential tax on the gains (and offsets on the losses) of the largest holdings would be correspondingly huge: in 2021, for example, the

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<sup>68</sup>From [OECD Revenue Statistics](#), accessed November 22, 2021; at an exchange rate of £1=€1.2.

<sup>69</sup><https://coinmarketcap.com/charts>; accessed November 11, 2022.

<sup>70</sup>See Zucman (2013) and Alstadsæter et al. (2019).



implied tax on the realized gains of those 116 largest addresses would be around USD 17 billion. In the ‘normal times’ scenario, it would be around USD 1.4 billion.

One might also consider—not as a recommendation, though nonetheless with the corrective considerations discussed above in mind—the revenue that would be raised by applying to cryptocurrencies a financial transactions tax of the kind sometimes proposed or applied to trading in securities. At, for example, the rate of 0.1 percent on securities trading in the still-lingering proposal of the European Commission (2011), revenue, if applied to all crypto transactions, which amounted to USD 15.8 trillion in 2021,<sup>71</sup> would be around USD 15.8 billion.<sup>72</sup>

An alternative approach is to focus on the use of cryptocurrency as a means of payment. A difficulty here is that some transactions would in principle be fully taxable (such as purchases of goods and services or property by final consumers)<sup>73</sup> others (purchases of business inputs, including salaries) would be wholly or partly deductible. Even generous allowance for the latter, however, suggests that large amounts could be at stake. Suppose, for example, that all cryptocurrency transactions were in the form of a VAT chain, with final sales accounting for 5 percent of all transactions by value. With total transactions of USD 15.8 trillion in 2021, at a VAT/sales tax rate of 15 percent the implied revenue loss would be a massive USD 118.5 billion. It may be, of course that many of the current transactions relate to serious crime, and in that sense likely an order of magnitude harder to recover than tax on legal activities. But if only 2 percent of transactions were for legal final sales, the implied revenue would still be a sizable USD 47.4 billion.

These calculations are scandalously simplistic, with more caveats—the assumption, for example, that tax changes would not affect volumes or values—than are worth listing. And of course, since some of that potential revenue is presumably already being collected, they do not indicate how much tax is being evaded. Some sense of that is provided by the estimate of the US Joint Committee on Taxation (2021) that revenue in the first year of operation of the new crypto reporting requirements described below—presumably additional to what would have been raised through self- or other reporting, and perhaps affected by the cumulation of losses since 2021—would be USD 1.5 billion, rising to USD 4.6 billion in 2031. This is around one percent of total (federal, state and local) revenue from individual capital gains tax in 2020.

All this does suggest some lessons. One is that the revenue at stake worldwide is plausibly in the tens of billions of dollars, perhaps even, if cryptocurrencies were to perform strongly, in the

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<sup>71</sup>Chainalysis (2022a). Trading volume in 2022 is around 30 percent lower than in 2021.

<sup>72</sup>At the still lower rate of 0.0118 percent applied to certain transactions in Brazil, it would come to only USD 1.8 billion (KPMG).

<sup>73</sup>Use for this purpose may not be trivial: HMRC (2022a), p.6, report 9 percent of crypto owners as having been paid for work in crypto assets. While, as noted above, only 4 percent indicate having received crypto for the provision of goods and services; for Group A this rises to a strikingly high 26 percent (HMRC, 2022a, Table 8.3).



high tens. How much of that is plausibly recoverable is another matter: even leaving aside the problems of detecting evasion associated with quasi-anonymity, controlling serious criminality lies far beyond the reach of tax administrations. A second is that a large part of the revenue at issue relates to large and wealthy holders of cryptocurrencies. And a third is that, in revenue terms, the use of crypto as a currency for legal transactions rather than for investment purposes might perhaps become a still greater concern. Much of the attention that has been paid to cryptocurrency in the tax literature has been around income tax issues; it may be, however, that it is in relation to VAT and sales taxes that the most significant issues will arise.

## 5 The Heart of the Matter: Implementation

In any area, a prerequisite for effective and efficient tax enforcement is a clear and complete statement of the rules to be implemented. Even in some of the most advanced countries, however, some important detail remains unclear.<sup>74</sup> Indeed so rapid are developments in the area, and so hard have they proved to accommodate within pre-existing legislation, that the process of tax rules reactively trying to catch up with innovations in technology and associated financial operations<sup>75</sup> seems likely to continue for some time.

### 5.1 The Implications of Anonymity

The fundamental obstacle to tax enforcement in relation to cryptocurrencies is the element of anonymity. The novelty of the problem was nicely expressed by the discussant of this paper (paraphrasing): in the old days, the tax authorities' problem was that it knew who you were, but not your income; now the problem is that it knows your income but not who you are.<sup>76</sup> Taken literally, this somewhat misstates the issue: income can be hard to identify from transactions (as amplified later); and it is not simply that the tax authorities cannot identify individuals—nobody can. Sight must also not be lost of taxes other than on income, not least those on goods and services; for these, information (potentially very precise) is also needed on the purpose of a transaction. Nonetheless, the aphorism conveys important element of truth that the use of cryptocurrencies raises problems not so much in identifying transactions but in linking them with specific entities of a kind, and in discerning their purpose, of a kind never before faced. Nor is this an accidental by-product of the development of cryptocurrencies. Their creation has been driven precisely by

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<sup>74</sup>As, for instance, with the issue noted above of whether wash rules in the US apply to cryptocurrencies.

<sup>75</sup>A recent example is the consultation on the tax issues related to staking and lending crypto assets launched by HMRC in July 2022 (HMRC, 2022b).

<sup>76</sup>The idea, though not quite the same turn of phrase, is in Baronchelli et al. (2022).

an intention (whether for libertarian or criminal purposes) to provide ways to undertake financial transactions without involving either government or any central authority that would be in a position to provide it with third-party information. With no intrinsic motivation to self-report crypto transactions (except perhaps when they make a loss), overcoming pseudo-anonymity is the core problem that tax administrations are now trying to address.

It is worth pausing, however, to reflect on the significance of anonymity for tax implementation. In itself, anonymity—meaning an inability to link transactions with specific individuals or legal entities—is not in itself fatal to any form of taxation. A single rate transactions tax requires no information on taxpayers' identities; what impedes its anonymous implementation in the blockchain case is an inability of the tax authorities to insert themselves into the chain. Similarly, implementing a flat rate income tax does not require the identification of taxpayers; it does though require information, also not available on the blockchain, on the nature of transactions (to pick out, for example, a payment of interest). More complex tax structures (nonlinear income taxes, or VATs involving both credits and output tax) require some means to identify distinct transactions with the same individual so as to aggregate over them, including transactions conducted by means other than cryptocurrencies. In the limit, if all transactions were conducted in cryptocurrencies, and individuals or firms each had a unique digital identifier, one could conceive of sophisticated tax systems being implemented, with the use of smart contracts, entirely on the blockchain—and this in principle would not require the tax authorities to identify the real individuals and firms behind those identifiers. Privacy in this respect could be fully respected, and, in principle, the dystopian prospects some see as an ultimate results of CBDCs<sup>77</sup> avoided. But whether governments would abstain from some building in some ability to identify individuals can be doubted.

For the foreseeable future, however, the challenge for tax authorities is the less profound but deeply challenging one of finding ways to accommodate the pseudo-anonymity of cryptocurrencies within systems not designed to do so.

## 5.2 Dealing with Anonymity

The good news for tax authorities, and regulators, is that—contrary to the vision of the original crypto designers—a core role has emerged for centralized institutions of various kinds in the transacting of crypto assets, notably exchanges through which they are bought and sold. Such institutions are in a position to obtain information on ownership, and so are at the core of current efforts, perhaps somewhat belatedly and certainly still incompletely, to obtain useful third-party information that can be shared with tax authorities.

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<sup>77</sup>See for example Baronchelli et al. (2022).

The use of intermediaries to either acquire or cash out crypto for fiat currency or other traditional instruments is a natural point for tax authorities to acquire information. An important step to this end is ensuring that anti-money laundering (AML) provisions apply to those providing services relating to transactions in cryptocurrencies. Key AML requirements include ‘know your customer’ (KYC) rules to verify identity—which in a crypto context, should enable linking of private keys with beneficial owners, at least in centralized exchanges—provide suspicious transaction reports (STRs) and attach customer information to transactions (‘travel rules’). In the US, the applicability to transactions in crypto of AML rules was made clear in 2013, and, more widely, in 2015 FATF<sup>78</sup> issued guidance on the application of established guidelines. At EU level, prior regulations applied only to “banknotes and coins, scriptural money and electronic money”<sup>79</sup> and so excluded cryptocurrencies; a proposal issued by the Commission for an appropriately updated regulation, in line with FATF guidance, now awaits Council approval. It was KYC provisions that provided the informational basis upon which the IRS has served ‘John Doe’ notices on crypto brokers seeking information on US taxpayers transacting USD 20,000 or more in cryptocurrency between 2016 and 2021.<sup>80</sup> In the UK, they enabled HMRC to write targeted letters to crypto owners reminding and informing them of their obligations.<sup>81</sup> Moreover, where ‘tax crimes’ are recognized as a predicate offence for money laundering, tax authorities in principle have access to the information collected by financial institutions under AML rules.

In practice, however, AML rules alone are commonly inadequate from a tax perspective (not only for crypto, but more generally). Not all jurisdictions fully comply with FATF guidelines,<sup>82</sup> and even where they do tax administrations may face obstacles in accessing the information they generate: surveying 28 of its members, OECD (2015) reports that only 20 percent of tax administrations had direct access to STRs, leaving a heavy reliance on financial intelligence units to spontaneously share information that they deemed potentially tax-relevant. Nor is it any case clear that even serious tax evasion will trigger STRs. Tax administrations’ access to AML information may have improved since the OECD survey.<sup>83</sup> But extending AML rules to crypto transactions, important though it is for other purposes, is evidently insufficient for enabling their effective taxation. KYC rules might enable the authorities to know, for instance, that some individual cashed out a certain amount of cryptocurrency; but from the transactions prior to that recorded on the

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<sup>78</sup>The Financial Action Task Force is the international standard setter in AML and countering the financing of terrorism.

<sup>79</sup>See EC (2021).

<sup>80</sup>Department of Justice (2022a).

<sup>81</sup>As described, for example, in Saffery.

<sup>82</sup>As of June 2022, FATF reports more than 20 jurisdictions as under ‘increased monitoring’ (FATF, 2022).

<sup>83</sup>OECD (2015) reports 57 percent of surveyed jurisdictions as planning to ease their tax administrations’ access to STRs.

blockchain it will not be possible, without further information, to identify any associated capital gain or loss.<sup>84</sup>

Going beyond AML, the natural aspiration for tax administrations is to secure direct and automatic sharing with them of information on crypto transactions similar to that already quite widely in place for traditional financial transactions. This is now the focus of considerable attention. In the US, the Infrastructure Improvement and Jobs Act (IIJA) of November 2021 includes two relevant provisions, requiring that: (1) A broadly defined set of digital service providers, potentially including even miners,<sup>85</sup> report details of their customers' transactions to the IRS annually, just as with bonds and shares: (2) All businesses report transactions in crypto assets of over USD 10,000, mimicking the pre-existing rule for cash payments. Both provisions take effect from tax year 2023. Similar measures are being adopted elsewhere. In Brazil, for instance, the Federal Revenue Service introduced regulations in 2019 requiring legal entities and individuals to report operations carried out with crypto assets.<sup>86</sup>

The application of reporting rules to domestic institutions may, however, drive transactions to either domestic mechanisms not subject to those rules or foreign ones that do not provide information to the domestic tax authorities. Cong et al. (2022) see signs of the latter effect at work in the US, finding that while IRS actions aimed at US taxpayers in general<sup>87</sup> appeared to increase legal avoidance activity in crypto markets, actions targeted at a specific US exchange (Coinbase) decreased activity on US exchanges.<sup>88</sup> In the UK, 22 percent of survey respondents in HMRC (2022a) indicated that they preferred using foreign exchanges.

The key tool to address this is cross-border exchange of information, with the reporting of assets and income to the country of residence. Existing frameworks for this, however, were not constructed with cryptocurrencies, or crypto assets, in mind, so that they risk falling into a grey area.<sup>89</sup> Recognizing the problem, OECD (2022) sets out a framework for cross-border exchange between tax authorities of information on crypto transactions to parallel that already being applied

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<sup>84</sup>Innovation around the implementation of KYC rules can also be expected, as with the use of ATMs to acquire or dispose of cryptocurrencies using credit cards or, leaving even fewer traces, cash. In the UK, the perceived threat is such that these are illegal; in the US, while they are in principle subject to KYC rules implementation appears to be problematic ((CNBC2021CashIn).

<sup>85</sup>The provision applies to "[A]ny person who (for consideration) is responsible for regularly providing any service effectuating transfers of digital assets on behalf of another person" (Section 8060).

<sup>86</sup>Individuals or legal entities conducting virtual currency operations for amounts exceeding USD 5,548 (30,000 Reais) on a monthly basis must report this information. Cryptocurrency exchanges domiciled in Brazil for tax purposes must also provide information, annually, in relation to each user of their services.

<sup>87</sup>Reminding them of their obligations, and announcing a compliance program focused on crypto.

<sup>88</sup>Fear of driving trading abroad may be one reason why the reporting requirements of the IIJA do not apply to non-US taxpayers.

<sup>89</sup>In the US, for instance, there is no explicit guidance on which foreign entities active in the crypto area are required to report under the Foreign Account Tax Compliance (FATCA) requirements.

for traditional financial assets and fiat currencies. This presumes that domestic authorities have in place requirements similar to those above, including for non-residents—so that implementation is likely some way off—but nonetheless provides a setting within which such rules can be developed with a substantial degree of commonality; the EU, for instance, appears to have been awaiting the outcome of this OECD work in order to build upon it among the member states. Importantly, the OECD framework reflects concern with the possible implications of crypto assets not only for income taxation but also for the VAT and sales taxes more generally: it includes a provision for the reporting of purchases by crypto assets of goods and services exceeding USD 50,000. General adoption of provisions along the lines of OECD (2022) remains, however, a somewhat distant prospect. In the (potentially long) meantime, all that entities will need do to avoid information reporting is “to have their servers in a country where the authorities are willing to tolerate their existence.”<sup>90</sup> And indeed the experience has been that as some jurisdictions adopt international standards of information exchange so activity tends to shift to others.<sup>91</sup>

Effective mechanisms of third-party reporting by centralised institutions involved in trading cryptocurrencies, including across borders, thus remain some way in the future. But it is at least possible to see how they might work. It is ultimately direct peer-to-peer transactions, including those facilitated by decentralized exchanges, that pose the toughest problems.

Decentralized exchanges simply could not meet the kind of reporting obligations now imposed in the US, from which, and perhaps for that reason, while not excluded from the reporting requirements of the Infrastructure and Jobs Act, are also not explicitly included.<sup>92</sup> The reporting envisaged by OECD (2022) would include any decentralized exchange “to the extent it exercises control or sufficient influence over the platform, allowing it to comply with the due diligence and reporting obligations”<sup>93</sup>—which, in most circumstances, it would be unlikely to do. In practical terms, it is extremely hard to assess the extent to which crypto transactions are currently peer-to-peer rather than through a centralized exchange. FATF, for example, asked seven blockchain analysis to assess the proportion of Bitcoin transactions conducted peer-to-peer: the estimates varied from close to zero to nearly 100 percent. In HMRC (2022a), only 8 percent indicated using a decentralized exchange; among the most tax-relevant and tax-informed Group A, however, the figure rise to

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<sup>90</sup>Makarov and Schoar (2021).

<sup>91</sup>As shown, for example, in Johannesen (2014).

<sup>92</sup>Decentralized exchanges were explicitly included in early versions of the Infrastructure and Jobs Bill, but in the final version the obligations apply to those “regularly providing any service effectuating transfers of digital assets on behalf of another person” (Sec 8606 (a)(2)(D)). Whether ‘effectuating’ is to include the facilitation services provided by decentralized exchanges will perhaps be clarified in the accompanying regulations, which are still waited. On language in the priori draft, see Forbes.

<sup>93</sup>OECD (2022), para 27, p.51.

nearly 50 percent.<sup>94</sup>

Whatever their current importance, however, the concern must be that as information reporting becomes more effective in relation to centralized trades so activity will shift to decentralized forms upon such rules cannot realistically be imposed. For these, more innovative methods may be needed.

One alternative approach, for example, may be to focus on requiring information reporting not (only) by things that resemble financial institutions but on the miners themselves.<sup>95</sup> These are involved in every cryptocurrency transaction and, moreover—always useful for tax administration (though less welcome for the security of cryptocurrencies)<sup>96</sup>—are relatively few in number: Makarov and Schoar (2021) estimate that around 55-60 controlled more than half of all Bitcoin mining capacity at the end of 2020. In these respects, they are attractive points at which to require information reporting. One might even envisage going further and imposing at that point some corrective transaction tax (if determined to be helpful) and/or applying a (creditable) withholding obligation: a charge on each transaction paid to, and credited/refunded by, the relevant tax authority. Compliance with these obligations might be pursued in a number of way. The traces that miners leave in the blockchain might help identify them as real entities. And/or incentives might be found to encourage their compliance, if not in the form of some explicit subsidy to the compliant (the optics of which might not be good) then in the familiar form of allowing some delay in remitting tax withheld to the authorities.<sup>97</sup>

For at least the immediate future, however, tax administrations in most countries must deal with potentially very limited directly usable information on cryptocurrency holdings and transactions. This of course does not mean they are helpless.

Working in their favor is the vast amount of information publicly available in unpermissioned blockchains. This provides scope for the application of techniques that have been developed for the forensic analysis of blockchain structures; some taste of this is provided by analyses discussed above, and there are, for example, firms that hold out the prospect of linking legal names, account numbers and IP addresses to virtual asset service providers (such as crypto exchanges).<sup>98</sup> Artificial intelligence applications can draw on past experience to identify potentially tax-relevant behaviours, and there is of course room too for traditional investigative methods that seek links

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<sup>94</sup>Figures for the use of peer-to-peer sites were much the same.

<sup>95</sup>This is suggested, from a perspective wider than that of taxation, by Makarov and Antoinette (2022).

<sup>96</sup>This is because concentration in mining increases the risk of a "51% attack", by which malicious actors become able to manipulate the contents of the blockchain.

<sup>97</sup>One could also conceive of levying some form of penalty on entities found to be using non-compliant miners. This though would require that users be able to select miners ex ante, an option not now available and which, by limiting the number of miners, might again have implications for the security of the blockchain itself.

<sup>98</sup>As for instance at <https://ciphertrace.com/solutions/>.

with information obtained outside the chain.

There also remain other and more standard measures to encourage self-reporting, such as taxpayer education, both general and targeted, and nudges. Large and successful actions can be used to send appropriately chilling messages: that the FBI, for example, “is able to uncover the source even the most sophisticated schemes and bring justice to those who try to exploit the security of our financial infrastructure,” and that a seizure of NFTs in the UK “serves as a warning to anyone who thinks they can use crypto assets to hide money from HMRC”.<sup>99</sup> Given the profundity of the fundamental challenges posed by quasi-anonymity, the astonishingly rapid pace of change in the area, its technical complexity, the vast information gaps, the uncertainties ahead, and a sense that the tide has not yet turned in the battle to incorporate crypto properly into the wider tax system, one might detect in such statements some element of whistling in the dark. It is clear, in any event, that living up to these confident assertions is not easy.

### 5.3 Value Added and Sales Taxes

Much of the discussion of the tax implications of cryptocurrencies, and of crypto assets more generally, has focused, implicitly or otherwise, on the taxation of income, and especially of capital gains. Looking forward, however, some of the greatest risks to the broader tax system may be those arising in relation to the VAT and sales taxes.

The use of cryptocurrencies to acquire goods and services directly is apparently modest now, and not a feature of everyday life (even where Bitcoin is legal tender). And indeed in some respect, as also seen above, current tax rules may impede its use as a means of payment. If such use were to become widespread, however, it could create potentially significant dangers to the integrity of VAT and sales tax systems. One obvious risk is that widespread use of crypto currencies could facilitate the underreporting of final sales. This is not a new problem: indeed a focus of tax administration for decades has been to counter this risk, especially in relation to cash purchases. And that has been done with some success. Crypto, however, may open up a new front in this battle, waged with new and complex weapons.

The first line of defense is imposition of a legal requirement on all businesses to report large crypto transactions, of the kind, noted above, that is now in place in the US and envisaged by OECD (2022). Such rules are clearly not sufficient to bring the dangers to tax systems set out above under

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<sup>99</sup>Quotations respectively from FBI Deputy Director (Department of Justice, 2022b) and HMRC Deputy Director of Economic Crime (Guardian, 2022). The UK seizure was not specifically crypto-related tax offence but was related to the financing of a potential VAT fraud. HMRC has also let it be known that it “is opening increasing numbers of investigations into people who have only disclosed modest amounts on their tax returns whilst transacting major amounts in crypto. HMRC is said to have [about] 20 new criminal investigations underway involving crypto and for every criminal investigation there are likely to be dozens of civil investigations” (Park, 2022).



control: they are neither self-enforcing nor all-encompassing. And they face the same difficulties as above from decentralized trading or use of non-reporting foreign exchanges. But they are close to necessary, in generating red flags, clues for audit, and increasing the downside risks of evasion.

For the VAT, further challenges may arise in the use of cryptocurrencies as a convenient device for fraud, for example in creating carousels that enable refunds to be claimed for tax that has not been paid.<sup>100</sup> This is again not a new problem, but one that the use of cryptocurrencies may cast in a new form.

Little systematic thought appears yet to have been given to protecting sales taxation and, bringing additional complexity, the VAT, against these challenges. The risks, for now, appear more latent than real. But this can change.

## 6 Conclusion

The future of cryptocurrencies is highly uncertain. For some, they are a bubble that will sooner or later fully implode. To others, they will prove the foundation for fundamental innovations in decentralized finance. In either case, however, tax systems need to accommodate them with a coherence, clarity and effectiveness that, not having been constructed without crypto assets in mind, they currently lack. They need to do so, moreover, in the context of continuing rapid and complex innovation, on the basis of limited information, and while balancing the core objectives of securing efficiency, fairness and revenue in taxation against the risk of stifling innovation. The challenges are both conceptual and, still more, practical.

Conceptually, the dual nature of cryptocurrencies as both investment assets and means of payment—the latter, though less prominent than the former, being a primary purpose for their development—creates potential difficulty in capturing capital gains and losses in their asset role without thereby constructing obstacles to their use as currency. For the VAT and sales taxes, while many issues of detail arise, the critical step is to ensure that cryptocurrency is treated the same way as national currencies. What is needed for income tax purposes (for instance providing exemptions for reasonable personal use as currency) will depend on existing national structures for the treatment of gains and losses and of foreign currency transactions.

Questions also arise as to a potential corrective role for taxation, whether, for example, to address externalities associated with gambling or as a stop-gap to dampen change pending the implementation of effective regulation. Much more clear cut, and now becoming the focus of some action, is the case for some charge—ideally as a part of a wider carbon tax, or if not as

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<sup>100</sup>On the nature of carousel fraud, see for example Keen and Smith (2006).



a sector-specific charge—to address the significant climate impact of proof-by-work consensus mechanisms.

It is in implementation, however, that cryptocurrencies pose the most severe problems. This is because their essence, and the core motivation behind their development, is precisely to avoid placing trust in centralized institutions of a kind that might be able to provide information to the tax authorities, or perhaps to levy some kind of withholding tax. The first step for governments, nonetheless, is to apply AML rules and third party reporting requirements where they can, as the US has recently done. The risk, however, is that transactions will to some degree migrate to forms (on decentralized exchanges or directly peer-to-peer) that no third party even sees. It might be, however—somewhat ironically, in terms of the original vision for crypto—that investors come to place more trust in well-regulated institutions than in the ‘Wild West’ of decentralized trading. More speculatively, miners—who do see every transaction in non-stablecoins—might in principle be given a role in tax reporting/withholding, consistent with the general principle of tax administration favoring collection, where possible, at a relatively small number of upstream points.

These difficulties are amplified, moreover, by the ease with which crypto transactions are conducted across borders, so that domestic tax measures might also result in trades shifting to non-reporting platforms abroad. The OECD (2022) has developed a framework for extending current arrangements for cross-border information to crypto, but implementation remains some way in the future and in any case will not in itself resolve the challenges posed by decentralized trading.

It is hard to assess the extent to which the quasi-anonymity of crypto facilitates tax evasion (beyond that associated with outright criminality, which accounts for a declining share of activity in cryptocurrencies). There is, however, evidence of a degree of compliance, at least for the US, with about one percent of returns reporting crypto sales and signs of significant avoidance activity. In terms of the amounts at stake, rough calculations suggest that in 2021, a ‘good’ year for cryptocurrencies, a global tax at 20 percent on accrued capital gains might have raised around USD 300 billion (which is about 12 percent of global revenue from the corporate income tax. But in the ‘bad’ year of 2022, revenue would likely be eroded by large capital losses.

As for those likely to have gains subject to tax, while information is limited, there is strong evidence that crypto wealth is highly concentrated, even more so than ownership of equities. This, it seems, is not just a matter of a handful of crypto billionaires, or of the few who have become wealthy by investing in crypto, but of holdings by a wider but unknown set of the rich whose wealth derives from other sources. It may be of course that the deepest problems here are not distinctive to crypto but apply to the capital gains taxation of other assets too, especially at the

top of the income distribution. Worth bearing in mind, however, is that, at least in the UK and US, many holders of cryptocurrencies are far from rich, with incomes that are lower than other investors and often no more than moderate.

Such literature as there is on the taxation of cryptocurrencies has focused on income tax aspects, which is indeed that most relevant to the taxation of the rich that is the topic of this issue. Much less attention has been paid to the implications for sales taxation and, especially, the VAT. These may, however, be profound, as cryptocurrencies potentially create problems similar to those associated with the use of cash, with which VATs have long struggled, and perhaps create new opportunities for fraud. It is in this area that the risks to existing tax systems created by the use of cryptocurrencies proves most profound—not least in emerging and developing economies in which demand for crypto appears relatively strong while tax administration is relatively weak.

## A Appendix: The Mechanics of Cryptocurrencies<sup>101</sup>

A *Distributed Ledger Technology* (DLT) is one that makes some database available, for inspection and/or amendment, to authorized users, with a protocol of consensus in place to ensure that—without any need for a central authority—all entries are accurate and protected against tampering. The best known and most widely used DLT is blockchain, the distinctive feature of which is that transactions are added to the database sequentially, with approval of each new block entailing confirmation of previous blocks, and the use of encryption to make it extremely difficult to change earlier entries. For many applications, such as tracking the movement of goods, the system is ‘permissioned’, meaning that access and/or rights are in some way limited, and authority to introduce and confirm changes restricted to particular users. Cryptocurrencies, however, are generally *permissionless*, meaning that access to the database is fully public; this requires particular measures to ensure trust in the database and avoid ‘double-spending’ of holdings.

Protection against tampering in cryptocurrencies rests on cryptographic methods that enable private information to be encrypted in such a way that its accuracy can be verified without revealing that information itself.<sup>102</sup> To implement this, users have a *private key* (or ‘address’) that is encrypted into a *public key* that is known to all users, but from which it cannot be inferred. Details of a proposed transaction, along with the public key, are then broadcast to all participants. The accuracy of that information and availability of the necessary coins is easily checked. The mechanism for validation, however—meaning addition to the chain—is made costly in order to deter tampering and the use of the same funds more than once (‘double spending’), which in turn requires some reward for doing so. Under *proof of work*, this is done by having validators (‘miners’) compete to solve—more accurately, guess a solution to—a complex numerical problem, requiring extensive computing power, in return for which they receive an allocation of the crypto currency and/or a fee. Under *proof of stake*, the task of verification is allocated probabilistically in proportion to an amount of crypto that is staked; the reward for such validation is again some amount of the cryptocurrency, with a loss of stake in the event of failure or misrepresentation. Once confirmed in this way, the new block is added to the chain.

Stablecoins, being backed or with their supply controlled algorithmically, do not require verification in this way.

Private keys, from which public addresses are derived by encryption, are held in electronic/digital *wallets*, which may be held offline (‘cold’) or by service providers, whether as custodians (taking

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<sup>101</sup>Many subtleties are skimmed over here; for more detail, see for instance Hallaburda et al. (2022) and Box 8-2 of Council of Economic Advisers (2023).

<sup>102</sup>This rests on the use of non-invertible ‘hash’ functions which map a number or text of arbitrary length into a unique number from which it cannot be inferred.

control of the key, executing trades at the customer's request) or simply providing security.

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