Distributed Ledgers

Design and Regulation of Financial Infrastructure and Payment Systems

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Building Financial Infrastructure on Distributed Ledgers: Practical Application in Emerging Markets

8.1 Application: Building Financial Infrastructure in Developing Country Contexts

In this chapter, two sources are used to document that existing financial infrastructure is quite limited in developing countries. We feature an application in Southeast Asia (SEA) and Thailand in particular, then present examples of smart contracts that would help: escrow, letters of credit, waterfall payments, savings, insurance, and credit. A general equilibrium perspective on decentralized contract competition then follows, with an example of a proposed digital ledger technology (DLT) innovation.

8.2 Limited Financial Infrastructure

Banks in low-income and emerging market countries use legacy infrastructure. A large number of them do not deliver reliable, flexible banking solutions for low-income households and small and medium-sized enterprises (SMEs). According to a study commissioned by the Asian Development Bank on financial access and digital solutions, the percent of needs met by formal financial service providers in Indonesia, Philippines, Cambodia, and Myanmar ranges from 16–74% for savings, 48–72% for credit, 1–4% for insurance, and 11–35% for payments (Asian Development Bank 2017). The report also attaches US dollar estimates of these supply gaps, typically in the billions, and the percent that could be met with digital finance, which ranges from 19–44%.

It is not uncommon for households in SEA to be unable to access basic financial products or financial services critical to improving their standard of living. More than 70% of people living in Asia have no access at all to basic banking products such as bank loans. In some contexts, credit cards are not prevalent, and asset management services are rare indeed. While peer-to-peer lending services are emerging, the underlying custodian banking services are still lacking.

SMEs can only access a limited number of financial products, often at prohibitively high costs, even though SMEs constitute as much as 89–100% of all enterprises and account for 52–97% of total employment in countries that are part of the regional Association of Southeast Asian Nations (ASEAN 2017). SMEs are regularly credit-constrained, as financial institutions favor seemingly reputable and larger enterprises, such as those that are state-owned or owned by business magnates.

8.3 Analysis on the Ground: Townsend Thai Project

The Townsend Thai project (Townsend 2016), with its many years of collected data, allows for an in-depth study of financial access and informal markets. Overall, the sharing of risk so as to mitigate the impact of shocks onto consumption and production is good but not perfect. Idiosyncratic household and business-specific shocks are large and occur frequently; they constitute the bulk of the risk in a village economy. But notably, these idiosyncratic shocks are mostly, though not entirely, pooled away (Chiappori et al. 2014).

The mechanisms are local village or *tambon* (county) level "money markets." Households borrow to repay other preexisting loans and borrow to lend, making new loans; these behaviors are shown to be one source of consumption smoothing (Sripakdeevong and Townsend 2018). Delayed repayment on loans goes back through the credit chain, causing delays for those who have borrowed in order to lend. But early repayment also goes back through the credit chain, even more so quantitatively. Network maps trace out kinship and transaction-based links (Kinnan et al. 2018; Kinnan and Townsend 2012).

Within this scenario, one detects shortfalls and things not working well. Risk-sharing depends more on family/kin and how closely people are related in an ancestry tree. Trust may be an issue. Aggregate village-level or *tambon*-level shocks, by definition, are not diversifiable at the village level and, as confirmed in the data, end up in consumption. As in sophisticated financial markets, households with businesses running projects with self-financed or borrowed assets have rates of return that reflect those risk premia: Idiosyncratic shocks are largely pooled and have low-risk premia, and village-level aggregate shocks have higher-risk premia. But by the same standard, aggregate shocks across villages could be, but on average are not, pooled (Samphantharak and Townsend 2018). Thus there are geographic limitations.

8.3.1 Impact of Interventions: The Million Baht Fund with Scope for Improvement

In 2002, the government of Thailand set up a Million Baht Fund in every village, creating a quasi-formal, village-level institution run by local committee. Preexisting baseline and post-intervention panel data provide insights into how this influx of capital affected villages and households. Levels of consumption increased, among other variables (Kaboski and Townsend 2011, 2012). Investment and profits of those already in nonagricultural businesses increased if they had access to credit and productivity (Banerjee et al. 2018).

The informal sector acted as a catalyst, playing an augmenting, complementary role. For the relatively poor, the lowest-wealth quartile initially, the best-fitting financial regime shifted from a buffer-stock-saving regime to a costly-state-verification regime. In the latter, output levels can be claimed, but only claimed low outputs levels, which result in indemnities, are verified. This is a model of debt with contingencies. It is as if there were simple debt contracts with constant transfer back to investors, except that default with lower repayment is possible if underlying conditions are verified. Verification costs are shown to be lower when there are kinship households in the village (Ru and Townsend 2018).

But there is still room for improvement. Kinship ties can be a mixed blessing—what if no kin live nearby? Village fund committees did not allocate funds efficiently, as those who got loans were not found to have higher rates of return. The allocation was based more on family and political connections (Vera-Cossio 2018). Some of the village fund loan money did make its way indirectly to other households that were not engaged in direct borrowing, again through kin connections, as in the network credit chains. So this was helpful in mitigating efficiency losses. But it was not enough.

In summary, village funds, from this government program, did not reach, directly or indirectly, all of those who should have been ex ante optimal targets. The trust limitation of existing systems could be alleviated with DLT, as will be explained below. Improvement in existing systems is, of course, an implementation problem in its own right (Roth and Shorrer 2017). More work is needed on designs that will work in practice, in this context. Finally, there is relatively little financial infrastructure that works at the inter-village level.

8.4 Specific Examples of Smart Contracts

8.4.1 Collateral

As a lead example of conditionality and what is feasible with smart contracts on distributed ledgers, collateral can be put in escrow and released on certain verifiable conditions. This conditionality allows the use of tokens as collateral for loans, for example, but other assets can be used as well. Collateral in turn allows more distant parties who know little about one another to lend. There need be no trust *per se*.

8.4.2 Letters of Credit

De facto bank notes and letters of credit require not a bank *per se*, as with traditional and contemporaneous infrastructure, but only some third-party validation and/or novation. In a letter of guarantee, a third party underwrites the risk of the loan by providing escrow accounts of coins or other collateral that back the credit.

8.4.3 Waterfall Payment

This refers to agents who are linked to each other via economic transactions. For an example of what is possible for SMEs, receivable revenue can be contracted and secured in a trusted account. This can be used to buy inputs, for example. It could also be used to fund employee payroll. Employee accounts, when secured and sequestered, can be used in turn as collateral for borrowing. As another example, for village funds, the chains previously mentioned linking borrowing and repayment can be automated and, more to the point, extended beyond village boundaries. This can improve welfare relative to the currently used technology, which relies at best on promises, without a contracting technology that securitizes payment streams.

8.4.4 Savings Products

A simple savings product can also take advantage of conditionality. Thai households need to convert their cash to investments, as noted. This becomes a less acute problem when currency income is converted somehow to a coin/token in an e-wallet, because at that point, tokens can pay interest, and the opportunity cost of holding cash could be virtually zero. Still, one could then take the next step and create a portfolio management tool as a smart contract that either transfers funds automatically across accounts conditioned on states, according to some liquidity versus return trade-off, or uses an app that at least sends encrypted messages back to the saver as reminders. Brokers with algorithms could provide this service; if written up as smart contracts, then effectively the service is implemented on DLT.

Commitment savings could earn higher returns in tokens, paid into the wallet. Commitment accounts would be investments into escrow that limit withdrawals, if the savers wish to enter into these accounts. A predetermined quantity of tokens could be locked in a smart contract, which is programmed to release the tokens to the appropriate parties via airdrops when a set of conditions is met—for example, at the maturity date, after a lock-up period, or if certain programmed system conditions mandate a liquidity infusion.

8.4.5 Insurance

For community-level insurance, the initial contributions are prepaid premia into the mutual fund. Participants can choose among various options such as duration of the agreement, frequency and amounts of payments, and if/how to cash out. These are social rules that, when agreed on, become the smart contract.

For the payouts, the indemnities part of the community insurance, suppose a participant has low income, which could potentially be evident if, for example, wages are in coin. Then a simple conditional code will work well. To make the indemnity known to everyone in the fund, as the level of the remaining funds, with benefits, would be lower, there could be automated conditional messages to others, so as to achieve a public record of payouts. Messages are part of the distributed ledger and would be in sync; hence in the language of Corda there is a unique consensus. Another contingency: Low or ill-timed rainfall could be the source of low income, and rainfall is verified by sending a message to a data source, an oracle, and receiving a trusted message in return. The message, rainfall as a fact, is on the ledger and a key state variable. The oracle might need to be compensated.

With private information on income, an agent can send a message about the underlying situation, which could trigger an indemnity. The message could be published as in a database if these messages are to be public, though as discussed, optimal design of published data, conditionality, is not obvious. The optimal incentive-compatible messages for a contract can be found as the solution to a dynamic mechanism design problem. In equilibrium there is no problem with respect to what is reported by the agent because the agent, by design, has the right incentives, and at this point the code cannot be rewritten. The incentives come from a careful weighing of benefits versus costs as a function of outcome and reports, working out the optimal contracting part, putting the design into the smart contract and ledger. The presumption is that these improvements in insurance would outweigh costs of messages and memory.

8.4.6 Loans

With loans, an issue arises about how to grant them. One way to allow improved contracts is to allow other households to send messages about the underlying situation of that initial applicant agent. Studies have shown there is accurate information in the community on who should get loans, as some borrowers have higher expected returns (Hussam, Rigol, and Roth

2017). On the other hand, when households know that what they report has consequences for the initial would-be borrowing agent, who could be a friend or relative, then these other households are dishonest or even could collude in these reports. A possible solution is to pay for truthfulness using a peer-prediction index of subsequent events such as profits or repayment to the lender. This history of prediction performance in the past could be used for future rewards and penalties. While public reporting of messages alone appears to give households incentives to predict accurately, suffering loss of face for discrepancies between predicted and actual events, money or tokens might be able to do better to monetize loss of reputation. While some of these features are implemented in microcredit initiatives, they are far from universal and systematic. DLT provides a relatively inexpensive technology for implementation.

Multiple agents could also be sending reports simultaneously, as many contracts are multilateral. The design of the contract is such that each agent has an incentive to report truthfully if others are doing the same. A problem of collusion thus arises as noted: Agents coordinate in reports to get off-equilibrium beneficial outcomes. Yet, as noted earlier in Harris and Townsend (1981), the implementation literature provides insights on how to thwart this threat through multilateral conditionality. So, this too can be implemented as a smart contract.

In summary, distinguishing commodities and securities, points in time, and multiple agents, virtually any multiparty contract can be written as a smart contract.

8.5 The General Equilibrium Perspective on the Provision of Financial Services

Here we take a standard general equilibrium perspective, but with the inclusion of contracts. As noted in chapter 2, an economy consists of standard items, but with an innovation on the provision of financial services. The commodity space of a well-specified economy consists of factors of production such as land, labor, capital, and intermediate and final produced inputs and outputs, including capital and consumption goods. The commodity space also distinguishes time, as if there were time stamps; location, allowing for distinct geographies and shipping; and uncertainty, conditioning on states of the world, both exogenous and endogenous. Key actors are the users—that is, households and traditional firms. Some households run micro and small to medium-sized enterprises and are thus both households and firms combined. More generally, there is an ownership structure that specifies the shares that a household has in particular enterprises. An economy also specifies who knows what, at least initially, though signals can be generated, and some observe what others do or can make inferences. There are information partitions that capture these ideas.

The generalized commodity space becomes the space of incentive-compatible contracts written on top of the underlying traditional commodity space, but subject to contracting costs, as is enumerated below.

Efficiency of an economy is judged by the Pareto criterion. An allocation of feasible contracts is said to be efficient, or constrained-efficient, if there are underlying obstacles, if there does not exist an alternative feasible set of contracts that makes some households and firms better off and others no worse off. The current system, with its symptoms of limited access to financial products a priori, is inefficient in this sense.

We could go on to specify, as would be traditional, banks and markets as primitives of the economy, but it is here that we depart from the traditional model and break new ground. All possible forms of financial intermediation are on the table. Prescott and Townsend (1984a, 1984b) show how to decentralize such environments with a competitive broker-dealer sector for a multiplicity of information specifications. Prescott and Townsend (2006a) embed individual and multilateral contracts, as enumerated above, into an entire economy with a nexus of activities under contracts connected to general equilibrium flows. Competition among broker-dealers and intermediaries drives profits to zero, but these intermediaries remain essential for pooling, hence the language of disintermediation should not be used.

Relatedly, private information *per se* is not a rationale for regulation. Many economies decentralize in the sense of the welfare theorems. Joaquim, Townsend, and Zhorin (2018) model imperfect competition among financial service providers, including adverse selection. In this context, frictions interact with profits. Improved contracting technologies that do not also bring more entrants can decrease household and SME welfare.

8.6 Featured Example of Innovation: EvryNet

EvryNet is an intelligent financial automation operating system that aims to provide open-source banking services and financial contracts to unbanked and underbanked populations. It is being built on the need-smart-contract premise and incorporates the general equilibrium perspective. The system is still under development as of this writing.

EvryNet is creating an interoperable smart-contract platform that enables not only traditional banks but also microfinance institutions and others to initiate and execute banking products and financial contracts. The envisioned provision of contracts should be at competitive prices because of competition across providers in the provision of computer memory (storage) and computation power. A rating system tracks performance of providers in validation.

The financial services consist of a multitiered architecture. The core component of the platform is a financial service portal that users and institutions can utilize to draft financial contracts, either standard or customized. The portal is underpinned by a smart-contract composer, which enables smart-contract creation using DLT. Once the user selects a smart-contract template, specifies necessary inputs, and selects nodes based on trust or reputation score, the smart contract will be processed through EvryNet's virtual machine.

The smart contract can optionally check for compliance or necessary regulations. For instance, the EvryNet platform can allow the relevant organizations to certify by signing the contract digitally or even by executing the compliance-check code to ensure regulation compliance. It allows event-hooking in smart contracts to seamlessly receive relevant events from external entities. Many real-world smart contracts may need external inputs to complete the conditional transactions—for example, the confirmation of a shipment.

In summary, rather than take as given the current set of institutions and markets, often sparse, the vision of EvryNet is to re-create them through the new, distributed ledger contract technologies, including executing nodes as a new production section. However, the costs of coding, validating, and provisioning memory for optimal contract design could, as noted earlier, impact contract design and/or have implications for validation systems and the degree of decentralization.