ERASMUS UNIVERSITY ROTTERDAM
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MSc Economics & Business
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Tokenization of Real Estate Assets

Ownership dispersion, diversification, liquidity and correlation with economic fundamentals and the crypto market sentiment

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PREFACE AND ACKNOWLEDGEMENTS

This thesis is written as part of the requirements for the MSc Economics & Business - Financial Economics program at the Erasmus University. During the process of making this paper, I noticed that I could combine a lot of knowledge I have learned in the University program and in my previous study. However I also needed to learn new skills, such as making python programs to call an API or how to effectively transform large data sets.

I would like to thank my thesis supervisor Laurens Swinkels. He guided me excellently through the process of writing my master thesis. He gave very useful feedback, gave me a lot of freedom and responded quickly to my questions. I enjoyed working on my thesis with him as my supervisor and I would recommend him to other students as supervisor.

Matthijs Bergkamp
Leiden, July 30th 2024

ABSTRACT

To better understand tokenization, its effect and how it is used by investors empirical studies need to examine this novel concept. This paper investigates tokenized real estate assets, how it is used and what their effect is in the real world. The paper focusses on the ownership concentration, investor diversification, token liquidity and the impact of economic fundaments and crypto market sentiment on the price of the tokens. The paper uses data from the gnosis blockchain, the FRED and CoinGecko. We look at 455 tokenized properties and 69,399 transactions. Graphs and OLS (pooled) regression are used to investigate various relationships. The analyses showed that tokenized real estate assets have dispersed ownership, investors are diversified, the liquidity per token decreased in comparison to previous studies, the token prices follow the same trend as the house prices and there is a negative relation between the token price and the crypto market sentiment.

Keywords: Cryptocurrency, Blockchain, Tokenization, Real Estate, Decentralized finance

JEL Classification: G1, G12, G23, G32, K22, K25, M13, O33, R30, R31

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CHAPTER 1: Introduction

Tokenization is the concept of offering tokens on the blockchain that represent a percentage of the value of the underlying asset. Swinkels(2023) researched this novel concept. His paper consisted of 58 properties. Most properties were tokenized about a year or less before his period end date. His conclusion gave us valuable insight in the concept of tokenization and how it is used by investors. However the data of his paper is limited because tokenization was still in its introduction phase. This paper uses 7.8 times more tokenized properties over a period of 3 years. Since the paper of Swinkels, tokenization has evolved. Cryptocurrencies overall are more mature and tokenization is not a brand new concept anymore. The income generated by the underlying assets has been paid out to investors from October 2019 until present. Tokenization has earned the trusts of investors and the assets under management, in our dataset, has increased to a little over 83 million USD. In the current stage of the tokenization, there are more methods to trade the tokens. This paper includes all available methods. The question remains what the effect of tokenization is on the real world and if the previous conclusion from Swinkels(2023) still holds. To answer this question we focus on the ownership concentration, investor diversification, token liquidity and the impact of economic fundamentals and crypto market sentiment on the price of the tokens.

1. How concentrated is typical residential property ownership after tokenization?
2. Do token investors use fractional ownership to diversify their real estate portfolios?
3. How liquid are individual residential properties after tokenization?
4. Are tokenized asset prices related to the economic fundamentals of the investment?
5. Are the prices of tokenized assets correlated with the prices of cryptocurrencies?

Note: The first 4 research questions are the same as in Swinkels(2023) as this paper is partly a period extension of his research.

We start with a brief introduction on how tokenization came to be. In 2009, the third layer of the internet was created. The goal of this third layer was to limit or eliminate the need for centralized corporations and organizations that controlled the second layer. Nakamoto (2008) created Bitcoin, an electronic cash system. The goal of Bitcoin is to be “a purely peer-to-peer version of electronic cash that would allow online payments to be sent directly from one party to another without going through a financial institution” (Nakamoto, 2008). Nakamoto integrated several innovations, such as digital signatures that helped eliminate the double-spending problem, the blockchain and the proof of work principle.

In the past 16 years, blockchain technologies have evolved. One of the biggest innovations within the cryptocurrency industry is the ability to create smart contracts and decentralized applications, also known as dapps. A smart contract is a program which runs on a blockchain. Not all blockchains

support smart contracts. The Ethereum blockchain is the second-largest blockchain, by market capitalization of the native token, and the blockchain that introduced smart contracts (Ethereum Whitepaper | Ethereum.org, 2013).

With the introduction of smart contracts and dapps, a new category of cryptocurrencies arose: Decentralized Finance or DeFi. DeFi tries to eliminate centralized middlemen, such as banks or other financial institutions, using transparent protocols on a decentralized blockchain. Examples of a DeFi application are Uniswap or Levinswap, these are decentralized exchanges allowing users to swap cryptocurrencies and/or provide liquidity.

Historically, real estate investments are effective diversifiers of an investor's portfolio (Hoesli et al., 2004). Besides their diversifying aspects, real estate assets had sizable returns in the past (Ibbotson & Siegel, 1984). However, the real estate investment class also has disadvantages. Real estate assets are illiquid. Smaller investors encounter diversifying issues when wanting to invest in real estate. For example, the average house purchase price in the Netherlands was €416,153.00 in 2023 (CBS Statline, n.d.). Owning a house as part of your investment portfolio as a small investor will result in a concentrated and undiversified portfolio. Creating a diversified portfolio is possible as a small investor with Real Estate Investment Trusts(REIT) or real estate mutual funds. A REIT is a company which invests in properties and property loans ("Cambridge Business English Dictionary," 2024). Investors can buy shares in these investments. However, when investing in a REIT or a real estate mutual fund the investor is still depending on the manager of the REIT or fund.

The tokenization of real estate assets solves this problem by dividing the real estate properties into small parts. RealT is a platform that offers tokenized real estate properties. "RealT replaces paper deeds with digital tokens; a new mechanism for asset ownership, based on the Ethereum and Gnosis Chain." (What Is RealT? | RealT Knowledge Base, n.d.). RealT purchases real estate properties and offers tokens of these properties, which give the right to a percentage of the rent collected after fees. Each property has its own legal entity, this entity is then tokenized into RealT tokens, tokenization is very similar to the traditional securitization.

CHAPTER 2: Theoretical Framework

Although tokenization is relatively a new concept, there is already done some research. This research paper is partly a period extension of the research of Swinkels(2023). The paper also reexamines the relationship between the crypto market sentiment and the prices of tokens of tokenized real estate properties, which Kreppmeier et al. (2023) found.

2.1 'Empirical evidence on the ownership and liquidity of real estate tokens

Swinkels'(2023) data is from March 2021 and before. The provider of the real estate tokens, RealT, switched to the Gnosis Blockchain and added 397 more real estate assets after this date. Swinkels drew four main conclusions in his research: The ownership concentration is generally low, most investors have a well-diversified portfolio, the average turnover of a property is around 15% in the first half of his sample and in the second half it decreases to around 5%. Finally he concluded that the tokenized asset prices are correlated with the economic fundamentals of the investment.

2.2 Crypto market sentiment and prices of tokenized properties

Kreppmeier et al. (2023) researched the tokenized real estate tokens and properties. One of their conclusions was that the crypto market sentiment has positive impact on the capital inflow of RealT tokens. They regressed the inflow of capital in the ETH price, Gas fees ETH shock, Gas shock, one-month T-bond and 10 year T-bond. However, the implication that the crypto sentiment has a positive impact on the price of RealT tokens raises questions. The fifth research question will dive deeper into this topic. Steininger (2023) did a risk return analysis of tokenized real estate properties. He made a index based on 180 RealT tokens. For our 4^{th} and 5^{th} research question we also constructed a similar index. In his research, Steinberger found no significant relationship between a combination of the following variables: the monthly return of ETH, S&P Case-Shiller IL-Chicago Home Price Index and the RealT indices(equally or value weighted).

2.3 Risk and return analysis real estate tokens.

Steininger (2023) researched RealT tokens. He found that the self constructed RealT index has a unique risk-return pattern and does not follow the same pattern as other assets classes. He also found that the crypto market and house prices do not effect the return of the RealT index significantly.

2.4 RealT - Fractional and frictionless real estate investing

RealT is a relative new organization, founded in 2019. They tokenize Real Estate assets. These assets can be a single family home or an entire complex. The tokens are sold to whitelisted investors. RealT tries to offer the tokens for around 50 USD. This makes it possible for anyone to access to world of investing in real estate. The low minimum investment also makes it possible for small investors to diversify their real estate investments. RealT is required by law to know their customers, after this KYC check, the investors' wallet is whitelisted and he or she can trade RealT tokens. For more information on RealT and their legal structure you can visit https://faq.realt.co/en/.

2.5 Traditional Finance

Tokenization is a new tool for investors to use. However, to investigate how it is used we should also look at the traditional finance space. Barber and Odean (2013) stated that individual investors are under diversified. Goetzmann and Kumar (2008) also claim this. They also conclude that "there is little evidence that portfolio size or transaction costs constrains diversification" and that under diversification has a negative effect on the portfolio performance for most investors. Wang et al. (2021) use the consumer confidence index as a proxy for economic sentiment. They show a negative relationship between the economic sentiment and stock returns. The negative relationship is more durable effect in developed markets. Esrig et al. (2011) state that larger more valuable properties have bigger returns in real estate and Sirmans et al. (2005) show that the age of a property has a negative effect on the selling price of the house. Collett et al. (2003) looked at the holder period of real estate investments by institutions. They analyzed U.K. real estate and concluded that the average holding period is 11.4 years. Aljinović et al. (2022) found a significant negative relationship between real estate assets and cryptocurrencies. The negative relation is stronger after the COVID-19 crisis.

CHAPTER 3: Data Collection

This chapter discusses how the data is collected. To answer the research questions of this paper, the holder data of all RealT tokens is collected. The transaction data of those tokens is also collected and finally this information is supplemented with data from the RealT website. To start the data collection we first need to collect the contract addresses of all RealT tokens.

3.1 Contract Addresses

The site of RealT lists all the properties they have tokenized. The page also contains a link to www.gnosisscan.io, which is the blockchain explorer of the gnosis blockchain. These links contain the contract address of the corresponding token. To collect the contract addresses of the tokens we extract the links from the webpage of RealT and extract the contract address of the tokens from these links.

3.2 Holder data

The holder data contains information about each token and it's holders. To collect this data we make a python program that uses the REST API of www.blockscout.com. Blockscout offers multiple APIs, but there main service is providing an opensource explorer. This API retrieves the wallet addresses and the balances of all holders of the contract address provided by us. We assume that a single investors has only 1 wallet address. The API also provides some statistics of the token itself, such as its total amount of holders and the name of the token. The output of the REST API is a JSON format file. The python program loops through all contract addresses of the RealT tokens, downloads all pages of the data provided by the API and saves this data to a CSV. The output of the program is a CSV file for each token containing all holder data. These CSV files are later appended in a database. This database contains all holder data of each token.

3.3 Transaction data

The transaction data is more difficult to obtain. There are different ways to buy or sell RealT tokens:

1. Levinswap
2. YAM, Swapcat or similar services
3. Directly from/to RealT

Levinswap is a decentralized exchange, also known as a DEX. On a DEX investors can trade tokens. Liquidity providers earn part of the transaction fees for providing liquidity. Most decentralized exchanges, including Levinswap, make use of an automated market maker, in short an AMM. An AMM works differently than an order book on traditional trading platforms. How an AMM works on a DEX is best explained using an example:

Assume we want to by the RealT token X with 50 xDAI. xDAI is a stable coin always worth almost exactly $1.00. We want to buy the RealT token X on Levinswap. The current price of the RealT token X is $50.00. The AMM makes use of the following formula to decide on the price:

*(amount of RealT token X in liquidity pool) * (amount of xDAI in liquidity pool) = constant.*

The constant always equals the same number and is determined by the first liquidity provider for this token pair. Anyone can become a liquidity provider, however, you always need to add both tokens of the token pair to the liquidity pool in the same ratio as it is before you add liquidity. This makes sure that the constant stays constant.

In the case of our example, assume there are 10 RealT token X provided as liquidity and 500 xDAI. The constant equals 5000. If someone adds or removes liquidity this has to be done in the same ratio, the constant can not change. If we buy RealT tokens X with our 50 xDAI, we add 50 xDAI to xDAI side of the liquidity pool. Now the AMM calculates how many RealT token X we get back so that the constant stays equal. In this case, 0.909091 RealT token X. the new liquidity balance equals:

*9,090909 * 550 = 5000*

The new price of the RealT token X, according to the AMM, is: *550 / 9.090909 = 60.50 xDAI.*
As you can imagine multiple investors trade at the same time, that is why investors set a maximum slippage percentage when trading on a DEX. This slippage percentage is the maximum difference between the expected amount of tokens you get and actual amount of tokens you receive after the transaction executes. Some DEXs also offer limit orders, however this is not offered by Levinswap.

YAM and Swapcat are platforms on which 2 investors can come to a transaction. One party sells and the other party buys RealT tokens in exchange for a pre-agreed upon price. YAM and Swapcat use smart contracts to ensure the agreed upon price is paid and the RealT token is transferred to the buyer's wallet.

The final option is buying from or selling to the RealT organization. Once a property is tokenized, the tokens are available for sale on the RealT website. If you buy a token you can pay with xDAI. These transactions are visible on the blockchain. You can also pay with Credit Card, but these transactions are unfortunately not visible on the gnosis blockchain. The same goes for selling your tokens back to RealT. These transactions are only visible if there are crypto tokens returned in the same transaction on the Gnosis blockchain.

To obtain the transaction data from all these sources, we make another python program. This program first uses another endpoint of the Blockscout API. This endpoint downloads all transfers of a specific token. The program loops over all RealT tokens and gathers the transaction hash from each transfer. These transaction hashes are used as an input for the next program. This next program we make, uses

again another Blockscout API endpoint. It uses the transaction hash to download all the transfers in the transaction, including the transfer of non RealT tokens in the transaction.

This transfer data does not only contain transactions like a buy or a sell, but it contains other transfers of a RealT token. So, the data is filtered on if the method of the transaction is one of the following: *'swap', 'swapTokensForExactTokens', 'swapExactTokensForTokens', 'swapExactTokensForETH', 'swapETHForExactTokens', 'swapExactETHForTokens' or 'swapTokensForExactETH'.* And the desired data fields are saved to a CSV file. This makes sure our data only contains transactions.

The CSV file contains a row for each transfer. This means we still need to match the row of the transfer of the RealT token with the amount it is bought or sold for. This sounds simple. Unfortunately, due to different platforms, methods and changes in protocols this is a challenging process. After matching the rows, some more filtering is done:

- Based on Exchange Rate: Some transactions are done with Wrapped ETH or Wrapped BTC instead of a stable coin. The exchange rate is obtained from CoinGecko and the Wrapped coins are converted to a USD amount. However, there were a few transactions done with small coins as payment. These transaction are filtered out.
- Transactions involving more than 1 type of RealT token are excluded, as it is difficult to decide on the value of the separate types of RealT tokens if there are multiple types included in one transaction. For example, one transaction might involve 2 RealT token A and 5 RealT token B bought for 150 USD. In this transaction we can not determine the price of both types of tokens.
- Small transactions, meaning less then $5.00 or less than 0.1, are also excluded. This is done because we want to limit the impact of trading bots on the outcome of the research.
- A number of transaction involve the token Levin. This token has unfortunately no exchange rate available. For a transaction involving 3 tokens, RealT token, Levin Token and a third, we use the third token to calculate the price. This is checked randomly and the prices are correct. Transactions involving more than 3 tokens and the RealT token is matched to the Levin token are excluded.

After this extraction and filtering we are left with a database of 69,399 transactions. This is significantly more than only extracting the transactions from a single platform, such as YAM or Swapcat, resulting in a more representative sample.

3.4 Data from the RealT site.

The holder and transaction data we already obtained is also supplemented with data from the RealT website. To extract the data we need from the site, we make a python web scraper. This scraper visits the webpage of each property and collects the underlying assets value, the income start date and the contract address of the property. The contract address is needed to match the obtained data with the already existing data sets.

3.5 Additional data

For the analyses done in this research paper we also need additional data that has no direct connection with RealT tokens. We download the average transaction fee on the Gnosis blockchain data from Gnosisscan.io. This is used in the final two regressions of this paper and in figure 6. For research questions 4 and 5 we also need the market cap of the entire crypto market. This is obtained from CoinGecko.com. Research question 4 includes data from the S&P CoreLogic Case-Shiller MI-Detroit Home Price Index. This data is downloaded from the FRED of the Federal Reserve Bank Of St. Louis. The final research question contains a regression with the independent variables: ADS index, 1-month US Treasury bond yield and 10-year US Treasury bond yield. The ADS index is the Aruoba-Diebold-Scotti Business Conditions Index. This index tracks economics indicators and business conditions. The data of this index is downloaded from the Philadelphia FRED. Finally the 1-month US Treasury bond yield and 10-year US Treasury bond yield are downloaded from the St. Louis FRED.

CHAPTER 4: Method

This chapter will discuss the analytical methods that are used to answer the 5 research questions. Most methods for analyzing the data are the same as or similar to the methods used by Swinkel(2023). For the final research question a slightly different method is used compared to the method Kreppmeier et al. (2023) used.

4.1 How concentrated is the ownership of a typical residential property after tokenization?

As mentioned in the introduction of this paper, tokenization of real estate properties gives small investors the opportunity to create a diversified real estate portfolio. Swinkels (2023) researched the ownership concentration of tokenized properties, to see whether the tokenized properties are owned by a small amount of investors, or if the tokenized properties are divided up between a larger number of investors. To investigate the ownership concentration, a histogram with the number of owners per property is made. The adjusted Herfindahl-Hirschman Index for every property is also calculated and shown in a histogram. The Herfindahl-Hirschman Index is calculated accordingly:

$$HHI = \sum_{i=1}^{N} s_i^2$$

Here the s_i equals the ownership percentage of holder i out of N total holders. The ownership percentage is calculated by dividing the tokens of holder *i* by the total outstanding tokens. The index equals 1 when there is a single person who owns all of the tokens. The minimum value of the HHI is $\frac{1}{N}$. This happens when all tokens are distributed equally over all the holders. To account for a difference between the total number of holders each tokens has, we use the adjusted Herfindahl-Hirschman Index:

$$HHI^* = \frac{HHI - \frac{1}{N}}{1 - \frac{1}{N}}$$

The adjusted Herfindahl-Hirschman index is close 1 if one person owns almost all tokens of a single property. The adjusted index equal 0 when all holders have the same ownership percentage. To further investigate the ownership concentration we run a regression:

$$N(or\ HHI^*) = \alpha + \beta_1 * NUM_i + \beta_2 * AGE_i + \beta_3 * DETROIT_i$$

Where N equals the total number of holders, NUM equals the total number of tokens also known as the total supply. AGE is the number of months ago the property started to collect rent and DETROIT is a dummy variable that equals 1 if the property is located in the Detroit. This regression is slightly different from the regression Swinkels did in his paper. He used an extra variable. This variable was the underlying value of the property. We excluded this variable because it is has a high correlation with the NUM variable as RealT aims to provide tokens worth about $50.00. If an property is more expensive, more tokens will be minted and sold.

We expect that the results of this regression to be similar to the outcome of the regression of Swinkels. However, because the tokens have traded for longer, we expect that the intercept will be slightly higher in case of the regression with depended variable being the total number of owners N.

4.2 Do token investors use fractional ownership to create diversified real estate portfolios?

The research question aims to investigate the diversification of portfolios containing tokenized real estate assets. For this paper we assume that a single investor has all his RealT investments in one wallet. This is not necessarily true, however it is likely for most investors. Unfortunately there is no possibility to match wallet addresses with investors to check this. This can only be done by RealT organization.

To examine the diversification of the RealT portfolios, 2 different histograms are made. Both histograms show the number of wallets on the vertical axis. The first histograms shows the total amount of different RealT tokens in the portfolio. The second one shows the total invested amount in RealT tokens in USD. To calculate the value a RealT token and thus of the portfolio, we use the underlying value of a RealT token and divide by the total amount of tokens.

The final method we use to investigate this research question is again another histogram. This histogram shows the number of wallets and the adjusted Herfindahl-Hirschman Index for portfolios with value of more than 5,000 USD. In this case the HHI* is calculated again. The s equals the value of the of token i out of the total N amount of RealT tokens in the portfolio divided by the total value of RealT tokens in the portfolio. If the portfolio contains multiple RealT tokens and the value invested in each token is equal the HHI* equals 0. If the portfolio is not diversified and holds most of its value in a small amount of tokens, the HHI* will be close to 1.

4.3 How liquid are individual residential properties after tokenization?

This research question focuses on the liquidity of the RealT tokens. As mentioned in Chatper 3: Data Collection, RealT tokens are traded in 3 different ways: Buy or sell directly to RealT, trade on YAM or Swapcat and trade on the DEX Levinswap. Levinswap shows the liquidity of a RealT token. However, this is only the value which is locked in the liquidity pool for that particular token. For this

paper we look at turnover as a measure of liquidity, as this will include all 3 ways to trade RealT tokens.

The first method that we use to examine the research question is a chart showing the average monthly turnover of all RealT tokens and the average monthly transaction fee of the Gnosis blockchain. Swinkels' paper also added the average turnover of RealT tokens listed on Uniswap. However, this is not applicable since RealT switched to the Gnosis blockchain. On the Gnosis blockchain the replacement of Uniswap is Levinswap and all tokens are listed on this DEX. Gnosis uses Proof of Stake or PoS as validation method, unlike Ethereum which used Proof of Work at the time RealT switched blockchains. (Rewards & Penalties | Gnosis Chain, 2024). This makes the transactions costs a lot cheaper on the Gnosis blockchain. Thus we expect no relation between the transaction costs and the turnover.

To further investigate the liquidity and it's drivers we do a pooled OLS regression analysis:

$$L_{i,t} = \alpha + \beta_1 * VAL_i + \beta_2 * AGE_{i,t} + \beta_3 * DETROIT_i + \beta_4 \cdot TRCST_t + \varepsilon i$$

Where L is the turnover of a token *i* in period *t* . VAL is the underlying value of property *i* (USD in thousands). AGE is the number of months ago property *i* started to earn rent. DETROIT is a dummy variable, which equals 1 if property *i* is located in Detroit. TRCST is the monthly average transaction cost on the Gnosis blockchain in period *t.* The regression does not use random effects or fixed effects. However, we do run a second regression with includes time fixed effects. Where one period equals a single month. Swinkels(2023) research also included the total supply in the regression. In this paper it is left out, because of its correlation with the underlying property value.

The higher the underlying value of a property, the higher the amount of tokens. Thus we expect that the VAL has a negative effect on the liquidity as there are more tokens to be traded while the demand stays stable and the measure for our liquidity is the turnover of the tokens. We expect that the AGE of property has a negative effect on the liquidity as people are expected to buy these tokens and hold them for a longer period, similar to tradition real estate assets (Sirmans et al., 2005). The transaction cost on the Gnosis chain is always very low during our time period, and thus we expect it to have no significant impact on the liquidity.

4.4 Are prices of tokenized assets related to the economic fundamentals of the investment?

This research question aims to examine the relationship between the price of the RealT tokens after tokenization and the real estate market. To investigate this relationship we first plot a graph of the price of a random RealT property. We also plot the underlying value divided by the total supply. In comparison to Swinkels(2023), we only plot the price in USD. As explained in chapter 3 Data Collection, most transactions are done using a stable coin and not wrapped ETH.
Secondly, we create a RealT index. Swinkels(2023) and Steininger (2023) also create a RealT index, however the index used in this paper is slightly different. This index looks at the 50 most traded RealT tokens in a month, Swinkels(2023) used all the traded tokens. We chose to use the 50 most traded tokens, because the turnover in our population is lower. Our index takes the monthly closing price of these tokens and compares it to the closing price a month later. We assume that liquid tokens in month t are also liquid in month $t+1$. This comparison generates a percentage change. With this percentage change, the index was made. The starting value of this index is the same as the value of the S&P Core Logic Case-Shiller MI-Detroit Home Price Index. Both indices are plotted in a graph, including the percentage change. The Detroit Home Price Index is used because most properties of RealT are located in Detroit Michigan. It is expected that the 2 indices move inline with each other. As it is rational to assume that the price of a token is equal to its discounted cash flows. Which in turn is affected by the same variables, such as interest rates, as the properties in the Detroit Home Price Index. Another argument to expect that the price of the two indices move together is that if a token or property is over or underpriced, arbitrage traders will make sure that the prices converge to each other again. A possible example of this is the RealT property 18983 Alcoy Ave, Detroit, MI 48205. This property was detokenized, meaning the tokens were burned by RealT and the property was sold after a vote by the token holders. RealT received an offer of a third buyer which was +35.38% higher than the original property valuation (RealToken, Inc, 2024). The token holders got their share of the sale price after taxes and other costs.

4.5 Are the prices of tokenized assets correlated with the prices of cryptocurrencies?

This research question is not based on a period extension from Swinkels' paper. This question is based on the research done by Kreppmeier et al. (2023). They found a positive link between capital inflows and crypto market sentiment. This goes against the believe that the prices of the RealT tokens are based on the underlying value. Kreppmeier et al. used transactions on the Ethereum network. An increase in the price of ETH could generate more capital inflows if investors already holding ETH, believe it is overvalued compared to the RealT assets and therefore buy RealT tokens with the 'overvalued' ETH. However the data this paper used is from the Gnosis blockchain. As stated earlier, most transactions use a stable coin to buy RealT tokens. This should eliminate the perceived increase in capital inflow. To investigate the effect of crypto market sentiment on capital inflows we plot a graph with the RealT index, this time with starting value 100 USD. We download the global crypto market index data from CoinGecko, calculate the percentage change in price and use this to make our own index with starting value 100 USD. To further investigate this relationship a regression analysis is done:

$$RealT\ index = \alpha + \beta_1 * Monthly\ return\ Crypto\ Market\ Index + \beta_2 * Average\ montly\ transaction\ fee + \beta_3 * 1\ month\ US\ T\ bond\ yield + \beta_4 * 10\ year\ US\ T\ bond\ yield + \beta_5 * ADS\ index$$

The expectation is that there will be no significant positive relations between the crypto market index and the RealT index. This is because RealT tokens are mostly bought with stable coins on the Gnosis network and therefore the prices of crypto currencies should have no significant effect on the RealT token prices.

CHAPTER 5: Results

The goal of this paper is to investigate tokenized real estate assets, how they are used and what their effect is in the real world.This chapter discusses the results from the analysis described in the previous chapter. The chapter will go through the research questions one by one.

5.1 How concentrated is the ownership of a typical residential property after tokenization?

To investigate the first research question, first two histograms are made. These histograms show the frequency of RealT tokens in a certain range. Figure 1 categorizes the tokens based on the amount of holders it has.

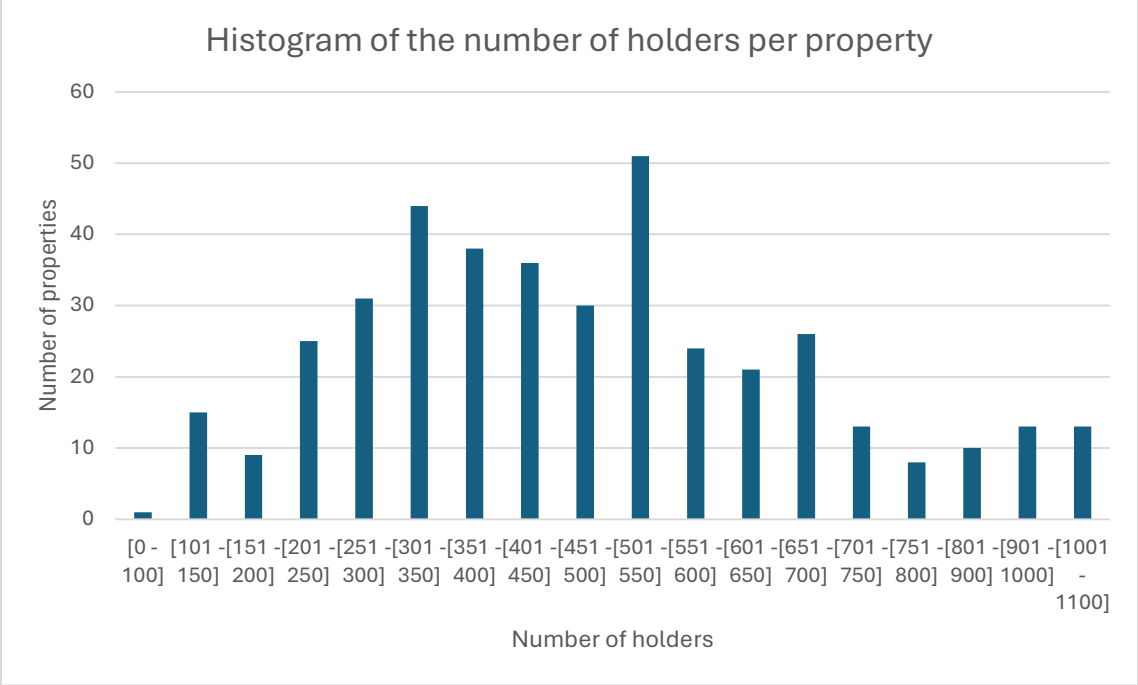

Figure 1: Histogram of the number of holders per property. Based on data from may 2024. Contains data from 455 properties.

We looked at a total of 455 tokens. Most tokens have between 200 and 700 different holders. There is only one property with less than 100 holders. This is RealToken 9943 Marlowe St Detroit MI. This property has 66 holders. The property has and underlying asset value of 68,000.00 USD. Note that this is the most recent valuation. The total supply is 1,000 and the property has started to collect rent on August 24, 2019.

The property with the most owners is RealToken S 10110 Cadieux Rd Detroit MI. This property has an underlying value of 970,000.00 USD and a total supply of 23,000 tokens. The property has only been collecting rent for about a year. The income start date is June 23, 2023. The histogram shows that the tokenized properties indeed have a series of investors. The tokenized properties have on average

573 holders and the average underlying value of the tokenized properties is 181,471.04$. This indicates that an investor invests on average 316.70 USD in a single property.

Figure 2 categorizes the properties based on their adjusted Herfindahl-Hirschmann Index.

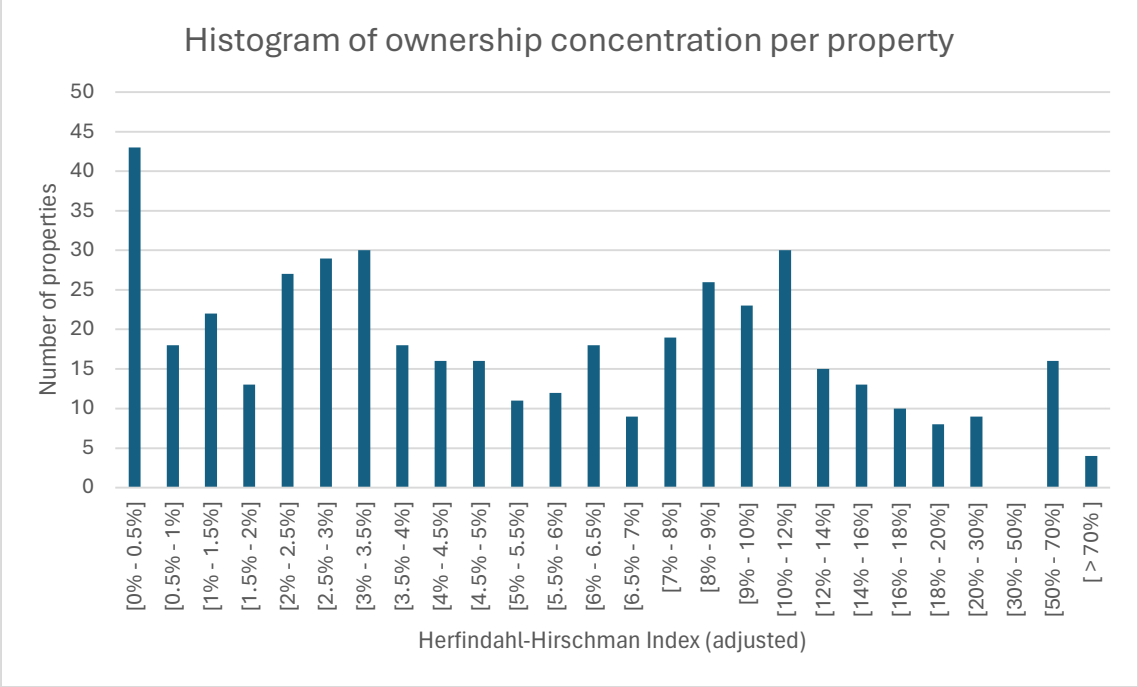

Figure 2: Histogram of ownership concentration per property. Based on data from may 2024. Contains data from 455 properties.

The histogram uses a variable interval in the horizontal axis. Most, 350 out of 455, properties have a HHI* of below 10%. There are 96 properties that have a HHI* of below 2%. Only 20 properties have a HHI* of above 50%. The minimum HHI* is 0.125% and the maximum is 77.179%. The token with the maximum HHI* has one owner who owns 7030 out of 8000 tokens, which is an ownership percentage of 87,875%.

	(1) Number of holders(N)	(2) Adjusted Herfindahl-Hirschmann Index(HHI*)
Total supply(NUM)	0.0370***	3.47e-06***
	(0.00195)	(9.80e-07)
Months since property started to collect rent *reference date: 2024-06-27* (AGE)	-8.903***	0.00339***
	(0.761)	(0.000383)
Detroit dummy	-2.254	-0.00223
	(25.26)	(0.0127)
Intercept	615.3***	-0.00244
	(22.82)	(0.0115)
Observations	455	455
R-squared	0.525	0.168

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1: Regression results showing the driving factor behind ownership dispersion

Table 1 shows the results from the 2 regression we ran. The total supply has a slightly positive effect on the number of holders. The relation is significant at a 1% level. The positive impact of the total supply is also statistical significant in the second regression. However, in this regression, for every extra holder the HHI* increases with $3.47 * 10^{6}$. So this coefficient has no economic significance. The AGE variable has a negative effect of the total number of holders and a slightly positive effect on the HHI*. Both effects are significant on a 1% level. The Detroit Dummy has no significant effect in both regressions. The R-squared is 52.5% and 16.8% in the 2nd regression respectively. This percentage indicates in percentage the dependent variable is explained by the independent variables.

5.2 Do token investors use fractional ownership to create diversified real estate portfolios?

The second research question was examined with the help of 3 histograms. Figure 3 categorizes the RealT investors based on how many different RealT properties they own.

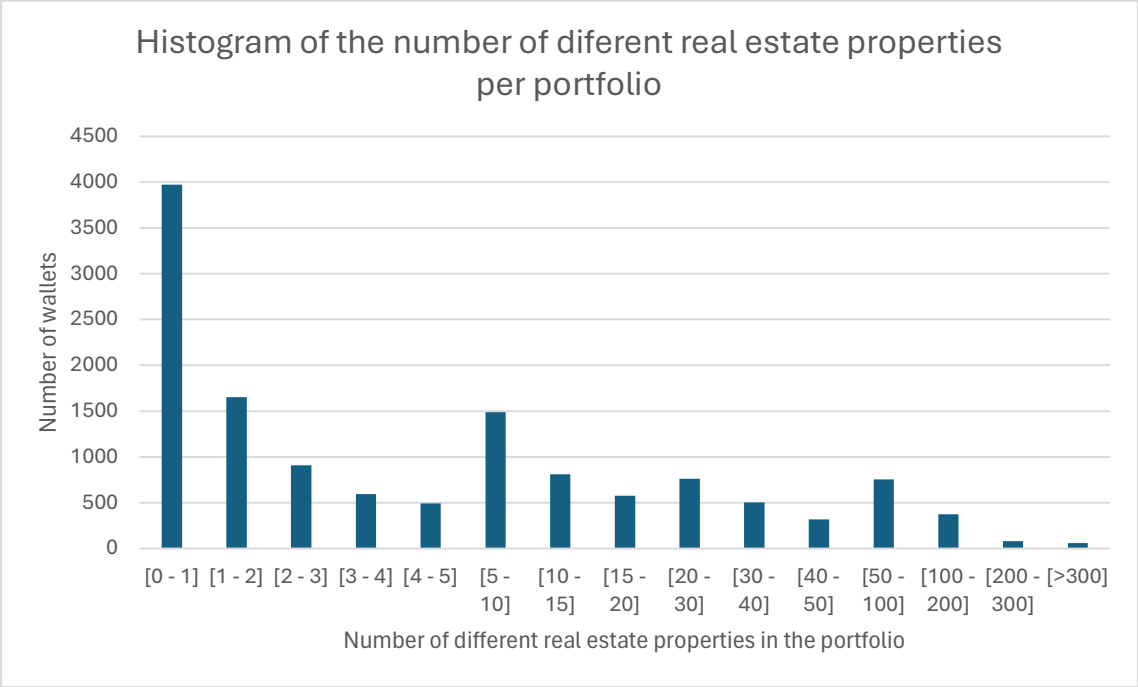

Figure 3: Histogram of the number of different real estate properties per portfolio. Based on data from may 2024. Contains data from 455 properties.

A large portion of investors, 3,974 out of 13,327, only own one type of RealT token. There are 59 wallets that own more than 300 different types of RealT tokens. Note that these wallets could be the wallets of RealT them selves. However it is not possible to find the identity of the persons behind the wallets addresses unless they make this public themselves.

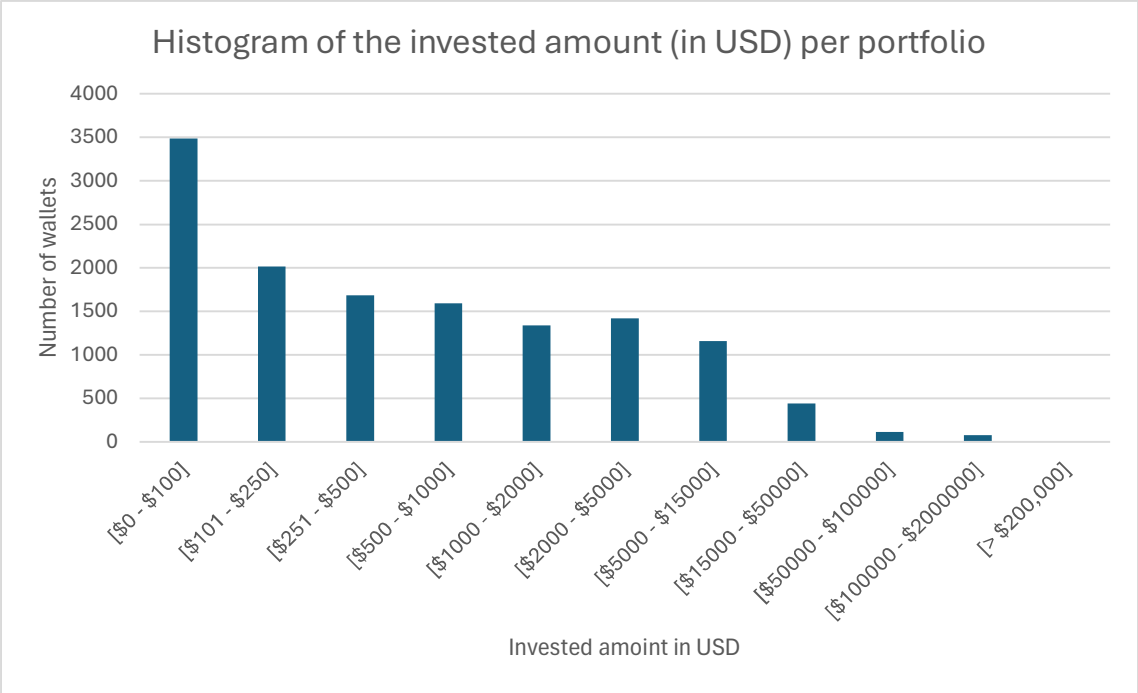

Figure 4: Histogram of the invested amount (in USD) per portfolio. Based on data from may 2024. Contains data from 455 properties.

Figure 4 categorizes the owners based on their RealT portfolio value in USD. There are 3,489 wallets with a value of 100 USD or less. There are 194 wallets with a value below 1.00 USD. These investors sold almost all there RealT tokens but there was a small part of the token left. There are 30 wallets with a value of above 300,000 USD. The most valuable portfolio has a value 2,927,870.83 USD.

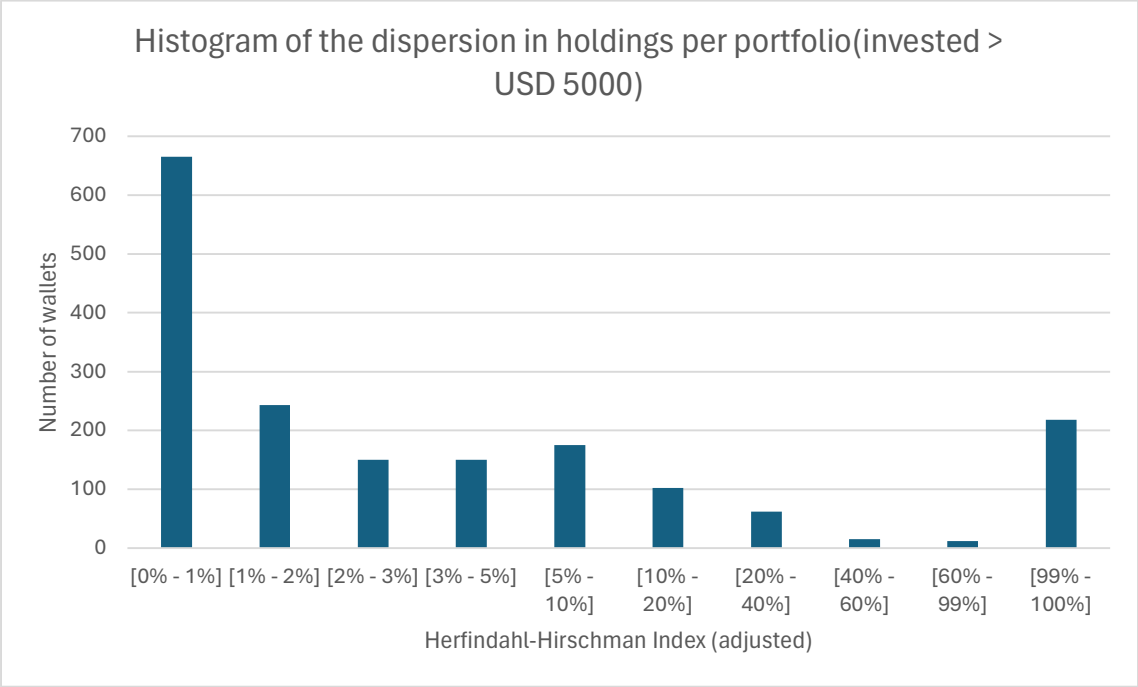

Figure 5: Histogram of the dispersion in holdings per portfolio(invested > USD 5000). Based on data from may 2024. Contains data from 455 properties.

Figure 5 depicts the HHI* of the portfolios. There are 655 wallets with a HHI* between 0% and 1%. There are 218 wallets which have a HHI* of 100%. These wallets only hold 1 type of RealT token. If you only hold 1 RealT token, the HHI* formula returns an error because the denominator equals 0. Mathematically this is not possible so we manually change the HHI* for these wallets to 1 or 100%.

5.3 How liquid are individual residential properties after tokenization?

This research question aims to examine the liquidity of RealT tokens. This paper looked at turnover as a measure of liquidity and not at the liquidity available in liquidity pools of a DEX.

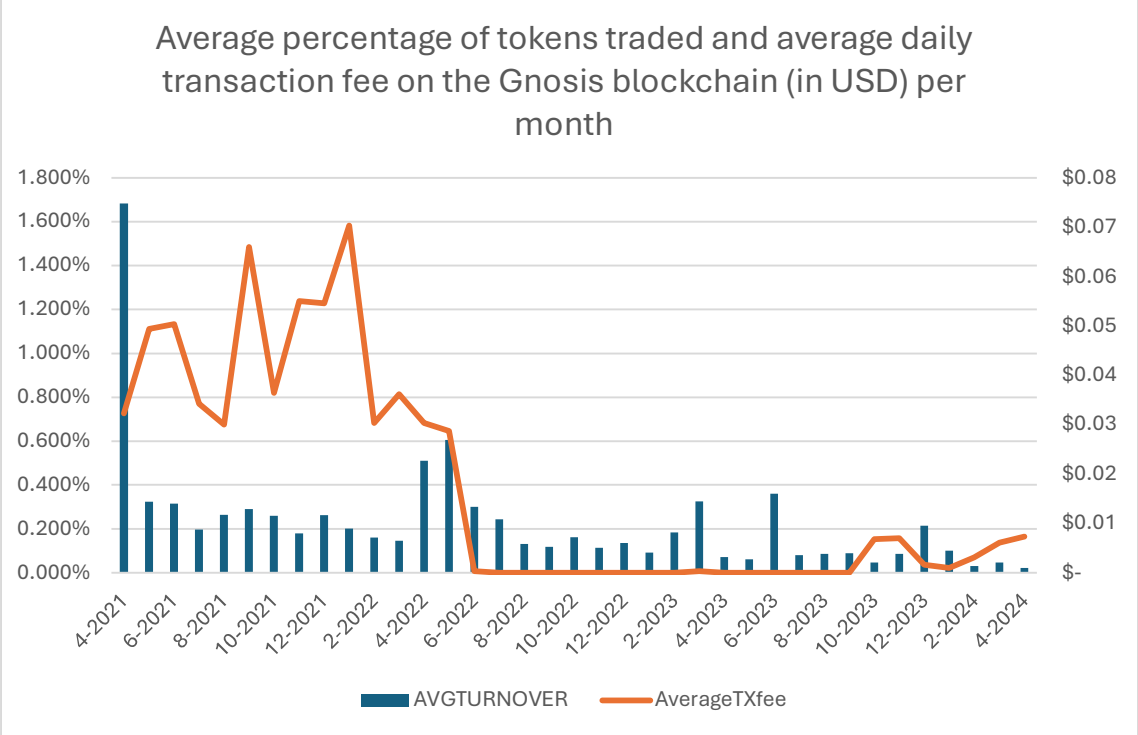

Figure 6: Average percentage of tokens traded and average daily transaction fee on the Gnosis blockchain (in USD) per month. Based on data from may 2024. Contains data from 455 properties.

Figure 6 is a histogram of the average turnover of the RealT tokens per month. The figure also contains a graph of the average transaction fee on the gnosis blockchain. In the beginning of the plotted period there were less tokenized properties available then in the end. Once new properties were tokenized they were added to the population. The first period of the data we collect, March 2021, only contains data of a single property. We choose to not include this period in the figure. The transaction fee on the Gnosis blockchain is very low in comparison to the transaction fee of Ethereum at the time. Figure 6 shows a highest transaction fee of 0.07 USD and a lowest of less than one hundredth of a cent.

VARIABLES	(1) Liquidity	(2) Liquidity
Underlying property value in thousands (VAL)	-0.000114***	-0.000115***
	(1.35e-05)	(1.34e-05)
Months since property started to collect rent *reference date: 2024-06-27* (AGE)	0.00107***	-0.00107***
	(0.000357)	(0.000385)
Detroit dummy	0.0235**	0.0195*
	(0.0108)	(0.0111)
Transaction cost Gnosis	1.042***	
	(0.192)	
Constant	0.0754***	2.060***
	(0.0145)	(0.0197)
Monthly fixed effects	NO	YES
Observations	5,480	5,480
R-squared	0.052	0.216

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Regression results explaining the liquidity drivers.

To examine the liquidity drivers of the RealT tokens we performed a OLS pooled regression. The results are shown in Table 2. The Detroit dummy variable in the regression with monthly fixed effects has a p-value between 5% and 10%. The Detroit dummy has a p-value between 1% and 5% in the regression without monthly fixed effects. The other variables in both regressions have better statistical significance, with p-values below 1%.

The underlying property value has a small negative effect on the liquidity, with and without including monthly fixed effects. The months since property started to collect rent variable has a small positive effect on the liquidity in the first model, however this effect reverses when including time fixed effects. The Detroit dummy has a bigger positive effect. The R-squared is for model 1 5.2% and for model 2 21,6%, indicating that the addition of monthly fixed effects increases the explanatory value of the independent variables on the liquidity.

5.4 Are prices of tokenized assets related to the economic fundamentals of the investment?

This research question aims to examine the relationship between the prices of RealT tokens and the economic fundamentals. To first get an idea of this relationship figure 7 was made. In this figure multiple graphs are plotted. The blue graph shows the price of 3310-3312 Sturtevant St Detroit Michigan according to the transaction data. The orange line indicates the current underlying property value divided by the total supply. Note that this is called the original price, however it is not always equal to the price RealT sold the token for during the initial token offering. The graph depicts that, although the trading price of the RealT token can diverge from the original price in the short term, in the long term the 2 price converge to each other again.

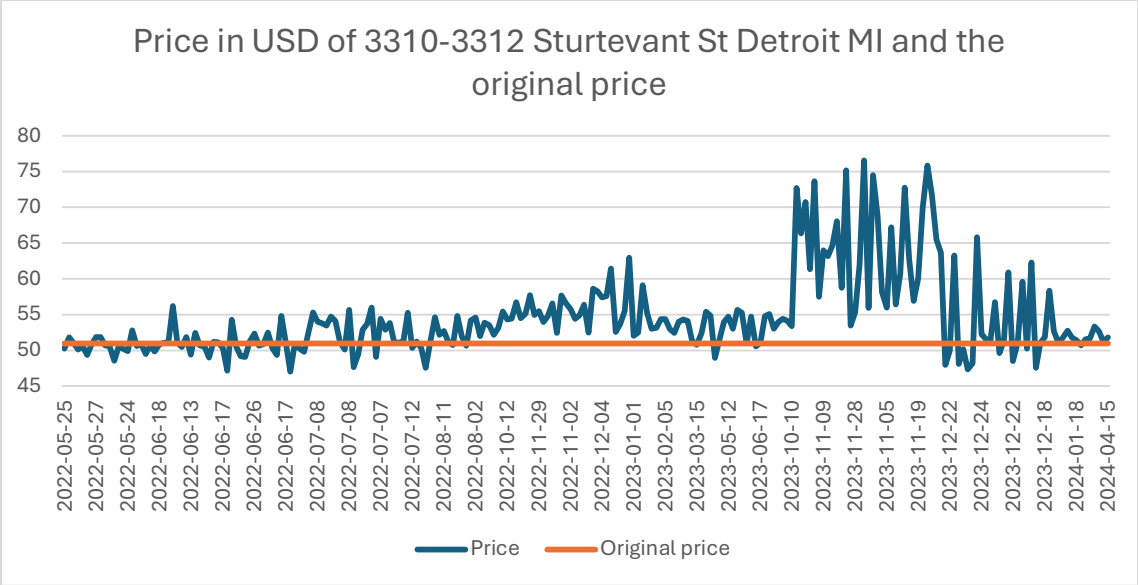

Figure 7: Price of 3310-3312 Sturtevant St Detroit Mi and original price of the property.

As explained in the methods chapter, there was also a RealT index constructed. This index contains the 50 most traded tokens each month. Figure 8 shows this index plotted against the S&P/Case-Shiller MI-Detroit Home Price Index. The first period, March 2021, is excluded because in this period only one token was traded on the Gnosis chain. Figure 8, shows that the RealT index and the home price index follow the same trend.

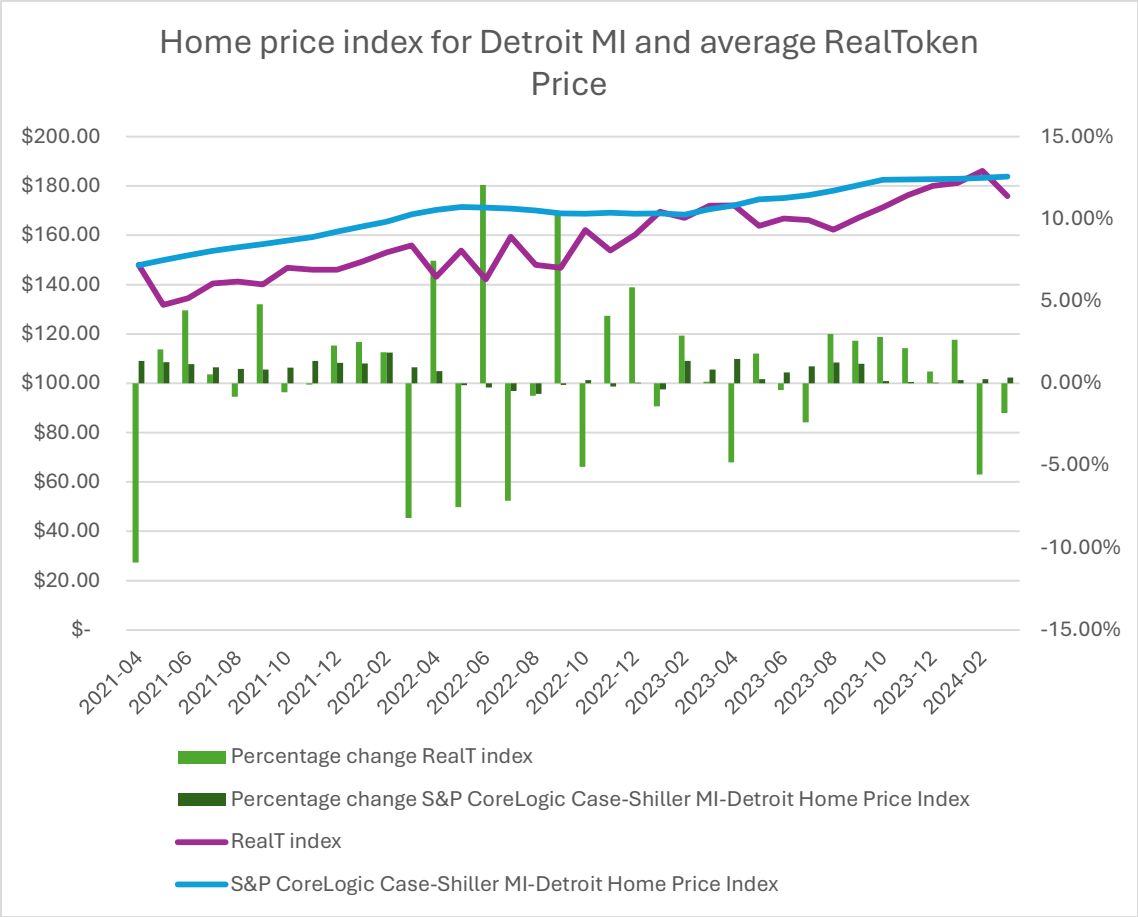

Figure 8: Home price index for Detroit MI and the price of the RealT index. Left-hand side axis shows the value of the index. Right-hand side axis shows the percentage change of the indicis.

5.5 Are the prices of tokenized assets correlated with the prices of cryptocurrencies?

This research question examines the relationship between the crypto market sentiment and the RealT prices. To first investigate this relationship figure 9 was made. This figure plots the RealT index and a crypto market index. This crypto market index is constructed by using the crypto market capitalization data from CoinGecko and is used as indicator of the crypto market sentiment.

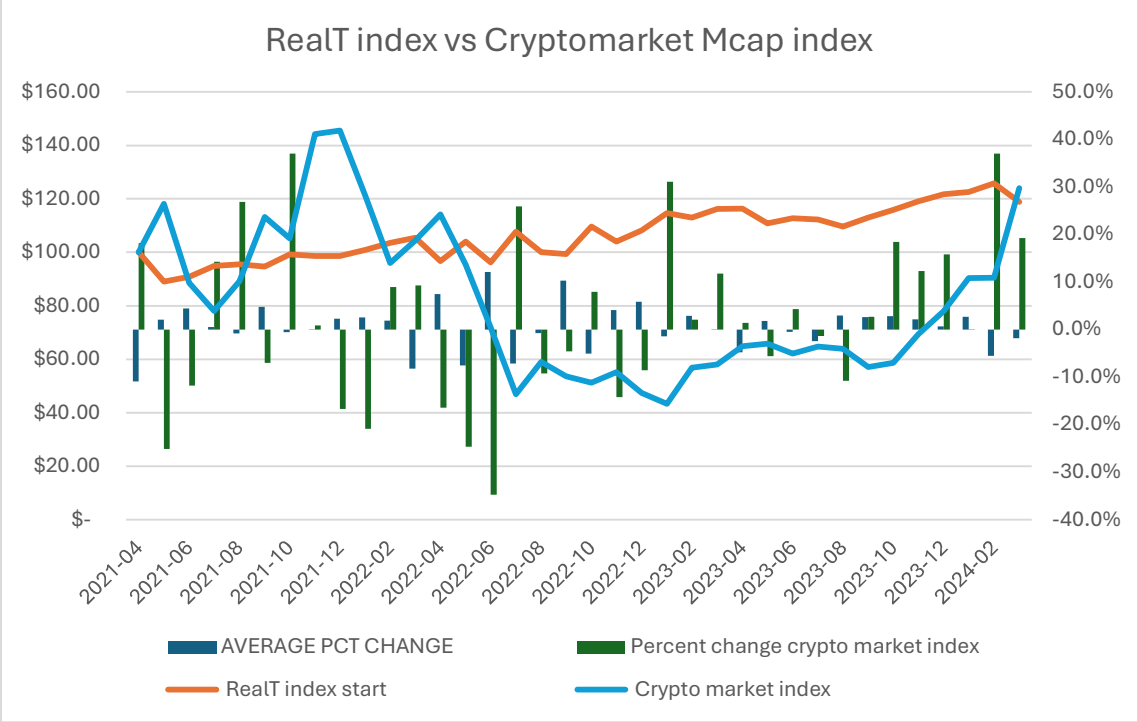

Figure 9: RealT and Global Crypto Market Index

To further investigate the relationship between the prices of RealT tokens and the crypto market sentiment and OLS regression was performed. The results of the regression are shown in table 3.

VARIABLES	(1) Pct Change RealT index
Pct change Crypto Market Index	-0.158***
	(0.0494)
Gnosis chain transaction fee	0.0650
	(0.656)
1-month US T-bond yield	0.000974
	(0.00952)
10-year US T-bond yield	0.00946
	(0.0221)
ADS index	0.0197
	(0.0229)
Constant	0.978***
	(0.0570)
Observations	36
R-squared	0.289

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Regression results investigation the relationship between crypto market sentiment and RealT token prices.

There is a significant relationship ($p < 0.01$) between the RealT index return and the Crypto market index returns. For every percent point increase in the crypto market index return, the RealT index return decreases with 0.158 percent points. The R-squared of this regression is 28.9% , indicating that the independent variables explain the change in the dependent variable for 28.9%.

CHAPTER 6: Discussion

This chapter discusses the results of the paper and relates them to the papers of Swinkels(2023) and Kreppmeier et al. (2023). The research questions are discussed one by one.

6.1 How concentrated is the ownership of a typical residential property after tokenization?

For this research question we will first compare figure 1 and figure 2 with there corresponding figures in the Swinkels' paper. This paper contains data from 397 more properties. The average holder amount of the properties that are analyzed in this paper is 573. This is higher than the data in Swinkels(2023), where 81.0% of the properties have between 150 and 400 holders. The median is 499 in this paper and 254 in Swinkels(2023). This can be explained by the fact that the new properties in this data set have a higher underlying value and thus a bigger total supply. The total supply has a positive effect on the number of holders, as shown in Table 1. RealT aims to provide tokens for a price around 50 USD. If they tokenize a more valuable property they will issue more tokens. More tokens could mean more investors. The adjusted Herfindahl-Hirschmann index seems to be distributed similarly to Swinkels's results, with 76.9% of the properties having a HHI* of below 10% in this paper and 94.8% of the properties in Swinkel(2023). This indicates that the ownership is relatively distributed evenly for most properties.

To fully answer this research question an regression was also performed. We expected that the results of this regression would be similar to the outcome of the regression of Swinkels. However, because the tokens have traded for longer, it is expected that the intercept will be slightly higher in case of the regression with depended variable being the total number of owners N. This last expectation is true. The first regression shows that the total supply has a significant positive effect on the number of holders. Swinkels' research shows a significant positive relation between the property value and the number of holders, but no significant relation between the total supply and the number of holders. This is a difference, however in our data set the total supply is highly correlated with the property value and thus we can conclude that this relationship could still be valid. Our regression also shows that the months since the property started to collect rent has a significant negative effect on the number of holders. Swinkels(2023) also shows this significant relationship. The Detroit Dummy in our regression is not statistically significant. Swinkels(2023) has a significant negative coefficient of -128.3 for this relationship. The reason for why we don't perceive the same relation could be that in our dataset there are more properties outside Detroit.

The regression with depended variable being the HHI* shows different results. Where Swinkels' achieves significant coefficients with the underlying property value variable(-0.000020), this research did not include the underlying property value variable because of collinearity with the total supply

variable, as stated earlier. We did achieve positive and significant coefficients for the total supply and month since the property started to collect rent variables. However for every extra token in the total supply the HHI* only increases with $3.47*10^{-6}$. Thus this coefficient has no economic significance. Swinkels(2023) did not find statistically significant coefficients for these variables. We used months since a property stated to collect rent instead of days. Our coefficient(0.00339) is smaller than the coefficient of Swinkels' paper(0.022). So we can stated that the effect of the age of a property on the HHI* has declined. The R-squared for both regression decreased in comparison with the Swinkels' regression. Meaning less explanatory power of the independent variables.

6.2 Do token investors use fractional ownership to create diversified real estate portfolios?

To examine this research question we made 3 histograms. The histograms will be compared to the respective histograms of Swinkels' paper. The first histogram is figure 3. This figure shows the number of portfolios with the number of different real estate properties in that portfolio. In total there are 13,327 wallets that own at least one or part of one RealT token. This is a significant increase from the 2,173 wallets in Swinkels' data. There are 59 wallets with more than 300 types of RealT tokens. There are 3974 portfolios with only one type of RealT token in it. This is 29.8% compared to 37.9% in Swinkels' research. So there are relatively less portfolios with only one type of RealT token in it. Figure 4 has the number of wallets on the vertical axis, this is similar to figure 3. Figure 4 shows most portfolios have an value of less than 1,000 USD. There is a decreasing trend in the amount of portfolios in the categories. The category 0 USD to 100 USD has the most portfolios in it. The next category, 100 USD to 250 USD, has 2,015 portfolios in it. Note that in Swinkels' research the number of portfolios slightly increased from the first to the second category, while in this data set the amount of portfolios almost halves.

Figure 5 shows the number of portfolios divided in categories based on the HHI*. Most portfolios have a HHI* of below 10%. This is consistent with Swinkels's research. The category with most portfolios is 0% to 1% HHI. This means a very well diversified portfolio. This is different for Swinkels' research, where 2% to 5% is the biggest category. There are 218 portfolios with a HHI* equal to 100%. This means that these portfolios have equally divided their investments in RealT tokens. In our dataset this only happens if there is only 1 type of RealT token in the portfolio.

To conclude this research question, while most portfolios still have a small number of tokens in their portfolio, the adjusted Herfindahl-Hirschmann index has decreased for portfolios worth more than 5,000 USD. This means that most portfolios have better diversified their investments in RealT tokens. The invested value in RealT tokens is similarly distributed, but the amount of portfolios with RealT tokens has drastically increased.

6.3 How liquid are individual residential properties after tokenization?

To answer this question, we first looked at figure 6. This figure show a the turnover of the RealT tokens decreasing drastically. The average turnover during the entire period is 0.23%. In the first part of the sample of Swinkels(2023), the average turnover is 15% and in the second part it decreased to 5%. Reasons for this decrease in liquidity could be that the supply of RealT tokens increased faster due to new properties being tokenized than the demand for these properties. The increase in available tokens to buy while the demand for these tokens doesn't increase at the same rate, would result in a lower average monthly turnover. Another reason for the decrease in turnover is the crash of the crypto market in the end of 2021. This crash could have resulted in less confidence in the crypto market and therefore less investment. This reliability on the crypto market sentiment is investigated in the final research question. Lastly, the decrease in liquidity could also be related to a decrease in the economic environment. This is examined in the next research question. The decrease in liquidity is not necessarily bad. Real estate assets are invested in for longer periods of time. According to Collett et al. (2003) the mean holding period of a real estate investment is 11.4 years. If the behavior is replicated for tokenized real estate assets, a low turnover seems rational.

The liquidity drivers were also investigated. This was done with a regression. This paper did not include the total supply in the regression because it is highly correlated with the underlying value of a property. For the regression without fixed effects, the underlying property value has a negative significant effect on the liquidity of the token. If the value of the property increases with 1,000 USD, the liquidity decreases with 0.000114 percent points. Swinkels(2023) found no significant effect of the property value or the number of tokens without monthly fixed effects. However he did find a negative significant relationship between de depend variable and the months since the property was listed. Our regression showed a significant positive effect: for every month the property gets older, the liquidity increases with 0.00107 percent points. Thus this paper conflicts with the results of Swinkels(2023) on this aspect. The more matured tokenization concept could explain this. We also found positive and significant results in this regression for the Detroit dummy and Gnosis transaction costs variables. The coefficients of these variables are relatively large compared to the previous variables. 0.0235 and 1.042 respectively. Swinkels(2023) did not find a significant relation with the Detroit dummy variable. Swinkels(2023) did find significant negative relationship between the transaction cost and the liquidity. However, the transaction costs on the Ethereum blockchain is not comparable to the transaction costs on the Gnosis blockchain.

The regression with monthly time fixed effects shows significant negative effects for the underlying property value in thousands and the months since the property started to collect rent. The coefficients are -0.000115 and -0.00107 respectively. Swinkels' paper only shows a significant relation between the total supply or property value and the liquidity. This relation is positive. Note that the coefficient of the variable months since the property started to collect rent switches signs when including monthly fixed effects (from 0.00107 to -0.00107). The inclusion of monthly fixed effects can also capture

omitted time varying variables, such as seasonal effects. This could be a reason for the switch from sign. The R-squared is 5.2% in the regression without monthly fixed effect and the model with monthly fixed effects has more explanatory power with a R-squared 21.6%.

6.4 Are prices of tokenized assets related to the economic fundamentals of the investment?

To investigate this relationship, we first showed the trading price and the original price of a random property. The traded price does diverge from the original price during some periods. However, it also converges again to the original price. This seems to be consistent with the Swinkels' research, however his chosen property does have a positive outlier in the final month. To compare, not just a random property but the whole RealT universe with the economic fundaments figure 8 was plotted. This figure shows that, although, the percentage change of the indices do differ each month and sometimes are in the different direction, the indices do follow the same trend. This is consistent with the research of Swinkels, where the Detroit home price index also follows the same trend as the average RealToken price.

6.5 Are the prices of tokenized assets correlated with the prices of cryptocurrencies?

This research question examines the relationship between RealT tokens and the rest of the crypto market. Kreppmeier et al. (2023) stated that the crypto market sentiment has a positive impact on the capital inflow into RealT tokens. To investigate this figure 9 was made. The graphs show that the movement of the crypto market and the RealT index do differ from each other. There is no clear trend visible that applies to both graphs. However, there was also an OLS regression done. The results from this regression show an negative relation between the crypto market index and the RealT index. This relationship is highly significant($p<0.01$, coefficient -0.158). This indicates that for every percent point increase in the price change of the global crypto market index, the RealT index price change decreases with 0.158 percent points. Aljinović et al. (2022) find a negative relationship between real estate and cryptocurrencies. This negative relationship between the real estate sector and the crypto market could explain the negative coefficient we found.

Kreppmeier et al. (2023) performed a similar regression but with the dependent variable Inflow or Outflow of capital. They found a significant relationship between the ETH price and the inflow of capital, however they did not find a significant relationship between the ETH price and the outflow of capital. Steininger (2023) also research this relationship. He found no significant relationship between the monthly ETH return and the RealT indices.

CHAPTER 7 Conclusion

This research paper aimed to provide answer on the question how tokenization is used and what the effect of it is in the real world. We use 455 properties tokenized by RealT over a time period of 3 years. These 455 properties have a value of over 83 million together. We also analysed 69,399 transactions. We find that tokenization adds value as an investment instrument for individual investors. The ownership of tokens is distributed evenly. This results in risk sharing across the token holders. Portfolios worth more than 5000 USD are generally well diversified, which is in contradiction with individual investors active in the stock market and similar to the results from Swinkels(2023). This could because investors, who are already aware of the need to diversify, use tokenization as a valid tool to diversify. Previous research showed a decrease in the liquidity of tokenized properties, this trend has continued and the liquidity of tokenized properties is low. This could be an imitation of the long holding periods in traditional real estate investments. The prices of tokens can differ significantly from the underlying value, however they seem to converge to the same value in the long term. The cryptocurrency market has negative impact in the price of real estate tokens. One of the reasons for this relationship can be the negative correlation between real estate and cryptocurrencies. According to this relationship cryptocurrency prices effect the underlying value of the tokens. This in turn effects the price of the tokens.

Limitations of this paper are the following, we do not have information of the investors. This information can only be obtained with help from RealT, however they are not allowed to share this information. Second, while most data is available on the Gnosis blockchain there are some investors who own tokens of old tokenized properties that are still listed on Ethereum. These investors and their transactions are not included in our dataset. It should be noted that this data is very limited. Lastly, we compared the RealT portfolios of investors, however we did not investigate the investments into other assets by the investors.

Further research can include other blockchain assets of the investors into the data, however you are still not able to include real world assets. Research can also be conducted on the impact of increased cyber security risk involved with investing in cryptocurrencies or on the long term financial performance of tokenized properties.

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Appendix

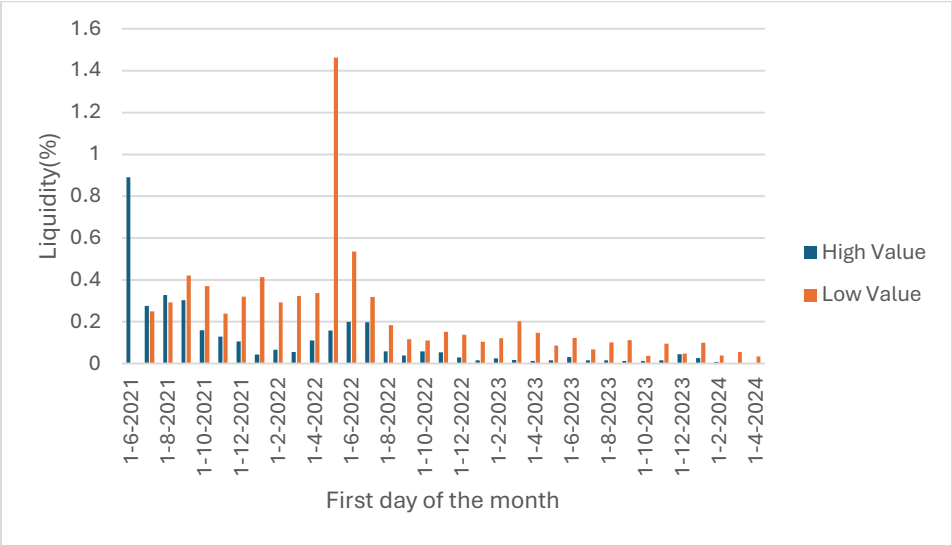

Figure 10:Liquidity of high value(> 750,00 USD) versus low value properties (< 55,000 USD).

VARIABLES	(1) RealT index percentage change
Home price index percentage change	-0.389
	(1.661)
Transaction cost	0.504
	(0.803)
1 month US T-bond yield	-0.00746
	(0.0110)
10 year US T-bond yield	0.0254
	(0.0255)
ADS index	-0.00202
	(0.0253)
Constant	0.943***
	(0.0659)
Observations	36
R-squared	0.050

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Regression results investigation the relationship between economic fundamentals and RealT token prices. No significant independent variables.