Distributed Ledgers

Design and Regulation of Financial Infrastructure and Payment Systems

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Economies, Obstacles, Welfare, and Measurement

The term *economy* here does not refer exclusively to nation-states. It means villages or towns as communities, regions within a country, and international, cross-country economies. We are not shy about starting with villages as small, open economies in a developing country, then moving to interregional and international money transfers, for example. Of great interest to this conversation are the economies of developing countries that typically have limited financial infrastructure. This is a useful context in which to think about innovation and regulation because in some cases much is known from research about the underlying environment and its current institutions and markets. But these are quite limited on the formal side. Such emerging-market economies also provide useful step-back contexts in which to think about the advantages of various possible versions of DLT for those more familiar with heavily banked economies. There is much that needs to be done in developing countries, where the potential for welfare gains is large and significant. However, as is already apparent, innovation is going on in developed economies, too, where gaps also remain, and those cases are also featured.

2.1 Economy

An economy consists of the commodity space, preferences of agents, endowments, and technology. The meaning of the term *agents* depends on the context and applications: households, farms, micro and small businesses, and larger nonfinancial and financial firms, including money-transfer organizations. Each agent has endowments of goods and/or factors of production, preferences in the form of utility functions over goods or profits, and access to technology. Agents can be individuals in a family, households in a village, or firms. Agents can be separated in space, across villages and regions, or traveling about. Key features of an economic environment include time, as in dynamic decision problems, uncertainty and realization of states of the world, and location. An economy is conceptualized in a sufficiently general way so that all the examples above and those in the text below apply.

How should an economy function? Ideally, economies should achieve solutions to programming problems that determine Pareto optimal allocations: an allocation of resources such that one cannot make any one agent or type of agents better off without harming others. Incorporated as well into the programming problem are additional constraints—not simply budget or resource constraints, but constraints that lead to a determination of constrained-optimal allocations: limited information, limited commitment, transaction costs. Alternatively, exogenously imposed contacts can be imposed as realistic, in some settings. More generally, obstacles can vary depending on groups and matches—for example, weak or nonexistent constraints locally in a village but binding constraints among strangers. Money can play a role, as trades are limited among strangers, and money allows such trade—for example, as a communication device displaying past history.

But money can coexist with contracts and other mechanisms or arrangements for those with enduring relationships. Constraints can also vary over time.

The commonality of this framework deserves emphasis. One can think of households running small and medium-sized enterprises (SMEs) interacting with each other in a village in some kind of financial-information regime. Agents in this example are SMEs with capital, labor, and consumption. One can include households that provide wage labor, and in both cases not all transactions need be within the village: Firms purchase inputs and sell products as imports and exports. Furthermore, the same notation applies equally well to groups of financial firms with balance sheets and dividends interacting with each other, such as money-transfer organizations in different countries or broker-dealers in New York financial markets, acting on behalf of clients or on their own account, in the context of larger markets.

In all cases the time line of what happens when is crucial: a specification of unobserved, underlying states; messages among the parties; and multiple actions at potentially different points in time. A recurring focus is what the multiparty arrangements look like currently and whether they are constrained optimal or not.

An example of such a time line is given in figure 2.1.

In addition to contemporary examples of economies, one can go back in time. Economic history makes clear the importance of even rudimentary technologies. Furthermore, when technology changed, so also did economic and financial organizations (Townsend 1990). To highlight one feature, agents can send messages to one another, and the technology for doing this has changed over time, anticipating the discussion of distributed ledgers.

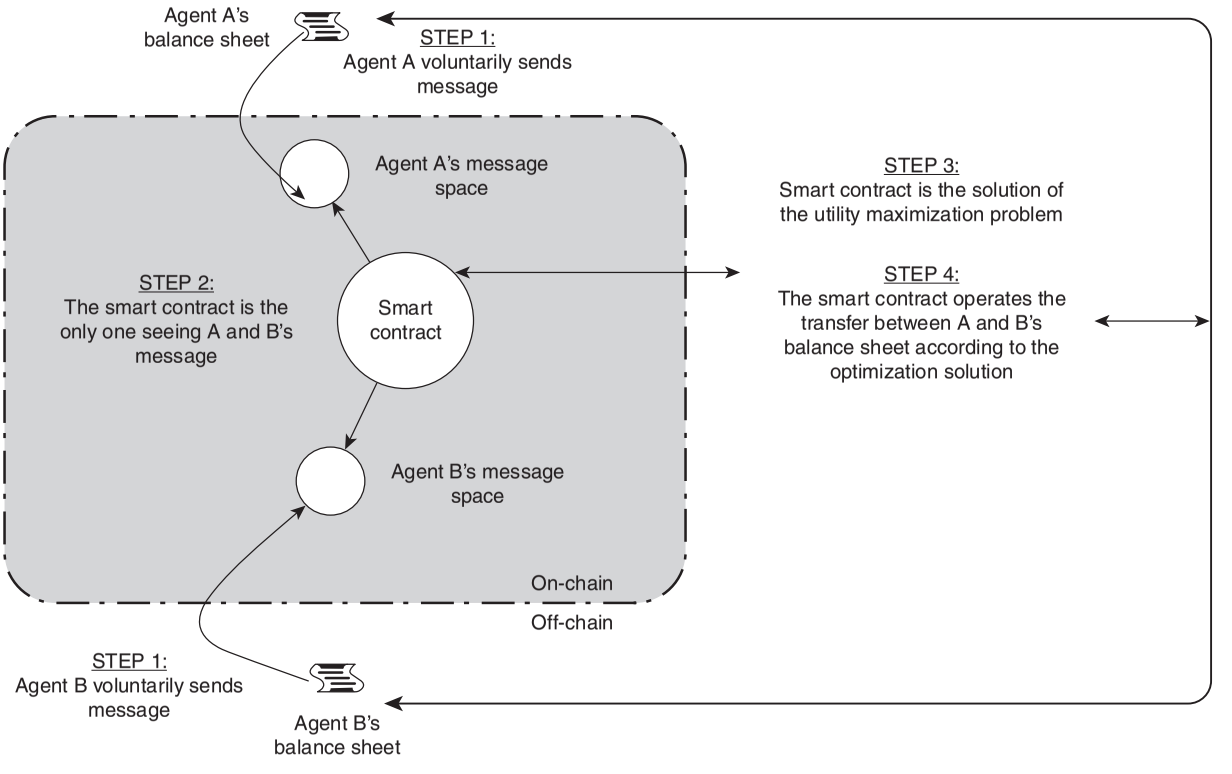

Figure 2.1
Schemata of financial accounts and agent interaction through smart contract. Agents A and B with financial accounts are sending messages from an a priori message space; these messages are input into a designed smart contract and execute a transfer that alters the financial accounts. *Source:* Nicolas Zhang (2019).

2.2 Measurement

Hand in hand with the conceptualization and presentation of economies come issues of measurement. The standard framework for measurement of economic activity takes the form of integrated financial accounts: the income statement, balance sheet and its change, and the statement of cash flow. This applies for all actors in the economy, households, financial and nonfinancial firms, broker-dealers, government, the standard sectors of the national income and product accounts, and on occasion, more detailed and alternative breakdowns. We may have all these data in some instances for a given economy, as in integrated regional financial accounts, but obviously not always. Sometimes available measurements are sparse. Nevertheless, integrated financial accounts remain the premier organizing principle for economic data.

Bear in mind the obvious: The ledgers of distributed ledgers are a database. Indeed, we present a schematic that we return to below: two agents, *A* and *B*, each with financial accounts interacting with each other through a smart contract, in effect creating yet more data that can be put on ledgers. We shall explain more subsequently, below, regarding messages, smart contacts, on-chain and off-chain concepts.

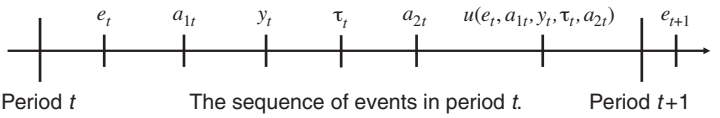

Figure 2.2
Illustrative time line of events within a given period t under a contract. The agent observes its current underlying state, e_t, then takes an action a_{1t}, determining publicly observed state y_t, which in turn activates transfer τ_t. Then, toward the end of the period, the agent takes another action, a_{2t}, resulting in utility as a function of these actions and events $U(e_t, a_{1t}, y_t, \tau_t, a_{2t})$. At date $t+1$, the state e_{t+1} is realized (determined in part by previous actions) and the time line of t repeats at $t+1$, and so on.
Source: Doepke and Townsend (2006).

Figure 2.2 is an example featuring the time line under a particular contact written between two parties, and again we come back to such time lines in subsequent sections. The point here is that ledgers and contracts need to be understood in the context of the underlying economy and its measurement.

2.3 Townsend Thai Project

One featured context that appears at various points through this book are the surveyed areas of the Townsend Thai project and the associated database.

An initial, baseline survey conducted in 1997 included villages from four provinces: two in the relatively poor agrarian northeast and two in the developed central region near Bangkok. Within each of these four provinces we chose 12 *tambons* (subcounties) per province. Four villages per tambon were selected randomly. Within each village, households were selected at random from rosters held by the headman. The 1997 household survey has 15 households for each of 192 villages, or 2,880 households. There are also survey instruments for the 192 headmen, 161 preexisting village-level institutions, and 1,920 sets of soil samples.

The baseline survey and data collection were done in April/May of 1997 for rural areas. With the unanticipated Thai financial crisis emerging in July 1997, we began in 1998 the first of many subsequent rural annual resurveys in four randomly chosen tambons in each of the original four provinces. An additional tambon per province was selected for fielding an intensive monthly survey, starting in August of that year.

The scale of the survey expanded: Two more provinces were added in the south in 2003 and two more in the north in 2004, though one province was dropped in each region for insurgency or budgetary reasons. An urban baseline and subsequent annual urban resurvey were added beginning in 2005

to compare urban neighborhoods to rural villages within the same sampled provinces.

The final rounds of data collection gave us 20 years of annual rural surveys, from 1997 to 2017; 11 years of annual urban surveys, from 2005 to 2015; and 231 months of rural monthly surveys. Additional monthly urban data were gathered for 45 months in total. The rural and urban monthly data have been used to create complete financial accounts. The Townsend Thai project data, including these accounts, have been used to measure and analyze financial access, thus making the obvious connection to the social implications of distributed ledgers, as better understanding of what is happening on the ground allows beneficial innovation.