Dual Pools Audit

Questions to Cyberscope
1) I changed SignedSafeMath from solidity 6 to 5. Is this okay?
2) Did I fix the re-entrancy vulnerabilities correctly?
3) Could front-running be a big issue here? How could we help prevent this?

Cyberscope Audit Fixes

1)* Potential Arithmetic Overflow (critical)
- solution: used SafeMath and SignedSafeMath in trade model

2)** Re-entrancy Vulnerabilities (critical)
- added nonReentrant modifier to sendTokenOut (in VToken), swapExactETHForTokens (in VBNB), and swapExactTokensForTokens (in VBep20)
- in swapExactETHForTokens moved the referral reward until after dTokenOut.sendTokenOut() external call
- in swapExactTokensForTokens, moved doTransferIn() before dTokenOut.sendTokenOut() external call
- I am not 100% if all these changes are to prevent the reentrancy attack. Please advise

3)** Fixed Address Deployment (minor)
- solution: cleaned tradeModel, set as parameter in vToken

4)** Permissions Handling Inconsistency (minor)
- solution: Changed to Venus Error Reporter system

5)** State Variables could be Declared Constant
- solution: set isTradeModel as constant
- made trade discount percents upgradeable in _updateTradeFeeDiscountPercents()

6)** Unused State Variable
- removed isTradeModel, closeFactorMinMantissa and closeFactorMaxMantissa

7)** Tautology or Contradiction
- solution: removed unnecessary condition (uint always >0)

8)** Potential Transfer Amount Inconsistency
- solution: stored doTransferIn actual amounts as actualAmountIn and used that for amountsOut calculation
  - new Problem: receiving the BEP20 transfer before the amountsOut calculation created a problem where swapExactETHForTokens did not include BNB transfer value (since amountsOut used getCashPrior() which deducts msg.value) in the equity calculation but the swapExactTokensForTokens did include the deposited value in the equity calculation.
  - new Solution: getCashCurrent() was created which included the BNB msg.value deposit amount. So now both swap functions are consistent and include the deposited amount of BNB or BEP20 tokens in the equity value. The TradeModel

was adjusted in amountsOut() line 463 (original file) to remove cashPost value and input availCash directly into the _availCash parameter of amountOutUSDInternal()

9)** Missing Events Arithmetic

- Events were added to Trade Model and VToken model

10)** Uninitialized Variables in Local Scope

- Tolerate this error

Additional changes beyond audit

- Removed cashPlusUSD() from VToken to not exceed contract size limit
    - including associated require checks in getExchangeCash() can getAvailableCash()
    - was not necessary, would only catch errors if the trade model was malicious

Testnet Deploy Instructions

Deploy and Configure Comptroller

1. Deploy XDP token
    - File name: XVS.sol
    - Inputs: 20000000000000000000 (as example, doesn't really matter)
    - Instructions: Paste address in comptroller.sol function getXDPAddress() ~line 1520
        - Hardcoded, cannot updated after deployement
2. Deploy Chain Link Oracle
    - File name: VenusChainlinkOracle.sol
    - Instructions: setFeed() for dTokens (dBNB, dBTCB, dBUSD to start)
        - "dBNB","0x2514895c72f50D8bd4B4F9b1110F0D6bD2c97526"
        - "BTCB","0x5741306c21795FdCBb9b265Ea0255F499DFe515C
        - "BUSD","0x9331b55D9830EF609A2aBCfAc0FBCE050A52fdEa"
            - Set feeds for BNB requires "dBNB" since there is no underlying
3. Deploy ComptrollerLens
    - File name: ComptrollerLens.sol
4. Deploy Comptroller
    - File name: Comptroller.sol
5. Deploy Unitroller
    - File name: Unitroller.sol
6. Configure Comptroller
    - _setPendingImplementation(Comptroller address) in Unitroller

- _become(Unitroller address) in Comptroller
- Using Unitroller address but Comptroller ABI:
    - setPriceOracle(VenusChainlinkOracle address) from step 2
    - setComptrollerLens(ComptrollerLens address) from step 3
    - May also add the following (optional):
        - _setPauseGaurdian: testers address
        - closeFactor: 1000000000000000000 (allows 100% of underwater amount to be liquidated)
        - liquidationIncentive: 1100000000000000000
            - This gives 10% (excess of 100%) to liquidator
    - May also send XDP tokens to Comptroller (to test XDP distributions later)

Deploy and Configure dTokens

1. Deploy Trade Model
    - File name: TradeModel.sol
2. Deploy JumpRateModel
    - File name: JumpRateModel.sol
    - Inputs: 10000000000000000,150000000000000000,3000000000000000000,400000000000000000
        - (base: 1%, baseMultiplier: 15%, jumpMultiplier: 300%, kink: 40%)
3. Deploy dBNB
    - File name: VBNB.sol
    - Inputs: Comptroller, JumpRateModel, TradeModel, 1000000000000000000,"Dual Pool BNB","dBNB",18, testersAddress
4. Deploy Delegate (implementation for dBep20 tokens)
    - File name: VBep20Delegate.sol
    - Notes: This is the implementation for dBep20 (ex, dBTCB, dBUSD, etc) tokens. For testing you may use the same implementation for each dBep20 token.
5. Deploy Delegator (repeat for each dBep20 token)
    - File name: VBep20Delegator.sol
    - Inputs: 0x8301F2213c0eeD49a7E28Ae4c3e91722919B8B47,Comptroller,JumpRateModel,TradeModel,1000000000000000000,"Dual Pool BUSD","dBUSD",18,testerAddress,Delegate,becomeImplementationData
    - Notes: I am not too sure what becomeImplementationData is, when looking at how it relates to VBep20Delegate.sol it looks like it's unused. I just inputted the zero address and it worked.
6. Configure Comptroller for dTokens
    - _supportMarket(dToken)
    - _setCollateralFactor(dToken,0.60e18)
        - 0.60e18 is reasonable, allows user to borrow 60% of dTokens supplied underlying value

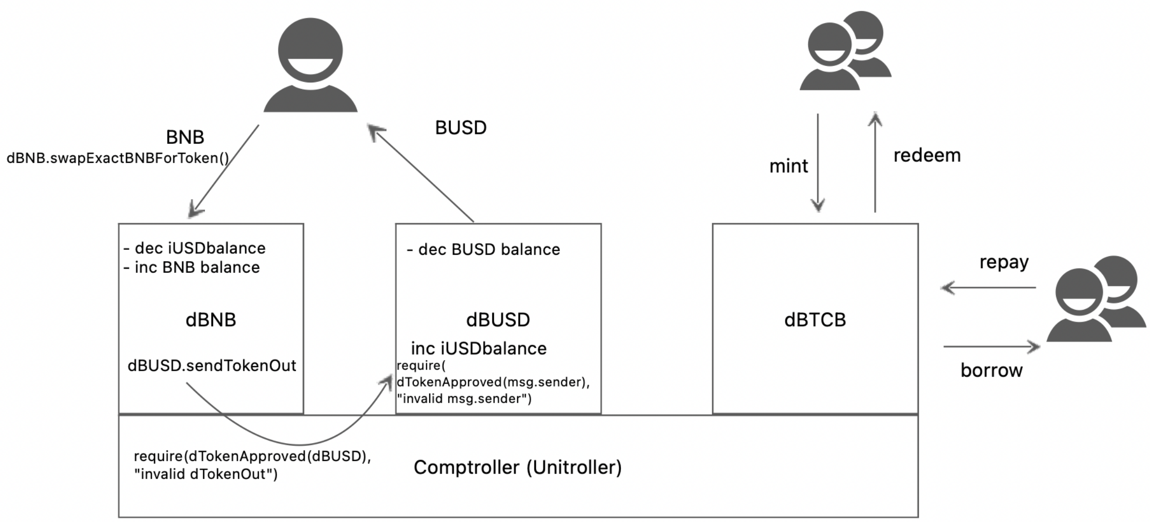
- _setXDPSpeed(dToken, 1e18)
    - This distributes 1 XDP per block to the entire dToken market

Potential Tests

- mint()/redeem()
  - Supply and redeem underlying from corresponding dToken market
- borrow()/repay()
  - Borrow and repay underlying from corresponding dToken
- liquidateBorrow()
  - Make sure able to liquidate borrow of underwater accounts and the liquidator receives liquidation incentive
- swapExactBNBForTokens()/swapExactTokensForTokens()
  - Tests selling BNB → token or token → token/BNB
- _puaseTrading()
  - Make sure it pauses buying or selling of this dToken
- _setProtocolPaused()
  - Make sure it pauses all actions of the protocol
- claimXDP()
  - Make sure XDP is distributed to dToken holders upon calling
- Admin only functions
- More functions! Thanks

Protocol Introduction

Dual Pools is a clone of the Venus Protocol. Dual Pools uses the supply/borrow functionality (lightly modified) of Venus, but also adds the ability to trade one currency for another. Traders can sell, for example, BNB to the dBNB pool (called vBNB on Venus) and receive the underlying asset from another pool such as BUSD from the dBUSD pool. As shown in the diagram below, this involves updating the iUSD balance (virtual USD balance) of involved dTokens. More information below.



The modifications and additions are noted at the top of each contract file, with the primary modified files being:

1. Comptroller.sol
2. VToken.sol
3. VBep20.sol/VBNB.sol
5. TradeModel.sol (addition)

I suggest comparing Dual Pools code to the Venus code on the mainnet branch (heavily audited and time tested) and keep and study the differences between the two.

Useful links:
https://docs.venus.io/docs/getstarted#introduction
https://github.com/VenusProtocol/venus-protocol/tree/master/contracts
https://dualpools.com/

XDP Token

The XDP token is an exact clone of the XVS token, except a name change, with no further modifications. It is the future governance token of the protocol

There is an additional use case for this token where users can gain a 10-70% trading fee discount based on how many XDP they hold in their wallet. This logic is found in the tradeModel file and does not require a modified XDP token contract.

File name: XVS.sol
XDP token address: 0x8549708b7c8dfAab00B5c5B97E483Caf008e4665

Price Oracle

Dual Pools uses the same Chainlink price oracle as Venus. There were no modifications or additions except removal of the VAI and XVS specific if-else statements in the getUnderlyingPrice() function

File name: VenusChainlinkOracle.sol
Oracle Address: 0x7966F821337Cdc8999c71a829d6676a93b7953c7

Comptroller Lens

There were no modifications or additions to the comptroller lens contract. This has additional code relating to the comptroller, but for contract size constraints Venus moved it to a separate contract.

File name: ComptrollerLens.sol
Comptroller Lens address: 0x4a2685A9F092d6DF0D6749327465460afa3Aad07

Comptroller

The comptroller is the risk management layers of the Venus Protocol which keeps track of the USD value of the supplied collateral users supplied across all dTokens. This sets the limit to how much the user may borrow (as determined by each dTokens collateral factors).

The comptroller also holds the code for the XDP (previously XVS) token distribution. The admin is able to set the venusSpeed (distribution rate) for each dToken which accrues XDP to each user who holds assets in a given dToken market.

The comptroller uses an awkward inheritance model. Following the deployment instructions above should give you a good idea of the architecture.

An addition was made to the comptroller to support trading functionality (bottom of contract). dTokens call the *dTokenApproved(address _dToken)* function in the comptroller which only returns true if the protocol is not paused, and the dToken is listed and not paused. This essentially allows dTokens to communicate and trust each other for trading purposes. If this value returns false, users cannot buy or sell the dTokens underlying asset.

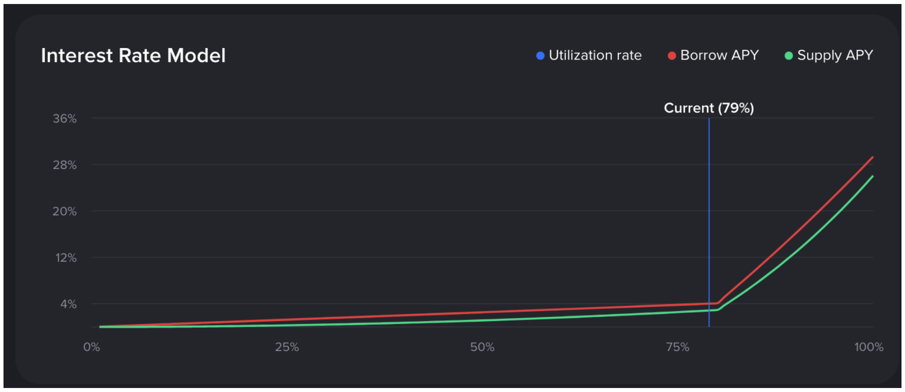
File name: Comptroller.sol
Comptroller: 0x8B0608890632c191C23749683ae0E43dC0C8383A

JumpRateModel

The Jump Rate Model is the interest rate model Venus uses to determine the borrow and supply interest rate based on the utilization rate of the market. This utilization rate is the percentage of assets borrowed relative to the total assets in the pool. The JumpRateModel contract is upgradeable in the dToken contracts.

The JumpRateModel allows for a “kink” in the interest rate curve which allows a more rapid increase in borrow/supply rates after this specified utilization rate.

This contract was slightly modified. Due to the inclusion of iUSD (virtual USD) balance in the dToken contract, the total cash in the market had to be adjusted to also include this iUSD balance. Due to this, the supply rate also had to be calculated a bit differently and required an additional parameter in the contract.



File name: JumpRateModel.sol
JumpRateModel Address: 0x2AC8e741DDD6a0A9620d5ac7D1b6A616b9329916

TradeModel

The trade model is a complete addition to the Venus protocol to support trading functionality for Dual Pools. This is essentially the “brains” behind the trading model. Much like the interest rate model described above for lending/borrowing. The trade model contract is upgradeable in each dToken and only consists of view functions (no storage or state-changing functions).

The tradeModel holds functions related to:

i) swapping functionality - calculating how much of tokenB to send to user based on deposited tokenA
ii) redeem/borrow functionality - charging a fee when redeeming/borrowing based on how much liquidity was removed and how much this affected the iUSDrate
iii) trading fee discount - determine how much of a discount on trading fees to apply based on how much XDP the user holds, and also the simple referral system.

Swapping Functions

Rather than varying the supply/borrow rates according to a utilization rate like the interest rate model, the tradeModel varies the effective prices of underlying assets (discount or premium to the oracle price) based on the iUSDrate.

To understand the iUSDrate we must first understand the iUSDbalance (internal USD). The iUSDbalance is essentially an USD virtual balance within each dToken that stores the net cumulative buying/selling pressure of that dToken market. If the iUSD balance is negative then there has been a net cumulative selling pressure, vice versa for a positive iUSD balance.

iUSDrate = iUSDbalance / (cash*oraclePrice + iUSDbalance)

- Ranges from -100% to 100%

The price impact (relative to Oracle Price) is a direct function of the iUSDrate

Price impact: iUSDrate * abs(iUSDrate)

- There is also an option for the trade model admin to include a priceImpactLimit, for example of 80%.

Example 1 (negative iUSD balance):

Token: BUSD
iUSDbalance = -1000 ($1000 more of BUSD sold than purchased in the dBUSD market)
Cash = 11000 (total amount of BUSD in the market)
oraclePrice = $1.00

iUSDrate = -1000 / (11000*1.00 + -1000) = -10%
priceImpact = -10% * abs(-10%) = -1%

adjustedPrice = $1.00 * (1 - abs(0.01)) = 0.99

Due to the net selling pressure in that market as determined by the negative iUSDbalance, the price of BUSD is now $0.99 which should theoretically increase buying pressure and help bring the iUSDrate() back to 0%.

Example 2 (positive iUSD balance):

Token: BTCB
iUSDbalance = 1000 ($1000 more of BTCB purchased than sold in the dBTCB market)
Cash = 0.5 (total amount of BTCB in the market)
oraclePrice = $18 000

iUSDrate = 1000 / (0.50*18000 + 1000) = 10%
priceImpact = 10% * abs(10%) = 1%

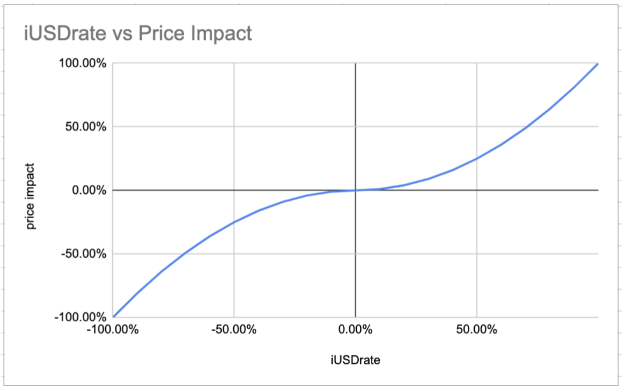
adjustedPrice = $18 000 / (1 - abs(0.01)) = 18 182

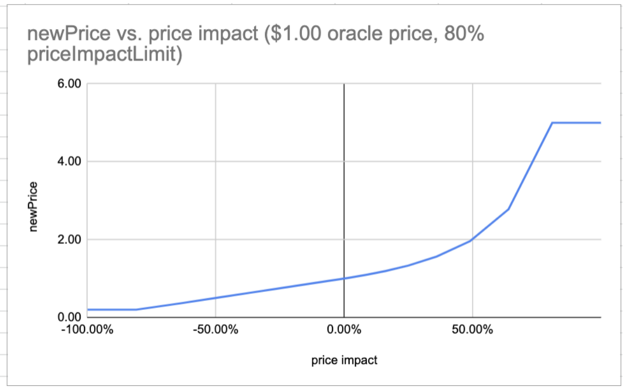
- Note, adjusted price formula varies * or / based on if the price impact is + or -

Due to the net buying pressure in that market as determined by the positive iUSDbalance, the price of BTCB is now ~$18 182 which should theoretically increase selling pressure.

The trade model and price impact formula may be updated and vary from token to token, for example the formula may differ between stablecoins and non-stablecoins. Perhaps a formula of iUSDrate ^3 would be more suitable for stablecoins so the price impact curve is more flat.

Diagrams





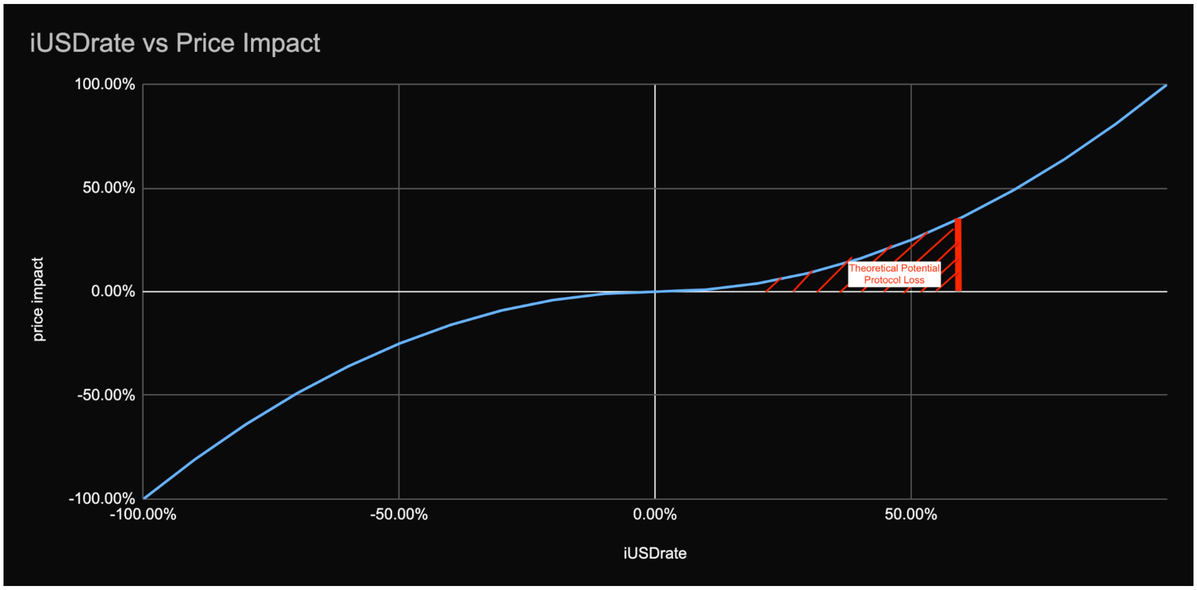
Ideally, the iUSDrate will stay between +/- 5-10% for each dToken. Arbitrage opportunities should help maintain iUSDrates within this range. An iUSDrate within this range would result in a more predictable price change of the dToken relative to the underlying asset. For example, an iUSDrate of -50% is essentially a 50% leveraged long position to the underlying asset for liquidity providers (dToken holders).

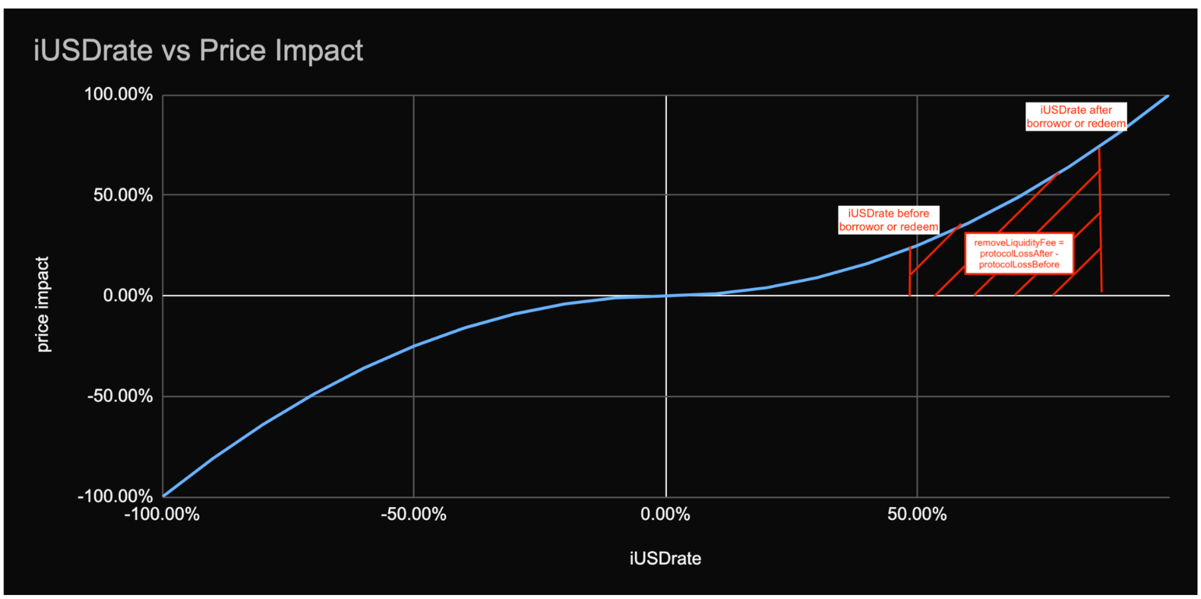
Assume dBTCB initially has $100 of BTCB in the market with a 0% iUSD rate, after excessive selling pressure bringing the iUSDrate to -50% there would be $150 of BTCB and a -50 iUSD balance (maintaining a pool value of $150-50=$100). Liquidity providers may not wish to hold a 50% leveraged long position to BTCB, but a iUSDrate of +/- 5-10% should be tolerable. If this becomes an issue with liquidity providers, the priceImpact model formula could be updated to keep the iUSDrate closer to 0% (such as changing it from iUSDrate*abs(iUSDrate) → iUSDrate)

Redeeming and Borrowing Functions

In addition to functions relating to buying and selling underlying assets, the TradeModel also includes view functions to adjust the redeem and borrow amounts in dToken contracts. This is to protect the exploit when the dToken has a nonzero iUSDrate and the user withdrawals liquidity from the pool (borrow or redeem) thereby resulting in a more extreme (more negative or more positive) iUSDrate. This would result in a greater price premium or discount that the user could take advantage of.

In order to protect against this exploit, the protocolLoss() value is calculated before and after the borrow/redeem in removeLiquidityFee() and deducted from the users borrow or redeem amount to off-set this potential exploit. The protocolLoss() function is the theoretical amount the pool of assets could lose if a trader took advantage of the price discount or premium by making infinitesimal trades until the price discount or premium has dissapeared.





Furthermore, the protocolLoss() function is used in cashAddUSDMinusLoss() which is ultimately used in the exchangeRate calculation in the dTokens. This effectively offsets the maximum theoretical trade loss due to the price premium/discount so the removeLiquidityFee is not realized until the iUSDrate approaches back to 0%. This behavior is more favorable as it may incentivize users to supply liquidity to dTokens with the most extreme iUSDrates which in return decreases the iUSD rate as more liquidity is added the pool (cash liquidity is in denominator of iUSDrate formula)

Trading Fees

The trade model also holds functions relating to the trading fees and referral program. The referral program gives a referralDiscount (default 10%) discount to referrals. There is also a scaled XDP utility token discount from 10-70% based on how much XDP they hold in their wallet at the time of the trade.

File name: TradeModel.sol
tradeModel contract: 0xd835cB6545b5107F7A8273d81cc4cAA41266e95f

dTokens

The majority of the Venus Protocol logic as well as modifications/additions are in the dToken contracts. The dTokens allow users to mint (underlying → dTokens), redeem (dTokens → underlying), borrow, and repay the underlying asset. With Dual Pool additions, users can now sell an underlying asset to its corresponding dToken contract and receive the underlying asset of another dToken.

The primary modifications/additions to the dTokens are noted at the top of the VToken contract. The VBep20 and VBNB contracts inherent from the VToken contract and hold additional code to handle BEP20 or BNB specific functions. Some optional functions were removed to create enough room for trading functionality additions.

dTokens also holds some logic regarding the referral program. The swapExactBNBForToken() and swapExactTokenForToken() functions send the reserveFee to the referrer. Although the dToken associated with the underlying token being purchased still sends the reserveFee to the reserves.

Primary Modifications and additions

1) Supply and borrow rates use available cash instead of total cash (getCashPrior()). This is so the rates increase as the absolute IUSDrate increases.
    a) availableCash = (getCashPrior() + iUSDbalance/getPriceToken) * (1e18 - abs(iUSDrate()))
2) The exchange rate formula uses exchangeCash() to include the maximum theoretical protocol loss. This is so the exchangeRate doesn't increase (much) as abs(iUSDrate) increases and decreases as abs(iUSDrate) decreases. Discussed in trade model section.
    a) ExchangeCash = cash + (USD - protocolLoss)/oraclePrice
3) mintBehalfInternal(), mintBehalfFresh(), redeemInternal(), _addReservesInternal(), and _addReservesFresh() removed to make room for trading functionality. The redeemTokensIn parameter in redeemFresh() and associated functionality in function was also removed due to removal of redeemInternal().
4) Integrations to the trade model were included at the bottom of the VToken contract. Minimum logic was included in dTokens and instead found in the TradeModel contract.

This was to decrease contract size and improve upgradeability. Require statements were put in place to ensure values from the trade model are reasonable in the event a malicious tradeModel contract address was updated.

5) Swap state-changing functions are included at the bottom of the VToken contract as well as the VBep20/VBNB contract.

VBep20 tokens have the option to have an upgradeable proxy model with the VBep20Delegate.sol and VBep20Delegator.sol contracts which is the option we used at Dual Pools. This is opposed to deploying VBep20 tokens with VBep20Immutable.sol. VBNB.sol is immutable, although the interestRateModel and TradeModel are upgradeable so there still remains some upgradeability.

File name: VToken.sol and VBep20Delegate.sol
vBep20Delegate (non-stable): 0x762b06eb432fb87df354801a3171f2bb6b8f9c08
vBEP20Delegate (stablecoin): 0x58a50E9AFFb6275716921bbfda6686996ef41b56

- Currently these two implementations are identical, although in the future stablecoin and non-stablecoin implementations may differ

File name: VBep20Delegator.sol
vBUSDDelegator: 0x1a276A66cf38F439aE8128a3735eC79e12E6ffe9
vBTCBDelegator: 0xBED992A075d24F6770F2e2Bacd523a484F768aC6

- dBUSD and dBTCB are identical except for the underlying token address

vBNB: 0x8Da8bEFb17086F34511359e226A2b0c9b93E6C36

Please note these verified contracts have been slightly altered to include the referral program. New dToken mainnet contracts will be updated after the audit.

If you have any questions feel to contact me via the following methods
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