Financial derivatives as smart contracts

1st Ivan Grgurina
Department of Electronics, Microelectronics,
Computer and Intelligent Systems
Faculty of Electrical Engineering and Computing
University of Zagreb
Zagreb, Croatia
ivan.grgurina@fer.hr

2nd Mislav Jakšić
Faculty of Electrical Engineering and Computing
University of Zagreb
Zagreb, Croatia
jaksicmislav@gmail.com

***Abstract*—Initial margin, capital charges and default funds exist because the derivative market has inefficiencies. Derivatives come with complex processes, like daily collateral process, possibly some frequent settlement process, separated collateral and derivative cash-flow transactions, insufficient collateral when default is declared if a counterparty does not collateralize correctly and at default, a ”margin period of risk” gives rise to additional uncertainty on the market value. Central counterparties (CCPs) have been introduces as intermediaries to improve this process, but a CCP still requires an initial margin and default fund contribution. It centralizes the risk, leading to systemic risk, enforces a proprietary valuation model and restricts a set of plain derivatives, maybe due to liquidity concerns in distressed markets, e.g. for swaptions. A smart derivative contract can be seen as an algorithm that explicitly defines contract terms and all possible contract states, embeds and defines collateral and margining in the contract, defines that failure to pay results in immediate termination, replaces counterparty risk by exercising a one-day option and introduces individual contract termination, reducing systemic risk. The smart contract can be defined such that it has a positive value for both counterparties and it is non-economical to terminate the contract. Properties and technologies are still under investigation.**

***Index Terms*—derivative, smart contract, blockchain**

I. Introduction

The financial derivatives market is inefficient and risky. [1] estimates that over 75% of all derivatives are traded over-the-counter (OTC), in off-exchange transactions. Because of this, the risk that the other party will not honour their obligation is high.

To mitigate risk parties establish a collateral exchange procedure [2]. If the asset upon which the derivative rests performs poorly, the party will have to increase the amount of collateral posted. Add to this the initial margin that has to be paid, the mismatch between the value of the derivative and the collateral and the barrier to entry becomes prohibitively high.

Before suggesting how these problems might be lessened, an overview of the derivatives is given: what they are, why they exists and how they are traded.

II. Common financial derivatives

[3] defines four types of institutionalized financial derivatives: options, futures, forwards and swaps.

While forwards and swaps are contracts that are almost always traded over-the-counter, options and futures are not [4]. This is because the latter have properties which make them suitable for standardization and therefor can be easily traded on an exchange.

A. Options

An option is a contract in which the option seller grants the option buyer the right to either buy an asset from or sell an asset to the option seller for the agreed upon price within the specified time period.

A right is not an obligation and so the option buyer may allow the option to expire without ever invoking the option right. However, if the option buyer invokes the option right, the option seller must fulfill it, for they have an obligation.

B. Futures

A future is a contract in which the future seller promises to either buy an asset from or sell an asset to the future buyer for an agreed upon price at the specified date.

Unlike options, futures cannot expire without effect. Assets must be transferred from one party to the other for the stated price at the specified date.

One caveat is that if both parties agree, they can virtually break the contract by making an offsetting transaction which exactly cancels the future [4].

C. Forwards

A forward is a contract just like a future, except it is too specific to be traded on the exchange. They are made between two private parties which makes assessing their value exceedingly difficult.

D. Swaps

A swap is a contract in which two parties agreed to exchange regular payments. There are at least three types of swaps: interest rate swap, commodity swap and credit risk swap.

In an interest rate swap a variable interest rate is switched for a fixed interest rate; in a commodity swap the price of an asset is fixed; and in a credit risk swap the parties enter into an agreement not unlike an insurance deal.

[5] describes how swaps are used to reduce market risk, an act known as hedging. If a party doesn't want its derivatives to be at the whim of the varying interest rate, it can enter into an interest rate swap where it will receive a fixed rate of interest and in return, it will pay a variable interest rate on the nominal amount.

III. Smart Derivative Contract

A. Background

Financial derivatives serve the fundamental business purposes of reducing, hedging or transforming risk, and can also be used for speculative investments. The appetite of the market for these products has always been high since financial markets exist. Yet, since the default of Lehman Brothers, the market struggles under the weight of credit counterparty risk, seen now as the main risk in this market. In order to address this risk, a load of new regulations have been produced. They were imposed onto a business model which is decades old, and in some cases they magnified the inefficiencies and increased the impression that derivatives are complex, obscure and confined to the community of large banks. Difficulty of management, opacity of valuation methods, and liquidity problems keep non-banks out of the safest derivatives market, where counterparty risk is controlled by top-level collateral agreements. [6]

Given the inefficiencies and complications in the settlement and processing of a standard derivative and the possibilities of smart contracts, there is a plenty of room for improvements. According to [1], [7], these improvements include, but are not limited to, equipping derivatives with bilateral and flexible state-of-the-art standardized valuation model and margining process, making it capable of handling trade based netting of cash-flows and collateral flows, but also able to manage a possible default of the counterparty.

Blockchain technology is aimed at reducing the amount of trust, and the number of intermediaries, in a business process, based on cryptographic tools like hashing and digital signatures, accounting on a shared ledger, and mechanisms of distributed automation like smart contracts. These techniques, at odds with the existing business model, can be enablers for a reform of the business model itself. Unfortunately, cryptocurrency blockchains are not ready to scale and lack privacy protection beyond pseudonymity, remaining outside the regulated world. Smart contracts, by efficiently managing collateral and automated covenants, are designed to compensate as much as possible for lack of legal recourse, to make it work even in a permission-less / pseudonymous space where suing the counterparty for breach of contract and rely on a legal default may be much harder than usual. [6]

B. Smart Contracts

Per [7], a smart contract is a computer protocol intended to digitally facilitate, verify, or enforce the negotiation or performance of a contract. It can be seen as an algorithmic description of the contract with clear and definite states and state transitions, where removing uncertainty about the state will remove risk. Therefore, all states of the contract and all transitions between states have to be defined.

C. Distributed Ledger

Per [7], a distributed ledger (also called a shared ledger, or distributed ledger technology, DLT) is a consensus of replicated, shared and synchronized digital data geographically spread across multiple sites, countries, or institutions. It is a platform which allows to run the smart contract under certain requirements on technology and infrastructure.

D. Desired properties

The desired properties, according to [7], that smart derivative contracts should have are as listed below:

- **True bilaterality**: The contract can be tailored between two counterparties, which allows for custom valuation models
- **Valuation**: Valuation model and market data source are defined as part of the contract, which leads to no disputes
- **Settlement**: Net cash flow is determined as part of the contract and settled, which means there is no settlement gap risk
- **Processing**: Cash flows are processed automatically, therefore there is no uncertainty on settlement / margin period of risk
- **Termination**: If settlement / processing fails, the contract terminates immediately in a deterministic way, which leads to no cure period, no uncertainty, no counterparty risk

[8] pioneered the implementation of a classical financial derivative (interest rate swap) on a blockchain, possibly using cryptocurrency, but that implementation didn't address the problem of termination properly, which left us with a lot of uncertainty upon failure to pay. The solution for that was presented in [1]: terminate the contract if the wallets do not show sufficient balance, but that left us with other problems. If the contract is terminated given that the two wallets show insufficient balance, we effectively have a bilateral American option.

An American option allows the holder to exercise their right at any time prior to the contract's maturity date, while European options can only be exercised on the maturity date. Most securities traded on an exchange today are American options. [9]

Both parties can wilfully terminate the contract by not providing funds to the wallet (or withdrawing the funds). A bilateral American option is quite useless, because nobody can rely on the other parties payment. The solution is presented in [1], where the authors introduce a termination fee P, which servers as an option strike, making it economically unfavourable to exercise the option.

E. Definition

1) Setup: Lets assume that smart derivative contract operates on three accounts / wallets:

- W^A and W^B: Account accessible for Bank A or B. Cannot turn negative.
- W^P: Account holding the termination fees, leaving it segregated and non accessible by A nor B after trade inception. [1], [7]

2) Trade inception: Trade inception happens when banks agree on contract details and supply initial funds to wallets, such that their margins M do not exceed the funds, including the account holding the termination fees, where W^P is greater than the termination fee P. [1], [7]

3) Trade life cycle: Trade life cycle of the smart derivative contract has multiple phases, as seen on Fig. 1:

1) **Access**: Banks may access wallets to post margin amounts.
2) **Precheck**: Check if wallets contained specified margin amounts (else: termination).
3) Wait for market data / fixing.
4) **Fixing**: Calculate net cash flows / settlement amount.
5) **Precheck**: Check if wallets allow settlement (else: termination).
6) **Settlement**: Adjust wallets.
7) Check for maturity, otherwise continue. [1], [7]

4) Termination: Termination can happen under two circumstances:

- If a counterparty failed to provide the required funds (margin) or its margin was too small to allow for the transaction, the other counterparty receives the termination fee of the failing counterparty.
- If the contract matures, both counterparties receive their termination fees. [1], [7]

5) Interpretation of the margin buffer M: The margin buffer M covers the settlement. It determines the probability at which the contract is terminated by unexpected market moves, something like a quantile. Since M determines the probability of market induced termination, it assigns a contract specific rating. The contract does not differentiate between a termination due to a market move or a termination due to the failure of a counterparty to provide funding to the wallet (default). The contract detaches from default, and upon termination the not-terminating counterparty receives termination fee P covering the gap risk. [1], [7]

6) Interpretation of the termination fee P: The termination fee P is paid to the non-terminating party. Lets consider the case where the settlement amount X exceeded the margin buffer M, i.e., X is greater than M. This will result in termination. If X - M is smaller than P the termination fee covers the gap risk. If X - M is greater than P the termination fee does not cover the gap risk. A fair choice of P might be shown as $E(X - M|X > M)$. [1], [7]

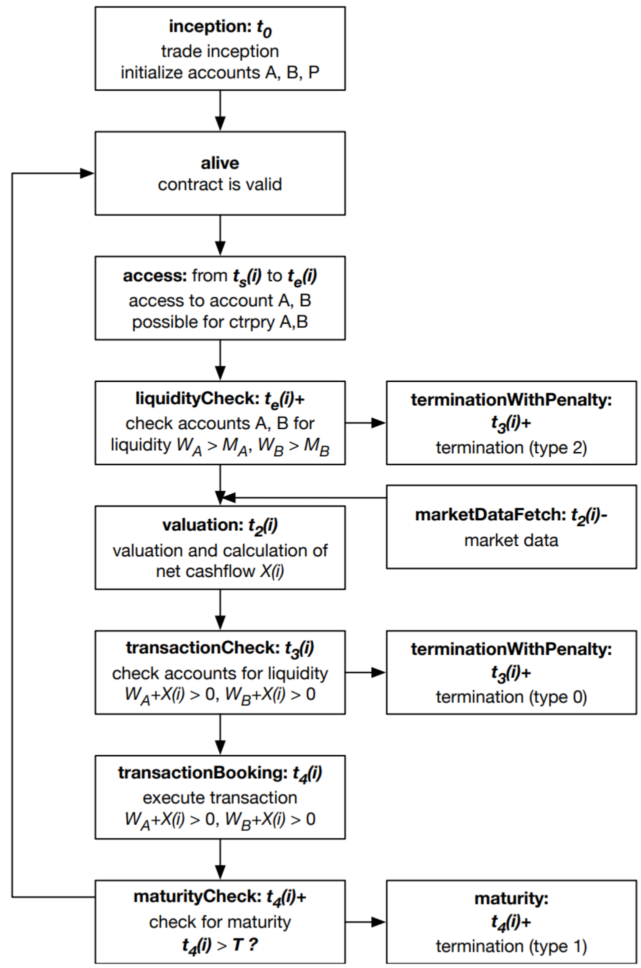

Fig. 1. Trade life cycle of smart derivative contract [1], [7]

F. Open issues and outlook

1) Technology: Is there a need for third party? The distributed ledger technology allows to protect the termination fee, by using cash-on-ledger, crypto-euro etc. A third party (escrow service) handles the accounts. A central bank provides the accounts with required properties. [1], [7]

2) Operations: Can we embed the contract into current operation infrastructure (reporting, limits checks, etc.)? [1], [7]

3) Legal: What is the legal state of the contract upon counterparty default? [1], [7]

4) Regulatory: Will the regulator acknowledge the risk reduction of the smart contracts? [1], [7]

References

[1] Dimitris N. Chorafas, ”Introduction to derivative financial instruments”, The McGraw-Hill Companies, pp. 60–61, 2008.

[2] Christian P. Fries, Peter Kohl-Landgraf, ”Smart Derivative Contracts: Detaching Transactions from Counterparty Credit Risk – Specification, Parametrisation, Valuation”, April 2018., https://ssrn.com/abstract=3163074

[3] Dimitris N. Chorafas, ”Introduction to derivative financial instruments”, The McGraw-Hill Companies, pp. 39–43, 2008.

[4] National Association of Pension Funds, ”Derivatives and Risk Management Made Simple”, p. 4, December 2013., https://www.jpmorgan.com/jpmpdf/1320663533358.pdf

[5] National Association of Pension Funds, ”Derivatives and Risk Management Made Simple”, pp. 6–7, December 2013., https://www.jpmorgan.com/jpmpdf/1320663533358.pdf

[6] Morini, Massimo, Managing Derivatives on a Blockchain. A Financial Market Professional Implementation (May 5, 2017). Available at SSRN: https://ssrn.com/abstract=3075540 or http://dx.doi.org/10.2139/ssrn.3075540

[7] Fries, Christian P. and Kohl-Landgraf, Peter, Smart Derivative Contracts (Presentation Slides of the 14th Quant Finance Conference) (September 27, 2018). Available at SSRN: https://ssrn.com/abstract=3262277 or http://dx.doi.org/10.2139/ssrn.3262277

[8] Morini M., and Sams, R. Smart Derivatives can cure XVA headaches, with R. Sams, Risk Magazine, August 2015. Paper used by the U.S. Commodity Futures Trading Commission for survey on Distributed Ledger Technology. http://www.risk.net/risk-magazine/opinion/2422606/-smart-derivativescan-cure-xva-headaches

[9] https://www.money-zine.com/definitions/investing-dictionary/american-options/, Date: January 14th, 2019