# Economics of the Exactly Protocol

Audit Report

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## Content

# 1 Introduction

Exactly Protocol is a decentralized, non-custodial, and open-source protocol that allows users to frictionlessly exchange the time value of their assets at a fixed and/or variable interest rate.

The protocol allows users to take loans and make deposits at a fixed interest rate for different maturity dates through the interaction with the "*Fixed Rate Pools*". Such an algorithmic protocol can offer non-custodial lending, as users are only allowed to borrow assets for a collateral that they must provide upfront.

The fixed interest rates for lending and borrowing are determined based on demand and supply ("*utilization rate*") at the time of the transaction. The funds of each Fixed Rate Pool are provided by depositors that lock their assets for a fixed duration. Besides this, funds can be placed in a "*Variable Rate Pool*". This second pool is characterized by funds that can be shifted between different maturities and is funded by depositors who do not commit for a predefined duration.

Exactly is going to be implemented on the Ethereum Blockchain. It is planned to launch the protocol in the coming months before which various audits ensure that the protocol runs as intended.

As part of these audits, Swiss Economics / cryptecon audited the economic model of Exactly. The work focuses on the mathematical correctness and plausibility of the model outcome. In four work streams, Swiss Economics / cryptecon

a) created an **overview of Exactly's ecosystem** and reviewed its **economic principles**,

b) conducted a **mathematical validation** of Exactly's model,

c) conducted a **numerical plausibility check** of Exactly's model outcome, and

d) coordinated this auditing project and concluded their findings in this report.

The findings of these workstreams and the work progress are described as follows:

- Section 2: Review of Economic Principles
- Section 3: Mathematical Validation
- Section 4: Numerical Plausibility Analysis
- Section 5: Conclusion

Based on our audit we conclude that Exactly's model is economically plausible, mathematically correct, and theoretically feasible as summarised in the following:

- Exactly offers a unique lending protocol design focusing on fixed instead of variable terms. At the cost of less flexibility, it can offer fixed rates and conceptually a lower spread than comparable projects. Thus, if lenders and borrowers are sufficiently flexible, Exactly's unique design will likely succeed.
- From the audit of the technical paper, we find that the mathematical specification of the model correctly reflects the conceptual idea of Exactly's decentralized credit market protocol. Minor remarks that cryptecon made on the computations are or will be considered.
- Our numerical calculations revealed that the results are plausible. Based on a first initial calibration we find that the protocol is in principle able to produce competitive spreads.

To ensure that lending and borrowing is balanced, we advise putting effort into the calibration methodology and the specification of the collateral mechanism.

# 2 Review of Economic Principles

## 2.1 Description of the Ecosystem

In its most basic form, Exactly Protocol is a marketplace where borrowers and lenders, holding different crypto assets, can lend and borrow assets. The principles of lending protocols are illustrated below.

**Figure 1: Principles of lending protocols**


Source: cryptecon

Figure 1 shows the interaction between lenders (or depositors), borrowers, and Exactly to lend and borrow crypto assets. Lenders deposit assets and earn interest. Borrowers borrow assets and pay interest while depositing another asset as collateral.

As a decentralized lending platform for crypto assets, Exactly is comparable to other platforms like Aave, Compound Protocol, and dYdX (see e.g. Gudgeon et al., 2020).[1] However, it differs from existing platforms as will be described in more detail further on. Most importantly, Exactly offers fixed interest rates determined by asset pools of defined maturities for lending and borrowing. This allows for interest rate security and, in comparison to other lending platforms, a reduction of the liquidity problem.

The incentives of lenders and borrowers to participate in such an ecosystem can be summarised as follows.

**Table 1: Motivation and incentives of actors in the ecosystem**

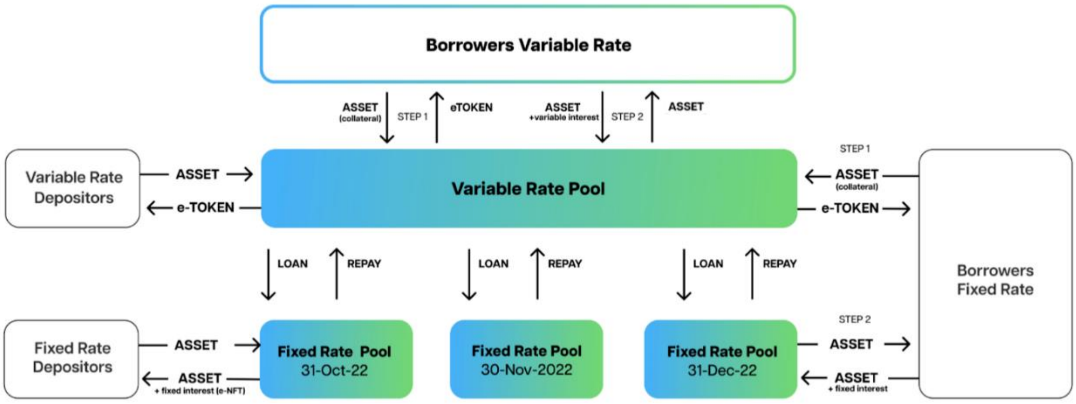
| Lenders | Borrowers |
|---|---|
| ▪ Holders of crypto assets can earn interest rates by depositing their assets in Exactly's pools.<br>▪ Depending on the duration for which they want to deposit their assets, they earn different levels of fixed or variable interest. | ▪ For users who require but do not own a certain crypto asset (or enough of it), Exactly offers the opportunity to borrow the currency for a defined interest rate over a defined period.<br>▪ Instead of exchanging a crypto asset they hold, borrowers can use their own assets as collateral for borrowing another asset and thus leverage their position. |
| → Lending crypto assets allows to generate profits and offers an alternative to, e.g., staking. | → Instead of selling their crypto assets in return for another asset, borrowers can borrow other assets and use what they own as a collateral. |

The interest rates for fixed and variable borrowing and lending are determined by the demand and supply for different crypto assets in the protocol. The way different maturity pools and the

[1] Gudgeon, L., Werner, S.M., Perez, D., Knottenbelt, W.J.: DeFi protocols for loanable funds: Interest rates, liquidity and market efficiency (2020). https://arxiv.org/abs/2006.13922.

Variable Rate Pool interact in this ecosystem is illustrated in Exactly's white paper as shown in **Figure 2** (white paper version June 2022).

**Figure 2: The interaction between Exactly's users and asset pools**




Source: Exactly white paper

As illustrated in the previous Figure, the platform has two types of pools for each asset:

- **Fixed Rate Pools**: These pools have a specific maturity date and a unique interest rate for every transaction. The interest rate is determined by the relationship between lending and borrowing amounts (utilization rate) at the specific moment of the transaction and is fixed until maturity. The Fixed Rate Pool receives liquidity from fixed rate depositors and/or from the Variable Rate Pool.
- **Variable Rate Pool**: The depositors receive a variable rate similar to a money market. Loans can stem directly from users wishing to borrow at variable rates or from Fixed Rate Pools.

Different borrowing and lending options at fixed and variable rates are possible on the platform. The four common ways of borrowing and lending are described in Table 2.

**Table 2: Main user actions**

| Lender (depositor) | Borrower |
|---|---|
| ▪ Fixed rate: Users can deposit an asset in a specific Fixed Rate Pool and receive a fixed interest rate at maturity.<br>▪ Variable rate: Users can deposit an asset in the Variable Rate Pool and receive a variable interest rate. | ▪ Fixed rate: Users can borrow an asset from a specific Fixed Rate Pool and pay a fixed interest rate.<br>▪ Variable rate: Users can borrow assets from Variable Rate Pools without maturity dates. |
| Users receive a token that represents their deposits (eTokens). To close their position users can exchange these eTokens for their initial deposits. | Users can either use whitelisted crypto assets or their eTokens as collateral. They receive eTokens for the deposited collateral. |

## 2.2 Discussion of the Economic Principles

**General economic principles of lending platforms**

From an economic point of view, lending platforms constitute multi-sided platforms, acting as an intermediary between different interdependent groups (see Figure 2). There are many markets in which multiple groups try to interact with one another. The members of one group are looking for a good match with members of another group and vice versa. However, this matching process can be challenging and costly. Platforms, like Exactly, can act as intermediaries and facilitate interactions between these different groups.

Platform business models have several key characteristics:

- In particular, the different agent groups on a platform are exposed to (positive) cross-network effects. This is the case if a platform becomes more attractive/valuable for one group because the group on the other side of the platform grows.
- In many cases, these platforms are worthless if only one group is part of it. Thus, the main challenge for a platform with such cross-network effects is to bring all groups to the platform. The platform must notably decide on a pricing strategy, that can incentivize different groups of agents to join.
- The prices should be set to achieve maximum growth while considering the size of the various groups and their differing cross-network effects. When the cross-network effects on a platform vary among groups, a situation may arise in which optimal prices differ between groups and periods.

As already mentioned above, lending platforms facilitate the interactions between lenders and borrowers of crypto assets. Both agent groups induce positive cross-network effects: The higher the number of lenders, the more attractive is the platform for borrowers, and vice versa.

Thus, for Exactly it is crucial to balance lenders and borrowers – or more specifically – the lending and borrowing amounts. Exactly and other lending platforms balance both sides by measuring a utilization rate. The utilization rate describes the amount of the provided (lent) credit borrowed by users. The utilization rate is then used as an input for the "*interest rate model*", a function that computes the interest rates for borrowers and lenders (see eg. Gudgeon et al., 2020).

Interest Rate Models are designed such that, when the utilization rate is high – i.e., a high share of the provided liquidity is being borrowed – the borrowing interest rates are high as well. This will discourage users to take new loans and encourage lenders to deposit more. The opposite holds when the utilization rate is low. Then borrowing interest rates are low, encouraging users to borrow more, whereas the lenders are less incentivized to deposit more. This way lending platforms can balance lending and borrowing of credit.

Another important aspect of any lending platform is the collateral. Exactly must ensure at any point of time that borrowers' collaterals are more valuable than their loan. Otherwise, borrowers would have no incentive to pay back the loan since the protocol is decentralized and repayment cannot be enforced by law. Because the value of the loan may change over time Exactly must incentivize borrowers to keep their collateral aligned with the value of the loan.

This can be achieved by setting a collateral factor that defines the rate or ratio of assets that can be borrowed in relation to the value of the collateral provided. If the collateral is below a critical collateral factor the collateral will be liquidated. The collateral factor is defined by Exactly to ensure the security of lending and borrowing on the platform.

In conclusion, similar to other lending platforms, Exactly ensures the stability of the lending platform by using two types of mechanisms:

- An interest rate model that keeps lending and borrowing of credit balanced, and
- by adjusting the collateral factor that ensures repayments of loans.

**Exactly specific economic principles**

Exactly Protocol shares the basic concept of lending platforms, allowing automated lending and borrowing on the Blockchain. The main difference to most other lending platforms such as AAVE is that Exactly utilizes pools with specific maturity dates. Exactly focuses on interest rates that are fixed at the beginning of a lending and borrowing period. All other major lending platforms focus on variable rates (see, e.g., Gudgeon et al., 2020). Note that some of them offer so-called *stable* rates. However, these rates are only fixed under certain market conditions and the protocols do not provide the same reliable framework regarding the interest rates to lenders and borrowers as does Exactly.

In the few other protocols with fixed maturity pools, the maturity is predefined and premature withdrawal is disincentivized by penalties. This allows to minimize liquidity risk and to offer lower spreads. The Exactly Protocol stands out by allowing depositors and borrowers to leave a fixed maturity pool whenever they wish by paying the present value of the final debt or selling the deposit at its present value instead of paying a penalty. Thus, Exactly Protocol's users wishing to withdraw prematurely will incur the cost resulting from the difference between the present value of the debt/deposit calculated with the initial fixed rates and the present value of the debt/deposit calculated with the fixed rate at the time of withdrawal. This way Exactly's users are also disincentived to withdraw prematurely and thus liquidity risk is minimized, but in a arguably fairer way than with penalties. Exactly's approach is an innovative way to deal with early withdrawals in fixed maturity pools and unique in comparison to similar projects.

In addition, lending platforms face the chicken-and-egg problem. For a functioning borrowing and lending market, sufficient assets have to be initially supplied to guarantee liquidity. Generally, the interest rates which depend on the utilization rate should incentivize borrowing/lending. However, if there are only a few users on the platform (because of its novelty, perceived uncertainty, etc.) it is unsure whether these incentives are sufficient to attract more users and ensure liquidity. This lending protocol issue is less pronounced in the case of Exactly. Generally, compared to variable rate systems, Exactly can still function with lower levels of liquidity, because it concentrates liquidity at fixed terms.

To summarize Exactly offers a unique design focusing on fixed instead of variable terms. At the cost of less flexibility, it can offer a lower spread than comparable projects conceptually. Thus, if lenders and borrowers are sufficiently flexible, Exactly's unique design is likely to become successful. Based on the economic principles we thus conclude that the protocol is feasible.

# 3 Mathematical Validation of the Model

Cryptecon reviewed and commented on the current documentation of the model with regard to the formulas describing the protocol.[2] As part of our auditing work, we validated if the protocol is based on correct calculations as provided in the documentation.

Our analysis was based on two documents from Exactly Protocol: a white paper and a technical paper. Different versions of these documents were reviewed by Swiss Economics / cryptecon over the course of the audit. These versions include the

- white paper from
  - May 2022 shared as "Exactly v1 White Paper [WIP].pdf", and
  - June 2022 shared as "Exactly White Paper [Draft].pdf"

as well as

- the technical paper
  - from May 2022 shared as "tech_paper_rv3.pdf",
  - from August 2022 shared as " tech_paper+treasury_rv01.pdf", and
  - from August 2022 shared as "ExactlyMathPaperV1.1.pdf".

At the point of receiving the last version of the technical paper, the audit process was already terminated. We checked whether changes made compared to the former version (May 2022) would require additional audits. We found this not to be the case. Note, however, that some issues pointed out in this audit report are already implemented in the new Version (August 2022).

The audit included checking the correctness of the mathematical formulas and their notation. The feedback of Swiss Economics / cryptecon, including clarifying questions, was shared with Exactly Protocol in three emails. Additionally, the findings and comments were discussed in a meeting on Friday, 1st of July 2022.

For the mathematical validation, the focus of the audit was the technical paper in which the model is described in detail. The document is clear and allows us to understand the mathematical concept. As far as we can judge, the document reflects the economic mechanisms intended by Exactly Protocol.

The audit could not identify any critical mistakes. Minor issues identified are already implemented in the most recent versions of the white paper (June 2022) and technical paper (August 2022) available at the point of writing this report.

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[2] Our analysis and discussion of Exactly Protocol is consistent with the most recent documentation of the protocol available at the point of writing this report.

# 4 Numerical Plausibility Analysis

To investigate the plausibility of the model outcome, we created a simple quantitative model of Exactly Protocol's economic mechanisms. By doing so, we validated whether based on a first initial parametrization the calculations result in reasonable and competitive results.

We conducted the plausibility check of the model using Excel, extracts of which can be found in the appendix. It was previously shared with Exactly together with our feedback, as described in the previous section. A first sheet includes all parameters described in the technical paper.

In the following sections, we

1. derive the Interest Rate Model and calculate interest rates and spreads for an assumed utility rate, and then
2. compare the resulting Interest Rate Model and interest rates with competitors.

## 4.1 Interest rate calculation

Central to the platform is the interest rate function which is determined by the utilization rate or ratio of borrowed to lent amounts of a given asset on the platform. The interest rate as a function of the utilization rate, as described in 4.1.1 of the technical paper and 4.1 of the white paper, is

$$R(U) = \frac{A}{U_{max} - U} + B \ ,$$

where

$$A = \frac{U_{max}\,(U_{max} - U_b)}{U_b}\,(R_b - R_0),$$

$$B = \frac{U_{max}}{U_b}\,R_0 + \left(1 - \frac{U_{max}}{U_b}\right) R_b,$$

and

$$U_{max} = \Lambda, \ \ \Lambda > 1,$$

with parameters specified in our model as

$U_b = 0.20$, by assumption of cryptecon

$U_{max} = 1.01$, as a result of calculations

$R_0 = 0.015$, by assumption of Exactly (email)

$R_b = 0.04$, by assumption of Exactly (email)

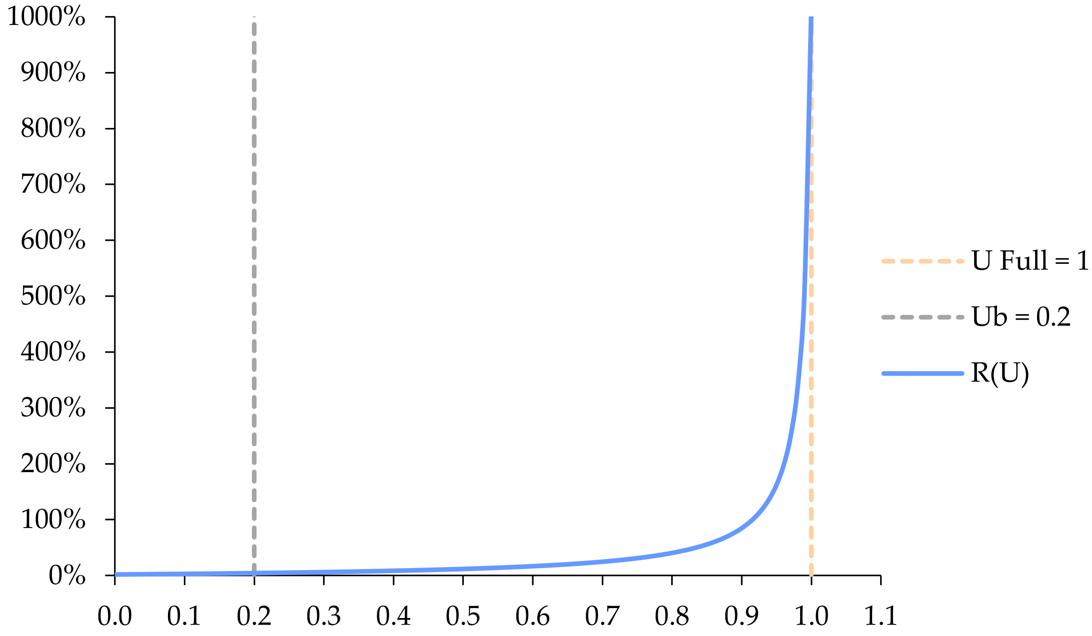
$\Lambda = 1.01$, by assumption of cryptecon

$A = 0.1022$, as a result of calculations

$B = -0.0862$, as a result of calculations

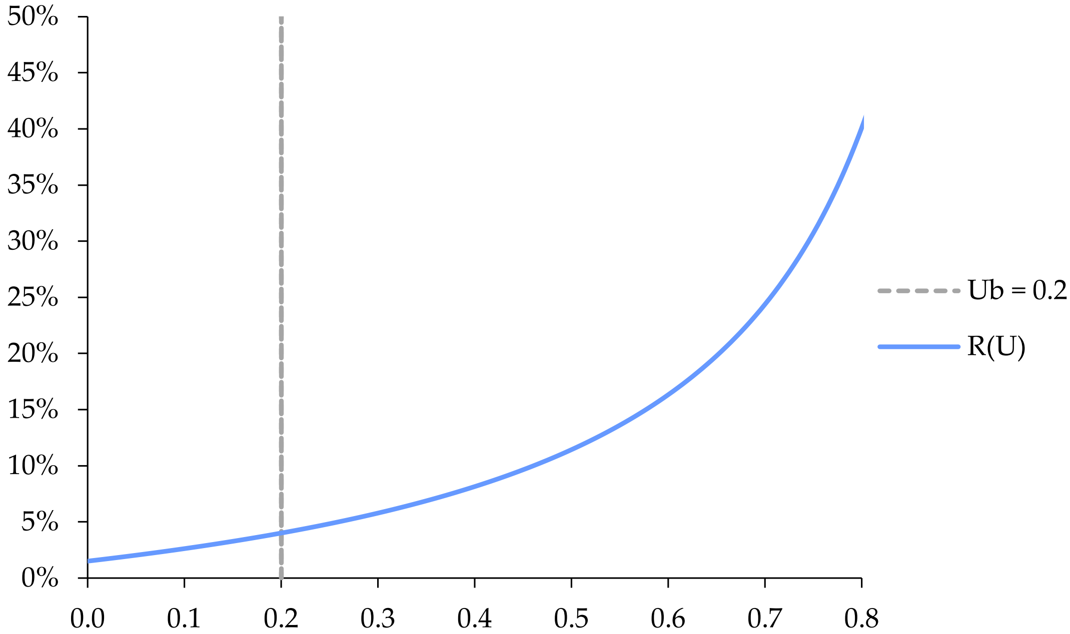
This parametrization produces the following interest rate curves on two different scales of the utilization rate (0 to 0.8 and 0 to 1.1).

**Figure 3: Borrowing interest rate as a function of the utilization rate [0, 1.1]**




Source: cryptecon

**Figure 4: Borrowing interest rate as a function of the utilization rate [0, 0.8]**




Source: cryptecon

Assuming a utilization rate of 0.17 (equation 8), this results in a borrowing interest rate of 3.84% (equation 12) and a lending interest rate of 3.46% (equation 18) which leads to a spread of 0.38%. This outcome seems reasonable.

It is important to note that this analysis is based on static calculations. Because borrowing and lending demand is uncertain and depends on the interactions of actors in this market over time, our numerical analysis for a single point of time cannot ensure the stability of the protocol over time.

To infer more about the dynamics of the system we recommend running dynamic tests or conducting dynamic modelling techniques before the public launch of the protocol.

## 4.2 Comparison

The model outcome is strongly dependent on alternative platforms where users can lend and borrow crypto assets at variable and stable rates. In the following, we analyze and compare the interest rate specification of Exactly with Aave. First, we compare the shape of the interest rate curves. Then, we compare the level of the interest rates and the spreads.

The borrowing interest rate curve of Exactly considers three well-differentiated regions depending on whether $U \leq U_b$, or if $U_b < U \leq U_{full}$ or finally if $U_{full} < U < U_{max}$. This is in contrast to the interest model of Aave which defines mainly two regions depending on whether the utilization rate is under or over a defined $U_{optimal}$: The borrowing interest rates increase slowly when $U < U_{optimal}$ and start rising sharply when $U \geq U_{optimal}$. Moreover, the interest rates are modelled by Exactly using a single, continuous, and differentiable rational function, whereas Aave uses a "kinked" interest rate model with a constant slope on both sides of the "kink": The slope of the interest rate model is much steeper above the $U_{optimal}$ than below. This aims at keeping the utilization rate at or under $U_{optimal}$ by strongly discouraging users to take on new loans and encouraging the repayment of outstanding ones. The difference with Exaclty is thus in the way borrowers are incentivised to stay under a defined threshold of borrowed assets.

Exactly needs to offer competitive interest rates and tight spreads to be successful. Thus, we compare the level of interest rates between Exactly and Aave. However, a meticulous comparison is cumbersome since the utilization rates of Exactly and Aave are defined differently. Therefore, we conduct a rough comparison between Aave's actual interest rates and Exactly's interest rates when the utilization rate is 100%. Aave's actual interest rates lie between approx. 0.5% (non-stable assets with variable rates) and 12% (stablecoins with stable rates). The fixed borrowing interest rate of Exactly when $U = 17.2\%$, with the parameters defined in section 4.1 of this audit report, is at 3.84%. This interest rate level seems to be reasonable in comparison to Aave.

Additionally, we compare the borrowing and supply interest rate spreads of Aave and Exactly. With the same parameters' calibration as presented in the section 4.1, assuming a utilization rate of 17.2%, a spread of 0.38% is calculated for Exactly. This is much lower than what can be observed on Aave Markets[3], where the spreads for *stable* (quasi-fixed) interest rates are, depending on the assets, at levels of about 5 to 10%. Therefore, Exactly's lower spread, under the described, assumptions is competitive compared to Aave.

The result of the conducted analysis in section 4.1and 4.2 depends on the dynamics of users in the protocol: it is likely that the utilization rate differs between different assets. For example, there might be higher demand for borrowing some asset than others because some assets can be used more broadly than others. Therefore, parameters of the Exactly Protocol should be calibrated based on the specific characteristics of each asset.

[3] See https://app.aave.com/markets/.

# 5 Conclusion

As part of this audit, the Center for Cryptoeconomics analyzed Exactly's whitepaper and technical paper. The documents are clear and allow us to understand the general and mathematical concepts. As far as we can judge from the provided information, the documents reflect the intentions for the protocol design of Exactly.

Based on the audit we conclude that Exactly's model is economically plausible, mathematically correct, and theoretically feasible:

- Exactly is a unique lending protocol design focusing on fixed instead of variable terms. At the cost of less flexibility, it can offer fixed rates and conceptually a lower spread than comparable projects. Thus, if lenders and borrowers demand fixed terms, Exactly's unique design is likely to become successful.
- From the audit of the technical paper, we find that the mathematical specification of the model correctly reflects the conceptual idea of Exactly's decentralized credit market protocol. Minor remarks we made on the mathematical concept and notation will be considered. Besides feedback sent directly to Exactly Protocol, we created an Excel sheet with all model parameters to test the completeness and plausibility of the parametrization.
- Numerical calculations revealed that results from the model presented in the technical paper are plausible. Based on an initial calibration we find that the protocol is in principle able to produce competitive interest rates and spreads.

To ensure that lending and borrowing is balanced, we recommend focusing on the following topics before the launch:

- The choice of the level and steepness of the interest rate curve R(U) is important to balance lenders and borrowers and could incentivize arbitrage between different pools, e.g., between Exactly and Aave, or even between different pools in the protocol itself. Parameters should be calibrated such that equilibrium interest rates are always below full utilization and above $R_0$. These parameters will vary among different asset types and hence Exactly Protocol should calibrate the parameters per asset.
- The collateral is an important aspect for risk management and an important bottleneck of activity on the platform. It is hence important to cautiously choose collateral assets and collateral factors that reflect the risk management strategy of Exactly Protocol. Moreover, it is important to specify how the collateral factor is potentially updated in the future.
- Since fixed rates are offered to lenders and borrowers at the same time, a loan or credit shock could induce a shortage on either side. It is possible that under certain conditions this shortage cannot be solved by using regular incentives from the Variable Rate Pool. To mitigate this risk further, Exactly has introduced a Liquidity Reserve. Nevertheless, we recommend analyzing under which conditions such imbalances might happen and whether, through careful calibration, the Variable Rate Pool can react properly.

To find reasonable parameters and finalize the model we propose an extensive dynamic evaluation of the protocol (e.g., using a test-net) or in-depth modelling analysis (e.g., using agent-based-modelling). A particular focus should be placed on the dynamics around the individual interest rates. Besides possible evaluations before the public launch of the project, consistent monitoring and adjusting of parameters should ensure a sustainable growth of the platform once it is launched.

# A Appendix

### Excel Model Quantification Extracts

Below are extracts from the Excel file created for the numerical plausibility analysis (section 3).[4] Green cells report parameter values as stated in the paper, orange cells are assumptions for not yet specified parameter values and white cells are the result from calculations of green and/or orange cells. All parameters are rounded to the nearest four decimal places. The Excel makes references to sections in the technical paper where parameters and formulas are described (e.g., "4.1.1 Credit Demand Interest Rate Function").

### Parameters

**Baseline Parameters**

| Parameter | Value | Remarks |
|---|---|---|
| eta | 0.1000 | |
| R0 | 0.0150 | |
| Rb | 0.0400 | |
| Lambda | 1.0100 | |
| betaslow | 0.0046 | |
| betafast | 0.4000 | |
| delta | 0.1000 | |
| Gamma | 1.2500 | |
| nuliq | 0.0500 | |
| nuBD | 0.0100 | |

**3. Variable Rate Pool**

| Parameter | Value | Remarks |
|---|---|---|
| TSSt | 150.0000 | |
| SSt | 135.0000 | eq (1) |
| RSST | 15.0000 | page 3 |
| TSSt | 150.0000 | eq (2) |

**4.1.1 Credit Demand Interest Rate Function**

| Parameter | Value | Remarks |
|---|---|---|
| U | 0.1724 | = UtFR,i from eq (8) |
| TBtFR,i | 25.0000 | |
| TDtTR,i | 10.0000 | |
| tauFR | 5.0000 | page 5 |
| Ufull | 1.0000 | page 5 |
| Umax | 1.0100 | eq (9) |
| Ub | 0.2000 | page 5 |
| A | 0.1023 | eq (6) |
| B | -0.0863 | eq (7) |
| R(U=0) | 1.5000% | = R0, eq (4) |
| R(Ub) | 4.0000% | = Rb, eq (5) |
| R(U) | 3.5842% | eq (3) |
| UtFR,i | 0.1724 | eq (8) |

[4] Calculations are based on the version from May 2022 ("tech_paper_rv3.pdf"). Adjustments in the most recent version from August 2022 ("ExactlyMathPaperV1.1.pdf") do not have a significant impact on those calculations.

### 4.1.2 The Effective Interest Rate for a Particular Loan

| Parameter | Value | Remarks |
|---|---|---|
| **TBtkFR,i** | 25.0000 | = TBtFRi from above |
| **TDtkTR,i** | 10.0000 | = TDtTRi from above |
| **Btk+1FR,i** | 5.0000 | |
| **UtkFR,i** | 0.1724 | eq (10) |
| **Utk+1FR,i** | 0.2069 | eq (10) |
| **<R>tk+1FR,i** | 3.8426% | eq (12) including eq (11) |

### 4.1.3 Time Averaged Variabel Rate Pool Supply

| Parameter | Value | Remarks |
|---|---|---|
| **tk-1** | 0.1000 | < tk [years] |
| **tk** | 0.1500 | > tk-1 [years] |
| **tk+1** | 0.2000 | > tk |
| **SStk** | 135.0000 | from eq (1) |
| **SStk-1** | 101.0000 | |
| **<SStk>** | 101.0078 | eq (13) |
| **alpha** | 0.0002 | eq (14) |

### 4.2.1 Supply Interest Rate

| Parameter | Value | Remarks |
|---|---|---|
| **Sum(BVtnFR,i)** | 250.0000 | one pool |
| **<R>tnFR,i** | 3.8426% | |
| **tk** | 0.1000 | |
| **Ti** | 0.2500 | 3 months |
| **DtkFR,i** | 10.0000 | |
| **PIBVPtkFR,i** | 1.4410 | eq (15) |
| **RDtkFR,i** | 3.4584% | eq (18) including eq (16) & eq (17) |
| **Spread** | 0.3843% | |

### 4.5 Aggregate Equations for Earned Interest on Loans in Fixed Rate Pools

| Parameter | Value | Remarks |
|---|---|---|
| **<R>nFR,l** | 3.8426% | one pool, same value as in 4.2.1 |
| **tk** | 0.1000 | same value as in 3.2.1 |
| **tk+1** | 0.2500 | same value as in 3.2.1 |
| **tlmat** | 0.4000 | |
| **BnFR,l** | 12.0000 | > DmFR,l, only portion of depositors in this FR pool |
| **RDmFR,l** | 3.4584% | < <R>nFR,l, same value as in 4.2.1 |
| **DmFR,l** | 10.0000 | same value as in 3.2.1 |
| **TAIBFP(tk,tk+1)** | 0.0692 | eq (19) |
| **TAIDFP(tk,tk+1)** | 0.0519 | eq (20) |
| **TAIVRP(tk,tk+1)** | 0.0173 | eq (21) |

## 5 Borrowing Assets at Variable Rates

| Parameter | Value | Remarks |
|---|---|---|
| TBtVR | 20.0000 | |
| <SSt> | 135.0000 | |
| <SSt+1> | 150.0000 | |
| Bt+1VR | 5.0000 | > 0 borrow / < 0 repay |
| Ufull | 1.0000 | page 5 |
| Umax | 1.0100 | eq (9) |
| Ub | 0.2000 | page 5 |
| A | 0.1023 | eq (6) |
| B | -0.0863 | eq (7) |
| UtVR | 0.1481 | eq (22) |
| Ut+1VR | 0.1333 | eq (23) Deposit or Withdraw |
| U0 | 0.1333 | page 9 Deposit or Withdraw |
| U1 | 0.1481 | page 9 Deposit or Withdraw |
| <R>t+1VR | 3.1396% | eq (25) including eq (24) Deposit or Withdraw |
| Ut+1VR | 0.1852 | eq (23) Borrow or Repay |
| U0 | 0.1481 | page 9 Borrow or Repay |
| U1 | 0.1852 | page 9 Borrow or Repay |
| <R>t+1VR | 3.5029% | eq (25) including eq (24) Borrow or Repay |

### 5.1 Repayment of variable rate loan

| Parameter | Value | Remarks |
|---|---|---|
| ShTBtk-VR | 60.0000 | |
| Bk,tkVR | 20.0000 | |
| TBtk-VR | 120.0000 | |
| TBtk+nVR | 150.0000 | |
| SHtBtk+nVR | 90.0000 | |
| ShBk,tkVR | 10.0000 | eq (26) |
| Bk,tk+nVR | 16.6667 | eq (27) |

### 5.2 Calculating the total outstanding debt

| Parameter | Value | Remarks |
|---|---|---|
| TBtkVR | 120.0000 | |
| <R>tkVR | 2.5000% | |
| tk | 0.1000 | same value as in 4.2.1 |
| tk+1 | 0.2500 | same value as in 4.2.1 |
| TAIBtk,tk+1VR | 0.4500 | eq (28) |
| TBk+1VR | 120.4500 | eq (29) |

### 5.3 Aggregate Equations for Interest Earned on Variable Rate Loans by the Variable Rate Pool

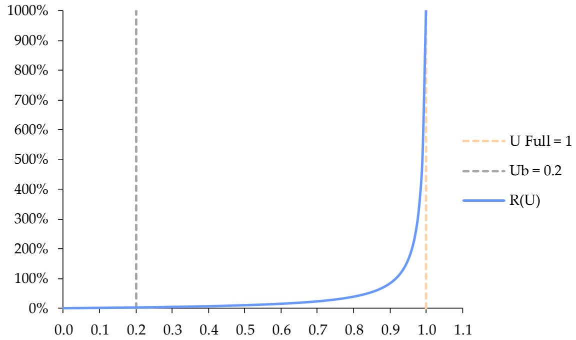
| Parameter | Value | Remarks |
|---|---|---|
| TAIVRk,tk+1VR | 0.4500 | eq (30) |

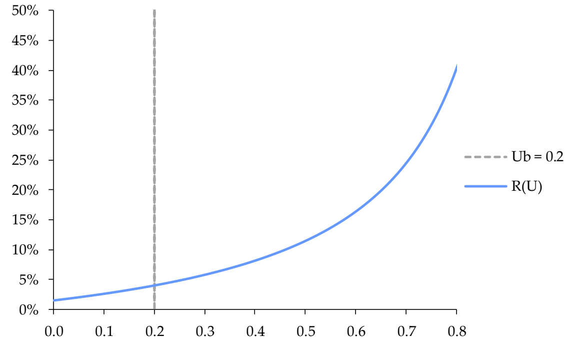
## 6 Liquidations

| Parameter | Value | Remarks |
|---|---|---|
| Cj | 20.0000 | |
| Dj | 10.0000 | |
| Ctildejbefore | 15.0000 | |
| Ctildejafter | 10.0000 | |
| Dtildejbefore | 14.0000 | |
| Dtildejafter | 8.0000 | |
| rhojC | 0.7500 | |
| rhojD | 0.7143 | |
| (1-kappajF)*Dj | 7.3812 | eq (36) |
| Cj-kappajF*(1+nuBD)*(1+nuliq)*Dj | 17.2227 | eq (37) |
| Gamma | 1.2500 | eq (38) |
| Gamma | 1.2500 | eq (38) check (second form for Gamma) |
| kappajF | 0.2619 | eq 39 |

## Results

| U | R(U) | U Full = 1 | Ub = 0.2 |
|---|---|---|---|
| 0.00 | 1.50% | 100% | 20% |
| 0.01 | 1.60% | 100% | 20% |
| 0.02 | 1.70% | 100% | 20% |
| 0.03 | 1.81% | 100% | 20% |
| 0.04 | 1.92% | 100% | 20% |
| 0.05 | 2.03% | 100% | 20% |
| 0.06 | 2.14% | 100% | 20% |
| 0.07 | 2.25% | 100% | 20% |
| 0.08 | 2.37% | 100% | 20% |
| 0.09 | 2.49% | 100% | 20% |
| 0.10 | 2.61% | 100% | 20% |
| 0.11 | 2.74% | 100% | 20% |
| 0.12 | 2.87% | 100% | 20% |
| 0.13 | 3.00% | 100% | 20% |
| 0.14 | 3.13% | 100% | 20% |
| 0.15 | 3.27% | 100% | 20% |
| 0.16 | 3.41% | 100% | 20% |
| 0.17 | 3.55% | 100% | 20% |
| 0.18 | 3.70% | 100% | 20% |
| 0.19 | 3.85% | 100% | 20% |
| 0.20 | 4.00% | 100% | 20% |
| 0.21 | 4.16% | 100% | 20% |
| 0.22 | 4.32% | 100% | 20% |
| 0.23 | 4.49% | 100% | 20% |
| 0.24 | 4.66% | 100% | 20% |
| 0.25 | 4.83% | 100% | 20% |
| 0.26 | 5.01% | 100% | 20% |
| 0.27 | 5.19% | 100% | 20% |
| 0.28 | 5.38% | 100% | 20% |
| 0.29 | 5.58% | 100% | 20% |
| 0.30 | 5.78% | 100% | 20% |
| 0.31 | 5.98% | 100% | 20% |
| 0.32 | 6.20% | 100% | 20% |
| 0.33 | 6.41% | 100% | 20% |
| 0.34 | 6.64% | 100% | 20% |
| 0.35 | 6.87% | 100% | 20% |
| 0.36 | 7.11% | 100% | 20% |
| 0.37 | 7.35% | 100% | 20% |
| 0.38 | 7.61% | 100% | 20% |
| 0.39 | 7.87% | 100% | 20% |
| 0.40 | 8.14% | 100% | 20% |
| 0.41 | 8.42% | 100% | 20% |
| 0.42 | 8.71% | 100% | 20% |
| 0.43 | 9.01% | 100% | 20% |
| 0.44 | 9.32% | 100% | 20% |
| 0.45 | 9.64% | 100% | 20% |
| 0.46 | 9.97% | 100% | 20% |
| 0.47 | 10.31% | 100% | 20% |
| 0.48 | 10.67% | 100% | 20% |
| 0.49 | 11.04% | 100% | 20% |
| 0.50 | 11.43% | 100% | 20% |



| | | | |
|---|---|---|---|
| 0.51 | 11.83% | 100% | 20% |
| 0.52 | 12.24% | 100% | 20% |
| 0.53 | 12.68% | 100% | 20% |
| 0.54 | 13.13% | 100% | 20% |
| 0.55 | 13.61% | 100% | 20% |
| 0.56 | 14.10% | 100% | 20% |
| 0.57 | 14.62% | 100% | 20% |
| 0.58 | 15.16% | 100% | 20% |
| 0.59 | 15.72% | 100% | 20% |
| 0.60 | 16.32% | 100% | 20% |
| 0.61 | 16.94% | 100% | 20% |
| 0.62 | 17.60% | 100% | 20% |
| 0.63 | 18.29% | 100% | 20% |
| 0.64 | 19.01% | 100% | 20% |
| 0.65 | 19.78% | 100% | 20% |
| 0.66 | 20.59% | 100% | 20% |
| 0.67 | 21.45% | 100% | 20% |
| 0.68 | 22.36% | 100% | 20% |
| 0.69 | 23.33% | 100% | 20% |
| 0.70 | 24.36% | 100% | 20% |
| 0.71 | 25.46% | 100% | 20% |
| 0.72 | 26.64% | 100% | 20% |
| 0.73 | 27.90% | 100% | 20% |
| 0.74 | 29.25% | 100% | 20% |
| 0.75 | 30.71% | 100% | 20% |
| 0.76 | 32.28% | 100% | 20% |
| 0.77 | 33.98% | 100% | 20% |
| 0.78 | 35.84% | 100% | 20% |
| 0.79 | 37.86% | 100% | 20% |
| 0.80 | 40.07% | 100% | 20% |
| 0.81 | 42.51% | 100% | 20% |
| 0.82 | 45.20% | 100% | 20% |
| 0.83 | 48.19% | 100% | 20% |
| 0.84 | 51.53% | 100% | 20% |
| 0.85 | 55.29% | 100% | 20% |
| 0.86 | 59.55% | 100% | 20% |
| 0.87 | 64.42% | 100% | 20% |
| 0.88 | 70.04% | 100% | 20% |
| 0.89 | 76.59% | 100% | 20% |
| 0.90 | 84.34% | 100% | 20% |
| 0.91 | 93.64% | 100% | 20% |
| 0.92 | 105.00% | 100% | 20% |
| 0.93 | 119.20% | 100% | 20% |
| 0.94 | 137.46% | 100% | 20% |
| 0.95 | 161.81% | 100% | 20% |
| 0.96 | 195.90% | 100% | 20% |
| 0.97 | 247.03% | 100% | 20% |
| 0.98 | 332.25% | 100% | 20% |
| 0.99 | 502.69% | 100% | 20% |
| 1.00 | 1014.00% | 100% | 20% |
| 1.01 | na | 100% | 20% |
| 1.02 | na | 100% | 20% |

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