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Article — Published Version

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Development Policy Review

Provided in Cooperation with:

John Wiley & Sons

Suggested Citation: Chen, Yushi; Volz, Ulrich (2022) : Scaling up sustainable investment through blockchain-based project bonds, Development Policy Review, ISSN 1467-7679, Wiley, Hoboken, NJ, Vol. 40, Iss. 3, <https://doi.org/10.1111/dpr.12582>

This Version is available at:

<https://hdl.handle.net/10419/287886>

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ARTICLE

Scaling up sustainable investment through blockchain-based project bonds

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Summary

Motivation: Most low- and middle-income countries face an urgent need to scale up sustainable finance for low-carbon and climate-resilient infrastructure investment, yet underdeveloped capital markets tend to inhibit domestic resource mobilization for infrastructure investment. At the same time, domestic savers face a scarcity of “safe” local-currency assets, resulting in the export of capital.

Purpose: This article explores options for mobilizing domestic savings through financial technology (fintech) solutions to scale up sustainable investment.

Methods and approach: The article discusses how fintech can help to complement conventional capital markets and mobilize financial resources for sustainable infrastructure investments.

Findings: The article puts forward a proposal for blockchain-based project bonds to raise finance through a digital crowdfunding platform which is able to record transparently and certify the use of proceeds, sustainability impact, and revenue streams of projects by combining timestamp, public and private key mechanisms, and smart contract technologies.

Policy implications: The proposed approach would not only provide investors of different sizes with the opportunity to purchase local-currency assets and issuers such as municipalities to raise funds for sustainable infrastructure investment, it would also facilitate project management once the project is operational, for example through metering and billing, and create full transparency over the life cycle of the investment, reducing problems concerning the misuse of funds.

KEYWORDS

blockchain, fintech, sustainable investment

1 | INTRODUCTION

Countries all over the world are facing an urgent need to scale up their investments in sustainable infrastructure, including renewable energy infrastructure, to foster a low-carbon transition and to align their economies with the Paris Agreement and the 2030 Agenda. The International Monetary Fund (IMF) recently estimated the additional

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need for annual public investment in infrastructure, low-carbon technologies, and other areas to achieve the Sustainable Development Goals (SDGs) to be more than USD 20 trillion over the next two decades (IMF, 2020). Especially in the Global South, finance is a key challenge to the achievement of these investments. Although the international discourse on financing for development—under the catchy slogan “from billions to trillions”—has highlighted the need to unlock domestic resources, much of the discussion has centred on incentivizing private capital from high-income countries to finance investment in low- and middle-income countries (L&MICs). While foreign aid and foreign private capital can play an important role in financing development, it is important to acknowledge the limits to the role of foreign investment in financing infrastructure and the financial vulnerability risks associated with foreign lending. It is also important to make better use of domestic savings in L&MICs, many of which invest significant amounts of their savings in low-yielding assets in the financial centres of high-income countries. Strengthening domestic resource mobilization is therefore crucial, and concerted efforts to this effect are necessary. Besides the mobilization of finance, a central problem regarding infrastructure investment is corruption. The IMF (2020, p. 1) estimated that “one-third of funds for public infrastructure is lost worldwide to inefficiencies.” It is hence crucial to identify ways to reduce this slack if not to eliminate it.

Against this backdrop, this article will discuss how financial technologies—or fintech—and blockchain-based solutions can facilitate domestic resource mobilization for sustainable investments and at the same time improve the implementation of infrastructure projects throughout the entire life cycle by facilitating processes and enhancing transparency. In particular, the article explores how fintech can help to complement conventional capital markets and mobilize financial resources for sustainable infrastructure investments. It proposes blockchain-based project bonds to raise finance through a digital crowdfunding platform, which is also able to record transparently and certify the use of proceeds, sustainability impact, and revenue streams of projects by combining timestamp, public, and private key mechanisms, and smart contract technologies. This approach would not only provide investors of different sizes with the opportunity to purchase local-currency assets and issuers such as municipalities to raise funds for sustainable infrastructure investment. It would also facilitate project management once the project is operational, for example through metering and billing, and create full transparency across the life cycle of the investment, reducing problems involving the misuse of funds.

The structure of the remainder of the article is as follows. Section 2 discusses the requirement to scale up domestic resources for the necessary investment in low-carbon sustainable infrastructure and to meet other sustainable investment needs. It also examines the problems facing low- and middle-income countries in mobilizing these resources locally for domestic investment. Section 3 then reviews the solutions for raising local savings and enhancing sustainable investment that fintech applications make possible, paying particular attention to blockchain solutions. Subsequently, Section 4 puts forward a proposal for an integrated blockchain-based fintech solution. Section 5 concludes.

2 | DOMESTIC RESOURCE MOBILIZATION FOR SUSTAINABLE DEVELOPMENT

The IMF (2020) estimated the additional annual public investment needs in infrastructure, low-carbon technologies, and other areas to achieve the SDGs to be 1.3% of the world GDP (Figure 1). Over the period 2020–2040, the estimated additional investment needs would exceed USD 20 trillion in current US dollars. To scale up finance for the SDGs, multilateral development banks (MDBs) have advanced the “billions to trillions” agenda to “unlock, leverage, and catalyze private flows and domestic resources” (African Development Bank et al., 2015, p. 2). The idea is to use official development assistance, or “blended finance,” to mobilize private capital for investment in sustainable development.

Critics of blended finance have voiced concerns about the financial stability risks associated with “the escorting of international capital by multilateral development agencies into frontier and emerging market settings” (Carroll &

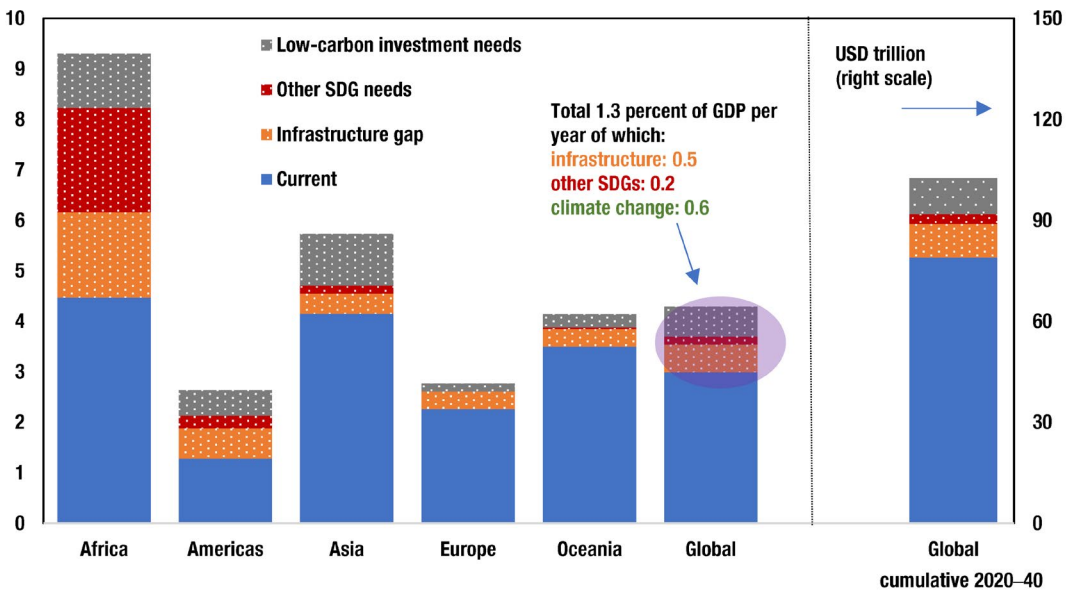


FIGURE 1 Global investment needs for infrastructure, climate change, and other SDGs (percentage of annual regional GDP; trillions of US dollars, right scale)

Note: The blue bars show the current investment levels across regions as of the end of 2017. The estimates for additional global investment needs are, on average, 1.3% of the global GDP per year during the period 2020–2040 (exceeding USD 20 trillion in current US dollars) and comprise infrastructure (0.5% of GDP), other SDGs (0.2% of GDP), and low-carbon investment (0.6% of GDP). The right panel shows the cumulative investment needs in trillions of US dollars (constant 2019 prices and exchange rates) over the next two decades. SDGs = Sustainable Development Goals.

Source: IMF (2020, p.29). The source publication drew on data from Global Infrastructure Hub, Oxford Economics, and IMF staff estimates.

Jarvis, 2014, p. 540). A fundamental problem of initiatives aiming to leverage private investment by “de-risking” is that the risk itself does not disappear but merely shifts to public balance sheets (Mazzucato et al., 2018). In particular, critics have raised concerns that issues concerning the “complexity, accountability and transparency” of blended finance (Mawdsley, 2018, p. 194) and the growing risks of related financial innovation and over-financialization in low- and middle-income countries (Akyüz, 2017) may contribute to debt crises. Financial stability risks may also arise from the fact that both development finance institutions and private financiers usually provide finance only in international currency, which leaves borrowers with foreign exchange risk.¹ The United Nations Conference on Trade and Development (UNCTAD) stated that “the focus of the development finance agenda on complex – and mostly non-transparent – new financial instruments and on securitized finance, does not bode well for its ability to deliver reliable financing at the required scale to where it is most needed” (UNCTAD, 2019, p. viii).

Instead of trying to lure international capital for blended finance solutions—which has not been very successful to date, as the small volumes and low leverage ratios reflect (Attridge & Eigen, 2019)—efforts should concentrate more on mobilizing domestic resources without creating complex financial structures. While foreign capital in the form of direct investment or foreign aid has played a role in the economic development of many countries, historically no economy has developed its infrastructure and financed its development primarily through foreign finance. Mobilizing domestic savings for local investments is hence a crucial part of economic development. The good news is that, for many countries, especially middle-income countries, domestic savings are not the main bottleneck.

¹For a discussion of the shortcomings of blended finance in leveraging private capital, see Attridge and Engen (2019).

In fact, many low-and middle-income countries, especially in Asia, are net capital exporters, as reflected in their current account surpluses. Even countries that do not record current account surpluses tend to invest parts of their savings at low or negative returns in the financial centres of high-income countries, only for these countries to reinvest them in their home countries, typically at higher returns, which then benefit the foreign investors. This phenomenon is known as round-tripping of capital. There are different reasons for investing domestic savings abroad, including macroeconomic instability at home, international portfolio diversification, and tax evasion. Two important reasons to invest savings abroad (which motivate this article) are the better financial services abroad and the lack of safe financial assets in the domestic economy due to underdeveloped capital markets.

The reliance on foreign currency borrowing to finance domestic investment has been associated with two major problems: currency mismatches and maturity mismatches (Goldstein & Turner, 2004). Financing long-term projects that yield returns in domestic currency with short-term foreign-currency credit creates financial vulnerabilities that can contribute to financial crises. The currency crisis literature has highlighted the importance of developing local-currency bond markets to overcome “original sin”—the problem that most emerging markets in the past were unable to borrow in domestic currency, even domestically (Eichengreen et al., 2003)—and avoid the financial vulnerabilities associated with currency mismatches (Burger & Warnock, 2006, 2007; Burger et al., 2012).

Since the emerging market crises of the late 1990s and early 2000s, countries have made progress in developing local-currency bond markets (Berensmann et al., 2015; Burger et al. 2012; Dafe et al., 2018). Nevertheless, these are in part still highly dependent on foreign investors. The large-scale withdrawal of international capital from emerging economies’ bond markets in March 2020 has once again highlighted the vulnerabilities associated with a shallow domestic investor base and heavy reliance on international portfolio investors (Beirne, Renzhi, Sugandi, & Volz, 2021; Beirne, Renzhi, & Volz, 2021; Hofmann et al., 2020). There is clearly a need to develop local-currency capital markets further with a strong domestic investor base. Can fintech help by mobilizing domestic savings and channelling them into sustainable investments?

3 | FINTECH SOLUTIONS TO ENHANCE SUSTAINABLE INVESTMENT

3.1 | Current state of debate

Emerging financial technology has already had significant impact on financial development and holds great potential to advance the sustainable finance agenda (Chishti & Barberis, 2016; Jeucken, 2010). The G20 Sustainable Finance Study Group highlighted the emerging practice of applying digital technologies to sustainable finance (G20 SFSG, 2018). As shown in Figure 2, the Sustainable Digital Finance Alliance (SDFA) identified several challenges to connecting the financial sector with the real economy and highlighted the potential of digital finance for improving information and efficiency in the financial sector through better systems and data and for fostering inclusion and innovation in the real economy by broadening sustainability choices and providing new sources of finance. It is possible to develop and apply digital technologies to leverage sustainable finance by facilitating better use of sustainability-related data for financial decision-making and by supporting nascent business models by enabling better access to funding. Digital finance can help to address the barriers that limit the scalability of sustainable finance, such as asymmetrical information between investors and other stakeholders and the lack of local community power. Consequently, digital finance can help to promote goals such as financial inclusion and energy justice, which are key issues in the sustainable transition (Aboushady & Gowaid, 2019; Arner et al., 2020; Demirgüç-Kunt et al., 2018; Volz et al., 2020).

The UN Secretary-General’s Task Force on Digital Financing of the SDGs recently emphasized the development of financial inclusion into citizen-centric finance as one of the transformational opportunities that digitalization offers (DFTF, 2020). Citizen-centric finance is not only about the financial return but also represents an aggregation of influence through different channels and organizations (DFTF, 2020).

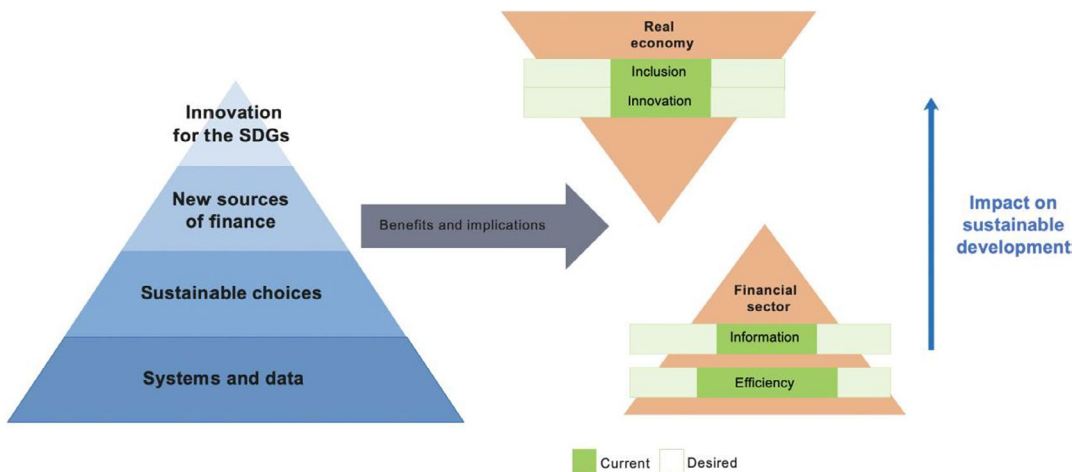


FIGURE 2 Implications of digital finance for sustainable development

Source: Authors' compilation based on Sustainable Digital Finance Alliance (2018).

Fintech or digital finance is a business approach dedicated to making financial services more efficient through internet-related technologies. Normally, fintech companies play two roles in the financial sector. One is as a challenger of traditional financial institutions, in which these fintech companies rely on algorithms or machine-based logic to replicate the back-office processes of traditional financial institutions and generate new technology-based business models. The other is as a pioneer in providing services in places where there is no traditional financial infrastructure, for example through mobile banking and other internet-based automated information platforms. Fintech comprises different applications, including lending, blockchain/crypto, regulatory technology (regtech), personal finance, payment service/billing, insurance, capital market solutions, wealth management, money transfer/remittances, and mortgage/real estate financing (Table 1).

Countries have developed mobile banking further to provide investment opportunities in capital markets for people who previous had neither the means nor the expertise and access to invest in securities. For instance, the M-Akiba project is a mobile-based fintech solution that the Government of Kenya has developed. The scheme focuses on local, small-scale, individual investors and engages them to raise funds for national building (National Treasury, n.d.). In a similar project in Kenya, called Treasury Mobile Direct (TMD), the Central Bank of Kenya enabled users to buy treasury bills and bonds on their phone (Central Bank of Kenya, n.d.). However, the value of these bonds and bills is questionable due to the abuse of government power in adjusting interest rates and potentially associated multiple transaction costs (Suri et al., 2018). Neither M-Akiba nor TMD are based on blockchain, a digital ledger that allows the recording of each party's digital property rights and curbs corruption (Kshetri & Voas, 2018).

Digital crowdfunding platforms can offer new solutions for personal finance and wealth management. For instance, digital crowdfunding platforms can mobilize financial power and accumulate local resources (Schwienbacher & Larralde, 2012). Belleflamme et al. (2015) classified crowdfunding into two groups: investment-based crowdfunding (financial-based crowdfunding) and reward- and donation-based crowdfunding (non-financial-based crowdfunding). The first category includes equity-based, royalties-based, and loan-based crowdfunding, in which the funders are investors in the campaign and may receive monetary gains through the growth of the company or based on the interest rate. In the second category, funders cannot expect to receive monetary compensation. They fund the campaign because they obtained the product or because they supported the purpose (or a combination of the two).

TABLE 1 Overview of fintech solutions

Fintech category	Examples
Lending solutions	Online marketplace lending and alternative underwriting platforms such as peer-to-peer lending platforms and digital crowdfunding platforms
Blockchain/crypto	Companies leveraging blockchain technologies for financial services
Regtech	Audit, risk, and regulatory compliance software
Personal finance	Tools to manage bills and track personal and/or credit accounts
Payment service/billing	Payment processing, payment transferring, card developers, and subscription billing software tools (a major function of mobile banking)
Insurance solutions	Online insurance services or data analytics and software for (re)insurers
Capital market solutions	Sales and trading, analysis, and infrastructure tools for financial institutions
Wealth management	Investment and wealth management platforms and analytical tools
Money transfer/remittances	International money transfer and tracking software
Mortgage/real estate financing	Mortgage lending and financing platforms

Source: Authors' compilation drawing from CB Insights (2019).

3.2 | Blockchain

3.2.1 | Technical features and added value of blockchain

Blockchain is an emerging technology that has attracted great attention from financial institutions, energy companies, technical developers, national governments, and academia (Hughes et al., 2019). Blockchain technology, which relies on distributed ledger technology (DLT), provides an encrypted, tamper-proof, and transparent system that can implement innovative business solutions by integrating or disrupting different business models. Zheng et al. (2018) summarized blockchain in four key characteristics, namely decentralization, network persistency, anonymity, and audibility. They also highlighted three challenges: scalability, privacy leakage, and selfish mining. Several reports, including Galen et al. (2018), World Economic Forum (2018), and Organisation for Economic Co-operation and Development (OECD) (2019), maintained that blockchain has the potential to bring significant innovation that can support the low-carbon transition.

DLT usually relies on a peer-to-peer (P2P) architecture with broadcast capabilities, recording transactions simultaneously in multiple locations. Generally, DLT systems allow computers to exchange information directly without going through a central server or an authorized institution (Lawrenz et al., 2019). The best-known DLT technology is blockchain, which usually uses a specific structure consisting of a chain of data blocks. People often use "blockchain" and "DLT" interchangeably.

3.2.2 | Blockchain applications in financial markets

In 2018, the World Bank launched a new type of bond, called bond-*i*, which is a blockchain-operated new debt instrument. The bond raised USD 100 million with a two-year maturity and a triple-A rating (Klopfer, 2018). In 2019, the World Bank raised an additional AUD 50 million and expanded the market participation with the bond-*i* platform (Reichelt, 2019). The purpose of this bond is to exploit the potential of disruptive technology for faster, more efficient, and more secure transactions. It should be mentioned, however, that bond-*i* was not an end-to-end digital bond. Neither the coupon payments nor the proof-of-impact reporting was digitized. The payments happened off-chain, hence not leveraging digital assets.

It is not only high-income countries that are leveraging blockchain for bond development; emerging market players are also exploring this niche market. BMT Bina Ummah, an Indonesian Islamic microfinance cooperative, raised IDR 710 million (USD 50,000) through the world's first issuance of Islamic bonds on a public blockchain (Gonçalves, 2019). In Thailand, the Public Debt Management Office sold THB 200 million saving bonds through Krungthai Bank's blockchain-based e-wallet system to engage retail investors in the market (Bank of Thailand, 2020).

Blockchain can play an important role in the green bond market. In the conventional bond market, it is hard for multiple stakeholders to monitor the flow of money, obtain or provide updates on the development status in real time, or demonstrate the impacts of green bonds (Banga, 2019). The use of blockchain in the green bond market could help to enhance system transparency and capital traceability. The Sustainable Digital Finance Alliance and HSBC (2019) indicated three directions for combining blockchain technology and the green bond market:

1. Building a blockchain-supported bond issuance platform, which could digitalize the whole bond-issuing process. This includes utilizing stablecoins—a digital form of money (or cryptocurrency) which is typically pegged to fiat money—for automatic settlement and payment to investors and for setting transparent nodes for supervision.²
2. Converting the manual reporting into data tokens, enabling investors to communicate in real time and establish a shared asset history on the ledger for the project aggregation.
3. Providing a “bond-as-a-service” platform to enlarge the local community bond market. This means that people can create their green bonds at low cost in the blockchain system and provide them in certain markets through security tokens. This would allow smaller entities (such as medium-sized companies or communities) to issue green bonds directly without the need for banks to provide expensive full services.

Apart from the traditional bond market, DLT is applicable as a new format of crowdfunding. Several studies have argued that blockchain has the potential to bring significant innovation to the crowdfunding sector and enhance financial inclusion (Muneeza et al., 2018; Zhu & Zhou, 2016). Blockchain technology provides a distributed, tamper-proof, and encrypted system that can disrupt the traditional model of crowdfunding (Hartmann et al., 2019). For example, it could be possible to back renewable energy assets as cryptocurrencies.

Blockchain-based crowdfunding activities have similarities to conventional crowdfunding models but conceptualize the monetary value in token form, such as Initial Cryptoasset Offerings (ICOs) and Security Token Offerings (STOs) (Ackermann et al., 2020). There are three types of blockchain-based crowdfunding models: utility token, payment token, and investment token (Howell et al., 2018). Utility tokens are the inherent carriers of value on the platform, protocol, or network that network participants need to hold to engage or access the products or services that the platform, protocol, or network provides (Hartmann et al., 2019). Utility token sales are similar to traditional reward-based crowdfunding models. Investment tokens such as security tokens bear more similarities to conventional equity-based crowdfunding. Payment tokens are similar to fiat money, especially in terms of stablecoins, which are typically pegged to fiat money.

Blockchain uses smart contracts to automate transactions and enhance reliability and efficiency (Peters & Panayi, 2016). The code, which aims to list and add conditions on every possible transaction, can embed the legal elements (Clack et al., 2016). Transactions will happen automatically when all the network participants have agreed to the set terms. Studies have argued that a large portion of the population can benefit from blockchain technologies, especially in L&MICs (Kshetri & Voas, 2018). With the increasing affordability and usability of smartphones, blockchain can offer a better value proposition because of typically weak rules, laws, regulations and enforcement in developing countries and regions (Kshetri & Voas, 2018).

²A stablecoin could be a digital currency issued by a central bank.

In an interesting case study from the Yale Open Innovation Lab, blockchain initiated the financing of a decentralized energy resource (DER) platform called OpenSolar (Wainstein, 2019). OpenSolar is a security-based (lending and equity) crowdfunding platform. Unlike a traditional public-private partnership project (which locks users or “off-takers” into a long-term payment agreement without final ownership), the project allows people to own the DERs in real time. Thus, they can participate in the local energy economy as co-owners of community-based microgrids. However, the scalability of such projects is still an issue. Other channels are necessary to scale up such projects, such as offering user-friendly applications to mobilize finance for infrastructure projects. For instance, mobile phone applications—such as those that M-Akiba or TMD use—could help to provide an investment opportunity for people to buy these assets and a platform for people to invest in rights to benefit from the local energy infrastructure.

3.2.3 | Blockchain applications in industries

In the context of energy, climate, and the environment, blockchain applications in the energy industry mainly include the following: (1) cryptocurrencies for funding renewable energy projects; (2) metering, billing, and security; (3) decentralized energy trading; (4) green certificates and carbon trading; (5) grid management; (6) internet of things (IoT),³ smart devices, automation, and asset management; (7) electric e-mobility; and (8) general-purpose initiatives developing underpinning technology (Andoni et al., 2019).

In the context of decentralized energy trading schemes, several applications are in the early stages of development: wholesale energy trading, energy trading support for small generators and end-consumers, energy trading for utilities and energy system stakeholders, and P2P trading in community projects and microgrids (Andoni et al., 2019). Although the scale of their adoption is limited at this stage, these applications have the potential to create radical changes that would disrupt the incumbent business model of energy suppliers or grid operators that have the monopoly power or own the physical infrastructure. The potential impact of emerging localized or community-based energy systems on the mainstream energy system, and the role of blockchain in this transition, remains to be seen. The way in which blockchain interacts with regulation, policy, and markets to fulfil certain promises for end users needs further investigation.

Blockchain is able to connect the energy and financial systems. For example, blockchain could finance local energy projects and, in the subsequent operational phase of the utility, work with IoT to collect metering and billing data, ensuring the certification of origin. In the following, we develop a proposal that combines different fintech- and blockchain-based approaches that countries could employ to mobilize domestic savings to finance and operate local energy projects.

4 | A PROPOSAL FOR A BLOCKCHAIN-BASED BOND FOR SUSTAINABLE INVESTMENTS

We propose a comprehensive blockchain-based approach that integrates multiple fintech applications to mobilize domestic financing for sustainable infrastructure investment. The approach should account for the interests of the various stakeholders involved, including local residents, public policy, multiple investors, and possibly international development agencies. Table 2 provides an overview of the likely interests of these stakeholders.

Our proposal would address these stakeholder interests. Moreover, it would help to tackle major concerns in the three key phases of an infrastructure project's life cycle: the inception and fundraising phase, the realization phase, and the operation phase (Figure 3). First, in the inception and fundraising phase, blockchain applies the

³The IoT refers to physical devices that are embedded with sensors, software and other technologies that are connected to digital communications networks through which data are exchanged with other devices and systems.

TABLE 2 Main interests of stakeholders

<p>From a Public Policy Perspective</p> <p>Investment in sustainable infrastructure to support local development</p> <ul style="list-style-type: none"> • Deliver and operate infrastructure utilities at low cost, with a reliable revenue stream • Favourable financing conditions • Raise long-term project finance in the domestic currency and avoid currency and maturity mismatches • Low interest rates <p>Financial-sector development and reduction of financial instability risk</p> <ul style="list-style-type: none"> • Strengthen domestic local-currency bond markets • Strengthen the local investor base • Broaden opportunities for investing domestic savings in safe assets <p>Strengthen accountability and “good governance”</p> <ul style="list-style-type: none"> • Strengthen the transparency of the use of proceeds and reduce corruption problems
<p>From an Investor Perspective</p> <p>Investment opportunity in “safe assets” (i.e. low risk of default)</p> <p>User-friendly investment process</p> <p>Easy access, even for small amounts for retail investors</p> <p>Aggregation of small-sized projects for institutional investors</p> <p>Sustainability-driven projects that qualify as impact investment</p> <p>Institutional quality/good governance practice</p> <p>Enhanced information transparency</p> <p>Credible proof-of-impact reporting via automation and lower risk of greenwashing</p>
<p>From a Local Resident Perspective</p> <p>Investment in sustainable infrastructure to support local development</p> <p>Access to quality infrastructure services at low cost</p> <p>No negative environmental externalities</p> <p>Positive local employment effects</p> <p>Return on investment to locals</p>
<p>From a Development Agency Perspective (if applicable)</p> <p>Support sustainable infrastructure development</p> <p>Promote access to affordable energy, water, etc.</p> <p>Promote “good governance”/anti-corruption efforts</p> <p>Support domestic financial market development</p>

Source: Authors' compilation.

crowdfunding logic to mobilize domestic savings for investment in the domestic local-currency bond currency market. The ledger can record the ownership structure to ensure customers' user rights. As the above cases show, fintech applications, such as M-Akiba and TMD, could be used to mobilize local savings for the domestic bond or bill market, allowing for small-size investments through easy-to-use online applications. However, transparency concerns and inflexible investment methods can hold back investments. Applying smart contracts can reduce problems of asymmetric information risk. By applying blockchain technologies, such as timestamp,⁴ as well as public and private key mechanisms,⁵ the bond-issuing entity can record the bond issuance, registration, and certification information in the blockchain network, augmenting the credibility of projects. By integrating crowdfunding and the local-currency bond market, blockchain can enhance the efficiency of the fundraising phase by engaging with multiple stakeholders and promoting accessibility.

Second, in the realization phase, all stakeholders can trace the use of proceeds and obtain information on the construction status in a transparent way. By ensuring investors' ownership, the issuing entity can collect funds from domestic customers and generate more sustainable projects. As mentioned above, one incentive to track

⁴A timestamp is coded information identifying when a specific event occurs, usually providing the date and time.

⁵The public and private key mechanism is an encryption system that uses a pair of keys: a public key that can be widespread and a private key that only the owner knows.

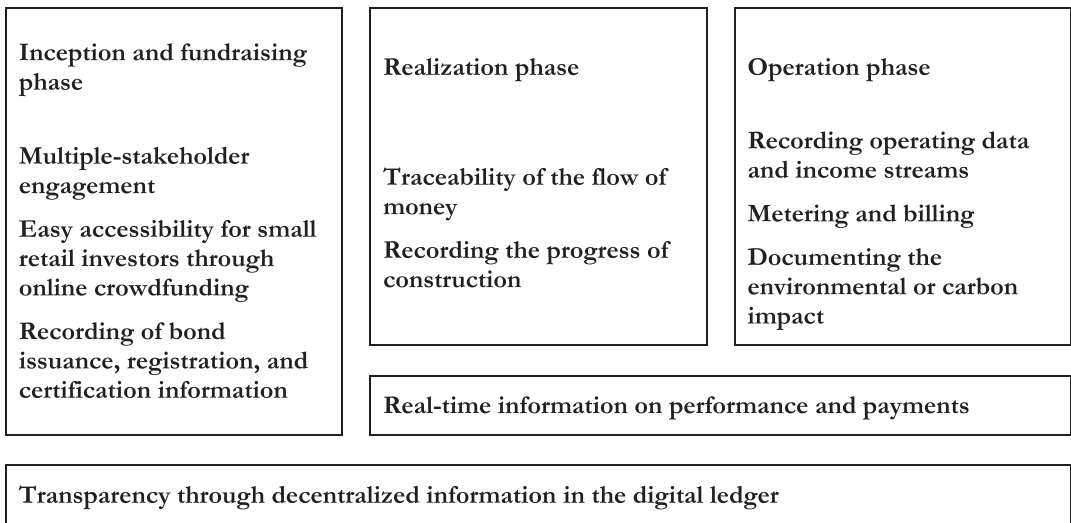


FIGURE 3 Key phases of the infrastructure project life cycle and advantages of a blockchain-based finance approach

Source: Authors' compilation.

financial flows with blockchain is that digitization can have a dampening effect on corruption. Investors face the risk that the issuing entities may misuse the funds and never return the investment. By recording information on the flow of money during the construction phase through blockchain, investors can better understand the status of the project and decide whether they will continue to devote money to the project. If the money that the issuance raises is misused or the project realization stalls, investors can take decisions with near real-time information. Smart contracts should format and automate the interest rate and return.

Third, blockchain cannot only be employed to finance an infrastructure project transparently but it could also help to manage the project when it is operational, for example through metering and billing applications. Downes and Reed (2020) showed that transparency should comprise three parts: evidence, disclosure, and access. "Evidence" refers to a record of relevant information, such as green certification for renewable energy or carbon credits. "Disclosure" means that the project operator should provide multiple stakeholders with information so that they can monitor and verify the operation process. "Access" means that stakeholders should have the right to access information to evaluate the operating status and decide whether to stay invested. By recording operating data with blockchain, stakeholders can receive transparent information on project revenue streams and reduce the risk that investors will receive no returns because a corrupt manager has absconded with the money. The whole data life cycle management offers a new way to raise funds for sustainable investment.

An example would be a community-based renewable energy project, in which investors can also play the role of consumers. A community ownership model would allow a "pay-as-you-go" approach, whereby the developers are the utility companies that sell, for example, electricity services through a pre-paid model. By recording the investor profile in the blockchain network, consumers can leverage their ownership of the project to use electricity and even trade with each other, that is, to become "prosumers"—producers and consumers at the same time. This is a suitable solution for adopting a net metering policy for micro-grid or other renewable projects, enabling investors to become prosumers (Hwang et al., 2017; Stoutenborough & Beverlin, 2008).

Blockchain also provides the option of documenting the environmental or carbon impact, which could, for example, enable the receiving of carbon credits through carbon emission trading schemes. The issuing entity can leverage blockchain to build an impact investing information platform, which incentivizes asset managers and customers in the space by quantifying the carbon certification or emission reductions, or any other positive

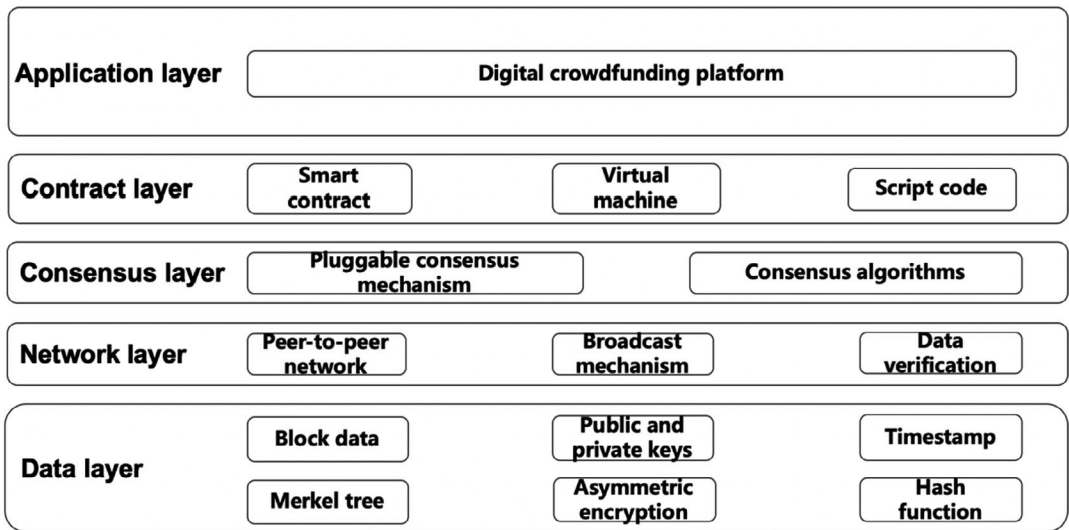


FIGURE 4 Technical structure of the proposal

Source: Authors' compilation.

impacts—be they ecological or social—that the project may have. Automated proof-of-impact reporting can deliver near real-time information on the sustainability impact, providing investors with assurance on the “greenness” or sustainability of their investment.

It is possible to configure our proposal in multiple ways to suit different situations. The main goal of this proposal is to leverage the strength of a decentralized governance model with the support of blockchain to achieve project-level financial inclusion. Through the blockchain-based project development platform, the issuing entity can engage with retail investors who would like to own parts of the project, such as a micro-grid project, by equity crowdfunding. Retail investors may receive deductions on their utility bill as part of their bond interests. Furthermore, by replicating this approach, it would be possible to aggregate multiple projects to create a larger portfolio that would be attractive to institutional investors, including impact investors.

Figure 4 illustrates the different layers and elements of the technical side of our proposal. This figure includes a digital crowdfunding platform for the funding as the main application in our proposal; technological features such as timestamp, public and private key mechanisms, smart contract, and other technologies that we mentioned in the text are part of the blockchain network. These technological features enable the process of registration and certification in the blockchain network and data life cycle management for using blockchain to mobilize information on (1) the use of proceeds; (2) the construction/realization of the project; (3) the operation of the project and its environmental/social impact; (4) metering/billing; and (5) revenue streams.

The use of blockchain, fintech applications, and also automated proof-of-impact reporting would of course require sufficient digital infrastructure, which in some locations would undoubtedly be a challenge. Technically, 3G or 4G would suffice to implement our proposal, even if 5G technology would be the ideal infrastructure to facilitate transactions through IoT and blockchain. But our suggested approach could also be used to mobilize investment for digital infrastructure to address the very bottlenecks that hold back digital development. Serious access gaps exist in digital infrastructure and finance along income, geographic, and gender lines. Digital inequality and exclusion may deepen income and economic inequality. As shown by Bahia et al. (2020), the broadening of mobile broadband coverage has positive effects on sustainable development, with favourable impacts on labour force participation and employment, especially among women, and higher household consumption levels. Scaling up investment to enhance the digital infrastructure is hence an important contributor to sustainable development.

5 | CONCLUSION

In this article, we explore how fintech can complement conventional capital markets and help to mobilize finance for sustainable infrastructure investments. Based on an analysis of the interests of relevant stakeholders, it puts forward a proposal for blockchain-based project bonds aiming to finance sustainable investments. It involves the use of a digital crowdfunding platform to raise finance, while the blockchain is able to record transparently and certify the use of proceeds, sustainability impact, and revenue streams of the project. The suggested approach would not only provide investors of different sizes with the opportunity to purchase local-currency assets and issuers such as municipalities to raise funds for sustainable infrastructure investment, it would also facilitate project management once the project were to be operational by offering easy technical solutions for metering and billing. Last but not least, this approach would create full transparency across the life cycle of the investment, reducing problems of misappropriation of funds. This in turn should increase the attractiveness of the underlying project.

Municipalities, for instance, could issue the proposed blockchain-based project bonds to finance local infrastructure, such as energy utilities, that would generate returns that they could use for payments of coupon and principal. Multiple applications to suit different situations would be possible, including community ownership structures, using the strength of a decentralized governance model with the backing of blockchain. While this approach is applicable to smaller investments, it would also be possible to aggregate smaller assets into bonds that would also be of interest to larger institutional investors. Development finance institutions could play an important role in implementing such investments. Through their involvement, they could also enhance the confidence of potential investors.

One challenge for implementing our proposal is the digital infrastructure gap that is prevalent in large parts of the Global South. The global digital infrastructure investment gap is estimated to reach USD 974 billion by 2040 (AIIB, 2020). Developing innovative ways of closing this investment gap are urgently needed. Indeed, our proposed approach could also be used to finance investment in digital infrastructure. Moreover, it would be important to address potential regulatory barriers. Authorities need to create a conducive regulatory framework that provides room for the development of innovative digital solutions while protecting consumers and investors.

To our knowledge, an approach like the one put forward in this article remains unexplored in practice. With support from the United Nations Development Programme (UNDP) and the United Nations Capital Development Fund (UNCDF), the UN Secretary-General's Task Force on Digital Financing of the SDGs has recently launched a Pathfinder Initiative with the Government of Bangladesh to explore how to use digital technology to mobilize small amounts of domestic savings for sustainable infrastructure investment (Chowdhury, 2020). Very much in line with our proposal, this initiative envisages the transformation of micro savers into micro investors and the reduction of the need for international borrowing, using blockchain as a technical backbone to improve the accountability of the funds and returning the dividends from infrastructure investment to the Bangladeshi citizens (Chowdhury, 2020). Going forward, it would be desirable to develop similar pilots and integrate some features of our proposal to gain operational experience with a view to scaling this up to mobilize much-needed investment in sustainable infrastructure.

ACKNOWLEDGEMENTS

We are grateful for very helpful comments and suggestions received from Cyn-Young Park, Matthias Pelster, Peter Rosenkranz, Grace Tian, and other participants in the September 2020 conference "Fintech to Enable Development, Investment, Financial Inclusion, and Sustainability" organized by the Asian Development Bank, the Institute of Global Finance–University of New South Wales, the Asian Bureau of Finance and Economic Research, the National University of Singapore Business School, and the Asian Development Bank Institute; and the 33rd Australasian Finance and Banking Conference hosted by the University of New South Wales in December 2020. The usual disclaimer applies.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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How to cite this article: Chen, Y., & Volz, U. (2022). Scaling up sustainable investment through blockchain-based project bonds. *Development Policy Review*, 40, e12582. <https://doi.org/10.1111/dpr.12582>