Real Estate Tokens -- Return-Risk Analysis of the First Years

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Abstract: This study analyses the return-risk metrics of real estate security tokens as digital representatives of fractional ownership in physical properties. I use around 40,000 daily pricing data for 180 real estate tokens in the U.S.A. over the period from 2019 to 2022 and construct a monthly equal-weighted index and value-weighted index. These indexes are used in univariate and multivariate analyses (correlation, regressions, and principal component analysis) to see whether the tokens' returns follow the performance of the underlying housing market, securitized real estate market, or sentiment on the crypto market. The token indexes show no clear similarity to the cryptocurrency or housing indexes but represent their own return-risk pattern. This is confirmed in multivariate analyses. The principal component analysis shows that the debt and macroeconomic factors are the major drivers and the crypto market and housing market are of minor importance to explain the variation of the assets' returns. This absence of a linear relationship with other assets makes real estate tokens attractive to use as diversifiers in a multi-asset portfolio.

Keywords: Digital Asset, Real Estate Token, Security Token Offering (STO), Blockchain, Distributed Ledger Technology (DLT), Decentralized Finance (DeFi)

JEL classification: G24, G32, K22, L26, M13

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1 Introduction

Innovation within the financial sector repeatedly tries to develop new products, services, and technologies that aim to improve and/or expand how financial transactions are conducted. The major driver of this trend is to make transactions faster, easier, and cheaper. An important driver of this trend was the development of new forms of intermediation and reducing their role during the transaction process. Since derivatives and exchange-traded funds (ETFs) have made it easier for retail investors to invest in assets around the world in the '90s of the last century, more investment vehicles have been developed to reduce the role of financial intermediaries (e.g. banks, brokers, and investment firms) and have increased the impact and power of retail investors on the markets. Crowdfunding platforms and peer-to-peer (P2P) lending networks have emerged and make it easier for small retail investors to invest in assets. Nowadays, this is summarized under the term decentralized finance (DeFi). Distributed ledger technology (DLT) or blockchain is the latest technology in this vein.

After solving the double-spending problem of digital assets by Nakamoto (2008), the long-lived idea of broader use of digital currencies (see, Chaum, 1982) and assets has gained momentum considerably. The crypto market for e-money-tokens (e.g. stable coins), referenced tokens (e.g. real estate tokens), and other crypto assets (e.g. utility tokens) increased in recent years. The White House (2022) reports that around 16% of adult Americans have bought digital assets and their market capitalization reached more than $3 trillion in November 2021. Despite the opportunities that digital assets offer to people, tech firms, and technological-oriented countries to reinforce control in the financial system and stay at the forefront in the application of technology, they also bear many risks as shown by the meltdown of cryptocurrencies after a crash of the so-called stablecoin 'terraUSD' that wiped out over $600 billion funds in May 2022 (see, The White House, 2022). The U.S. and European governments are developing strategies to encourage the potential benefits and mitigate the risks of digital assets and their underlying technology.

For decades, financial engineers have tried to develop solutions for allowing easier investment in the direct and private real estate market. Among the successful solutions are closed-end funds, open-end funds, or REITs. In the last years, various blockchain and tech companies (e.g. R3, RealT, DigiShares, ChromaWay) offer their expertise to securitize properties by using blockchain technology for institutional and private investors. The market for the latter increased enormously – it started with individual objects per month in mid-2019 and reached dozens per month at the end of 2022. Kreppmeier et al. (2023) identified 238,433 blockchain transactions based on 173 real estate tokens in the USA between 2019 and 2021.

So far, the research on real estate tokens is either theoretical and conceptual on how they are structured and may influence the market in the near future (e.g., Liu et al., 2020a; Baum, 2021; Markheim and Berentsen, 2021) or with an empirical analysis of the diversification of the token holders' portfolios, determinants of security token offerings (STOs), secondary market trading, and daily aggregated capital flows (see, Swinkels, 2023; Kreppmeier et al., 2023)

While I want to contribute methodologically to open up avenues for constructing real estate token indexes for this new type of fractional real estate investments, I also aim at contributing to the more general literature on real estate investment analysis using empirical data. My study sample covers around 40,000 daily pricing data for 180 real estate tokens in the U.S. over the period from 2019 to 2022 that I averaged to monthly index values for an equal-weighted index and value-weighted index.

By comparing the monthly returns with other real estate investment vehicles, stocks, bonds, T-bills, and macroeconomic variables, I find that token indexes show no clear similarity to the cryptocurrency or housing indexes but represent own return-risk pattern. Univariate and multivariate analyses confirm that the absence of a linear relationship with other assets makes real estate tokens attractive to use as diversifiers in a multi-asset portfolio. A principal component analysis (PCA) confirms the previous findings that the debt and macroeconomic factors are the major drivers and the crypto market and housing market are of minor importance to explain the variation of the assets' returns. My findings might help to better understand the return-risk metrics of the real estate token market and that it is not a simple linear combination of housing, securitized real estate, and cryptocurrency.

In the following Section 2, I present the motivation, concept, and literature about real estate tokens. The data collection, index construction, and descriptive statistics are described in Section 3. On this basis, I run univariate and multivariate tests in order to compare the performance of real estate with stocks, direct & indirect real estate, cryptocurrency, and macroeconomic data in Section 4. Section 5 concludes by highlighting the practical applications of my findings.

2 Real estate tokens: motivation, idea, theory, concepts, and literature

2.1 Motivation and background

Different regulators (e.g. The White House, 2022) and industry reports (Pang et al., 2020) describe the need of the actors in the financial markets to keep pace with the technology development if they intend to remain at the leading technological and economically prospering frontier. In addition to the various applications of digitalization for property companies (e.g. marketing, valuation, maintenance), also the generating, issuing, and holding of financial assets have changed over the last years and will highly influence how we own and trade assets in the future. The digital native generations (Millennials and Generation Z) receive and process information by using electronic devices and platforms; their decision-making is mainly influenced by these sources, and they demand easy-to-process technology for banking and investment activities.

Tokenization of financial assets is in the vein of this trend. It combines the constant pressure of the industry to increase the efficiency in handling and processing the administration of creating, issuing, and holding financial assets but also makes it easier for investors to trade them and change or split ownership rights in a way that digital natives are used – their smartphones.

2.2 Idea, definitions, and previous research

At a first glance, real estate tokens are digital assets that have similar characteristics as traditional assets but are issued and transferred using distributed ledger technology (DLT) or blockchain technology, see SEC (2019). DLT – blockchain is a subtype of DLT[1] – is a decentralized and distributed ledger database that records transactions between parties. The idea of decentralization means havening no central authority for the approval and consensus mechanism such as notaries. This characteristic is emphasized by proponents as a tool for 'democratizing' the process or at least to reduce the power of central authorities and an important tool for the DeFi movement. Also, central authorities like central banks see advantages in this technology since such systems reduce the risk of hacking, intrusion, or manipulation as there are many decentralized participants/nodes as validators in the peer-to-peer (P2P) distributed network. The validators in the network need the exact same copy of at least a part of the records to be able to find consensus in the validation process. There are mainly two types[2] of consensus used at the moment: Proof of Work (PoS) and Proof of Stake (PoS).

[1] In the following, I use the two terms blockchain and DLT synonymously; for a detailed discussion, see Liu et al. (2020b).

[2] A new method is proof of capacity (PoC) trying to fix the problem of high-energy consumption by PoW and hoarding protocols by PoS. So far, it is not widely used on large networks.

The former is the predominant type as it is used for Bitcoin; it is highly limited in scalability due to a longer processing time and is highly criticized for its energy consumption needed for doing the ‘work’. PoS solves these drawbacks and is applied in the latest blockchain ecosystems (e.g. Gnosis).

At the early stage of the tokenization development, real estate tokens were mostly organized as security tokens for larger commercial properties – mimicking traditional securities and representing the ownership rights of real estate off-chain but traded and held on a private/permissioned blockchain (e.g. Hyperledger, Ethereum Enterprise, R3 Corda). Mainly institutional investors were involved in these proofs-of-concept.

Since the St. Regis Aspen Resort in Colorado was tokenized for the retail market instead of placed in a REIT in 2018, more security tokens for the broader retail markets are issued on public/permissionless blockchain and trading platforms (e.g. Ethereum, Uniswap). Most of them use the widely accepted technical standard for fungible tokens on the Ethereum blockchain (ERC-20).

In order to process transactions efficiently, smart contracts are required. They are program codes written into a DLT and automatize the necessary actions needed to execute the terms of an agreement or contract without the need for trust between the involved parties or a central authority conducting this for them.

Real estate tokens satisfy the long-lasting demand for fractional real estate in order to be able to pay the otherwise high price for a property. This high investment sum discourages people from integrating this asset class in a diversified manner in a multi-asset portfolio. See Baum (2021) for a more detailed discussion on the different forms of fractional ownership over the last decades (e.g. physical subdivision, time share, freehold/leasehold, tranching, syndication, funds, securities, etc.). Baum (2021) also gives a good overview of the idea, concept, and motivation for using real estate tokens and concludes that an intermediate structure is likely to be both necessary and suitable when fractionalizing a single asset. Figure 1 shows the process of tokenization through distributed ledger technology as it is currently mostly used – it combines elements of traditional and DeFi securitization. In the first step (see dashed block numbered with 1), a property is prepared to be transferred to a legal entity that can be easily fractionalized (e.g. LLC). All the needed procedures as ‘know your customer’ (KYC) and ‘anti-money laundering’ (AML) are handled in the traditional way using traditional authentication authorities. In step 2, the property is transferred to a legal entity, which holds, protects, and manages the property with its deed and legal requirements (financial accounts, settlements, compliance, and tax issues) as an asset custodian. All these steps are necessary since property cannot be tokenized (digitally securitized) directly so far. In step 3, the legal entity is tokenized by a token security provider, which is in most cases involved from the beginning of the process. With this step, the fractional ownership of this entity holding the property is transferred from traditional finance to the blockchain system. In step 4, the tokens are prepared for issuance to retail investors on the primary market. This process is called Security Token Offerings (STO). The tokens are now on a token platform often organized as a decentralized exchange (DEX; e.g. Uniswap) and a tradeable for investors on this secondary market as shown in step 5. The ownership changes and periodically rent payment is now settled through a blockchain using smart contracts without traditional authentication authorities involved. The token security provider is responsible to perform KYC and AML for all investors involved in the primary and secondary markets.

Most of the previous literature on real estate tokens is very theoretical describing the conceptual procedure (Gupta et al., 2020; Liu et al., 2020a; Markheim and Berentsen, 2021), financial application and first deals (Baum, 2021), legal aspects (Konashevych, 2020), and technical aspects (Gupta et al., 2020). Markheim and Berentsen (2021) present descriptive data based on a small sample for real estate tokens in the USA and Switzerland and also highlight the disadvantage of high energy consumption by using PoW as a consensus mechanism. Swinkels (2023) uses a large dataset of 58 tokens empirically analyze the number of owners, the actual portfolio diversification of the investors, liquidity aspects, and the relationship of tokenized assets to economic fundamentals. By relying on the same token provider but with 178 tokens, Kreppmeier et al. (2023) conclude that this type of real estate investment provides in theory ownership for small investors with low entry barriers, while current token investors do not yet hold well-diversified real estate token portfolios. They find that crypto-market-specific determinants, such as transaction costs and the related sentiment, are relevant both to the STO and capital flows. Based on the fact that empirical research on real estate tokens is scarce and it is not clear how the return-risk relation is linked to existing direct and indirect real estate returns, this question has to be settled empirically.

3 Data

3.1 Variables and definitions

The empirical analysis is based on monthly real estate token returns in comparison to the returns of other direct and indirect real estate, returns of stocks, bonds, T-bills, and macroeconomic variables in the U.S. between December 2019 and December 2022.

For the real estate tokens, I construct an equal-weighted and value-weighted total return index based on security tokens issued by a RealT to U.S. investors and non-U.S. investors (Regulation D)[3] and traded publicly on the secondary market. For the index construction, I used all tokens available with transaction data for 3 months on the secondary market (Ethereum) between November 2019 and December 2022. In total, I had around 40,000 daily pricing data that I averaged to monthly index values. The equal-weighted index (*RE Token (ew)*) breaks all token prices down equally and the value-weighted index (*RE Token (vw)*) recalibrates monthly the weight of a token price based on a property's monthly market value relative to all properties in that specific month. Since 2021, a second layer constructed as an Ethereum sidechain (Gnosis blockchain) offers another possibility for a secondary trading. This blockchain uses delegated Proof-of-Stake (PoS) consensus to increase the speed of transaction (i.e. we are only talking of minutes) and reduce the transaction cost; I have not included this transaction in my index construction. In total, I use 180 real estate tokens starting with 3 tokens in December 2019 and 165 tokens in October 2022. The token price data are obtained Security Token Market, whereas the rent data, location, and token amount are collected from the issuer's website.

The real estate tokens are compared with two interest rates that are mainly used to proxy the long-term and short-term financing opportunities of real estate investments: the 10-year Long-Term Government Bond yield (*Bond*) and 3-month Treasury Bill secondary market rate (*T-Bill*). In order to compare the inflation hedging potential of the total return indexes, I compare them with the realized inflation measured by Consumer Price Index: All Items (*CPI*). The interest rates and CPI are obtained from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis.

For common stocks within the class of other assets, I use the blue-chip index of Standard & Poor's (S&P) 500 (*S&P 500*) index as well as the broader and small cap-oriented Russell 2000 Index (*Russell 2000*). Both indexes' returns allow comparison in the context of diversification in a multi-asset portfolio context whereas the latter also illustrates a better stock-to-property comparison since the values of properties are small or even microcap entities. For securitized real estate, I rely on the Dow Jones U.S. Real Estate Total Return Index (*RE Securitized*). It comprises both real estate investment trusts (REIT) as well as other firms investing directly or indirectly in the asset class of real estate (management, ownership, development, etc.). It allows

[3] Regulation D allows smaller companies to sell securities without registering with the S.E.C.

a comparison between different forms of securitization of properties (stock market vs. blockchain). The data are obtained from Thomson Reuters Datastream/Eikon.

For private and direct real estate, I use indexes out of the S&P/Case-Shiller Home Price Index family. Around 90% of the tokenized properties are located in Detroit, MI, the remaining part is almost equally distributed between Chicago, IL, and other cities. In order to incorporate the different house price movements in these cities, I construct a combined house price index weighted with the respective monthly weight of the cities Detroit, Chicago, and other cities. The latter performance is incorporated by the S&P/Case-Shiller 10-City Composite Home Price Index. The newly calculated index (*House Index*) shows a correlation of 0.66 with the S&P/Case-Shiller MI-Detroit Home Price Index and 0.69 with the S&P/Case-Shiller 10-City Composite Home Price Index. The housing data are obtained from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis.

To capture the sentiment from the crypto market, I incorporate the price movement of Ether (*ETH*), the second largest cryptocurrency in market capitalization and the native cryptocurrency of the Ethereum platform used for real estate token transactions. The data are obtained from CoinMarketCap. See Table 1 for a summary of the variable names, definitions, and sources.

3.1 Descriptive statistics

In Table 2, I show the descriptive statistics of the key variables. The asset classes of T-bills, bonds, real estate, and common stocks exhibit a common pattern. The yields for the debt products have low average returns p.m. (e.g. mean is 0.0015 for *Bonds*) and the lowest risk (e.g. standard deviation is 0.0008 for *Bonds*). They are right-skewed explained by more extreme positive outliers and with high auto-correlations for the lag length of 1, 2, and 3 months. The high serial autocorrelation (e.g. AR(1) = 0.970, AR(2) = 0.913, and AR(3) = 0.861 for *Bonds*) is given by the nature of the relatively stable interest rate in general and over the last years since there were rarely changes of the rates over the months so that the rate of month t is a good predictor of the rate in month t+1, t+2, and t+3. As already known from the literature (see, e.g. Clayton, 1998), the securitized real estate and common stocks have a higher average return (e.g. 0.002 for *RE Securitized* and 0.0069 for *Russel 2000*) and risk (e.g. 0.0649 for *RE Securitized* and 0.0767 for *Russel 2000*). They are left-skewed triggered by more extreme negative returns during downturns, crashes, or crises. In line with the literature (see, e.g. Fama, 1970), the autocorrelations of stocks and securitized real estate returns are not significantly different from zero at the 10% level corresponding with the conclusion that these markets are information efficient. Surprisingly, the newly calculated home price index (*House Index*) has a high average return for the observation period (mean: 0.01) corresponding with an increase of 35% for the 10-City Composite Home Price Index within 37 months. In line with the literature (see, e.g. Case & Shiller, 1989), the autocorrelation of the first order is significantly different from zero at the 5% level consistent with the conclusion that the direct real estate market incorporates information sluggishly. Unsurprisingly, cryptocurrency (*ETH*) has the highest average return (0.044) and risk (0.2191).

The two real estate token indexes show partly a different pattern. The equal-weighted index (*RE Token (ew)*) has around 9 times higher average return (0.019) and risk (0.062) than the value-weighted index (*RE Token (vw)*). This is driven by the higher performance and volatility of the smaller tokenized property in the equal-weighted index. The first-order autocorrelation is for both significantly different from zero at the 10% and 5% level, respectively, but negative for the equal-weighted index indicating a mean-reverting behavior, and positive for the value-weighted index a mean-averting behavior of the returns.

The coefficient of variation (CV) allows for comparing the risk of different assets relative to their specific means. It is calculated by the ratio of the standard deviation to the specific mean times 100. *Bonds* have the lowest standardized risk with 0.55 times their means; direct real estate (*House Index*) follows with 1.32 times its mean. Both real estate token indexes have roughly the same CVs with around 3.27 (*RE Token (ew)*) and 3.38 (*RE Token (vw)*) times their means. *S&P 500* has a risk of 8.35 times its mean and *RE Securitized* 32.65. Its CV is even greater than for *ETH*.

Based on the descriptive statistics, real estate tokens have a return-risk relationship between the housing and securitized real estate index. The token indexes show no clear similarity to the cryptocurrency or housing indexes and are auto-correlated to the underlying housing index. The equal-weighted real estate token index has a greater return and risk of around the same factor than the value-weighted real estate token index so the CV is the same for both index types. The skewness and kurtosis of the equal-weighted real estate token index are closer to stocks and securitized real estate index, the figures for the value-weighted real estate token index are closer to the housing index – the higher valued properties shift their returns in line with the housing index.

4 Analysis and results

4.1 Correlation

I start with univariate analyses to see whether the tokens' returns follow the performance of the underlying housing market, securitized real estate market, or sentiment on the crypto market. The linear and pairwise relationship between the variables is shown in Table 3.

By focusing on both real estate token indexes with the other assets, the pairwise correlation coefficients between the *Russel 2000* and the token indexes are slightly positive (0.37 for *RE Token (ew)* and 0.29 for *RE Token (vw)*) but only significant at the 5% level for the equal-weighted token index. The value-weighted token index is moderately negatively correlated with *CPI* and both token indexes are moderately negatively correlated with *GDP*. This means that with an increasing *CPI* the token returns go down – an unfavorable characteristic and contrary to the correlation between the housing index and *CPI*. The negative correlation between the token returns and the *GDP* index is unique among all other assets and corresponds to lower returns for higher *GDP* values – a favorable characteristic for decreasing GDP values but not for improving macroeconomic conditions.

The token indexes are highly correlated to each other (0.77). The remaining correlation coefficients are not significantly different from zero for the token indexes. *Bonds* and *T-Bills* as well as *CPI* and GDP have a very high correlation with each other so I cannot use both of them in the later multivariate OLS regression analysis.

The not existing or low linear relationship with other assets makes real estate tokens attractive to use as diversifiers in a multi-asset portfolio. Even if real estate tokens are traded on the Ethereum platform using *ETH* and based on houses represented by the home price index (*House Index*), they are not correlated with both real estate token indexes. The non-existing correlation with securitized real estate shows that real estate tokens show no similar return pattern to REITs and REOCs. Summing up, real estate tokens show no similar linear relationship as existing (real estate) investment vehicles.

4.2 Multivariate tests

To get a broader overview of the potential influencing factors on the real estate tokens' returns, I also run multivariate OLS regressions. The potential influencing factors are clustered in the financing of real estate (*Bonds*), macroeconomic variable (*GDP*), common stocks (*Russel 2000*), crypto market sentiment (*ETH*), and direct vs. indirect real estate returns (*House Index* and *RE Securitized*). To avoid multicollinearity and similarity issues, *T-Bills* (highly correlated with *Bonds*), *CPI* (moderately correlated with *GDP*), and *S&P 500* (not highly correlated with *Russel 2000*) are excluded in the regressions.

In line with the literature (Ibbotson & Siegel, 1984; Jack Rubens et al., 1989; Chan et al. 1990), most debt rates have a negative influence on the house price movements since they are often highly debt-financed; commons stocks are normally slightly positive related to the real estate market (see, e.g. Eichholtz, 1996; Hoesli & Moreno, 2007; Norman, 2021); the crypto market may have a positive nexus to financial products using blockchain technology; and the same assumption applies to direct and indirect real estate returns which are another form investing indirectly in this asset class or the underlying asset itself.

$$RE\ Token = f\,(Bonds,\ GDP,\ Russel\ 2000,\ ETH,\ House\ Index,\ RE\ Securitized) \qquad (1)$$

The results for the regression estimations are shown in Table 5. Model (1) presents the results for *RE Token (ew)* and Model (2) for *RE Token (vw)* as the dependent variable. For the equal-weighted index, *GDP* has a negative (–0.001) and the *Russel 2000* index has a positive coefficient (0.254) as assumed; all other factors have no statistical significance at any conventional level. For the value-weighted index, *Bonds* and *GDP* have negative impacts (–2.498 and –0.0002) on the dependent variable; all other factors have no statistical significance at any conventional level. The adjusted R^2 ranges from 0.081 to 0.356. The results remain qualitatively the same even by using log-returns or other proxies for securitized real estate and broader cryptocurrency index.

In summary, these results are in line with the univariate results. The GDP has a negative nexus to both types of real estate return token indexes; the small-cap stock index and the debt yields respectively are linked to one of token indexes. A higher performance of the *Russel 2000* goes in line with a higher *RE Token (ew)* and a higher debt yield is negatively linked to *RE Token (vw)*. All the other potential influencing factors are not significant at any conventional level so the performance of *ETH*, *House Index*, or *RE Securitized* are not relevant in linear and multivariate models for explaining the real estate token returns. Consequently, their returns are not only a linear combination of them as could be assumed from the construction of tokens.

4.3 Principal component analysis

In the next step, I decompose the variables' influence on explaining the returns using a principal component analysis (PCA). In particular, PCA allows reducing the high dimensionality if closely related variables exist. Thus, it allows incorporating explanatory variables with near multicollinearity (i.e. *Bonds* vs. *T-Bills*) so that all variables applied in the univariate test of the first subsection can be used. PCA decomposes the structure of the variables into factors that are common to each variable and a proportion that is specific to each variable. For a more detail discussion of PCA see Fase (1973) in the general finance context and Kroencke et al. (2018) for the use in the real estate market.

Figure 2 shows that three principal components (PC) explain together around 99% of the total variation, where PC1 explains around 40%, PC2 around 31%, and PC3 around 27% of the variation using the equal-weighted real estate token index (see Figure 1, Panel A); the corresponding numbers for the value-weighted real estate token index are 46% (PC1), 31% (PC2), and 23% (PC3); see Figure 1, Panel B.

The disadvantage of using PCA is that the factors are not directly interpretable. By using square cosines (Cos2), we can observe the contribution of each variable for all three PCs together (see Figure 2). The representation is high for all variables for both token indexes where debt financing variables (*Bonds* and *T-Bills*), common stocks (*S&P 500* and *Russel 2000*), and macroeconomics variables (*CPI* and *GDP*) are higher represented on the components than direct and indirect real estate returns (*House Index* and *RE Securitized*) and the cryptocurrency price development (*ETH*). This is interesting since the later play a lower importance.

By dissecting each PC alone in Table 5 and Figure 4, we observe that PC1 is highly long in debt financing variables (*Bonds* and *T-Bills*) and macroeconomics variables (*CPI* and *GDP*), whereas short in common stocks (*S&P 500* and *Russel 2000*) – this applies for both token indexes.

For the equal-weighted real estate token index, PC2 is highly long in the token index (*RE Token (ew)*) and short in the macroeconomics variables (*CPI* and *GDP*) and (in-)direct real estate returns (*House Index* and *RE Securitized*). For the value-weighted real estate token index, PC2 is highly long in debt financing variables (*Bonds* and *T-Bills*) and short in the macroeconomics variables (*CPI* and *GDP*) and (in-)direct real estate returns (*House Index* and *RE Securitized*) .

PC3 is highly long in cryptocurrency price development (*ETH*), indirect real estate returns (*RE Securitized*), and big-cap stocks (*S&P 500*), whereas it is short in short in small-cap stocks (*Russel 2000*), direct real estate returns (*House Index*), and tokenized real estate returns.

Simplified, we can conclude that PC1 is the ‘macroeconomic factor’ explaining more than 40% of the variations, PC2 is the ‘financing factor’ explaining more than 30% of the variations, and PC3 is the ‘big-cap stocks, securitized real estate, and crypto factor’ explaining more than 20% of the variations. This confirms the previous findings: the debt and macroeconomic factors are the major driver and the crypto market and housing market are of minor importance.

5 Conclusion

Financial engineers have developed various solutions to make investments in the direct and private real estate market for institutional and retail investors easier; among the most successful solutions are closed-end funds, open-end funds, and REITs. In the last years, various DeFi and P2P solutions arose where blockchain technology is used. Real estate tokens in the form of security tokens are digital representatives of fractional ownership in physical properties. Most paperwork for owning and trading shares of properties are moved to the digital world by using the decentralized ledger technology (blockchain) but the securitized assets are still physical and not digital properties. This technology will change how we trade and handle transactions by introducing smart contracts as (semi-)automatic steps for low-skill tasks in the intermediary process – the existing idea of fractional ownership remains the same. Previous research describes mostly the conceptual framework of tokenization since its first proof-of-concept in 2018. For example, Baum (2021) describes how blockchain can be used to securitize real estate, presents the first deals, and concludes that an intermediate structure is likely to be both necessary and suitable when fractionalizing a single asset. Swinkels (2023) and Kreppmeier et al. (2023) use a dataset of 58 and 178 respectively real estate tokens to analyze empirically the diversification of the token holders' portfolios, determinants of security token offerings (STOs), secondary market trading, and daily aggregated capital flows.

I use around 40,000 daily pricing data for 180 real estate tokens in the U.S.A. over the period from 2019 to 2022. I contribute methodologically to opening up avenues for constructing real estate token indexes with a monthly equal-weighted index and value-weighted index that can be used for risk-return metrics. Furthermore, I run univariate and multivariate analyses (correlation, regression, and principal component analysis) to see whether the tokens' returns follow the performance of the underlying housing market, securitized real estate market, or sentiment on the crypto market.

Based on the descriptive statistics, real estate tokens have a return-risk relationship between the housing and securitized real estate index. The token indexes show no clear similarity to the cryptocurrency or housing indexes but represent their own return-risk pattern.

A slightly positive (0.37) and significant correlation only exists between the small-cap stock index proxied by the Russel 2000 index and the equal-weighted token index. The correlation coefficients with the other assets (blue-chip stocks, securitized real estate, housing, or cryptocurrency) are not significantly different from zero. The multivariate analyses confirm these results. In addition to a link to the GDP and bond yields, only the performance of the small-cap stock index is positively linked to the equal-weighted token index. This absence of a linear relationship with other assets makes real estate tokens attractive to use as diversifiers in a multi-asset portfolio.

In the final step, I use a principal component analysis (PCA) allowing to include all variables in mind even if they are closely related. PCA reduces the high dimensions (ten in this study) and decomposes the structure of the variables into factors that are common to each variable and a proportion that is specific to each variable. Three out of the ten principal components (PC) explain together around 99% of the total variation. The first PC representing mostly 'macroeconomic' factors explains more than 40% of the variations, the second PC exhibiting the 'financing' factors describes more than 30% of the variations, and the third PC explains with its 'big-cap stocks & securitized real estate & crypto' factors more than 20% of the variations. This confirms the previous findings: the debt and macroeconomic factors are the major drivers and the crypto market and housing market are of minor importance to explain the variation of the assets' returns.

My findings might help to better understand the return-risk metrics of the real estate token market and that it is not a simple linear combination of housing, securitized real estate, and cryptocurrency. Even if the market for tokenized real estate is in its infancy, it increased enormously over the last years and has attracted investors who have not previously invested in real estate (see Kreppmeier et al., 2023). This and the fact that the market is still young may have an influence on the results so that various effects may simultaneously influence the performance so far and it might be worthwhile to take a closer look at behavioral and non-behavioral aspects via additional studies.

References

Baum, A. (2021) Tokenization–the future of real estate investment? The Journal of Portfolio Management 47, 41–61.

Case, K.E., & Shiller, R.J. (1989) The Efficiency of the Market for Single-Family Homes. The American Economic Review, 79(1), 125–137. http://www.jstor.org/stable/1804778

Chan, K.C., Hendershott, P.H. & Sanders, A.B. (1990), Risk and Return on Real Estate: Evidence from Equity REITs. Real Estate Economics, 18, 431–452. https://doi.org/10.1111/1540-6229.00531

Chaum, D. (1982) Blind signatures for untraceable payments, http://blog.koehntopp.de/uploads/Chaum.BlindSigForPayment.1982.PDF

Clayton, J. (1998) Further Evidence on Real Estate Market Efficiency, Journal of Real Estate Research, 15(1), 41–57, https://doi.org/10.1080/10835547.1998.12090915

Eichholtz, Piet M.A. (1996) Does International Diversification Work Better for Real Estate than for Stocks and Bonds?, Financial Analysts Journal, 52(1), 56–62, https://doi.org/10.2469/faj.v52.n1.1967

Fama, E. (1970) Efficient Capital Markets: A Review of Theory and Empirical Work, Journal of Finance, 25(2), 383–417. https://doi.org/10.2307/2325486

Fase, M.M.G. (1973) A principal components analysis of market interest rates in The Netherlands, 1962–1970, European Economic Review, 4(2), 107–134. https://doi.org/10.1016/0014-2921(73)90001-9

Gupta, A., Rathod, J., Patel, D., Bothra, J., Shanbhag, S. & Bhalerao, T. (2020) Tokenization of real estate using blockchain technology, in: Zhou, J., Conti, M., Ahmed, C.M., Au, M.H., Batina, L., Li, Z., Lin, J., Losiouk, E., Luo, B., Majumdar, S., Meng, W., Ochoa, M., Picek, S., Portokalidis, G., Wang, C. & Zhang, K. (Eds.), Applied Cryptography and Network Security Workshops, Springer International Publishing, Cham, 77–90.

Hoesli, M. & Moreno, C. (2007) Securitized Real Estate and its Link with Financial Assets and Real Estate: An International Analysis, Journal of Real Estate Literature, 15(1), 57–84, https://doi.org/10.1080/10835547.2006.12090193

Ibbotson, R.G. & Siegel, L.B. (1984), Real Estate Returns: A Comparison with Other Investments. Real Estate Economics, 12, 219–242. https://doi.org/10.1111/1540-6229.00320

Konashevych, O. (2020) General concept of real estate tokenization on blockchain: The right to choose, European Property Law Journal 9, 21–66.

Kroencke, T.A., Schindler, F. & Steininger, B.I. (2018) The Anatomy of Public and Private Real Estate Return Premia. Journal of Real Estate Finance and Economics, 56, 500–523. https://doi.org/10.1007/s11146-017-9646-8

Liu, N., Duncan, R. & Chapman, A. (2020a) A critical review of distributed ledger technology and its applications in real estate, RICS Research Report.

Liu, X., Farahani, B. & Firouzi, F. (2020b) Distributed ledger technology, in: Firouzi, F., Chakrabarty, K., Nassif, S. (Eds.), Intelligent Internet of Things, Springer, Cham. pp. 393–431.

Markheim, M. & Berentsen, A. (2021) Real estate meets blockchain: Opportunities and challenges of tokenization of illiquid assets. Zeitschrift für Immobilienökonomie 7, 59–80.

Nakamoto, S. (2008) Bitcoin: A Peer-to-Peer Electronic Cash System, https://assets.pubpub.org/d8wct41f/31611263538139.pdf

Norman, E., Sirmans, S. & Benjamin, J. (2021) The Historical Environment of Real Estate Returns, Journal of Real Estate Portfolio Management, 1(1), 1–24. https://doi.org/10.1080/10835547.1995.12089516

Pang, P., Tang, H.F., Lam, J., Chan, J., Hobler, N., Kan, K.K.K., Jeong, H., & Lau, R. (2020) Real Estate Tokenization, https://assets.kpmg.com/content/dam/kpmg/cn/pdf/en/2020/04/real-estate-tokenization.pdf

Rubens, J., Bond, M. & Webb, J. (1989) The Inflation-Hedging Effectiveness of Real Estate, Journal of Real Estate Research, 4 (2), 45–55, https://doi.org/10.1080/10835547.1989.12090578

SEC (2019) Framework for "Investment Contract" Analysis of Digital Assets, https://www.sec.gov/files/dlt-framework.pdf

The White House (2022) FACT SHEET: White House Releases First-Ever Comprehensive Framework for Responsible Development of Digital Assets, https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/16/fact-sheet-white-house-releases-first-ever-comprehensive-framework-for-responsible-development-of-digital-assets.

Tables

Table 1: Definition of variables

Variable	Description & Source
Bonds	Monthly rate of the long-term government bond yields with a maturity of 10 years; the rates are not seasonally adjusted. The monthly rate has been calculated from the annual yield using the following formula: $R_{month} = (1 + R_{year})^{(1/12)} - 1$. Source: Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis
T-Bills	Monthly rate of 3-month Treasury Bills on the secondary market; the rates are not seasonally adjusted. The monthly rate has been calculated from the annual yield using the following formula: $R_{month} = (1 + R_{year})^{(1/12)} - 1$. Source: Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis
CPI	Change rate of the monthly Consumer Price Index: All Items for the United States; the index is not seasonally adjusted. Source: Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis
GDP	Change rate of the Brave-Butters-Kelley Index (BBKI) measuring the monthly real gross domestic product growth by using a collapsed dynamic factor analysis of a panel of 490 monthly measures of real economic activity and quarterly real GDP growth. The values are divided by 100. Source: Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis
S&P 500	Monthly total return of the Standard and Poor's 500 index capturing the stock performance of the 500 largest companies listed on stock exchanges in the U.S. The index is a free-float weighted and capitalization-weighted index. The return calculation is based on the last trading day of the month. Source: Thomson Reuters Datastream/Eikon
Russel 2000	Monthly total return of the Russell 2000 index capturing the stock performance of the 2,000 smallest companies listed in the Russell 3000 index tracking the performance of the 3,000 largest companies representing approximately 96% of the investable U.S. stocks. The index captures approximately 7% of the total market capitalization of the Russell 3000 index and is a capitalization-weighted index. The return calculation is based on the last trading day of the month. Source: Thomson Reuters Datastream/Eikon
ETH	Monthly price return of Ether (ETH), the second largest cryptocurrency in market capitalization and native cryptocurrency of the Ethereum platform used for real estate token transactions. The return calculation is based on the last trading day of the month. Source: CoinMarketCap
House Index	A combined house price index weighted with the respective monthly weights of the cities Detroit, Chicago, and other cities corresponding to their weights in the tokenized real estate index. The used city indexes are S&P/Case-Shiller IL-Chicago Home Price Index, S&P/Case-Shiller MI-Detroit Home Price Index, and S&P/Case-Shiller 10-City Composite Home Price Index. Source: Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis
RE Securitized	Monthly total return of securitized real estate proxied by the Dow Jones U.S. Real Estate Total Return Index. It comprises both real estate investment trusts (REIT) as well as other firms investing directly or indirectly in real estate (management, ownership, development, etc.). The return calculation is based on the last trading day of the month. Source: Thomson Reuters Datastream/Eikon
RE Token (ew)	Monthly total return of an equal-weighted total return index for tokenized real estate. The price component is based on the monthly average price of a token traded on Ethereum, and the rent component is based on the expected rent per token per month as announced by the token issuer. The paid rent is not re-invested. Source: own calculation
RE Token (vw)	Monthly total return of a value-weighted total return index for tokenized real estate. The price component is based on the monthly average price of a token traded on Ethereum, and the rent component is based on the expected rent per token per month as announced by the token issuer. The paid rent is not re-invested. The value-weights are based on the monthly market capitalization. Source: own calculation

This table list the key variables, their definitions, and data source.

Table 2: Summary statistics

	Mean	Median	Std. Dev.	CV	Skewness	Kurtosis	AR(1)	AR(2)	AR(3)	*N*
Bonds	0.0015	0.0013	0.0008	55.3	0.862	-0.262	0.970***	0.913***	0.861***	37
T-Bills	0.0007	0.0001	0.0010	150.5	1.669	1.699	0.973***	0.918***	0.826***	37
CPI	0.0039	0.0039	0.0045	116.8	0.154	-0.022	0.559***	0.197	0.217*	37
GDP	1.6081	3.3102	19.2214	1195.3	-1.724	8.056	0.625***	-0.024	-0.444***	37
S&P 500	0.0072	0.0227	0.0603	835.0	-0.268	-0.486	-0.131	-0.214*	0.142	37
Russel 2000	0.0069	0.0183	0.0767	1112.4	-0.381	1.214	-0.032	-0.016	0.193	37
ETH	0.0440	-0.0198	0.2191	497.9	0.208	-0.671	0.207	-0.004	0.202	37
House Index	0.0099	0.0094	0.0132	133.5	2.857	11.457	0.333	0.214	0.092	37
RE Securitized	0.0020	0.0152	0.0649	3265.0	-0.873	1.203	-0.104	-0.208	0.101	37
RE Token (ew)	0.0190	0.0173	0.0620	327.4	0.133	1.279	-0.216*	-0.207	0.221*	37
RE Token (vw)	0.0020	0.0003	0.0068	337.6	2.042	5.561	0.275**	-0.031	0.186	37

This table shows descriptive statistics for the monthly returns and growth rates of the key variables. See Table 1 for the definitions of the variables. Std. Dev. stands for standard deviation, AR(*x*) for the *x*-order autocorrelation coefficient of a variable (*** $p \leq 0.1$ %, ** $p \leq 1$ %, * $p \leq 5$ %.), and *N* for the number of observations.

Table 3: Bravais-Pearson correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	*Bonds*										
(2)	*T-Bills*	.858***									
(3)	*CPI*	0.126	-0.284								
(4)	*GDP*	0.021	-0.018	.408*							
(5)	*S&P 500*	-0.209	-0.153	-0.125	0.069						
(6)	*Russel 2000*	-0.153	-0.101	-0.226	-0.138	-0.145					
(7)	*ETH*	-.385*	-0.247	-0.229	0.012	.570***	0.144				
(8)	*House Index*	-0.270	-.452**	.394*	0.121	0.022	0.02	-0.103			
(9)	*RE Securitized*	-0.156	-0.169	0.012	0.157	.903***	-0.257	.505**	0.107		
(10)	*RE Token (ew)*	-0.035	0.026	-0.307	-.348*	-0.133	.368*	-0.005	-0.088	-0.206	
(11)	*RE Token (vw)*	-0.237	-0.117	-.385*	-.581***	0.076	0.289	0.037	-0.143	-0.068	.770***

This table presents the Bravais-Pearson correlation coefficients for the key variables. All of the variables are defined in Table 1. *** $p \leq 0.1$ %, ** $p \leq 1$ %, * $p \leq 5$ %.

Table 4: Results of OLS regressions of real estate tokens

	(1)	(2)
	RE Token (ew)	*RE Token (vw)*
Bonds	-1.264	-2.527*
	(14.319)	(1.321)
GDP	-0.093*	-0.019***
	(0.053)	(0.005)
Russel 2000	0.254*	0.021
	(0.143)	(0.013)
ETH	-0.008	-0.006
	(0.062)	(0.006)
House Index	-0.269	-0.103
	(0.829)	(0.076)
RE Securitized	-0.06	0.017
	(0.198)	(0.018)
Constant	0.024	0.007***
	(0.028)	(0.003)
R^2	0.234	0.463
Adj. R^2	0.081	0.356
N	37	37

This table presents the results of OLS regressions of *RE Token (ew)* in Model (1) and *RE Token (vw)* in Model (2) on *Bonds*, *GDP*, *Russel 2000*, *ETH*, *House Index*, and *RE Securitized*. The independent variables are defined in Table 1. Standard errors are reported in parentheses.
*** $p \leq 0.1$ %, ** $p \leq 1$ %, * $p \leq 5$ %.

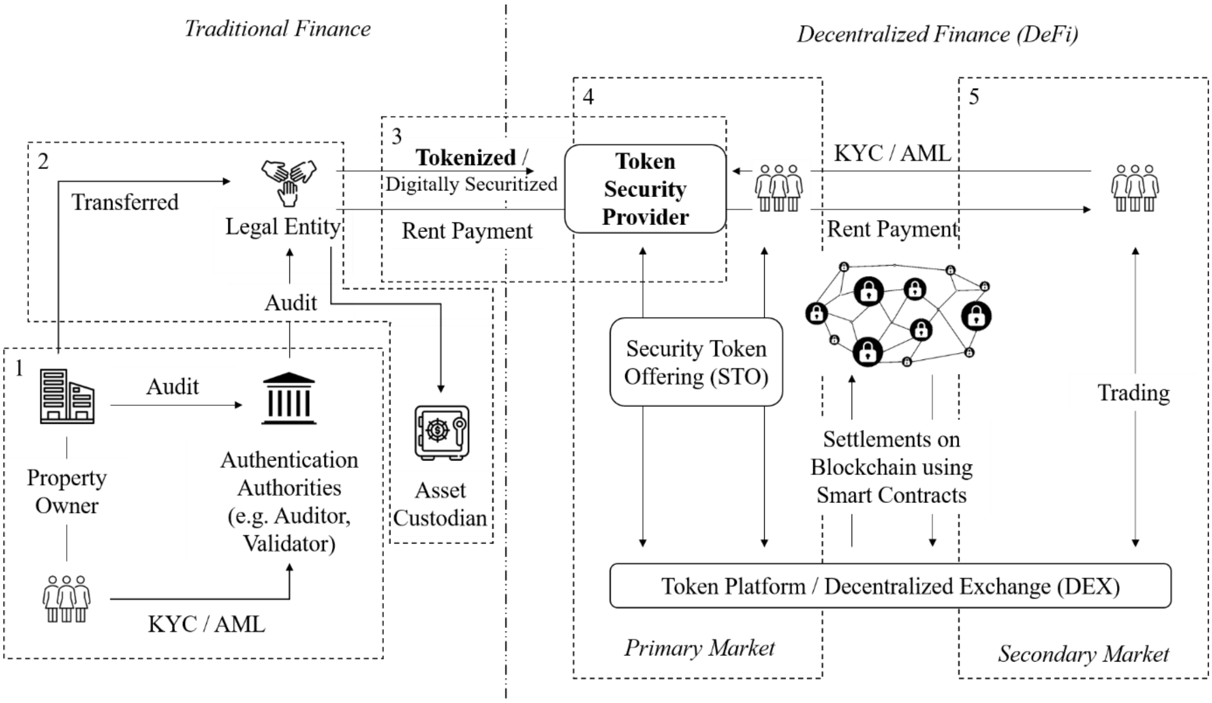
Table 5: Factor loadings of PCA

	RE Token (ew)			*RE Token (vw)*		
	PC1	*PC2*	*PC3*	*PC1*	*PC2*	*PC3*
Bonds	0.436	0.214	0.270	0.313	0.433	0.153
T-Bills	0.463	0.176	0.300	0.340	0.428	0.186
CPI	0.300	-0.400	-0.189	0.408	-0.303	-0.018
GDP	0.204	-0.468	-0.204	0.351	-0.405	0.003
S&P 500	-0.349	-0.261	0.338	-0.252	-0.227	0.455
Russel 2000	-0.451	0.123	-0.286	-0.410	-0.175	-0.291
ETH	-0.219	-0.200	0.447	-0.165	-0.084	0.519
House Index	0.058	-0.352	-0.409	0.201	-0.437	-0.235
RE Securitized	-0.220	-0.319	0.396	-0.124	-0.208	0.530
RE Token	-0.200	0.442	-0.197	-0.426	0.224	-0.209
% Variation	40.4%	31.3%	27.2%	46.0%	30.5%	22.5%
% Cum. Variation	40.4%	7.1.6%	98.9%	46.0%	76.5%	99.0%

This table shows factor loadings for the first three principal components (*PC1-PC3*) for the subsamples with *RE Token (ew)* and *RE Token (vw)*. In addition, it states the percentage of the total variance *(% Variation*) which each principal component explains and the cumulative variation *(% Cum. Variation*) explained by principal components.

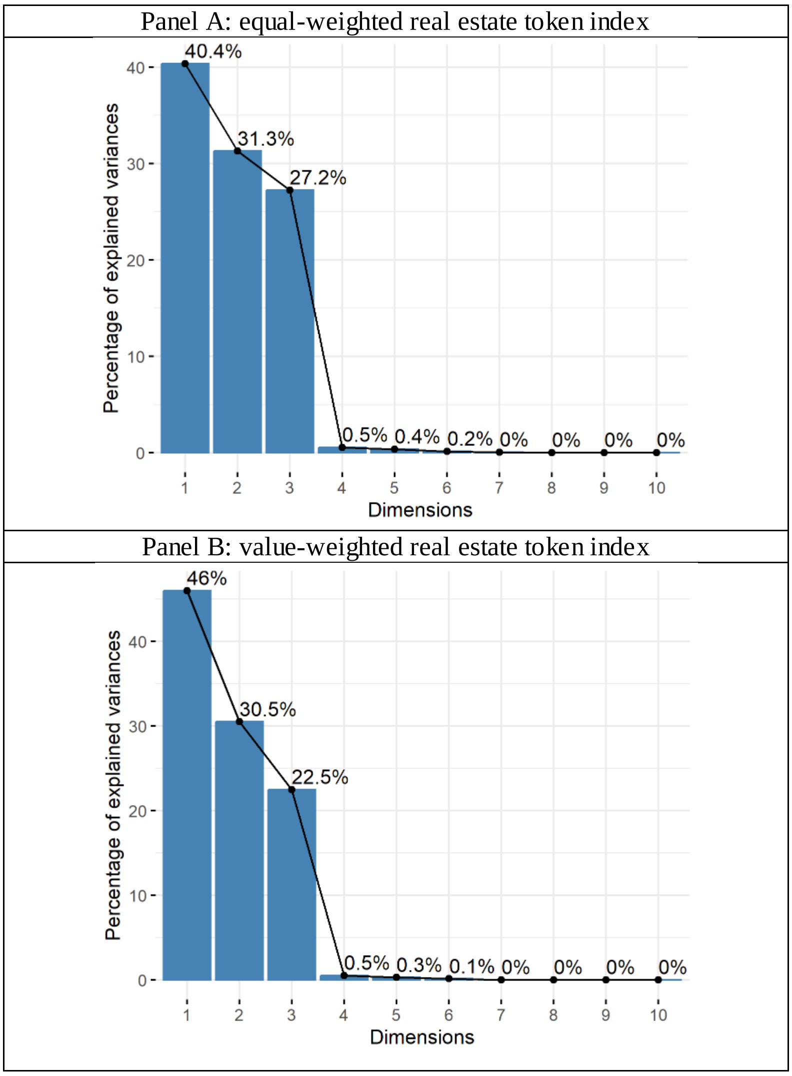
Figures

Figure 1: Tokenization process



Note: This figure shows schematically the tokenization process split in the traditional and decentralized fiancé sphere; KYC stands for know your customer and AML for anti-money laundering.

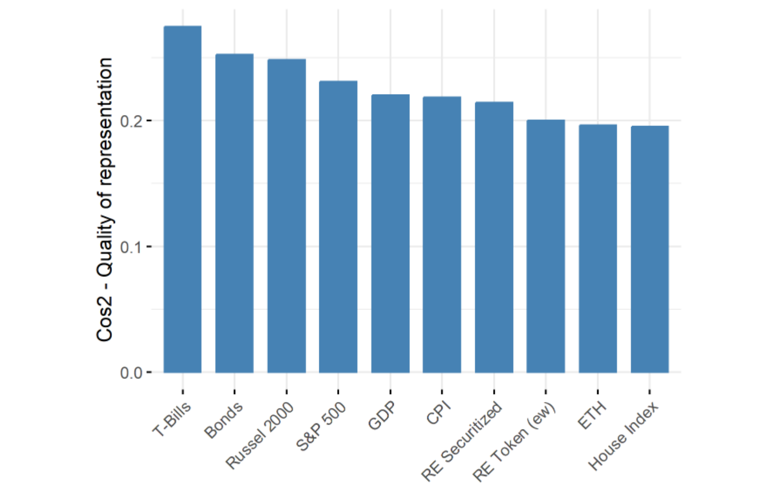
Figure 2: Importance of principal components



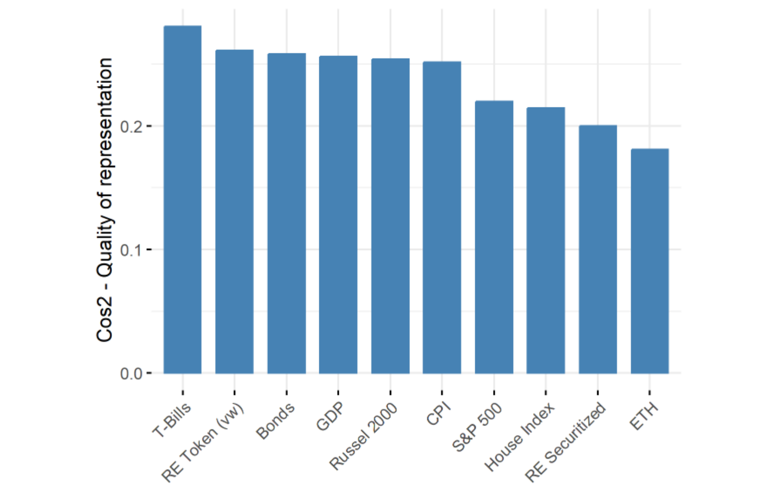
Note: This figure presents the scree plots for visualizing the importance of each principal component in explaining the variance in percentage using the equal-weighted real estate token index (Panel A) or value-weighted real estate token index (Panel B).

Figure 3: Variables' contribution to principal components

Panel A: equal-weighted real estate token index

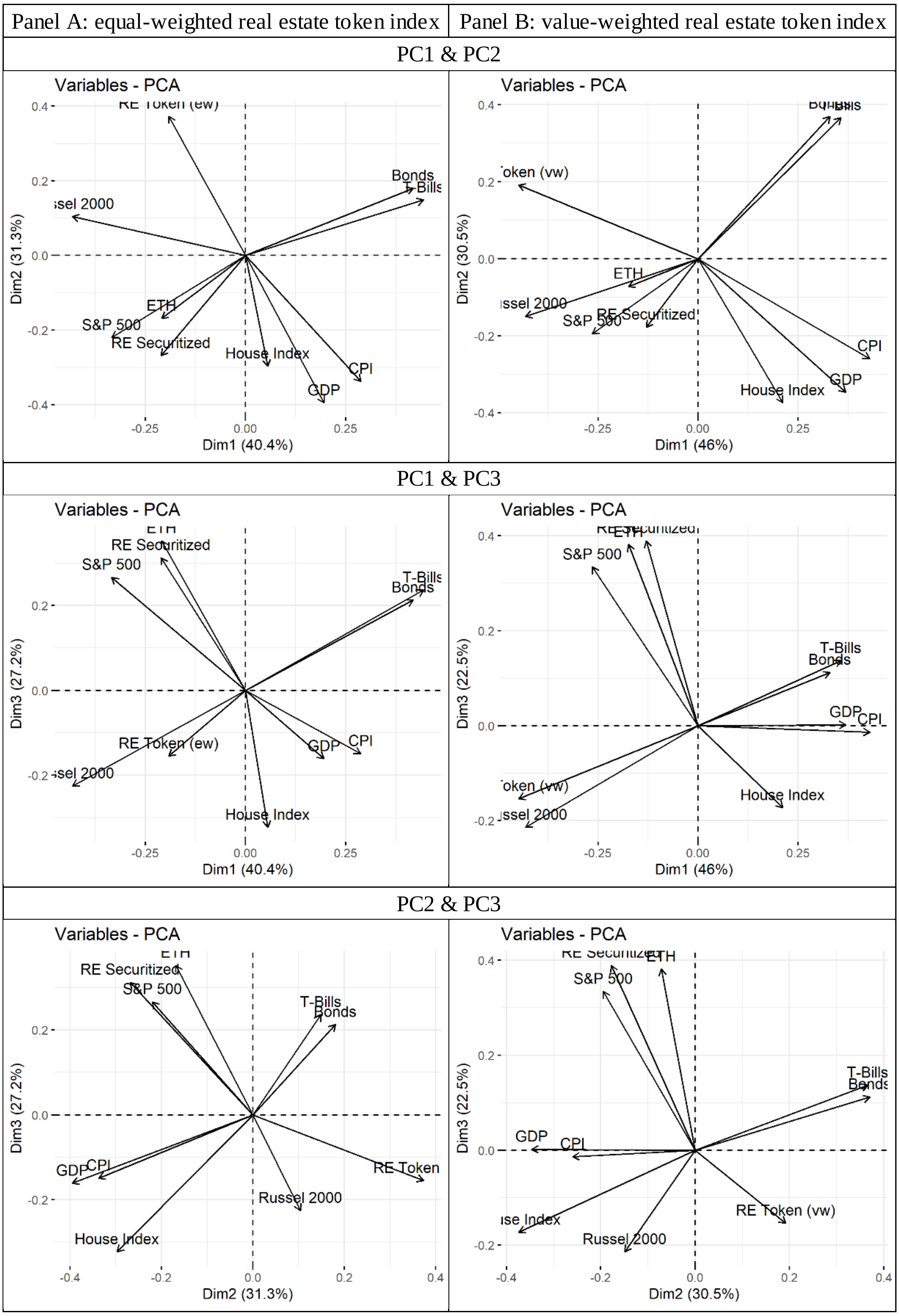


Panel B: value-weighted real estate token index



Note: This figure presents the square cosine value (Cos2) for each variable with respect to the first three principal components visualizing their importance using the equal-weighted real estate token index (Panel A) or value-weighted real estate token index (Panel B).

Figure 4: Biplots of variables



Note: This figure presents the biplots of each two principal components (PC1 & PC2, PC1 & PC3, and PC2 & PC3) with three information. 1) The orientation of a variable's vector shows its contribution to a specific PC (the more parallel to a PC axis, the more does it contributes to that PC). 2) The length in the space shows the how much variability is explained with the PC (the longer the vector, the more variability is represented by the two PCs). 3) The angles between variables present their correlation (small angles stand for high positive correlation, right angles stand for no correlation, and opposite angles stand for high negative correlation).