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Blockchain: Proposition of a New and Sustainable Macroeconomic System

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Analyzing the potential of blockchain in combination with the concept of a circular economy, the results of this research project indicate that blockchain could promote sustainable solutions by (1) enhancing business models that contribute to resource efficiency, (2) enabling reliable resource tracking, (3) making resource pricing effective and executable, and (4) introducing complementary currency systems that give an incentive for sustainable behavior. Based on the results of this work, the foundations for a new and sustainable macroeconomic system are outlined.

Blockchain and the common good

In 2008, an individual or group under the pseudonym "Satoshi Nakamoto" published the paper "Bitcoin: A peer-to-peer electronic cash system", describing a protocol that enables the verification of digital assets through a "blockchain" (Nakamoto, 2008). The true innovation within this paper was the solution of the so-called double-spending problem. Before the publication of Nakamoto's paper, it was not possible to verify whether a digital asset had been replicated and spent multiple times. The newly introduced blockchain protocol, however, enabled the tracking of the sequence of a digital asset's ownership from the inception to the current owner and, thereby, made digital ownership reliable and unambiguous. Besides digital currencies, based on the

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blockchain protocol other applications are currently in development. In particular, the application of the blockchain technology in the areas of financial services, healthcare, smart contracts, and property identification seem promising.

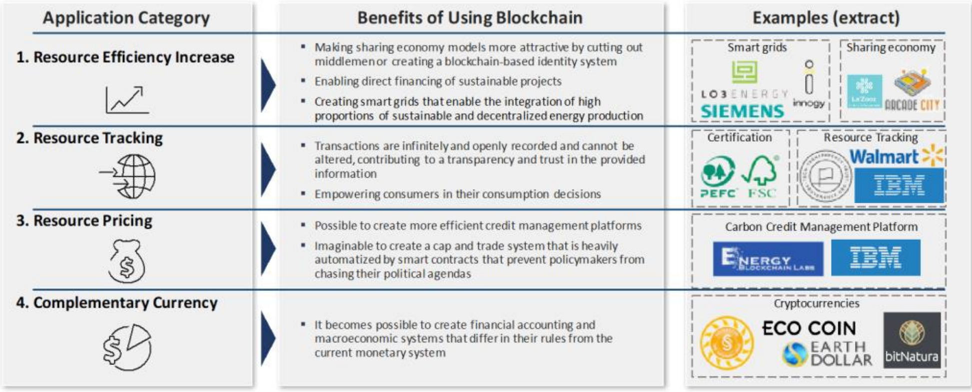
Interestingly, even state governments have begun to experiment with the blockchain technology. For example, Estonia as a leading e-government is using blockchain for health records, judicial and security purposes since 2012 (e-Estonia, n.d.). Dubai implemented a "Global Blockchain Council" to discover potential blockchain applications for the private and public sector in 2016 (Dubai Future Foundation, n.d.). In the same year, the UK Department of Work and Pensions started experimenting with blockchain-based welfare payments (Cellan-Jones, 2016). Even the United Nations has announced to provide legal identity for everybody as part of the UN 2030 Sustainable Development Goals (Irrera, 2017). According to a survey conducted by IBM, 90% of government organizations plan to invest in blockchain in 2018 (Kwang, 2017). Obviously, the public sector is starting to understand and assess the technology for policy applications. However, the way that blockchain could be applied to benefit the common good and, more precisely, its potential for achieving a more sustainable economy has not yet been analyzed.

Four blockchain applications promoting sustainability

Although blockchain is still in its technological infancy, it is rapidly being developed into mature applications and blockchain-based innovations might drive ecological and societal advancements in the near future. In the following, the possible contribution of blockchain to the creation of a sustainable economy is to be examined. In principle, four possible applications are imaginable: First, it is possible to apply blockchain in order to achieve efficiency increases. Second, blockchain can be used to track resources. Third, resource pricing systems, implemented through cap and trade or Pigovian taxes, could benefit from the use of blockchain. Fourth, complementary currency systems incentivizing individuals and corporations to act in a sustainable manner could be implemented. See Figure 1 for an overview of the different blockchain applications.

Figure 1

Blockchain applications for achieving sustainability



Application 1: Resource Efficiency Increase. Increasing overall efficiency through the application of blockchain is one of the technology's more basic possible impacts. One promising area is the electricity market, a highly complex sector with many middlemen and clearing mechanisms (Clancy, 2017). Blockchain exhibits the potential to cut out energy companies, energy traders, and payment providers, making the system less costly and more efficient (Hasse et al., 2015). In combination with smart meters, the blockchain system can be utilized to transmit payment transactions, record these tamper-proofed and control electricity flow and storage, thereby managing payment as well as energy flow via smart contracts deployed into a blockchain infrastructure. Furthermore, peer-to-peer (P-2-P) trading becomes feasible. Local energy producers, such as households using a photovoltaic system, are able to sell their energy directly to neighbors without any middlemen. Thus the flow of electricity can be directed more effectively to short-distance consumers, reducing energy transportation losses and the need for energy storage (Dabbs, 2017). Through this, an increase of systematic grid performance is to be expected and it has the potential to become an important cornerstone in the transition to sustainable electricity transformations, such as the German "energy transition" that aims to cover 60% of nation-wide energy consumption through renewables by 2050. Blockchain startups, such as GridSingularity, are currently developing DApps (Decentralized Applications) to enable such automated energy system. The relevance of such a vision is illustrated by the startup LO3's recent partnership with the German electricity infrastructure giant Siemens (Keane, 2017). Also, it becomes feasible to introduce "roaming" tariffs for the

anonymous and automatized charging of electric vehicles. Innogy SE, a subsidiary of the German electric utilities company RWE, is currently trailing blockchain-powered charging stations (Lielacher, 2017). From this vantage point, the application of blockchain to the Internet of Things (IoT), a network of smart devices, will not be far off. Apart from the electric market and IoT, the sharing economy can also become a great beneficiary of the blockchain technology. For instance, companies such as Uber or Airbnb may become dispensable, as the blockchain system allows two contractors or middlemen (P-2-P) to interact directly. In the case of decentralized car sharing, advantages are that drivers are empowered to work independently from a central institution like Uber while riders benefit from reduced prices. First decentralized car sharing startups, such as ArcadeCity or Lazooz, are working on developing DApps. Furthermore, a sustainable and fair economy can be supported by using blockchain-powered tools, such as crowdsourcing or P-2-P lending, to finance sustainable assets (e.g. through the blockchain startup Sun Exchange). All these blockchain applications support the transition to a more electrified, efficient and sustainable economy. However, fundamental ecological issues are not directly tackled.

Application 2: Resource Tracking. Blockchain technology allows the tracking of transactions and creates tamper-proof validation systems without the need of centralized authorities. Transactions are infinitely and openly recorded and cannot be altered, contributing to a transparency and trust in the provided information (Dabbs, 2017). These attributes make blockchain highly interesting for environmental groups. For instance, the PEFC forest certification organization is currently investigating whether blockchain can be used to track the origin of timber (Düdder & Ross, 2017). Also, in the for-profit sector promising solutions contributing to sustainability are presently being developed. For instance, the startup Provenance intends to design a blockchain system that is able to track all used materials, including the dimensions of quality, quantity and ownership, over the whole supply chain in real-time. Basically, Provenance is trying to achieve a digital passport for any product, which enables consumers and producers to track the whole production process (Provenance, 2015). Further, IBM in cooperation with a consortium of big food companies, such as Nestlé, Unilever and Walmart, has developed a trail based on Hyperledger blockchain technology, which follows a similar approach as Provenance with the goal of increasing food safety. The use of the technology establishes substantial trust in the supply chain and opens the possibility for real-time intervention (Lardinois, 2017). Thereby, it becomes possible to attach digital certifications, such as emission allowances or proof of origin records, to materials (Hasse et al., 2015). For example, BHP Billiton is partnering with Everledger to track the origins of diamonds to enhance compliance with regulations concerning “blood diamonds” (Clancy, 2017). Also, NASDAQ intends to introduce blockchain-powered solar energy certificates that can be sold anonymously via NASDAQ’s platform. Ensuring the validity of certificates and empowering consumers in their purchasing choice is a big step forward. If reliable information about the input and processing of products was available, the idea of a bottom-up push towards economic sustainability, as intended by de-growth movements, could become reality. If the idea of transparent supply chains became mainstream, no company could refuse to keep their supply chains in the dark. This may lead the economy to a better version, nevertheless the problem of an economy in the right scale cannot be reached with this blockchain application type alone.

Application 3: Resource Pricing. Blockchain provides several possibilities to establish a cap and trade system (a regulatory tool that typically comprises the issuance of a limited amount of use rights for a certain resource and the creation of a market to trade those rights). From a company-side perspective, it is possible to create efficient credit management platforms. For instance, IBM partnered with the company Energy-Blockchain Labs to develop a “Carbon Credit Management Platform” on the basis of the Hyperledger blockchain for the Chinese carbon market. According to Energy-Blockchain Labs, the application of blockchain makes cost reductions of up to 30 percent feasible (IBM, 2017). Other benefits of the application of blockchain and smart contracts are that transparency, auditability and credibility of the Chinese carbon market can be increased (Göß, 2017). Further applications, in particular on the side of regulators, are possible. The creation of an automatized cap and trade system regulated by smart contracts to prevent policymakers from chasing self-serving political agendas is becoming a highly conceivable idea. For instance, a system could be implement that automatically aligns the license creation, thus avoiding an over- or undersupply of certificates and thereby keeping market prices in a politically pre-defined range without the need of policy interventions. Other interesting combinations of blockchain and cap and trade systems have been proposed, such as a “Regulation by Reputation” in combination with a cap and trade system (D’Angelo, 2014).

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Even more interestingly, Edward Dodge is proposing an escrow mechanism on the basis of the blockchain technology (Dodge, 2015). In such a system, for every ton of CO_2 deposits have to be made, which would be recorded as a digital asset on a blockchain. Those funds are kept in escrow until the sequestering of a ton of CO_2, e.g., through reforestation or industrial carbon capture and sequestration (CCS) methods, is verified (ibid.). In theory, when all digital escrows have been claimed, all CO_2 emissions produced during the existence of the escrow mechanism would have been absorbed. The benefit of such a system is its global effectiveness. Whereas current cap and trade systems solely punish "bad" behavior, this system also monetizes "good" behavior and competition for the escrowed resources would result in concentrated actions to save the environment. Generated funds flow directly and only into activities that counter the emissions – even across borders, which would also directly encourage participation of developing countries. It is a fair system, as those producing CO_2 have to bear the financial burden and those caring for the environment would benefit. Advantages of using blockchain are clear; the use of blockchain is cost-effective, transparent and auditing measures can be implemented into the protocol, making monitoring and enforcement easier (ibid.). Through the application of blockchain oracles (data feeds that verify real-world occurrences), the fulfillment of CO_2 reducing activities could be verified in an objective and decentralized manner. Furthermore, a decentralized and thus depoliticized system would substantially facilitate international cooperation between political actors and it would become easier to negotiate and agree on a carbon pricing system of global scale. Of course, practical issues of fraud, geopolitics, and the implications of large amounts of frozen assets on the escrow need further assessment. Nevertheless, the benefits of a blockchain escrow mechanism are obvious. The concept resembles (offline) deposit-refund systems that are already implemented for PET-bottles and beverage cans in some states, such as Sweden or Germany. With blockchain it might become possible to digitalize and implement more sophisticated systems (e.g. on consumer electronics or plastic). When supply-chain tracking applications become market-ready (see Application 2), it will be even possible to determine the deposit value on the basis of the materials used. The advantage of such an extended deposit-refund systems is that real-time monitoring becomes feasible, illegal dumping is disincentivized, and cost evasion is made difficult (Walls, 2011). Thus, blockchain could become an important tool for establishing an effective economy in the right scale.

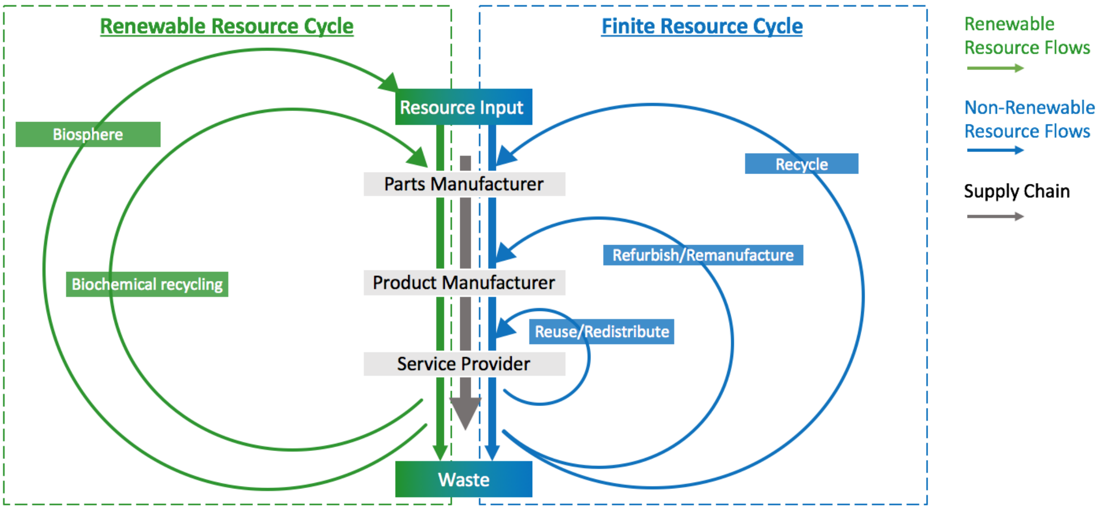
Application 4: Complementary Currency. Compared to the previously described blockchain applications, the introduction of cryptocurrencies aiming at incentivizing sustainable behavior seems less tangible. Those at sustainability aiming cryptocurrencies in general do not intend to replace, but to complement conventional fiat currencies. There are several approaches in development, mostly based on the blockchain solution Ethereum, to implement cryptocurrencies with an ecologically-driven mission statement. EcoCoin, for example, envisions a community-based cryptocurrency, in which the EcoCoin community decides "case by case" what is worth supporting and what can be bought with EcoCoins. The hope is that thereby ecological and sustainable trading is supported. Another example is SolarCoin, which essentially is a point scheme, similar to air-miles, that rewards the production of solar electricity. However, the ecological impact of such a point system can only be limited. On the contrary, EarthDollar aims at changing the whole economic system. For instance, it intends to support Natural Capital Accounting (NCA) instead of conventional financial accounting. Furthermore, it aims to solve "problems like world hunger, sustainable energy, poverty, and climate injustice" (Earth Dollar, n.d.). However, how this is supposed to be achieved by introducing a cryptocurrency, is not elaborated any further. EarthDollar also states, "We do not in any way impose our values on anyone. We just offer people an alternative choice" (ibid.). This highlights the main issue of all such newly implemented cryptocurrencies: the question of intrinsic value. While big cryptocurrencies, such as Bitcoin, can provide value by having achieved network effects and broad acceptance, this is probably not achievable for the hundreds of newly created cryptocurrencies. Some solutions, such as the cryptocurrency bitNatura, try to answer this question by backing the currency with real assets. Nevertheless, the question arises why anybody should substitute fiat money for cryptocurrencies that promote sustainability. Current models cannot answer this question convincingly, but rather rely on the argument that people will participate due to philanthropic motives. So far, only sustainability-driven cryptocurrency that follow a bottom-up-sustainability approach are in existence. But what about cryptocurrencies following a top-down sustainability approach?

The foundations of a new macroeconomic system?

The following paragraph discusses the concept of a government-backed, complementary cryptocurrency system that aims at fixing systematic shortcomings of the current financial system. The introduction of a government-backed cryptocurrency would generate instant acceptance through the states' sovereignty. Despite all criticism, the current financial system has its rationales. It is an incentive system that greatly promotes efficiency. However, the current economic system does not take into account the depreciation of natural capital. A complementary currency could be a chance to complement the current, for efficiency striving, financial system with an incentive system for sustainability. Thus, the logic of the current financial and economic system could be altered in a way that efficiency, as well as sustainability, are promoted at the same time. How could such a system look like? Based on the blockchain technology, it is imaginable to create a macroeconomic incentive system that promotes the transformation to a circular economy. The conventional economic system draws raw materials from nature, transforms these into products, and in the end, disposes these products in nature (Ellen MacArthur Foundation et al., 2015). This "take-make-dispose" model is called a linear economic model and is criticized for its resource wastage. While the linear model can incorporate recycling, materials in such a system have not been designed for reuse or regeneration, resulting in significant material degradation and accumulation of waste in the environment. In contrast, the circular model envisions a waste-free system and aims for eco-effectiveness. The aim is to establish an economy, which functions in loops and maintains materials ecological value over time. This concept is also called a "gradle-to-gradle" economy (McDonough & Braungart, 2010). To devise such an economy, it is necessary to generally think of the economy in circular systems and products have to be designed in a way that allows them to re-enter the economic cycle after being disposed of. In a cyclical economy, it can be distinguished between technical and biological components (ibid.). Technical components must be constructed so that they can be easily recovered or upgraded. For instance, the production of washing machines could follow modular concepts so that parts can be replaced or updated easily and the economy should shift increasingly from selling products towards offering product services. Biological components must be composed of non-toxic elements, which can be easily returned to nature through biologic degradation. For instance, any packaging should be manufactured from materials that are compostable or can be fully recycled for the production of other products (see Figure 2).

Figure 2

Schematic illustration of resource flows in a circular economy[1]



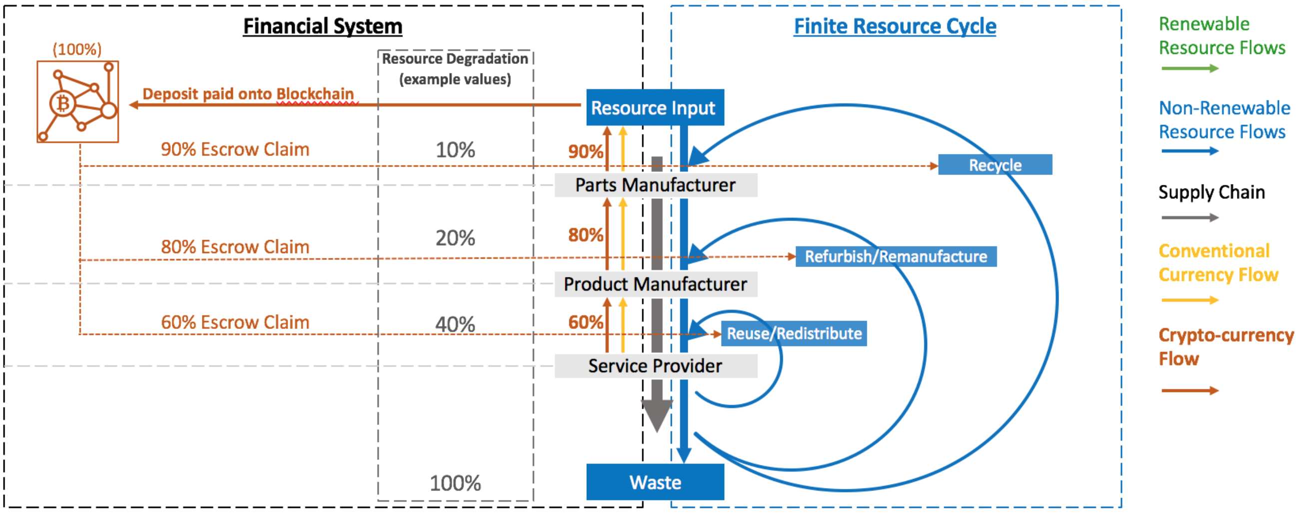
As a result of blockchain technology, it will be generally feasible to track resources in the future (see Application 2). Thus, it will become possible to unambiguously identify a product's input materials, including the material's quantity, quality and origin. Also, information regarding a product's biological or technical components could be tracked on a blockchain. Based on this knowledge, a sophisticated cap and trade system for resources could be implemented (see Application 3). The system would need to distinguish between natural and technical resources. Technical components would always be object to the cap and trade system. The levied prices for the use of technical resources could be adjusted to the ecological severity of the specific material. For instance, a ton of plastic could be object to higher taxes than a ton of sandstone. Furthermore, based on a blockchain-based system, which is able to track product attributes, it would be possible to adjust the tax according to the level of material degradation. For instance, a high-quality plastic producer that produces recyclable products would not be affected by the tax, as no degradation of material would occur. Contrary, when material is degraded by a producer, this would be recorded and a smart contract would trigger the resource tax. Thus, a cap and trade system in cascades that directly incentivizes the transformation towards a circular economy model would be established. Natural resources would be exempted from the system, if they can be safely disposed of in nature without any ecological concerns. If natural resources do not fulfill this aspect, the producer (or importer) would need to acquire digital resource certificates.

Based on the blockchain technology, it is imaginable to create a macroeconomic incentive system that promotes the transformation to a circular economy.

One step further, this cap and trade system could be enhanced by a blockchain-based escrow mechanism (see Figure 3). Thereby, individuals or corporations that care for the environment (e.g. by collecting plastic) would receive a direct financial benefit. Due to the government-backing, the value of claimed escrows would remain stable, thus fulfilling the characteristics of money as unit of account, store of value and medium of account. A financial system would have been created taking into account the logic of natural capital. Furthermore, a system such as this could alter fundamental financial principles. For instance, a demurrage could be introduced that would create a fundamental incentive for a transformation of the economic system from short-term towards long-term orientation (Lietaer, 2007). Moreover, the antagonistic relationship between financial value and ecological value would be mitigated in such a system.

Figure 3

Blockchain-based financial system promoting sustainability



All these processes would be automatized and controlled by blockchain-based smart contracts in the background. Thus, after the system has been established once, the system would neither increase transaction costs of an economy nor hinder trade. Certainly, there are other drawbacks and practical difficulties. For instance, the synchronization between digital and real world could be difficult. However, technical solutions, such as oracles, are already in development to counter those issues. Furthermore, in practice one would probably have to implement not only one single national cryptocurrency, but different national cryptocurrencies for every resource type. Nevertheless, first startups aiming to mitigate these types of issues are already evolving. For instance, the startup Bancor is developing a reserve cryptocurrency that enables the frictionless exchange of various tokens. Many more issues of practical and theoretical nature may arise, but the enormous potential of creating a government-backed national cryptocurrency may make this undertaking worth the challenge.

The blockchain technology is developing rapidly and in different directions as demonstrated by recent developments, such as Hyperledger, Ethereum or Bancor. Further innovative applications promoting a sustainable economy might evolve in the near future. Therefore, this work can only provide a snapshot of current developments in the blockchain space. Also, this work concentrated on giving an overview on an economic level. Further research has to be conducted on a technical level to prove the feasibility of the discussed concepts.

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[1] Based on Ellen MacArthur Foundation et al., 2015.