# Mobilising central bank digital currency to bend the curve of biodiversity loss

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## Abstract

Humanity is at a critical juncture. Despite our efforts to set targets and goals, biodiversity and climate are both changing rapidly, pushing us towards a biosphere our species has not known. To solve this problem one view is that we need transformational change of the economic paradigm, but that might be more an ideal than pragmatic. A new idea could be to take inspiration from recent developments in global carbon market theory and spatial finance, and devise a new central bank digital currency (CBDC) for nature, paid to individuals for reductions in anthropogenic pressure. We could then track a conjunction of anthropogenic pressures from space or remotely, combine that with a model predicting biodiversity change, and then link that to our new global currency that would self-regulate those pressures towards bending the curve. In biodiversity modelling alone there is a lot we would need to learn to make this work, but I think one federated currency for nature might be the economic mechanism we need to fully integrate the pathway of detection, attribution, and action into one global biodiversity observing system (GBiOS), and finally slow biodiversity change.

## Main

Humanity is at a critical juncture. Biodiversity and climate are both changing rapidly, pushing us towards a biosphere our species has not known (Xu *et al.*, 2020). For climate and biodiversity change our efforts to halt both are insufficient (Mace *et al.*, 2018; Nordhaus, 2019). We have a 1.5°C target for climate change and some understanding of how to get there (IPCC, 2022), but such agreements and targets are not enforceable. For biodiversity the situation is worse. The Convention on Biological Diversity (CBD) regulates goals for biodiversity change, but our 23 Targets (Ainsworth, 2022) and associated indicators are not fully agreed by the broader scientific community (Geldmann *et al.*, 2023; Veríssimo *et al.*, 2023). Importantly, our Targets do not explicitly recognize that the mechanisms of the service of biodiversity are borne of biodiversity itself, and that the uncertainty of this relationship is large (Nicholson *et al.*, 2009). For both biodiversity and climate change our failures are the fault of no one individual. The institutions and structures of our globalised economy feel to have locked us into a trajectory that has become unstoppable.

In parallel, private investment in biodiversity conservation is growing, with companies aiming to monitor biodiversity and the contribution it makes to people (e.g. NatureMetrics, NatureBound, Xylo Systems). These companies are wanting to make reasonable choices on the measurement and value of biodiversity, but a clear message and direction is not coming from us as biodiversity researchers. There is now I think a significant and real risk that private companies find ways of monitoring biodiversity at scale in real-time, but build systems that optimize parameters from the literature that we know are not correlated with metrics that are meaningful for process and function. This will be compounded I think when that same problem occurs independently across tech companies, such that collectively we will measure metrics that are not meaningful, and that don't map between one another.

There are ideas for how we might solve the biodiversity crisis. One view is that we need transformational change of the economic paradigm (IPBES, 2019). That might be an ideal, but it is not pragmatic. Our current economic paradigm I think is too embedded in the structure of states and the psyche of what's possible, such that a shift from without seems unlikely. Another view is that within the current paradigm organisations such as the TNFD (Taskforce on Nature-related Financial Disclosures (TNFD, 2023)) can incentivise a more equitable approach to biodiversity. The TNFD is a new government-supported initiative recommending 14 disclosures against which companies should report their impacts on nature (TNFD, 2023). There may be some ways in which we can say the TFND has worked for localized biodiversity change, and it will undoubtedly help to leverage knowledge of biodiversity in financial institutions, but it alone gives us no quantifiable roadmap for approaching a stable state. Most importantly, at present the TNFD will not regulate or enforce metrics. Companies will be able to record one biodiversity metric and then make a decision to switch, meaning reported change in biodiversity will not be meaningful either within or between companies. There are also developments in biodiversity credits (Bruggeman *et al.*, 2005), biodiversity offsets (Maron *et al.*, 2016), and payments for ecosystem services (PES) (Farley and Costanza, 2010). Some of these may work at a given scale to shift metrics of biodiversity (although the evidence is scarce, e.g. see (Börner *et al.*, 2017; Salzman *et al.*, 2018)), but given their decentralization and the heterogeneous consensus on the value of biodiversity, it seems unlikely that these policies will pull biodiversity in any one consistent direction, and very unlikely with any associated degree of quantifiable uncertainty.

Central banks are increasingly taking note of the systemic risks associated with a rapidly changing environment (Campiglio *et al.*, 2018). Central banks ordinarily function to implement monetary policy for the stability of fiat currencies, taking actions such as changing interest rates or buying up government bonds to control inflation (e.g. the Bank of England, The European Central Bank, the People's Bank of China). These actions are distinct from fiscal policies such as taxes and subsidies which are set by the government. Importantly, central banks at least in principle act independently of government, meaning they can take more long term decisions on financial stability that don't necessarily concern immediate consumptive gain. Central banks are historically highly resistant to mandate change and intervention that might itself cause financial or political instability (Campiglio *et al.*, 2018), but as the risks of inaction on biodiversity change become more apparent, significant intervention does not seem unreasonable given the precedent set by the global financial crisis (GFC) of 2007-2009 and the COVID-19 pandemic (Haas, Neely and Emmons, 2020). Importantly, the GFC of 2007-2009 caused a significant shift in central bank philosophy, moving from an exclusive aim of price stability to including a mandate on financial stability (Das, 2023), despite the resultant inflationary impacts and feedbacks on price stability. Although climate risks predominate central bank concerns, representatives of the European Central Bank (Elderson, 2023), the German Federal Bank (Mauderer, 2023), and the Central Bank of Malaysia (Endut, 2023) have all spoken recently of increasing concern regarding financial instability caused by biodiversity change. A key consideration for these central bankers is on the distinction between transitional and physical risks: transitional risks are those consequences that are caused by significant shifts in monetary policy during a transition to sustainable finance, whilst physical risks are those that are caused by physical changes in the environment (Semieniuk *et al.*, 2021). When the certainty and magnitude of physical risk is high, significant intervention will carry a relatively low transitional risk, leading to a high likelihood of monetary intervention.

Central bank digital currencies (CBDC) are an emerging technology that enable the creation of digital money by central banks (Bordo and Levin, 2017), as opposed to via commercial banks in the form of debt. Although there are many concerns regarding privacy and greater government control (Baronchelli, Halaburda and Teytelboym, 2022), CBDCs potentially enable a more efficient means of money transfer and better control of the money supply (Meaning *et al.*, 2018). Notably, money could be created by central banks without the indirect means of quantitative easing (i.e. ordinarily quantitative easing involves the lending of money to governments by central banks via the purchase of government bonds), and then distributed directly to a population in the form of “helicopter money” (Reis and Tenreyro, 2022). CBDCs are currently being actively researched by ~86% of central banks (Deloitte, 2022), with the first launch in a major economy in China in 2021 (Popper and Li, 2021). Although CBDCs are primarily a response to the development of private company stablecoin currencies (Soderberg, 2023), which are stabilized through pegging to a reserve currency or some standard, the International Monetary Fund specifically mentions CBDCs as a means for monetary stimulus following “wars, pandemics, or natural disasters” (Soderberg, 2023).

Taking inspiration from developments in central bank digital currencies (CBDC) and global carbon market theory, a new idea for biodiversity change could be to develop a CBDC for nature, modelled on the global carbon reward (Chen, Beek and Cloud, 2017). The philosophy of the global carbon reward is that central banks should back a new form of carbon currency, that can be issued to entities upon some action to mitigate emissions or capture carbon. Whereas cryptocurrencies are mined by using energy to validate transactions, a carbon currency would be mined by reducing emissions or storing carbon, and then awarded by central banks to individuals through a process called carbon quantitative easing. Two crucial outcomes of the global carbon reward are that it would be a single global carbon standard, and that it could ultimately help to self-regulate towards net zero. One of its core insights is that the floor price of carbon should be allowed to emerge as a function of systemic risk, rather than from consumption alone. For biodiversity, what that would mean is that if we could find some set of biodiversity metrics that capture enough of what’s important to process and function, and an associated target and timeframe, our biodiversity pricing can in theory emerge without needing to value contribution in the form of an ecosystem service. Or in other words, rather than asking ‘what is the value of biodiversity?’, we ask ‘what do we need the value of biodiversity to be to keep the biosphere within some systemic risk boundary?’. As far as I know, biodiversity researchers have not been talking about a standardized nature currency that would be backed and issued by central banks, such that biodiversity change is slowed through a coordinated international monetary intervention (although see (Ledgard, 2022) for a similar idea on interspecies money). If we can find a way to put the brakes on environmental change with a new CBDC for nature, and allow the Court Jester to catch up (Barnosky, 2001), it might be that biodiversity stability emerges organically.

We would however need to guide the way in which our CBDC for nature reduces anthropogenic pressure. If we do not, we risk mitigating inconsequential anthropogenic pressures, either because their effect size is smaller than we anticipated, or because their effect is actually inherited from elsewhere. To do that we would need a set of reasonable models that guide our decisions (Bateman and Balmford, 2023). The emerging field of spatial finance might hold a solution (Patterson *et al.*, 2020). Spatial finance refers to the integration of geospatial data and financial policy (Patterson *et al.*, 2020), giving a means through which land assets or environmental risks can be quantified from space unambiguously and remotely in real-time (Caldecott *et al.*, 2022). Leaning on these developments, we could track a conjunction of anthropogenic pressures from space or remotely, combine that with our model predicting biodiversity change, and then link that to our new federated CBDC that would self-regulate those pressures towards bending the curve. Given the unambiguity of spatial finance (Caldecott *et al.*, 2022), landowners would be awarded a nature coin only when pressure change has been confirmed remotely for some specific period of time, thereby reducing the likelihood of false reporting. Such an algorithm could be made open, helping to increase buy in from low income countries that lack their own influential central banks, and to guide decision makers themselves on anthropogenic pressure reduction to maximise return on downregulation. We would still then need to monitor future biodiversity, but that comes secondarily to confirm that the currency is functioning. And then if it's not, we use that future record to refine our model of biodiversity change and shift the reward weighting of the CBDC.

Recent developments in global carbon market theory rest on two principles: a target for climate change (1.5°) and a unit of measure responsible (carbon). With both of these parameters a floor price of carbon over time emerges organically. For biodiversity we have no such simplicity. There is mixed consensus as to the value and importance of biodiversity at the global level (Seddon *et al.*, 2016); we don't know with a quantified degree of uncertainty the extent to which these metrics can change before the biosphere reaches a tipping point or is overcommitted (Brook *et al.*, 2013); and among taxonomic groups we don't know the extent to which multiple anthropogenic drivers are causally responsible for biodiversity change (Gonzalez, Chase and O'Connor, 2023). To settle some of these debates, we perhaps need to see that each individual means through which we measure biodiversity is to some extent capturing the variation of others. I don't think we need to measure everything. Rather, I think we need the minimum number of metrics such that we capture enough of the uncorrelated ways in which all metrics are collectively important, to both the processes and functions on which future economic stability depends (Mace, 2019; Bateman and Mace, 2020). That could then be manageable, and perhaps more crucially and hopefully, enough.

A federated CBDC for nature could be built into GBiOS (Gonzalez et al, 2023) as a deliberate guiding principle for action on biodiversity change, helping to solve two problems. First, as far as I know GBiOS does not yet provide a modelled mechanism that can flow from detection and attribution to action. Although it is true that significant gaps remain in geographic and taxonomic coverage, arguably our bigger issue is that even if we can measure biodiversity change comprehensively and understand why it's changing, our mechanisms of action are highly distributed and assumed to emerge from change in indicators and engagement alone. This is also the case for climate change and the WMO's Integrated Global Observation System (WIGOS), despite this monitoring system being some way ahead of biodiversity monitoring (Gonzalez et al. 2023). Given that biodiversity change is highly spatially resolved, it's unclear to me how the levers of action will be pulled in the future without direct government intervention that infringes on the liberties of individuals. What we need, I think, is some economic mechanism that can respond to models of detection via GBiOS. Second, GEOBON provides comprehensive guidance on EBVs (Essential Biodiversity Variables) and EEVs (Essential Ecosystem Variables), and on the logistics of setting up a BON, but not yet on how BONs should fit into networks of currently existing institutions within states. BONs I think do need to be federated, but federated within a consistent set of institutions that already exist, that can both understand the common goal and communicate in one terminology. We also, I think, to justify the quantity of funding required for GBiOS, need to see that although our proximate goal might be slowing biodiversity change, we need to align that our ultimate goal is to capture at least the most important dimensions of systemic risk.

Mid to late this century, I think we should aim towards a system in which GBiOS, a constellation of remote sensors of anthropogenic activity, a set of causal inference models of biodiversity change, and a federated CBDC for nature are combined to create one self-regulatory system for anthropogenic pressure. It would work something like the following. A custodian or owner of land consults an open-access algorithm for payment of a CBDC for nature. That custodian then makes a set of management changes or pressure reductions on their land for a specific period of time, before being paid some quantity of currency in the form of a CBDC, according to anthropogenic pressure reduction measured unambiguously from space. That quantity of currency paid out would be a function of systemic risk mitigation, derived from some function of land area, quantity of pressure reduction, and a systemic risk threshold or magnitude at that time. A federated network of central banks would facilitate BONs that take future measures of biodiversity to confirm whether the currency is functioning, coordinate a constellation of satellites, and iterate over a prior model of biodiversity change; and an exchange authority independent of central banks would act to ensure that fiat currency devaluation is at least consistent between states (Chen, Beek and Cloud, 2017). Effectively it would be one global control-system that, to a quantifiable degree of uncertainty, could do at least enough for systemic stability. Crucially, a system such as this only needs to monitor biodiversity as far as it's useful to model validity, both in building an initial causal inference model and in continually updating predictions. This both brings down our overhead on biodiversity monitoring (i.e. we don't need to monitor everywhere at very high temporal and spatial resolution), and anchors our currency to measures that we know individuals can directly control and we know we can measure (i.e. anthropogenic activities). A system in which a custodian makes some management change, and then needs confirmation of biodiversity change in that specific location to receive payment, is I think naïve to both the difficulties we will likely always have in predicting absolute change in biodiversity at a given time, and to the likelihood of buy in from custodians when management change is always a gamble. What we need I think is not to know that biodiversity always changes in a specific instance, but to know that management interventions made will on average be enough.

Such a joined up self-regulatory system for anthropogenic pressure would however be associated with significant risks itself, for a number of reasons. First, there is a danger that we create a control-system that moves beyond our own control, causing systemic existential risks themselves. This is particularly pertinent given that a CBDC control-system would be designed to down-regulate anthropogenic pressure, or in other words it would create a mechanism that rewards land-grab and removal of populations. Before embarking on any federated CBDC for nature, we would need to be confident that biodiversity related systemic risks are real and quantifiably predictable; we would need to know that they cannot be solved through corporate enterprise alone; and we would need to understand the transitional risks of demonetising the currency if needed. Second, there is a risk that a federated currency destabilises reserve currencies such as the US dollar. Third, although such a system might be sufficient to mitigate against known systemic risks, it can't guard against unknown future risks, and may propagate unintended consequences. Fourth, although the intent in building such a system might be to down-regulate anthropogenic pressure for the sake of biodiversity related systemic risks, there is a danger that states coopt the currency for their own nefarious intentions, in the form of population control or currency warfare (Crespo, 2018). Fifth, the degree of inter- and intra-state cooperation required would be wholly unlike any like prior central bank intervention, for an intervention would need to occur in advance of the full realization of systemic risk, which is not ordinarily how central banks operate (Mosser, 2020).

Irrespective of all of the above, for a CBDC for nature to be workable, there are at least nine areas I think in which we would need to make significant advances in biodiversity modelling alone: 1) We need to be confident that the anthropogenic variables we measure do explain change in biodiversity. To do that we need more models built on the basis of causal inference (Arif and MacNeil, 2022); 2) we need to be confident that through valuing only some set of biodiversity metrics, we are not going to overlook something important, and we need to settle on what those metrics of value are; 3) we need to get better at building models that consider multiple anthropogenic variables together, such that we will not overlook surprising high magnitude interactions; 4) we need to be better at accounting for uncertainty by incorporating variation predicted by temporal or spatial autocorrelation (Johnson *et al.*, 2022); 5) we need to sample biodiversity in space across more locations and across a greater breadth of anthropogenic intensities (Daskalova *et al.*, 2021); 6) we need to know that space-for-time models can be used to back-project time series, in a manner that is not consistently wrong; 7) we need to build a consistent global monitoring system such that we can track biodiversity at future intervals (Gonzalez, Chase and O'Connor, 2023), to check the currency is working; 8) we need infrastructure in place for tracking change in anthropogenic variables from space or remotely at high resolution (Antonelli, Dhanjal-Adams and Silvestro, 2023); and 9) we need to stress test how the consequences of local biodiversity change might ripple out across the globalized economy, as well as understand from when and where such rippling effects might propagate (Cisneros-Pineda *et al.*, 2023).

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