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majority voting.[50] Hence, a DAO can have the essential features of an unregistered partnership with unlimited liability of its members, which is certainly not the right investment vehicle for retail investors.

All transactions between the funders and prospective investors of The DAO were made online. A traditional investment contract is typically concluded between two (or more) parties, and until recently each party could safely assume that the other party is a (natural or legal) person that can enter into a valid contract. This is not necessarily so for online communications that look like a contract but actually are none because the other party is not incorporated and hence does not have a legal personality. As long as an entity (which may be a global network with participants in many different jurisdictions) is registered or licensed nowhere, it is also not regulated. This leaves the responsibility for the verification of the legal status to the communicating parties. Another peculiarity is that a traditional ("face-to-face") contract usually does not activate a computer code that starts an immutable self-enforcing series of actions, as a smart contract does. This happens quite often the case in online contracts (e-commerce), but the activated computer code is usually far less complex than that of a DAO. There is no central authority in a blockchain-based DAO that could stop a self-enforcing process even if it becomes apparent the results are contrary to the intentions of the parties involved. Another challenge pose investment decisions by majority voting. The joint capital of all DAO members will be invested in those assets or projects that have been chosen by a majority vote. This implies that there is no individual exit option. Which – again – makes a DAO unsuitable (and impermissible?) for retail clients. And finally, the debate on the legal quality of a computer code with irreversible consequences – "code as law" – has not yet come to a generally accepted conclusion.

(50) The sale of CFDs to retail clients is restricted or prohibited in a growing number of jurisdictions, but often only since the last quarter of 2016. A DOA could become a channel for the sale of otherwise restricted CFDs to retail customers that could only be controlled by a transnational (or even global) cooperation of regulators.

are based on their direct majority voting.[47]A group of "curators" prepares the decision by "whitelisting" investment projects, i.e. by the verification of the identity of fund seekers and the legality of proposed projects.

Before it became operational, The DAO imploded in June 2016 after a hacker leaked about one third of its funds for investments (approx. USD150mn) to a subsidiary account where the money was frozen, i.e. nobody had access to it under the existing code. The remarkable point is that the hacker did not manipulate the code but used a specific routine (a splitting function) embedded in the code in a way quite different from what the programmers had intended.[48] In other words, the code worked exactly as prescribed, but it produced results different from what was intended. "The issue … was a divergence of software developers' complex intent, having a specific use in mind for the splitting function, and the de-facto result of the software implementation".[49]

In a stylised form, a DAO as a collective investment venture consists of (1) a moderator who communicates the idea of the scheme with some information on the envisaged types of investment projects and (2) participants who (a) install an (open source) software that establishes the investors' network and facilitates the project presentation and selection by majority voting, and (b) contribute to the capital of the investment pool. The participants may not know each other and the individual capital contributions of the other members, and they do not have any contracts among themselves. They also do not have an explicit contract with the moderator who provided the open source software and organises the presentation of investment projects. The investment projects could be, in principle, of any conceivable type. DAOs of this type pose major challenges to regulators and lawyers. A first challenge is that a DAO is not registered anywhere, does not have a legal personality, and may be composed of members in a variety of jurisdictions. This makes it extremely difficult for national authorities to regulate DAOs if they see a need to do so, because DAOs may attract tech-savvy individuals with little or no investment experience.

These retail investors could be exposed to extremely high risks – even beyond a total loss of their initial capital if, for example, speculative derivatives based on contracts for difference (CFDs) were selected by

(47) "Investors in The DAO have voting rights that permit them to collectively determine whether projects are funded. Each investor has a voting share that is proportional to the amount of tokens the investor DAO held. The voting investor has the ability to irrevocably vote once per proposal, and a vote freezes that investor's DAO tokens. However, for The DAO to engage in any investment activity, at least 20% of its Dao Token holders must vote for the project" (Hinkes 2016).
(48) For more details see Greenspan 2016.
(49) Buterin 2016.

the residual term on some predictor variables). This can frequently occur in big data analysis as a result of selection biases, measurement errors and omitted variables.

Because of these peculiarities, existing sophisticated statistical methods have to be adapted and modified before they can constitute the core of predictive models. There is a large and growing number of different models. Prospective users face the problem of selecting the appropriate model. This requires an understanding of the technical features of the various models. It is beyond the scope of this survey to go into these details. For a "formula-free" survey of the basics of the most commonly used types of predictive models see Finlay 2014; for a kind of "formula-loaded" textbook see Larose and Larose 2015; for a summary of analytical platforms in an IT perspective see Skyrius et al. 2017.

Appendix

"The DAO"

One of the earliest and most ambitious smart contract structure was launched in 2016, i.e. roughly one year after the roll-out of the Ethereum blockchain, namely a system of smart contracts that formed a decentralised autonomous organisation (DAO). DAOs are "sophisticated arrangements of rights and powers encoded through smart contracts that emulate the attributes and activities of business entities or regulated financial contracts, including insurance, futures, options, etc[45].".1 The initiators of the first DAO launched their DAO with the name "The DAO" on the Ethereum blockchain in April 2016. The aim of The DAO was to emulate a kind of investor-directed equity crowdfunding or venture capital scheme. Some of the outstanding features were[46] its open source architecture, its financing by then the largest crowdfunding campaign (attracting 11,000 investors and a capital of approx. USD120mn) in May 2016, and the fact that The DAO is no corporation. It has no legal personality and is not registered or licensed anywhere (although it operates in the regulated finance industry). Its governance system has no managers or board of directors but only shareholders; investment decisions

(45) Hinkes 2016.

(46) See Waters 2016, Bramanathan 2016.

structures for community detection and social influence analysis (e.g. by social and activity graphs).[43]

Software packages are available for the various types of analytics, but as an alternative to in-house processing capabilities services of specialised data analysis firms can be utilized.

Predictive Analytics

Having prepared the raw data, they can be processed in a predictive model. There are two major approaches of predictive analytics:

- to extrapolate historical patterns of the behavioural (outcome) variables into the future,
- to capture interdependencies between explanatory (predictor) and behavioural (outcome) variables.

Predictive analytics are largely based on statistical methods like linear regression models, but the peculiarities of big data sets require modifications. First, "the notion of statistical significance is not that relevant to big data. Secondly, … many conventional methods for small samples do not scale up to big data. The third factor corresponds to the distinctive features inherent in big data: heterogeneity, noise accumulation, spurious correlations, and incidental endogeneity" (Gandomi and Haider 2015, 143).[44]

- The large sample size allows a better understanding of heterogeneity, i.e. the specificities of small subgroups of the total population and their impact on regression results for the total population.
- Big data models estimate many parameters simultaneously, which implies an accumulation of estimation errors. This accumulated noise may cover up the true effects of variables.
- Spurious correlation are false correlations between variables that could be found due to the large size and heterogeneity of the data set although the variables are actually independent (e.g. random variables).
- Regression analysis assumes that predictor variables are independent of the difference between their observed and estimated values ("residual term"). This assumption is violated in cases of incidental endogeneity (i.e. a dependence of

Blogger and WordPress), microblogs (e.g., Twitter and Tumblr), social news (e.g., Digg and Reddit), social bookmarking (e.g., Delicious and StumbleUpon), media sharing (e.g., Instagram and YouTube), wikis (e.g., Wikipedia and Wikihow), question-and-answer sites (e.g., Yahoo! Answers and Ask.com) and review sites (e.g., Yelp, TripAdvisor)" (Gandomi and Haider 2015, 142).

(43) Social graphs show the structure of communities, activity graphs illustrate the interactions between the members of a community.

(44) See also Fan, Han and Liu 2014, 297-302.

density. The focus should be on data which are plausibly somehow linked to the questions which the data analysis shall help to answer, e.g. whether a borrower will default (credit risk assessment), a money transfer is fraudulent (AML/CTF measures), or a customer may be interested in an offer for a particular product (personalised marketing). The aims of the data analysis will determine the type and source of data to be processed.

A very important type of data is usually available to incumbent banks but not to FinTech start-ups, namely data on past financial transactions of customers for many years (credit history, savings and investments, home ownership, regular payments, etc.). Most of these data are well structured and reliable and usually rest in transaction-oriented relational databases of the legacy computer systems of banks. These internal data plus unstructured internal data such as e-mail, letters, protocols, memos, reports can be made available for big data analytics. It can be safely assumed that these data have the highest value density as it has been found that data on past behaviour are the best predictors of future behaviour.

This does not mean that the quality of predictions (or pattern recognitions) could not be improved by adding further data from external sources, but a selection (guided by formal tests of value density or common sense) should be made. FinTech with nor or only limited access to financial histories were forced to select and experiment with a much wider range of external data than incumbent banks.(38) For example, data from e-commerce play a more important role for credit assessments of start-ups than for incumbent banks, while both FinTechs and incumbent banks use these and data from web-browsing and social media for marketing purposes.(39)

Such data are unstructured and require a transformation in more structured data since many analytical models are based on statistical methods which can handle only variable of specific types (such as binary, continuous, categorical, discrete, or ordinal variables).(40) The techniques applied depend on the type of unstructured data and include(41)

- text analytics ("text mining") by information extraction, text summarization, question answering, and sentiment analysis ("opinion mining"),
- audio analytics by speech recognition and phonetic-based systems,
- video analytics for detecting objects or events and for content analysis,
- social media(42) analytics of contents (e.g. for "sentiment analysis") and

(38) For a Chinese case study see Dawei, Anzi and Gen 2018.

(39) On the connection between bank lending and social media see Schulte 2018.

(40) „[F]or all types of unstructured data analysis, eventually some kind of structured data is produced, and this makes possible to apply known algorithms for processing and discovery" (Skyrius et al. 2017, 471).

(41) For more details and further references see Skyrius et al. 2017, Gandomi and Haider 2015.

(42) "Social media can be categorized into the following types: Social networks (e.g., Facebook and LinkedIn), blogs (e.g.,

Characteristics of big data

The steep rise of the use of the internet and mobile communication devices resulted in an unprecedented growth of the volume of data "about people's lifestyles, movements and past behaviors" (Finlay 2014, 2). A likewise rapid drop in the cost of data storage and increase in computing power made it technically possible and economically viable to process large volumes of structured and unstructured data for commercial purposes. "[B]y the early 2010s "Big Data" had become the popular catch-all phrase to describe databases that are not just large, but enormous and complex" (Finlay 2014, 13). Big data "relates to extraction of important insights and valuable information from vast and often chaotic data" (Skyrius et al. 2017, 453). More precisely, big data can be characterised by the following dimensions (Gandomi and Haider 2015):

- Volume: The size of datasets is in the magnitude of multiple terabytes and petabytes.
- Variety: Datasets are heterogeneous and comprise structured and unstructured data of various sources (e.g. spreadsheets, text, sensor data from telematic and medical devices, images, audio, and video).
- Velocity: Data are often generated at high speed (or continuously) and require real-time analytics to be of commercial value (e.g. for situation- or location-specific personalised offers).
- Veracity: Some data sources are inherently unreliable; for example, customer sentiments expressed in social media are imprecise and uncertain.
- Variability and complexity: The velocity of data flows is not stable. Data are generated through an indefinite number of sources. They need to be pre-processed (e.g. connected, cleansed, transformed) before they can be fed into analytical models.
- Value: Usually only a few core data in a big dataset have a high predictive power (i.e. a high "value density"). Most other data typically have a low value density, i.e. large volumes of these data must be added to the core data in order to increase the model's predictive power.(37)

"The principal goal of Big Data processing is refining and extraction of important information, or discovery [of] hidden meanings, leading to important information" (Skyrius et al. 2017, 470). Although costs have decreased massively, data processing in not free and takes time. Therefore, financial institutions should not analyse whatever data they can get hold of, but focus on data that presumably have a minimum value

(37) "One feature of Big Data is that most of it has a very low information density, making it very difficult to extract useful customer insights from it. A huge proportion of the Big Data out there is absolutely useless when it comes to forecasting consumer behavior. You have to work pretty hard at finding the useful bits that will improve the accuracy of your predictive models – and this is why you need big computers with lots of storage, and clever algorithms, to find the important stuff amongst the chaff" (Finlay 2014, 16).

for parties to have a dispute: both parties are held to whatever outcome the smart contract determines" (Shadab 2014). Many processes and procedures in the financial industry could be "automated" by smart contracts, for example the documentation, invoicing and payments in trade financing, the trading and settlement of derivatives and syndicated loans, the origination of mortgages, automated claim processing in insurance, or insurance for the sharing economy.(36) The term "smart contract" suggests that the computer code itself has the legal quality of a contract, but that is challenged by lawyers. Their view is that a computer code cannot be legally binding. What can be legally binding is the agreement to apply the technical code for a specific purpose or an intended outcome. Such an agreement is necessary to "legalise" the results of the execution of the code such as automatic (micro)payments for the use of services or the automatic transfer of ownership and creation of a debt after an ordered object has been manufactured and shipped.

When parties agree to use a smart contract, its language would be computer code that is probably not understood by all contracting parties. Hence, it may be necessary to write down the will of the parties in human language so that, in case of a dispute, a third party can check whether the will was accurately reflected by the computer code and executed accordingly. However, a public blockchain technically does not allow a third party to intervene or reverse a transaction (as transactions are conceptually irrevocable). This raises a number of legal questions that can best be illustrated by a practical example which is provided in the annex ("The DAO").

2.2 Big Data

Established banks base lending decisions mainly on credit scores (provided by credit bureaus) and data on the financial history of applicants. People and businesses whose applications for a loan had been declined turned to crowdfunding platforms, and the platform operators had to decide whether a pitch is admitted to the platform. They had to deal with a number of cases where the credit history was poor or non-existent and the credit score was insufficient. However, as the fund providers in a P2P scheme bear the credit risk (in contrast to depositors in a bank), the investors might be willing to accept a higher risk if that is compensated by higher returns. But even then, the platform operator has to categorise the risk of a pitch for which the traditional credit assessment tools of banks were seemingly insufficient. Because of this, the FinTechs reverted to big data analytics to develop alternative or supplemental tools for credit risk assessment. Incumbent banks were also applying big data technologies, but primarily for fraud protection and anti-money laundering/combating the financing of terrorism (AML/CFT).

(36) See Capgemini Consulting 2016.

complex management and sale of household-produced solar energy at an electronic electricity exchange.

Simply speaking, smart contracts are software code representing business logic that run on a blockchain network.(33) The execution of the code is triggered by some external data (that are fed into the system via "oracles"), and the result is the modification of some other data (such as the transfer of monetary value). For example, the business logic may be that a leased car can be used only as long as leasing rates are paid on time. The external data may be an information that a leasing rate has not been paid. The modification of other data then may be the blocking of the keys of the leased car. This example indicates the link between finance and the material world, i.e. between the "Internet of Finance"(34) and the "Internet of Things" (IoT).(35) Key use cases for smart contracts in the financial services industry are listed in table 6.

Table 6: Smart Contracts' Key Use Cases for the Financial Services Industry

Capital Markets and Investment Banking	Commercial and Retail Banking	Insurance
Corporate Finance: Initial Public Offers (IPOs), Private equity	Trade Finance: Supply-chain documentation invoicing and payments	Automated claims processing in motor insurance, crop insurance, etc.
Structured Finance: Syndicated loans, leveraged loans	Mortgage Lending	Fraud prevention in luxury goods
Stock exchange market infrastructure	Loans and crowdfunding for start-ups and small and medium enterprises	New products: insurance for the sharing economy, autonomous vehicles, peer-to-peer insurance, cyber insurance
Regulatory reporting and compliance; Know Your Customer (KYC) and Anti-Money Laundering (AML)		

Source: based on Capgemini 2016, 9.

"By using a smart contract, parties commit themselves to be bound by the rules and determinations of the underlying code. Doing so in principle removes the potential

(33) For a technical introduction to Ethereum, its programming language, and smart contracts see Raj and Raman 2017.

(34) See Ali et al. 2014.

(35) On the IoT see Raj and Raman 2017.

is still a challenge as experiences with an advanced system laid bare (see the appendix on The DAO).[30]

In reaction to the success of bitcoin and to the discussions about its limited capacity and speed as well as about the huge electricity consumption for Bitcoin mining, alternative blockchains respectively DLT platforms were developed. Two of them are of particular relevance for DFTs: the permissioned DLT platform Ripple and the public blockchain project Ethereum.

- Ripple[31] is a real-time gross settlement system based on the open-source Ripple payment protocol and exchange network, launched in 2013. Its digital coin Ripple is not only used as a digital currency but also as a means for an exchange of national currencies. Like bitcoin, Ripple is based on a publicly shared distributed ledger. In contrast to bitcoin, Ripple does not use any mining protocol. Another important difference is that the validation of transactions cannot be done by any node of the network but only by trusted servers that are on a Unique Node List (UNL) in an iterative consensus process. As Ripple controls the UNL, the system is a permissioned DLT (private blockchain). For a monetary transfer, money hast to be deposited with and can be collected from gateways (= access points to the exchange network). This could be banks or any other financial service providers. Other than with bitcoin, access to the network through gateways implies for the consumers the risk that money is lost (by theft, fraud, or bankruptcy of the gateway).
- Ethereum was launched in 2015. This system uses digital tokens ("Ether") not only as a cryptocurrency but also and particularly as the carrier (platform) of smart contracts.[32] The Ethereum blockchain system provides also a powerful open-source language for the programming of smart contracts (from code for simple applications to code for complex decentralised autonomous organisations built on bundles of interlinked smart contracts).

Smart Contracts

The term "smart contract" was not coined by lawyers but by computer technologists to describe computer programmes that automatically execute particular actions – for example, the automatic payment of a bill for the use of digital content, or the more

(30) Irreversibility means that there is authority for appeal and dispute settlements in cases of disagreement or dispute between the parties of a transaction.

(31) See Buterin 2013.

(32) See Jagers 2016. „Bitcoin and Ethereum differ in purpose. While Bitcoin is created as an alternative to regular money and is thus a medium of payment transaction and store of value, Ethereum is developed as a platform which facilitates peer-to-peer contracts and applications via its own currency vehicle. While Bitcoin and Ether are both digital currencies, the primary purpose of Ether is not to establish itself as a payment alternative (unlike Bitcoin) but to facilitate and monetize the working of Ethereum to enable developers to build and run distributed applications" (Bajpai 2016).

- Consumers benefit from cheaper, faster and more convenient retails finance solutions.

In short, convenience, speed, reliability, and cost efficiency are the main promises of blockchains respectively DLTs. However, blockchains are not without challenges. A listing of challenges regarding the concept as well as its adoption in practice is given in table 5.

Table 5: Challenges to the Blockchain Evolution

Technical	Market/Business
Underdeveloped ecosystem infrastructure Lack of mature applications Scarcity in developers Immature middleware and tools Scalability Legacy systems Tradeoffs with databases Privacy Security Lack of standards	Moving assets to the blockchain Quality of project ideas Critical mass of users Quality of startups Venture capital Volatility of cryptocurrency Onboarding new users Few poster applications companies Not enough qualified individuals Costs issues Innovators dilemma
Behavioral/Eductaional	**Legal/Regulatory**
Lack of understanding of potential value Limited executive vision Change management Trusting a network Few best practices Low usability factor	Unclear regulations Government interferences Compliance requirements Hype Taxation and reporting
Source: Mougayar 2017, chapter 3.	

Some of the critique of the original bitcoin system does not apply to later blockchain systems, for example the slow confirmation of transactions, the substantial hidden costs of the system (due to the high electricity consumption of the proof-of-work consensus technique based on Bitcoin mining), or the limits to the scalability, i.e. the maximum number of transactions per second. However, the irreversibility of transactions on public blockchains (which is seen as advantage by some proponents)

Advantages and challenges of blockchains

The rather long list of advantages of blockchains or DLTs includes the following:

- Blockchain technologies have the potential to speed up transactions and processes very significantly,
- DLT networks are more robust and better protected against technical breakdowns than centralised systems,
- Public DLT systems of the blockchain type do not require trust in a central authority like a clearing house or central bank ("disintermediation of trust"),
- Public blockchains create extremely temper-resistant (immutable) ledgers – "immutability of record" – with total transparency of all transactions ever recorded (with a high degree of anonymity of senders and receives),
- Public blockchains make transactions irreversible (after block validation); however, this feature does not apply to all kinds of private blockchains,
- Distributed ledgers can record all kinds of intangible assets (from money to transferable rights) and facilitate a simple, fast and secure transfer,
- Blockchains facilitate substantial cost savings for financial institutions through real-time payments and fast reconciliation and settlement (i.e. less need of liquidity buffers),
- Private blockchains can direct (and restrict) the information flow and ledger access to authorised network participants only,
- Distributed ledgers reduce the (systemwide) need of and errors in manual data entry and reduce the costs of supervision,
- Distributed ledgers reduce costs for (redundant) data archiving and for the decentral validation of data authenticity,
- Permissioned access should reduce risk of fraud and data theft (e.g. by hacking a central server) and enhance privacy and data security,
- Consensus mechanisms require the adherence to clear business rules and detect errors,
- Private B2B platforms facilitate decentralised transaction tracking, auditing, and reconciliation,
- Private blockchains (may) allow the use of smart contracts for the execution of self-enforcing business rules, e.g. for globally accessible automatic procurement and vendor payments,

However, two banks which are very strong in FinTech by themselves – Santander and Goldman Sachs – have again left the consortium (Irrera 2016).

- An example from insurance is the Blockchain Insurance Industry Initiative (B3i) which was launched by 5 insurer and reinsurer in October 2016. The membership increased by 10 in early 2017 (Howard 2017). The aim of B3i is to "streamline paper work and reconciliations for reinsurance and insurance contracts and accelerate information and money flows, while greatly improving auditability" (Swiss Re 2016).
- An example from capital markets is the launch of a consortium of 21 financial investment companies and 5 blockchain tech firms in South Korea in December 2016; this consortium shall function as a leading blockchain think tank (Jung 2016).(28) Stock exchanges run "complex procedures that can be time consuming, cost inefficient, cumbersome, and prone to risks. The multi-layered processes – pre-trade, trade, post-trade and custody, and securities servicing – is [sic] extraordinarily complex. This makes a case for experimentation with blockchain, thanks to its potential ability to streamline the process" (Bajpai 2017).

Some of the significant differences between public and private blockchains are listed in table 4.(29)

Table 4: Significant differences between Public and Private Blockchains

Public Blockchain	Private Blockchain
Participants are not necessarily known	Participants are known
Participants are not necessarily trusted	Participants are trusted
Anyone without permission granted by another authority can read data	Only permitted participants can read data
Anyone without permission granted by another authority can write data	Only permitted participants can write data

.Source: Morabito 2017, 9

(28) For a survey of blockchain activities of stock exchanges around the world see Bajpai 2017.

(29) Not all private blockchains require that all participants are (know and) trusted. Trust (which implies knowledge) is essential for those nodes in the network that participate in the authentication of transactions or validation of ledger updates.

- ***Block validation:*** While all nodes share the distributed and continuously updated ledger, only some nodes act as validators. In a public blockchain (permissionless ledger), any node can opt to be a validator (which requires significant computer power and energy inputs in the case of the bitcoin blockchain), while in a private blockchain (permissioned ledger) only authorised nodes can validate blocks. The validation is done through an iterative process that is successful once a consensus on the validity by the majority of the validators is achieved. "Different blockchain networks use different validation techniques. Bitcoin's Block chain uses a technique called 'proof-of-work', Ripple uses 'Distributed Consensus', and Ethereum uses 'proof-of-stake' (Evry 2016, 11).(25) All techniques ensure that fraud is prevented.

- ***Block chaining:*** When all transactions are validated, the new block is added ("chained") to the existing blockchain and the updated ledger is broadcasted to the network. As the time for block creation and validation varies significantly between different types of blockchain, the process of ledger updating can take a few seconds or several minutes (up to an hour or more in worst case situations).

The bitcoin system is based on a permissionless blockchain which can be used by everybody. Financial institutions have not only realised the disruptive potential for some of their lucrative fee businesses such as money transfer and payments, but also the opportunities for better consumer experiences and improved administrative efficiencies (reduced operation costs,(26) faster transactions) when they adopt the blockchain technology by themselves. What the incumbent banks disliked about bitcoin was the lack of control over the blockchain as they must observe, among others, KYC, AML/CTF and data privacy regulations. Furthermore, the transaction volume of bitcoin is limited and by far not sufficient for the transaction volumes of large incumbent banks. Therefore, banks and other financial institutions formed alliances and teamed up with FinTechs to develop privately controlled blockchains (permissioned ledgers) (Morabito 2017, 138-140).

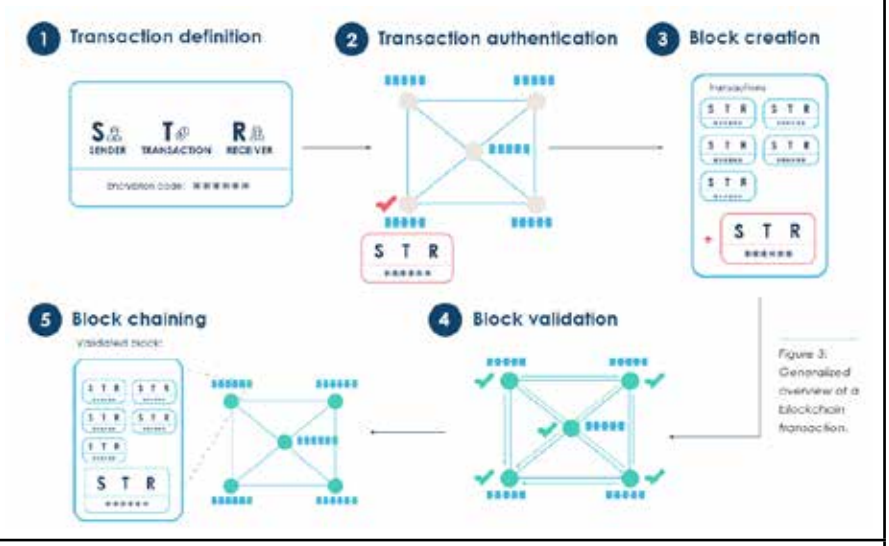
- An example from banking is the R3CEV initiative where the FinTech company R3 and global banks formed a strategic alliance for the development of the open source distributed ledger platform Corda in September 2015. The number of banks increased from initially 9 to approx. 80 by the end of August 2017.(27)

(25) For details on proof-of-work and proof-of-stake see Morabito 2017, 10-11; on various other blockchain security proofs see Narayanan et al. 2016 (on distributed consensus chapter 2.2).

(26) The operation costs of banks and other regulated financial institutions include the costs of regulatory compliance such as costs of the reporting to regulatory authorities. A branch of FinTech – "RegTech" – deals with the use of DTL and other digital technologies both from the perspective of the regulators and the regulated. This special class of DFTs is not covered by this paper; see Arner, Barberis and Buckley 2018.

(27) See the R3 website (www.r3.com); on Corda's key concepts see Brown et al. 2016.

Figure 1: Generalised Overview of a Blockchain Transaction



Source: Evry 2016, 10.

- ***Transaction definition***: A sender S creates a message that contains the valuable asset – e.g. the fraction of a bitcoin – to be transferred (T), his cryptographic digital signature as proof of ownership and of the validity of the transfer, and the public address of the receiver R. This message (transaction) is transmitted to the blockchain network. Electronic wallets for bitcoins or other digital coins (= the carriers of the valuable asset) simplify the creation, transmission and reception of transactions.
- ***Transaction authentication***: The message is received by the nodes (connected computers) of the network. They authenticate its validity by decrypting the digital signature and keep it "on hold" before it can be added (together with validated transactions of other senders) to a new block.

Block creation: The pending transactions are combined by one node into a block which is actually an updated version of the existing ledger (which itself is a chain of all blocks that have been added to the first block of the chain ("genesis block"). After a specific time (which is, for example, 10 minutes on average for the bitcoin blockchain), the new block is broadcasted to the network for validation.(24)

(24) The total time for the confirmation is longer as the time for the validation (in the next step) has to be added. Most bitcoin transaction are confirmed within 20 minutes, but sometimes it can take one hour or more; see figure 34 in Brennan and Lunn 2016, 33.

Table 3: Blockchain Applications and Solutions in Financial Services	
Brokerage services Cryptocurrency exchanges Software wallets Hardware wallets Merchant and retail services Financial data providers Trade finance solutions Compliance and identity Payments integrations	Trading platforms Brokerage services Payroll Insurance Investments Loans Global/Local money services Capital markets solutions Teller machines
Source: Mougayar 2017, chapter 4.	

"A distributed ledger is essentially an asset database that can be shared across a network of multiple sites, geographies or institutions. All participants within a network can have their own identical copy of the ledger. Any changes to the ledger are reflected in all copies in minutes, or in some cases, seconds. The assets can be financial, legal, physical, or electronic. The security and accuracy of the assets stored in the ledger are maintained cryptographically by 'keys' and signatures to control who can do what within the shared ledger. Entries can also be updated by one, some or all of the participants, according to rules agreed by the network."(20) The DLT emerged from the blockchain concept published by Satoshi Nakamoto in 2008 and was the basis of the first global cryptocurrency, Bitcoin.(21) In parallel to the implementation of Bitcoin (and a variety of other cryptocurrencies), FinTech start-ups as well as established global consultancies, law firms and government agencies explored the possible applications of the blockchain concept not only in the financial services industry (banking, money transfer and payments, stock trading, insurance) but also, among others, in the legal business and for public services.(22)

Blockchain Basics

The basic mechanism for the transfer of a valuable asset via a blockchain (of the bitcoin type) is as follows:(23)

(20) UK Government Chief Scientific Adviser (2016), 5; see also IOSCO (2017), chapter 5.

(21) See Nakamoto (n.d. [2008]); for a technical introduction to Bitcoin and cryptocurrencies see Narayanan et al. (2016), Antonopoulos (2017).

(22) Further applications of blockchain technology are under development, among others, for online music, car leasing, ride sharing/hailing (possibly disrupting disruptors such as Uber), real estate, healthcare, fraud prevention, and energy management. For a survey of blockchain applications beyond finance see Swann 2015, chapter 4.

(23) See Evry 2016 and (based thereon) Morabito 2017, 24-25; for an alternative visualisation see Brennan and Lunn 2016, 22-23.

2. Core Technologies of Digital Finance Tools

2.1 Blockchain and Distributed Ledger Technology

Among all technological innovations of recent years, the blockchain or distributed ledger technology (DLT) is often seen as the one with the greatest disruptive power for traditional banking and beyond.

Table 2: Blockchain Applications Beyond Currency

Class	Examples
General Escrow	transactions, bonded contracts, third-party arbitration, multiparty signature transactions
Financial transactions	Stock, private equity, crowdfunding, bonds, mutual funds, derivatives, annuities, pensions
Public records	Land and property titles, vehicle registrations, business licenses, marriage certificates, death certificates
Identification	Driver's licenses, identity cards, passports, voter registrations
Private records	IOUs, loans, contracts, bets, signatures, wills, trusts, escrows
Attestation	Proof of insurance, proof of ownership, notarized documents
Physical asset keys	Home, hotel rooms, rental cars, automobile access
Intangible assets	Patents, trademarks, copyrights, reservations, domain names

Source: Swan 2015, 10.

Jersey.[17] To overcome the conflict of interest between policyholders and shareholders, Lemonade only charges a flat fee of 20% of the insurance premium and earmarks the remaining 80% for claims settlement. Whether all of these 80% are spent for claim settlement (and reinsurance premiums) or only a part does not affect the income of the insurance company. Any underwriting surplus will not be pocketed by the shareholders but will be allocated proportionately to a range of social projects or non-profit institutions ("causes") which the policy holders can choose ("Giveback"). It is expected that policy holders will refrain from embellishing claims as soon as they realise that the excess would not by "paid" by the insurance company but hurts a cause that they want to support.

The model of German insurance broker firm Friendsurance (for mobile device insurance, home contents insurance, and car insurance) requires that policy holders transfer existing insurance contracts to Friendsurance.[18] These contracts remain in force for the policy holders, but the broker and the insurance companies agree to include new or increase existing deductibles.[19] This will result in a corresponding decrease of the premiums. The money saved by cheaper premiums is transferred to a solidarity pool out of which smaller claims (up to the deductibles) will be paid. If a surplus remains at the end of the period, this unused money will be paid back to the policy holders. On balance, the policy holders will not pay more for their insurance, but they benefit from the chance to receive a pay back if the claims remain low. The expectation is that claims will remain low because policy holders are organised by Friendsurance in small P2P affinity groups of approx. 10 members who all hold the same kind of insurance policy (e.g. home content). It is also possible that policy holders build their own peer groups with people whom they know and consider trustworthy (e.g. family, friends, neighbours, colleagues). A group of 10 is small enough so that any claim made by one member has a significant impact on the solidarity pool and is noticed by all other group members. It is highly probable that policy holders who want to be considered honest and whose actions are observed by the other group members will refrain from unnecessary, embellished or fraudulent claims. As the initial premiums were calculated by conventional insurers on the basis of their claims history it is reasonable to expect that the actual claims ratio of Friendsurance will be lower than the ratio assumed in the initial calculation. Hence, underwriting surpluses should materialise and can be shared.

(17) As the website www.lemoande.com explains, Lemondae offers in most cases a direct approval of online applications with an insurance premium quote that takes into consideration the personal situation of the applicant and the quality and location of the object. Furthermore, a fast claims settlement is achieved by the initial handling of claims by a claims bot which takes immediate decisions in conclusive cases.

(18) The concept is explained on the website www.friendsurance.de. As a consequence of the transfer, Friendsurance will receive all future brokerage commissions paid by the insurance companies for existing contracts.

(19) The model can be applied only to types of insurance where contracts with deductibles are used.

of a customer notes (e.g. from the GPS coordinates) that he has entered the showroom of a car dealer, the bank may send his smartphone tailored offers for car financing and insurance. Chances are that customers appreciate such personalised marketing activities.

Life cycle and situational marketing is not yet common practice of financial service providers, but they are examples for new applications of a (meanwhile) well-established DFT, namely big data analytics.

1.4 Protection

Big data analytics also plays an important role in InsurTech, for example for the calculation of risk-adequate premiums. An insurer may calculate a health insurance premium on the assumption of an average heath status of the policyholder. For policyholders with an above-average healthy lifestyle, this premium would be too high (not risk adequate). It can be reduced if the healthy lifestyle can be proven, for example by the regular transmissions of data from a wearable activity tracker (e.g. walked distances, calorie consumption, heart rate). Another example is the calculation of the amount insured and the risk premium for a home insurance. The insurance company may use big data sources and analytics to combine information on the applicant for insurance, the object to be insured, and the geographic, socio-economic, and crime situation of its immediate and wider neighbourhood as well as trends in the local or regional real estate market.

The following examples for InsurTech solutions draw the attention to another hot topic in insurance, namely the moral hazard problem. Insurers could use digital information and communication technology to create incentives to solve the basic conflict of interest in proprietary (i.e. shareholder owned) insurance companies:[15] Money paid by policyholders to the insurance company and not spent for claims settlements adds to the profit of the insurance company. Hence, the insurance company has an incentive to challenge policyholders' claims and to minimise the payouts. Anticipating this, policyholders mistrust insurers and tend to maximise ("embellish") their claims. Several insurance start ups have found different approaches to reduce or avoid this conflict, but a common denominator of the following two examples is a reliance on the solidarity in small affinity groups in contrast to egoism in large anonymous groups.[16]

Lemonade is a digital insurance company that offers fast and low-cost homeowners and renters insurance currently operating in New York, California, Illinois, and New

(15) This conflict does not exist in a mutual insurance companies where the policyholders are also the owners of the company.

(16) For the "Logic of Collective Action" see Olson 1965, and for experimental and empirical evidence of behavioural finance Baker and Nofsinger 2010. Lemonades "Chief Behavioral Officer" is Dan Ariely, one of the pioneers of behavioural economics; see as an example Ariely 2008.

interventions are made, e.g. for a finetuning of the portfolio composition. Still, due to the high degree of automation, robo-advisors have much lower operating costs than conventional advisors.

Robo-advisors use basically three types of technologies: First, they use basic techniques for investor profiling which are similar to those of banks and conventional advisory firms. The difference is that these techniques are not applied in personal interviews but in a web-based self-assessment. Second, robo-advisors should have access to and process comprehensive data on financial markets. Software for the analysis of "big financial data" and asset selection is a DFT that resembles quantitative finance ("quant") models (which started in investment banks in the 1980s and are now widely used in banking and asset management). The DFTs for the rebalancing of portfolios are similar algorithms which are applied in automated trading systems (which now dominate the stock markets of advanced countries).

Personalised marketing

Established banks (as one-stop providers of a complete range financial services) have been observing not only the success of the robo-advisors but also innovations in other segments of the financial services industry. While robo-advisors deal with "big finance data", P2P lending platforms use "big life data" for the profiling of borrowers and for the assessment of credit risks. "Big life data" comprise data from various sources about an individual's credit history, savings accounts and other investments, job situation, spending habits, shopping preferences, family status, housing conditions, special interests, vacations trips, etc.

Big data predictive analytics is deployed to detect, for example, correlations between all these variables (as predictors) and the probability of a loan default. The combination of big financial and big lifestyle data is also used to match investor's risk/return preferences with a suitable asset portfolio. As big financial data are updated continuously, a periodic rebalancing of the portfolio can maintain or improve the accuracy of its fit to the investor's preferences.

But not only financial data are continuously updated, also lifestyle data can be updated, at least periodically. Big data analytics could be used to try to identify particular constellations in a customer's life – such as marriage or divorce, change or loss of a job, birth of a child, moving to a new home, etc. – which are associated with typical financial needs. If such life cycle information is available to financial service providers (in particular banks and insurance companies), they could use them for 'life cycle marketing' and offer products which meet the specific needs of a particular life constellation. Even more granular marketing strategies have been proposed, combining more general information on life cycle, financial status, and consumer profile with specific actions of a customer. For example, if the smartphone

entries. Furthermore, advanced cryptographic techniques are applied to protect the data and valuables stored in digital devices and to ensure the safety of POS facilities (Yu, Kywe and Li 2018).

Electronic wallets and person to person payment facilities are gaining popularity and are now integrated in many online banking apps of traditional banks, but also in the Facebook Messenger. Banking apps are further enriched by personal finance management (PFM) tools. The more advanced PFM tools do not only provide historic records and a breakdown of financial activities (e.g. by splitting up household expenses to different expense categories like food, rent, car, utilities) but allow the definition of budgets for the various categories and analyses pf one's actual spending behaviour compared to one's past spending behaviour or to benchmarks of peer-groups; alerts can be sent if benchmarks are missed or limits exceeded. Such PFM tools use similar techniques as robo-advisors for a better personalised consumer experience.

1.3 Investment Advice

The global financial crisis brought to light a widespread mis-selling of financial products and faulty advice by banks. Retail investors found products increasingly appealing that incorporate a portfolio diversification but do not require discretionary interventions by asset managers such as exchange traded index funds with passive asset allocation. Nevertheless, investors still have to select from different ETFs, and ETFs are not the best investment vehicle under all individual circumstances. Hence, there still is a retail demand for investment advice. However, retail investment amounts are relatively small so that professional wealth managers either were not interested in retail customers or charged high fees which deterred retail investors.

Robo-Advisors

This dilemma was solved and a market niche was filled by start ups that came to the market as robo-advisors since 2008 (Sironi 2016). These FinTechs

- communicate with clients primarily via digital channels,
- take clients through a web-based self-profiling procedure to determine their risk appetite, return expectations, and investment horizons,
- identify suitable assets and assemble an asset portfolio that matches the client's investment preferences,
- maintain the relevant features of the portfolio over time by an automated rebalancing.

Ideally, the whole process from investment advice to portfolio management should be been automatic and does not require human intervention. In practice, help desks are available in case a client needs support, and it may also be that some human

expensive. Credit card payments would be better, but sellers are often individuals and small businesses who cannot accept credit card payments. PayPal's solution was the instant transfer of money to email addresses: Funds were loaded to the buyer's PayPal account (e.g. by bank transfer prior to the transaction or by direct debit or credit card charge during/after the transaction), an immediate notification on the payment was sent to the seller's email address, and the funds were credited to his PayPal account (which already existed or had to be created when funds were received for the first time). The payment service was initially free for buyers and sellers, but later – when PayPal offered its services to e-commerce merchants outside the eBay system – fees were charged from the merchants.

Digital wallets and contactless payments

Google launched Google Wallet as a free online P2P payments service that could be used from a desktop computer or a mobile Android or iOS device. Wallet users link their email address or phone number to their existing debit card or bank account (in the US). A user then can send money to the email address or phone number of any other user who can keep received funds in the wallet for later payments by himself or move them to the linked card or bank account. A technologically more advanced feature was the near-field communication (NFC) capability of the Google Wallet Card. With this debit card users could make contactless payments at NFC-enabled point of sales (POS) terminals. In 2015 Google changed its strategy and introduced Android Pay as an electronic wallet and NFC-based contactless payment system exclusively for Android phones. The Google Wallet Card was terminated subsequently. Users of Android Pay who upload their debit or credit card details to their Android Pay wallet can make contactless payments at any NFC card terminal with their Android Smartphone (with built-in NFC capability). Apple rolled out its competing Apple Pay digital wallet and mobile payment system with NFC capabilities for iOS devices in 2015. Its functionality is comparable to Android Pay (plus Google Wallet), and it can use the same POS hardware for contactless payments.(14) The DFT here is the NFC communication chip which meanwhile has become a standard feature of most debit and credit cards. It can also be purchased separately as a wristband, key ring or adhesive sticker (which has to be linked to a debit or credit card).

The 'upgrading' of smartphones to electronic wallets gave an additional impetus for new access and security technologies. The new technology of biometrics is not in itself a DFT but highly relevant for digital finance: Finger print identification, iris scans, voice recognition and face recognition are new technologies for smartphones that shall make access to wallets more secure and comfortable than traditional password

(14) Another (even the world's largest) provider of online payment services is Alipay. Its unprecedented growth and dominant market position is largely due to unique peculiarities of the Chinese e-commerce and banking system; see Clark 2016.

spreads do not accrue. The matchmaking platform charges a fee or commission which is considerably less than the typical charges, fees, and spreads. Second, as people in country X (Y) can dispose of funds in country Y (X), they can send money to any recipient in country Y (X) by cheap domestic transfers. This saves charges for the expensive international banking payment system SWIFT. Hence, the P2P approach eliminates two middlemen of the conventional money transfer business: a currency dealer and a payments facilitator.

However, the system hits its limits if the inflows and outflows of currencies are not sufficiently balanced. Demand/supply imbalances are a particular problem when the matchmaking platform has not instrument for price adjustments that could bring demand and supply closer to equilibrium.

International payment network based on private blockchain

Established transfer service providers face competition from the cheaper FinTech transfer services which compresses their fee income and profit margins. To remain competitive, the incumbents have to find ways to reduce costs (so that they can remain profitable despite lower fees) and enhance the service quality especially by faster transfers. Software for the matching of currency deals could reduce costs, and a blockchain network could speed transfers significantly. Such a network must be global but with access limited to members only. A private ("permissioned") blockchain with limited access is similar to bitcoin insofar as it applies a distributed ledger technology for the recording, execution and documentation of transactions through the transfer of tokens with monetary value (digital coins). It differs from bitcoin insofar as it assumes an authority that regulates the access to the blockchain, i.e. grants permissions to join the network of institutions that transact through this blockchain. While the core DFT – the permissioned blockchain – does exist in practice, payment networks of incumbent transfer service providers on this basis were still in the making until recently when SWIFT launched its own blockchain application (that applies a "Proof of Concept" for block validation). By July 2017, 28 leading global banks had joined the SWIFT initiative (SWIFT 2017).

Payment processors for e-commerce

The expansion of e-commerce in the 2000s has encouraged the emergence and growth of specialised payment processors.[13] For example, PayPal became the preferred payment option for eBay auctions. Its success is not based on a technological breakthrough but on a process innovation and a significant value added for eBay users (sellers as well as buyers): Successful auctions typically required only small payments for which sending a check was not an appropriate method; it was too slow and too

(13) See King 2013, Wewege 2016.

by combining the bitcoin system with the model of bank agents[10] as "human ATMs", i.e. individuals (or small businesses) who convert BTC into cash and vice versa against a fee. Abra started to build a network of "Abra Tellers" in a number of countries, but its focus is on the US and the Philippines. The competitiveness of the Abra approach will not only depend on the fees charged by the Abra Tellers; another serious problem is the extreme volatility of the BTC exchange rate. Although the transfer of bitcoins happens relatively fast, the whole process from the initial purchase of bitcoins to the final conversion into cash takes much more time (up to hours or days). Abra intends to shield its customers against the BTC volatility, but it is doubtful whether its hedging mechanism will survive a major depreciation of BTC (Zafar 2017). Furthermore, there is a risk that money launderers will be attracted, and finally it is uncertain how regulators will treat a Bitcoin based money transfer system. Nevertheless, Abra is an example for the application of the DFT "Bitcoin" in the practice of the international money transfer business which could make remittances cheaper and faster than incumbent systems.

International transfers based on P2P currency exchanges

While the Abra approach is quite new and unique in practice, a number FinTechs have penetrated the market with another concept that makes transfers probably not faster but cheaper and more convenient. The core DFT is an internet based P2P matchmaking software that brings together people in country X who want to sell currency A and buy currency B for transfers to recipients in country Y, with people in country Y who want to sell currency B and buy currency A for transfers to recipients in country X (Bajpai 2015). For this purpose, people in X and in Y who want to exchange their currencies and make a transfer to the other country, can open accounts with the transfer platform and credit respective amounts in their own currency to these accounts. Instead of actually buying currencies from a third party, the platform "switches" the right of disposal ("ownership") between the account holders: The people in X were initially owners of the funds on the accounts in X but after the switch become owners of the funds in Y, and the people in Y become owners of the funds in X (in respective amounts).[11] The P2P approach allows for two types of cost savings: First, as there is no actual purchase of currencies from third parties but only a conversion in the books at a favourable exchange rate.[12] Bank charges, brokerage fees, and exchange rate

(10) This model was successfully practiced in Kenya on a nationwide scale by the mobile phone money transfer system M-Pesa; see Ndung'u 2018 and with more examples Nicoletti 2014.

(11) "P2P currency exchanges … allow users to register online for an account and deposit money into it. Depending on the site, users can accept a given exchange rate or bid on an exchange rate of their choosing. Once the user finds an acceptable rate, the site makes a match, shows change of ownership of funds, and remits the funds within 1 to 2 days through a simple domestic transfer. No currency ever leaves the country, it is merely exchanged between users. Users can send money to any person, business account, or even their own account in another country" (Bajpai 2015).

(12) For example, currencies could be converted at the midmarket interbank rate; see Phillips 2014, Picardo 2015.

payments respectively the transfer of monetary values. It covers everything from huge global payments to small pocket money. Innovations in this field took off after the publication of the bitcoin concept by Satoshi Nakamoto in 2008. This paper outlined two innovative digital tools:

- the blockchain and, building on it,
- the decentralised digital currency "bitcoin" (BTC).

A blockchain is a technique to store, add and validate transaction data in an open computer network by cryptographic techniques in such a way that the correctness, immutability and safety of the data is ensured by a decentralised consensus mechanism.

Most existing payments systems are centralised systems which are systemically important but vulnerable to failures in the centre. For example, a wholesale payment system for large value transfers primarily between banks is usually operated by the central bank. As the Bank of England experienced a system failure in 2014, it started to explore decentralised alternatives,[8] and other central banks also started to explore the potentials of DLT for wholesale interbank payments systems.[9]

Retail payment systems process low value transactions in huge volumes. When payers and payees are customers of different banks, a trusted third party is needed for the processing and clearing of the transactions. This could be an automated clearing house (ACH) for transfers between bank accounts or a credit (or debit) card company for payments between (the bank accounts of) consumers and merchants. The vulnerability of such centralised systems at their centre has become apparent in recent years by large-scale hacks, data thefts and fraud. In addition, slow processing and high costs were pain points for retail customers, especially those who use money transfer services for international remittances frequently.

Bitcoin-based international money transfer

As a cryptocurrency and digital payment system, bitcoin has the capacity of very cheap and fast transfers of BTC from one internet-enabled device (e.g. smartphone) to any other irrespective of its location. However, BTC is no generally accepted medium of exchange. Remittances from one national currency (e.g. QAR) into another (e.g. PKR) require a conversion of QAR into BTC by the sender and of BTC into PKR by the recipient. BTC can be bought and sold through credit cards or transfers from bank accounts on internet platforms that function as unregulated exchanges. The conversion of BTC into cash and vice versa without a bank account or credit card is more complicated if not impossible. A FinTech start up – Abra – has found a solution

(8) Birch and Parulava 2017.

(9) The Bank of Canada, for example, came to the conclusion that, for the time being, DLT is not yet a viable option; see Wilkins and Gaetz 2017.

1.1 Crowdfunding

To overcome the limited availability of bank financing, some fund seekers started to present their projects in social media to potential fund providers. This idea was picked up by start ups who aimed at the creation of an "eBays for finance",[4] i.e. internet platforms where fund seekers and fund providers can meet and run auctions for the financing of all kinds of projects.[5] The basic technology of this crowdfunding are matchmaking peer-to-peer (P2P) internet platforms (Evans and Schmalensee 2016).

Financing contracts are concluded directly between the fund providers and the fund seekers. The platform operator is primarily a matchmaker but no financial intermediary. In most jurisdictions, the matchmaker has to check the legality of the projects admitted to the platform, and he has to ensure that the fund providers receive sufficient information for a project appraisal. Furthermore, platform operators may provide (as a service or in compliance with regulations) a risk scoring of projects. For this, some of them have applied an innovative DFT, namely big data analytics.

In the past crowdfunding platforms employed reverse auctions for the pricing of the projects, but it turned out that unexperienced investors under-priced the risks so that too many projects with a high default probability had been funded at relatively low rates. Consequently, default rates and losses for investors increased. As this damages the reputation of a platform, most crowdfunding platforms switched from auctions to the setting of risk-adequate lending and borrowing rates by the platform operator. The allocation of investors to projects could be on a "first come, first served" basis or through an automated slice, dice, and disperse mechanism.[6]

There were big debates on the disruptive potential of crowdfunding, in particular of loan-based P2P lending (called "marketplace lending" in the US). Although this form of non-bank lending has grown massively, it has been observed in many jurisdictions that a large portion of it has not replaced but supplemented bank lending, in particular to underbanked SMEs. Today, crowdfunding is often seen as a major vehicle of financial inclusion (both in emerging and advanced economies).[7]

1.2 Payment Systems

A second and multi-faceted area of FinTech and innovative DFTs is related to

(4) Here the focus is only on crowdfunding for financial returns. Prepayment or reward based as well as donation based crowdfunding is not covered.

(5) Usually distinctions are made with reference to the type of funding (loan or equity) and the status of the fund seeker (consumer or business).

(6) Projects with similar risk/return characteristics are bundled by the platform operator into "project classes" for which the operator sets the lending and borrowing rates. Fund providers do not select specific projects but project classes and specify the funding amount. The platform operator then splits this amount into smaller portions and allocates them within the selected project classes to different individual projects. This "automatic" diversification is a risk management service of the platform operator for the fund providers.

(7) See Jenik, Lyman and Nava 2017, Patwardhan 2018, 2018a.

financial technologies, bought start-ups, and implemented FinTech solutions by themselves.(2) It seems that the disruption now affects more traditional techniques than traditional financial institutions.(3)

Chapter 1 gives an outline of (selected) innovative FinTech products and services in practice and points to the underlying digital finance tools (DFTs). Chapter 2 will look in some more detail at two core technologies of a range of DFTs, namely the blockchain (or distributed ledger technology) and big data analytics.

1- FinTech Products and Services and Their Underlying Digital Finance Tools (DFTs)

There is a very wide and continuously growing range of FinTech applications and solutions in or for the financial services industry. It is impossible to cover all in this paper; table 1 is a listing of only those use-cases of FinTech applications that build on the blockchain technology. This paper will focus only on a selection of typical (and potentially disruptive) products and services.

Table 1: Blockchain Use-cases in Financial Services

Institutions	Regulators	Operations	Individuals
FX settlement	Compliance reporting	Client onboarding	Crowd-funding
Trade reconciliation	Risk visualization	Intra-company settlement	Virtual identity
Cross border payments	Basel III compliance	Normalize reference data	Credit scoring
Credit efficiency	Client fraud transparency	Time-stamping	Cross border remittance
Loan settlement	Know your customer/ Anti-money laundering	Account portability	Vault/escrow services
OTC derivatives clearing	Trade reporting	Broker fraud identification	Customer deposit cost
Collateral management		Securities agreements as smart contracts	Peer-to-peer lending

Source: Based on Brennan and Lunn 2016, 107.

(2) See the large number of examples reported by Skinner 2014.

(3) See Brennan and Lunn 2016, World Economic Forum 2017.

Banks apply digital tools since half a century. Mainframes and punchcards were used in the 1960s primarily for account management, the first ATMs became operational in 1969, and home banking started (via landline telephones) in the late 1980s but took off only with the spread of the internet in the second half of the 1990s (Sarreal 2016). Internet or online-only banks were established since 1996. They offered digital variants of (all or a selection of) core banking products and services such as transactional accounts, savings accounts, certificates of deposits, credit cards, auto loans, and home loans. Last century's internet banks were digital replications of traditional banks.

Over the last decade, a massive wave of innovation spread throughout the financial industry, spurred by developments in very different fields:

- The internet became mobile when cellphones evolved into smartphones – the first iPhone was launched in 2007.
- The global financial crisis of 2007-09 caused a massive erosion of trust in banks after illegal practices and widespread mis-sellings had become known. Disappointed bank customers became receptive for a new breed of financial service providers.
- The extremely low post-crisis interest rates caused bank customers to look for alternatives to traditional savings accounts, term deposits, etc. outside the traditional banking sector.
- The low interest rates did not benefit SMEs who had serious problems to meet their funding needs as banks deleveraged and curtailed their lending activities. They, too, were open for alternatives to bank financing.

Thus, the ground was prepared for financial innovations. Ingredients for digital innovations were also inspired by the business models and experiences of eBay as the leading peer-to-peer (P2P) auctioning platform, PayPal as its online payment system, and Amazon and Google as developers and users of big data analytics for an ever-growing e-commerce "everything store" (Stone 2013) and the leading internet search engine (Hillis, Petit and Jarrett 2013).

FinTechs and digital banks have introduced new digital products and services such as bitcoin exchanges and wallets, P2P lending, equity crowdfunding, social investing, affinity group insurance, themed investment funds, robo-advice, etc. (Wilson 2017). Many of these innovations were initiated by start-ups who considered themselves promoters of a new "sharing economy" (or "collaborative economy")[1] and as disrupters of traditional banks. However, the big hype about disruption has dampened somewhat since it became clear that incumbent banks did not sit still and waited to be disrupted. Instead, they started on their own or in consortiums research in innovative

(1) On the sharing economy see Chase 2015 or Sundararajan 2015 and with a critical perspective Slee 2015.

Digital Finance Tools in Practice

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