Transforming Climate Finance and Green Investment with Blockchains

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CHAPTER 15

Central Banks and Blockchains: The Case for Managing Climate Risk with a Positive Carbon Price

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15.1 Introduction

15.1.1 The Paris Agreement

The main ambition of the celebrated Paris Agreement—of the Twenty-First Conference of Parties (COP21) under the United Nations Framework Convention on Climate Change (UNFCCC)—is to hold global warming to well below 2°C above preindustrial levels and pursue a limit of 1.5°C of warming, recognizing that this would "… *significantly reduce the risks and impacts of climate change"* (UNFCCC, 2015; Article 2). Managing climate risk is clearly a major component of the Paris Agreement in terms of the intended actions, but what is meant by "risk"? A standard definition of risk is that it is "*the effect of uncertainty on objectives*" (ISO, 2009) and so the Paris Agreement should be concerned with improving the *certainty* that unwanted levels of climate change will be avoided.

Parties to the Paris Agreement have agreed to define their voluntary mitigation actions as Nationally Determined Contributions (NDCs) on a five-year pledging cycle. The NDCs and new technologies are helping to drive a low-carbon transition, but the Paris Agreement as a whole lacks a binding mechanism to enforce the 1.5/2.0°C limits (or any other limit). According to a group called "Mission 2020", to achieve the 2.0°C ambition, global carbon emissions will need to peak by 2020 and then decline, otherwise "… *the temperature goals set in Paris become almost unattainable*" (Figures et al., 2017).

15.1.2 Likelihood of a Climate Catastrophe

If the world's greenhouse gas (GHG) emissions were to cease completely in 2017, the GHGs already in the atmosphere would produce 1.3°C (0.9−2.3°C) of "committed

1 www.crcsolutions.org/.

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warming" by 2100 (Mauritsen & Pincus, 2017). When future GHG emissions are extrapolated, it becomes apparent that the 1.5/2.0°C limits will be difficult to achieve. Raftery, Zimmer, Frierson, Startz, and Liu (2017), who undertook a probabilistic assessment of future emissions, conclude that the 1.5°C and 2.0°C limits only have a 1% and a 5% chance of being met, respectively. William Nordhaus, who is well-known for developing the *Dynamic Integrated model of Climate and the Economy* (DICE), similarly found that "*...a limit of 2°C appears to be infeasible with reasonably accessible technologies...*" (Nordhaus, 2016, p. 3).

Nordhaus (2016, p.3) does not appear optimistic about limiting warming to 2.5°C, which he described as "*...technically feasible but would require extreme virtually universal global policy measures*." Garrett (2012), who developed a lumped-parameter model of the economy based on global energy requirements, deduced that future carbon dioxide (CO_2) emissions could be so difficult to mitigate, that future emissions could actually "*...push civilization towards an accelerating decline.*" In this chapter we will consider how central banks can address the climate crisis with new remits that specifically reduce the physical and socioeconomic uncertainties of climate change.

15.1.3 Central Bank Narrative on Climate Risk

The Prudential Regulation Authority (2015), which is part of the Bank of England, and the Financial Stability Board (2017), which is an international body promoting financial stability, have considered three causes/types of climate-related financial risk, namely: (1) physical causes that arise from climate and weather-related events; (2) transitional causes that arise from the process of adjusting to a lower-carbon economy; and (3) liability causes that arise from parties who have suffered loss or damage.

Aglietta and Espagne (2016) coin the term "climate systemic risk" in reference to the combined financial and physical risks, and they recommend that collective insurance against these risks be implemented as "*...equivalent of a value that society attributes to mitigation activities*" (p. 5). Some important questions arise from their discussion, such as: should central banks use Quantitative Easing (QE) to finance a low-carbon transition?

Appeals for climate-friendly QE, often called "green QE," have been made by numerous scholars, including: Sir David King (Harvey, 2012), Werner and Lucas (2012), Ferron and Morel (2014), Sirkis et al. (2015), and others. Matikainen, Campiglio, and Zenghelis (2017) assessed the QE programs of the European Central Bank (ECB) and the Bank of England to find that their asset purchases have actually favored emission-intensive sectors of the economy. This finding leads to another key question: should central banks remain "market neutral" with respect to the assets that they purchase?

If new remits are to be given to central banks to generate climate finance, such as with QE, then these remits will require clarity regarding policy objectives and tools. This clarity is needed because, as Volz (2017, p. 19) points out, the central bankers might not be prepared for the "*. . .demands and expectations that central banks should now become a jack of all trades and also solve the world's environmental problems*." The adoption of new central bank remits appears plausible if the role of central banks is assumed to be evolving (e.g., Goodhart, 2011). Given that mandates of central banks are currently compatible with managing "financial systemic risk", the feasibility of new remits for "climate systemic risk" appears to be mainly a political question (Volz, 2017, p. 20). In the following discussion, a case is presented for new central bank remits that provide a long-term macroprudential response to climate change.

15.2 Managing Climate Risk with a Positive Carbon Price

15.2.1 Positive Carbon Price

The proposal to manage climate systemic risk with a positive carbon price is explained here in terms of (i) what it is, (ii) why it is needed, and (iii) how it should be implemented. These descriptions are based on a global climate policy developed by Chen, van der Beek, and Cloud (2017), called *Global 4C Risk Mitigation* or "Global 4C." The tool that is recommended for creating the positive carbon price is a Central Bank Digital Currency (CBDC), and the generic name of the proposed CBDC is *Complementary Currencies for Climate Change* (4C).

15.2.1.1 What Is Recommended as the Positive Carbon Price?

The positive carbon price is a financial reward for each metric tonne of carbon dioxide equivalent (CO_2-e) that is mitigated relative to certain emissions baselines and under long-lived contracts that define the required standard of service. The reward is, therefore, a commercial offer that can incentivize *voluntary* mitigation, and the aggregate of this mitigation should limit the climate systemic risk over the long term. Under the Global 4C policy, any carbon that is abated or sequestered and then rewarded with 4C will not be traded in carbon markets. This implies that all of the carbon in the 4C stocktake is "retired" and cannot be used to offset other carbon emissions.

4C is a proposed parallel currency that can be traded with other currencies. Central banks will require remits to influence the 4C price with QE and currency trading, and the main objective of this currency trading is to set the price of 4C to reflect the average market price of limiting the climate systemic risk. When the 4C is correctly priced to the climate systemic risk, it will incentivize sufficient climate mitigation for an agreed risk limit to be achieved. The central banks will employ a trading strategy that involves "telegraphing" to the market their future trading intentions, and this can be used to generate private demand for 4C. This trading strategy is described below and in the "Avoiding Catastrophe" storyline (Section 15.3).

15.2.1.2 Why Should There Be a Positive Carbon Price?

The positive carbon price is recommended as preventative insurance against the possibility of dangerous-to-catastrophic climate change. It is a global price that can respond quickly and proportionally to man-made climate forcing and natural climate feedbacks. The operational objective is to stay below specific temperature changes over a rolling 100-year planning horizon and with a limited probability of failure (e.g., remaining below 4°C of warming with 3% chance of failure). The 100-year planning horizon is not a precise time period, but it is not arbitrary either because human activities could drive 2.0−4.9°C of global warming within 100 years[2] (Raftery et al., 2017).

15.2.1.3 How Does the Positive Carbon Price Work?

The positive carbon price works by offering in the marketplace a global reward for mitigating carbon emissions. By issuing the global reward as a digital parallel currency over the Internet—called 4C—the reward should bypass most political, social, and financial barriers that would otherwise inhibit the establishment of many low-carbon projects.

It is proposed here that central banks be given remits to use QE and currency trading—as much as is needed—to set 4C prices and influence the market's expectations for future 4C prices. These remits should be used to manage long-term "bull" and "bear" markets in private 4C trading: this is a core macroeconomic strategy of the approach. It should be made clear that 4C prices will actually mirror the cost of preventing dangerous-to-catastrophic climate change, and that the scheduled 4C price is a public safety announcement based on prices. The "bear" market in 4C trading will occur after the risk has peaked and is reducing. The utility of 4C during the "bull" and "bear" markets is unchanged, although the central banks will need to adjust their currency trading strategies to manage these phases of the 4C market.

15.2.2 New Model for Externalities

The standard model for assessing the external cost of carbon emissions, is as follows:

$$\text{External Cost} = \text{Social Cost of Carbon(SCC)} \tag{15.1}$$

The *Social Cost of Carbon* (SCC) is the time-discounted average economic welfare loss per tonne of CO_2-e emissions (IAWG, 2013); and the SCC is used to guide the price of carbon taxes to reach a welfare maximum. The new model, which was first proposed by Chen *et al.* (2017), identifies two types of external cost, as follows:

[2] About 60% of the equilibration surface temperature occurs 25−50 years after the CO_2 is emitted (Hansen et al., 2013); and atmospheric CO_2 concentrations adjust about 100 years after the CO_2 is emitted (IPCC, 2013).

$$\text{Total External Cost} = \text{Social Cost of Carbon(SCC)} + \text{Risk Cost of Carbon(RCC)} \quad (15.2)$$

The *Risk Cost of Carbon* (RCC) in Eq. 15.2 is defined as the average cost of climate mitigation services (per tonne of CO_2-e) that will be sufficient to avoid specific levels of global warming and in accord with politically agreed probabilities of failure. For example, the cost of not passing 4°C of global warming by 2120 with a 3% chance of failure can be used to define the RCC. The SCC and RCC are summed in Eq. 15.2 to aid our understanding that carbon emissions are creating two kinds of external cost. These costs associate with climate damages and systemic risk, respectively.

The possible existence of the RCC as a second external cost is explained by a market hypothesis—called the *Holistic Market Hypothesis* (HMH)—that was developed by Chen *et al.* (2017) based on a thermodynamic interpretation of carbon pricing and social networks. A critical issue is that carbon lock-in is a feature of the economy that produces dangerous carbon emissions (Unruh, 2002), and that a thermodynamic analysis of the economy reveals that carbon lock-in could be much worse than previously anticipated (Garrett, 2012). The HMH is a hypothesis that the carbon lock-in can be most effectively addressed with a combination of conventional carbon taxes and a global carbon reward that is delivered as a parallel currency (i.e., 4C). To be effective, 4C should be priced to mirror the RCC in Eq. 15.2, and 4C should be convenient to trade with national fiat currencies. It is recommended that 4C not be used to trade for goods and services, because this option will unnecessarily complicate the policy and its implementation. When holders of 4C decide to spend their 4C, they will first have to exchange their 4C for a local currency.

The RCC is the cost of limiting climate risk and avoiding climate "tipping points" (Lenton, 2012); and it should be estimated with comprehensive risk assessments that take into account the total cost of mitigation and all administrative costs, including the hidden costs of monitoring for carbon leakage and for managing bad actors. The application of Eq. 15.2 is illustrated in Fig. 15.1 in terms of a single market actor. Fig. 15.1 shows that the SCC is internalized with taxes linked to emissions, and that the RCC is internalized with rewards linked to mitigation. The SCC and RCC are interactive costs. Next, we will use a thought experiment to examine the utility of a positive carbon price created with a parallel currency.

15.3 The Avoiding Catastrophe Storyline

15.3.1 Hypothetical

A hypothetical 100-year storyline called "Avoiding Catastrophe" is presented as a thought-experiment and to illustrate how a positive carbon price could potentially "move the trillions"[3] of new climate finance. In this storyline an international political agreement is

[3] Sirkis et al. (2015)

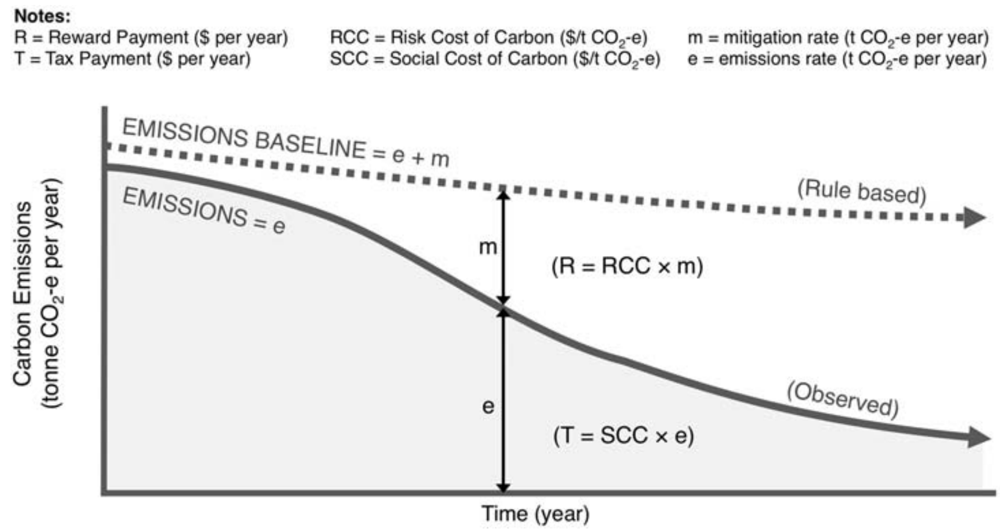

Figure 15.1
Illustrative example of complementary carbon pricing for a single market actor, including idealized representations of (e) carbon emissions and (T) tax payments for the internalization of the SCC; and (m) carbon mitigation and (R) reward payments for the internalization of the RRC.

established under the UNFCCC to prevent global warming from exceeding 2°C with a 33% chance of failure, and 4°C with a 3% chance of failure, and with both risk limits being addressed concurrently over a rolling 100-year time horizon.

The amount of additional finance that will be needed for a timely low-carbon transition could exceed USD$1 trillion per year based on published assessments (e.g., Global Commission on Economy and Climate, 2014; IEA, 2015). Of particular interest is whether 4C trading can help resolve the "Tragedy of the Horizon" conundrum that Mark Carney, the governor of the Bank of England, described in a speech:

> "*That is, climate change is a tragedy of the horizon which imposes a cost on future generations that the current one has no direct incentive to fix*" (Carney, 2016).

In this hypothetical it is assumed that all G20 nations and most non-G20 nations are supporting the Global 4C policy as active partners and beneficiaries of 4C rewards, and that central bank remits are internationally coordinated such that financial markets and the public can trust 4C as a store of value.

The "Avoiding Catastrophe" storyline begins in the year 2020 with the issuance of 4C to actors who abate carbon emissions or undertake direct air-capture and sequestration of carbon. At the beginning of each year, a risk assessment is conducted to estimate the RCC

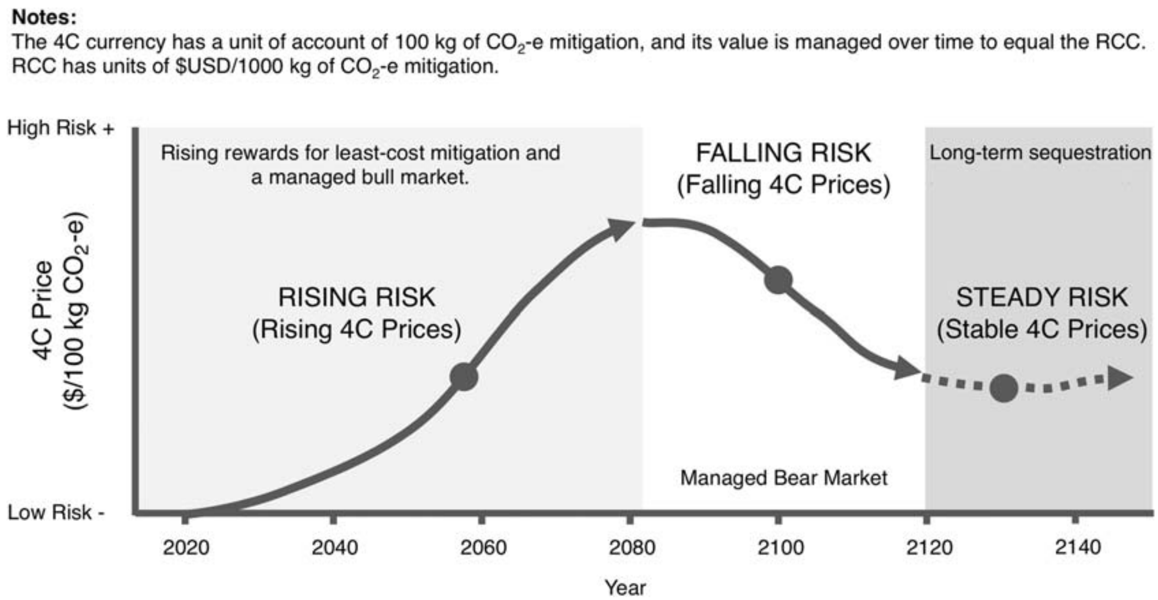

Figure 15.2
The "100-year advance 4C price alert" in the "Avoiding Catastrophe" hypothetical storyline. *Adapted from* Chen et al. *(2017)*.

over the following 100 years for the objectives of avoiding greater than 2°C with 33% chance of failure, and greater than 4°C with 3% chance of failure. The RCC time-series is known as the "100-Year Advance 4C Price Alert" (see Fig. 15.2), and it is advertised in the mainstream press so that markets are aware of the 4C reward price (for each 100 kg of CO_2-e mitigated) and the yield on 4C holdings.

15.3.1.1 The 4C Supply-Demand Storyline

In the storyline, the central banks of the G20 and other participating nations coordinate their QE and 4C currency trading to guarantee the prices shown in the "100-Year Advance 4C Price Alert" (Fig. 15.2), and they accumulate their 4C purchases in holding accounts. The monetary inflation created by QE is dispersed evenly across the world economy such that firms and citizens are minimally impacted by the QE.

During the first 60 years, the required yield on 4C is greater than the average interest paid on bank deposits and borrowings, and greater than the average return in stock markets (e.g., S&P 500, Dow Jones Industrial Average) and bond markets (e.g., Bloomberg Barclays US Aggregate Bond Index). Consequently, many private traders and institutional investors buy 4C during this managed currency bull market. The central banks trade 4C to help smooth the 4C price during the bull market, but by the year 2080 there is a peak in the climate risk, and for another 40 years (2080–2120) the central banks guide the 4C price to a lower price range by selling some of their 4C holdings (Fig. 15.2). Society accepts the 4C bear market as a trade-off for limiting the climate risk and stabilizing the climate over the long term. National governments accept 4C as an international trading currency and as an essential tool for ensuring international cooperation on climate change.

During the 100-year storyline (2020−2120), data within the carbon stocktake was shared globally so that market actors could optimize their investing across a wide spectrum of low-carbon technologies. The 4C rewards encouraged massive R&D and this was instrumental in finding radical new mitigation technologies, thereby increasing the long-term mitigation rate. 4C allowed market actors to qualify for larger commercial bank loans to finance new low-carbon projects, and the green/climate bond market received a huge boost because low-carbon projects were more profitable with 4C. The reported 4C earnings of each project were used to help quantify the "shade of green" of these projects, and 4C finance generated co-benefits by providing employment, reducing poverty, and protecting biodiversity. These co-benefits were especially relevant to people living in rural regions where the land was suitable for bio-sequestering carbon but economic opportunities were otherwise limited.

15.3.2 Resolving the Climate Paradox

"Resolving the Climate Paradox" is a speech presented by the Bank of England's governor, Mark Carney. Carney (2016) remarked on climate risks and the challenges of transitioning to a low-carbon economy. The hypothetical storyline is appraised against the two paradoxes[4] described by Carney (2016): (1) "Future will be past," and (2) "Success is failure."

15.3.2.1 Paradox 1: Future Will Be Past

> *"The catastrophic impacts of climate change will be felt beyond the traditional horizons of most actors including businesses and central banks. Once climate change becomes a clear and present danger to financial stability it may already be too late to stabilize the atmosphere at two degrees"* (Carney, 2016).

The "Future will be Past" paradox, as described above, is a result of the 25−50 year time lag between carbon emissions and resulting climate impacts (Hansen et al., 2013) and the time-discounting of future impacts by society. The "100-Year Advance 4C Price Alert" is a partial resolution to this paradox because it can incentivize near-term climate mitigation (Fig. 15.2) based on a socioeconomic feedback between the risk of future global warming and the 4C price. Resolution is based on the idea that a rising 4C price will generate optimism for a

[4] Jevons effect and growth vs. degrowth may be considered two additional paradoxes related to climate change (refer Chen, Cloud, & van der Beek, 2015).

low-carbon transition within the time horizon of most market actors, and will create a secular 4C "bull" market because of the positive yield on 4C investments.

15.3.2.2 Paradox 2: Success Is Failure

> *"That is, too rapid a movement towards a low-carbon economy could materially damage financial stability. A wholesale reassessment of prospects, as climate-related risks are re-evaluated, could destabilize markets, spark a pro-cyclical crystallization of losses and lead to a persistent tightening of financial conditions: a climate Minsky moment"* (Carney, 2016).

The "Success is Failure" paradox, as described above, is partly resolved because 4C finance is commensurate with the quantity of mitigation that is needed to limit the climate systemic risk, and because 4C prices are predictable and stable over many decades (Fig. 15.2). Also, the "100-Year Advance 4C Price Alert" should be designed to ensure that the financial transition is smooth by encouraging long-term investing and infrastructure planning for the low-carbon transition: potentially avoiding a "climate Minsky moment."

15.4 The FinTech Brief

Political challenges aside, the case for a positive carbon price is dependent on the technical feasibility of the 4C platform, which is a kind of CBDC. Notable examples of CBDCs are Project Ubin, developed by the Monetary Authority of Singapore (MAS, 2017), and Utility Settlement Coin (USC), developed by Clearmatics for UBS. The 4C system will require a new international authority for setting standards, notionally called the *Carbon Exchange Standard* (CES) (Chen *et al.* 2017).

A technical brief for the 4C platform is provided here for governance institutions, investors, and innovators who may be interested in collaborating on a business model for the 4C platform: a model that faces some technical challenges and political risks. A preliminary business case is to assume roughly USD$1 trillion per year equivalent of 4C issued in the marketplace as a global carbon reward (Global Commission on the Economy & Climate, 2014). An administrative fee of just a few percent of the 4C supply may be sufficient to finance the entire 4C platform—and this will provide the CES with political autonomy and independence from fiscal budgets.

15.4.1 The Global 4C Platform

The CES should target all geographic locations and all economic sectors with the 4C platform (incl. energy, transportation, agriculture, manufacturing, buildings, land and marine management, education, etc.). The design of the 4C platform should be geared for rapid scalability and to support a global market-driven program of climate mitigation; and it should maintain scarcity of 4C by linking the 4C supply to an official carbon stocktake.

The 4C platform will outsource the Measurement Reporting and Verification (MRV) to the private sector. The platform should also leverage mitigation and enhance social and ecological co-benefits. Ideally, the 4C platform will have access to global environmental monitoring data and satellite-based observations that can support the MRV.

The 4C platform should be developed using Blockchain distributed ledgers so that the various data-intensive services can be decentralized over the Internet and mobile devices: with the aim of ensuring that the data are secure and verified. The 4C platform might use a "consortium" Blockchain network (e.g., Microsoft, 2017) so that the CES can manage permissions. The CES should be able to regulate the 4C ledger for resolving errors, thefts, and for charging demurrage fees (Section 15.4.4).

The 4C platform will require the standardization of interconnections with external databases and with real-world devices for the automation and streamlining of MRV, and to facilitate peer-to-peer (P2P), business-to-business (B2B), and machine-to-machine (M2M) communications and trade.

15.4.2 Smart Contracts

The 4C will be a P2P currency that is easily traded for other currencies. The 4C currency—with a unit of account of 100 kg of CO_2-e mitigated—will be supplied as a reward for verified carbon mitigation. 4C rewards are a kind of *seigniorage* income for mitigation actors, but 4C is rewarded conditionally and with long-lived service agreements that will be managed with "smart" contracts for administrative efficiency (e.g., Buterin, 2014). The service agreements will be separated from the 4C currency ledger, and these agreements will be private contracts that link mitigation actors to the CES. The service agreements are needed to bond actors to their mitigation claims for the approximate time that it takes carbon emissions to impact on the climate system. A maximum contract duration of 100 years is suggested, and this duration has a precedent with 99-year leases on property under common law.

Smart contracts for the service standards should be able to request MRV at suitable times for updating the carbon stocktake and for triggering contract clauses. The main aim of the 100-year service agreements (and smart contracts) is not to impose harsh penalties on actors; rather, it is to ensure the integrity of the carbon stocktake on a rolling 100-year basis. Although most low-carbon projects might only operate for just a few years to a few decades, the service agreements should contain provisions to monitor emissions and carbon storage in case of carbon leakage. If low-carbon projects outlive their owners or change hands, novation provisions should transfer the service agreements to the new owners. If low-carbon projects have no owners, then the CES or another authority should take responsibility for these agreements.

Mitigation actors who fail to meet their service agreements will be required to return the outstanding 4C or a monetary equivalent; however, actors will also be permitted to go into debt to avoid financial hardship, but actors should not be allowed to accumulate debts indefinitely. To address these issues, there will be provisions for defaulting, *force majeure*, debt collection, and debt forgiveness; and the provisions should be legally enforceable. The unrecoverable 4C debts will be reconciled using a global demurrage fee on all 4C holdings (Section 15.4.4).

15.4.3 Fees and Commissions

The CES authority should encourage an open market by offering licenses to individuals and firms who wish to do auditing and assessments for financial compensation, and by paying for these services with commissions and hourly rates. By covering all of the running costs with a percentage of the 4C rewards, the 4C platform will avoid unnecessary financial intermediaries and will be self-funding.

Although the technical details are not presented here, the basic idea is that the 4C platform will be designed to detect, discourage, and punish gaming and data counterfeiting. A virtual trust economy should also be established in which stakeholders assign comments and reputational tokens to the rules, systems, data, and other stakeholders, and help ensure that the system is transparent and accountable.

15.4.4 Demurrage Fees

Holders of a demurrage currency are charged a fee for holding the currency over time. One example is the Wörgl demurrage currency that was issued in Austria between 1932–1933, and was called the "miracle of Wörgl" because it stimulated economic activity (Hallsmith & Lietaer, 2011). A variable demurrage fee (%) will be used to eliminate an amount of 4C that corresponds to the aggregate of defaults on service agreements. This is to maintain consistency between the 4C supply and the carbon stocktake. The demurrage fee should be charged uniformly, as a percentage of all 4C holdings, to minimize its impact on 4C holders. Charging the fee will require a re-organization of the 4C ledger by the CES.

Higher demurrage fees will likely correlate with greater climate risk and a higher 4C yield. An example would be when global warming triggers forest fires and results in a *force majeure* destruction of bio-sequestration projects. The annual demurrage fee (%) will, therefore, be a vital statistic that communicates the vulnerability of low-carbon projects to changing environmental and social conditions.

15.4.5 International Business Model

For political reasons, the CES may be required to franchise the 4C platform to "climate clubs," which are clubs of nations that are grouped by mutual interests (e.g., Sirkis et al., 2015). If this approach is followed, the central banks of each climate club will be required to coordinate their 4C monetary policy under the common rules of the CES. Climate clubs will be able to define their own 4C mitigation markets (i.e., by national borders); however, it is important that the assessment rules be based on international standards, and that the various 4C (i.e., of each climate club) are managed so that their exchange rates converge on a single exchange rate over time. The various 4C originating from each climate club will be openly traded in international markets.

The 4C platform should be designed to scale-up rapidly and encourage socioecological co-benefits. For example, the 4C platform should streamline feasibility reporting, certifiable valuations, and environmental/social impact assessments. These reports should assist actors in their efforts to attract financial capital and access bank loans. The platform should also support crowdfunding and socially responsible collaborations.

15.5 Discussion and Conclusions

The 1.5/2°C global warming limits of the Paris Agreement (UNFCCC, 2015) may be unachievable if global carbon emissions do not begin to fall by 2020 because of carbon lock-in (Unruh, 2002; Mission 2020, 2017). Overshooting 1.5/2°C might inspire efforts to ratchet-up Nationally Determined Contributions (NDCs) or, alternatively, it might create pessimism and weaken the NDCs (Young, 2016).

To address the carbon lock-in problem, Chen *et al.* (2017) revised the standard model for the external cost of carbon emissions with their hypothesis for the RCC. The RCC complements the conventional SCC, as shown in Eq. 15.2 and Fig. 15.1. The new model defines complementary market-based policies for correcting the market failure: (i) the orthodox policy of applying carbon taxes that, ideally, should approach the SCC; and (ii) the new policy of offering global carbon rewards that mirror the RCC.

The hypothesis of Chen *et al.* (2017) that supports the existence of the RCC needs to be verified and validated. Scientific validations may be attempted with experiments, computer simulations and field/pilot studies. If the RCC is shown to be inherently correct, then the implications for economic assessments and climate policy will be profound. A critical issue for policy makers is that under the Tinbergen rule (Tinbergen, 1952) each unique policy objective should be addressed with one policy tool; and so an effective response to the RCC will be to "internalize" the RCC into the economy with a dedicated tool. It is argued here that the ideal tool is the CBDC, called 4C. It is essential to note that 4C will be supplied as a reward for mitigation and it is not a carbon offset. In other words, the mass of CO_2 equivalent that is rewarded with 4C will be removed from carbon markets and will not be available for trading.

The RCC is directly relevant to Article 2 of the Paris Agreement by defining a target for limiting "*risks*" (UNFCCC, 2015). Parties to the Paris Agreement may wish to assess the RCC under Article 8, which seeks to enhance knowledge and understanding of comprehensive risk management. The most relevant topics relate to Sections 4 (a), (e), and (f), as follows:

(a) "*Early warning systems*" could include the "100-Year Advance 4C Price Alert," which is a public broadcast message that communicates the risk of dangerous-to-catastrophic climate change;
(e) "*Comprehensive risk assessment and management*" could include annual assessments of the RCC; and
(f) "*Risk insurance facilities, climate risk pooling and other insurance solutions*" could include the Global 4C policy as preventative global insurance and with the insurance premium covered by QE and currency trading.

The model for the SCC and RCC offers a doorway to new central bank remits that can limit climate risk and may inspire a new global risk management strategy:

> *"Climate risk management is in its infancy and not integrated into broader risk management frameworks, but this is likely to change as it moves up policymakers' agendas"* (PwC, 2017).

For central bankers, the take-home message is to look beyond market neutrality, green QE and conventional asset purchases, and to consider a new monetary policy for 4C trading—as explained in the "Avoiding Catastrophe" storyline—to break the "Tragedy of the Horizon" conundrum and resolve Carney's (2015, 2016) climate paradoxes. Resolution appears plausible by telegraphing future 4C prices to financial markets, because the resulting 4C bull market will convert tomorrow's risk into today's profits; and this will improve inter-generational equity.

What is special about the FinTech brief for the 4C platform (refer Section 15.4), is that it suggests that central bankers do not have to be burdened by carbon auditing and MRV. This technical work can be outsourced to the private sector under the auspices of a new international institution—the CES—which is needed to assess the RCC, set standards, and manage service agreements. The 4C platform should be designed to make full use of Blockchain technologies and open-source Blockchain standards for improved interconnectivity and to accelerate mass adoption (Maupin, 2017; Tapscott & Tapscott, 2017). It is anticipated that Blockchain ledgers will improve platform scalability, decentralization, security, accountability, and transparency. A governance model for 4C was not discussed in this chapter however a skeleton of a model is provided by Chen *et al.* (2017).

There is much to consider in this proposal. Central bankers and their governing bodies are in the driver's seat for this macroprudential policy that can address the climate systemic risk. The global 4C reward should be used to invite citizens and businesses of all nations to directly participate in a global transition, rather than committing billions of people to be spectators on a moving juggernaut. Given the enormity of the climate crisis, a brave decision is needed from central bankers and political leaders to pivot on the idea—and this is why:

> *"...the lions need to learn how to roar once again"* (PwC, 2017).

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Transforming Climate Finance and Green Investment with Blockchains

Edited by Alastair Marke

"The beauty of *Transforming Climate Finance and Green Investment with Blockchains* is that it brings together top experts from different backgrounds and presents a cohesive, considered and powerful exploration of blockchain's potential in tackling our planet's most pressing challenge. It is a must read for those of us involved in financing and putting resources into green investments, because it's clear that this technology has the potential to positively change the way we work, govern and collaborate in this space."—*Andrew Shaw, FMO, The Dutch Development Bank*

"Blockchain has become a catchword for disruptive innovation in a broad range of issue areas, including climate finance and investment. Frequently invoked and regularly misunderstood, however, this technology and its potential applications to climate change have so far lacked the authoritative scholarly analysis they deserve. By connecting some of the world's foremost experts on blockchain and the complex environmental challenges it could address, this new book fills an important gap."—*Michael Mehling, MIT Center for Energy and Environmental Policy Research*

"Blockchain technology has significant potential to increase confidence in asset ownership, improve transparency and enhance efficiency and effectiveness in support of the World Bank Group's goal to eradicate extreme poverty. We see interesting applications to accelerate decarbonization and broaden and deepen carbon markets through innovative solutions enabled by blockchain technology. This book is a valuable contribution to a debate which is starting to engage institutions, policy makers and practitioners."—*James Close, Director, Climate Change Group, World Bank*

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"Blockchains, or more broadly distributed ledger technologies, hold a great potential to spur innovation in a wide range of areas including peer-to-peer renewable energy trading, supply chain management, land titles, and climate finance and investments. *Transforming Climate Finance and Green Investment with Blockchains* can play an important role to raise awareness and to provide in depth academic insights on these emerging [exponential] technologies and their applications in the context of the urgent response needed to address climate change."—*Alexandre Gellert Paris, United Nations*

"No nonsense, hype-free, practical applications of how blockchain could completely transform the way we tackle climate finance. *Transforming Climate Finance and Green Investment with Blockchains* is a fascinating insight into how blockchain could revolutionise climate finance and can help to make this world a better place to live."—*Naseem Naqvi, British Blockchain Association*

"Digital ledger technologies offer the potential to transform the way we store, exchange, and record economic value and will develop over the same time period as the Sustainable Development Goals. This important book marks an early milestone in our understanding of how blockchain can play a role in confronting climate change, and will remain a key reference for policymakers to understand the potential this transformation will make possible."—*Darius Nassiry, Former Adviser to the Director-General of the Global Green Growth Institute*

Transforming Climate Finance and Green Investment with Blockchains establishes and analyzes the connection between this new technology and global efforts to combat climate change. Realizing the benefits of blockchain can only come through a variety of alterations: the adoption of smart contracts, for instance, changes in governance and regulatory structures, and global agreements on privacy issues. Each chapter contains a "problem statement" that describes the challenges blockchain technology can address. The first book of its kind, *Transforming Climate Finance and Green Investment with Blockchains* brings together original insights and opinions from experienced practitioners on a diverse range of practically relevant issues, helping readers understand blockchain technology and how it can accelerate the green economy.

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