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The Role of Multi-Family Properties in Hedging Pension Liability Risk: Long-Run Evidence[1]

Design/methodology/approach

We assess the risk-adjusted excess return that results from adding multi-family properties to a mixed-asset portfolio that aims to track wage growth. We also analyse the macroeconomic determinants of asset returns. Finally, we test whether a causal relationship exists between the growth rate of real wages and that of real net operating income.

Purpose

Using data spanning 145 years for Sweden, we investigate the benefits of holding multi-family properties for investors who aim to hedge wage growth.

Findings

The benefits from holding multi-family properties are the greatest for low-risk allocation approaches. For more risky strategies, the role of real estate is more muted, and it varies greatly over time. Holding real estate was most beneficial during the first two decades of the 21st century. Multi-family properties are found to be the only asset class to be positively related to wage growth. We show that the net operating income acts as the transmission channel between wages and property returns.

Practical implications

The paper assesses whether the growing interest of pension funds for multi-family properties is warranted in the context of a portfolio that aims to track wage growth.

Originality/value

Using long term data makes it possible to use a rolling windows approach and hence to consider multiple outcomes for an allocation strategy over a typical investment horizon. This permits to assess the dispersion of performance across several periods rather than just one as is commonly done in the literature. Our results show that the conclusions that would be drawn from looking at the past two or three decades of data differ substantially from those for earlier time periods.

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Introduction

Much research has documented the role of real estate in diversifying a mixed-asset portfolio (Lekander, 2015; Delfim and Hoesli, 2019a; Hoesli and Johner, 2022). For pension funds, focusing on diversification benefits is not sufficient as their primary objective is to meet their future liabilities. Studies that have assessed the role of real estate in an asset-liability management context confirm the positive impact of holding real estate in a portfolio (Chun *et al.*, 2000; Brounen *et al.*, 2010). However, they report a lower optimal allocation to real estate, in line with the average pension fund allocation of 10% (PREA, 2022).

Studies on the benefits of including real estate in a portfolio typically rely on data that cover two or three decades only. However, there is a lack of evidence on whether the conclusions hold when considering a similar time horizon that startsbut investing at different points in time. Stated differently, it is important to analyse whether the conclusions vary depending on the economic environment. Such analysis requires the use of long-term data series. This paper aims to provide a better understanding of the benefits through time of holding real estate in a portfolio that tracks wage growth.

The past years have seen the emergence of several studies that have developed long time series for housing (Eitrheim and Erlandsen, 2005; Knoll *et al.*, 2015; Eichholtz *et al.*, 2021). Comparative analyses of returns with those of other asset classes are undertaken. For instance, Jordà *et al.* (2019) construct a data set for equity, housing, bonds, and bills covering 16 advanced economies from 1870 to 2015. For example, they report that housing and equities had very similar real total returns, on average about 7% a year.

In contrast, the evidence concerning commercial real estate is scarce. Wheaton *et al.* (2009) construct a decade-interval price index of office properties in Manhattan for the period

1899-1999. In real terms, office property values were 30% lower in 1999 than they were in 1899. Over a decade, real values often change by 20-50%. Chambers *et al.* (2021) use U.K. data for 1901-1983 and report annualised real total returns ranging from 2.3% for residential to 4.5% for agricultural real estate. For multi-family properties, Bohlin (2014) presents an index for income-producing residential property in Gothenburg for 1875-2010. During 1875-1957, real prices rose during periods of deflation and fell during periods of inflation. Thereafter, nominal residential prices increased faster than prices overall, only due to the rally from the mid-1990s. Building on the work by Söderberg *et al.* (2014), Edvinsson *et al.* (2021) construct a multi-family property price index for Stockholm for 1818-2018. They show that in real terms there have been two long upswings, in 1855-1887 and 1993-2018, while prices were stagnant or slightly declining in other periods.

This paper takes advantage of long-run asset return data to investigate the role of multi-family properties in hedging the main component of pension liabilities, namely wage growth. The rationale is that residential rents should be closely related to wage inflation as higher wages permit households to afford higher rents (Bardhan *et al.*, 2004; Albouy, 2008; Davis and Ortalo-Magné, 2011). All else being equal, higher rent growth will positively impact upon both income and capital returns. This is a desirable feature for an asset class in a pension portfolio, as a positive correlation between assets and liabilities reduces liability settlement risk.

To investigate the impact of adding real estate in a pension portfolio, we assess whether real estate generates incremental risk-adjusted excess returns. -Given our objective of hedging liability risk, we use returns that are net of wage growth. We alsoand then verify the assumption that rents are the channel by which wages positively impact real estate returns. ~~Given our objective of hedging liability risk, we use returns that are net of wage growth.~~ Our analyses are undertaken using data for Sweden spanning 145 years. We construct a times series of income returns that make it possible to compute total returns for apartment buildings based on the available capital returns. We account for capital expenditures to yield figures that should more accurately depict the total return of income-producing residential properties.

We assess the difference between the out-of-sample performance of portfolios containing real estate and that of portfolios containing financial assets only. Portfolios of financial assets (stocks, bonds, and bills) are constructed using four different allocation strategies: (1) a fixed allocation of 60% to stocks, 35% to bonds, and 5% to bills, (2) a method that maximis~~z~~es the ratio between portfolio return and the standard deviation of returns (i.e., the information ratio using wage growth as "benchmark"), (3) a minimum variance approach (i.e., tracking error), and (4) a risk parity method. For each portfolio allocation strategy, we consider the benefits which result from adding a fixed allocation of 20% to real estate. The out-of-sample benefits are assessed over rolling 30-year periods, with the portfolio allocations rebalanced to target weights every three years. To test the impact of wage growth on asset returns, we then proceed to regress real returns for each asset class against real wage growth and a set of macroeconomic variables.

The Swedish case is interesting for at least four~~three~~ reasons. Firstly, the availability of long-run time series for apartment buildings rather than housing makes it possible to examine real estate's role in a portfolio in various environments. This is important as residential real estate is the preferred route to institutional real estate investment in many countries (e.g., Germany and Switzerland). Moreover, the sector is gaining traction in many other countries. Secondly, Sweden did not experience a war during the period and hence did not face destruction and subsequent reconstruction of the real estate stock as in many other European countries. This should limit the impacts of the wars on the real estate market to incidental economic and demographic effects. Thirdly, Sweden being an open economy, the conclusions of this study should apply to other countries . Indeed, Sweden being an open economy, its economy the Swedish economy should beis integrated with that of other developed countries and hence experienced similar growth patterns as well assimilar economic shocks and financial crises (de Soyres and Gaillard, 2022). One important example of the latter is the banking crisis of the early 1990s, which occurred in many developed countries, and led to the price of prime non-residential real estate in Stockholm dropping by 52% from its peak level (Englund, 1999). Finally, the Swedish residential rental market is a hybrid system between strict regulation and free market. This feature is observed in many developed countries, albeit in different shades. Both the commonalities in economic patterns and in rental market structures between Sweden and other developed countries indicate that the conclusions of this study should apply to other countries.

This paper makes the following contributions to the literature. Firstly, we assess the ability of multi-family properties to hedge wage inflation risk and hence if the recent interest of institutional investors for this sector is warranted. Secondly, we use a much longer time series of returns than most prior research. This enables us to assess the impact of adding real estate on portfolio performance for 86 rolling windows of 30 years, rather than just for one window covering two or three decades. In addition to gauging the expected benefits from adding real estate to a portfolio, we assess the likelihood of missing those benefits. Thirdly, we examine the effects of discarding the years 2000-2020, which were marked by a substantial compression of capitalisation rates, and estimate more conservatively the benefits of considering real estate in a portfolio. Finally, we offer evidence of the causal relationship between wage and rent growth, and hence of the association between wage growth and real estate returns. This provides a better understanding of the mechanisms underlying the role of multi-family properties in a pension portfolio.

Our results show that the benefits from holding real estate are in a range from 39 to 78 basis points (bps) per annum. The benefits are the greatest for portfolios that target low-risk allocations approaches. For more risky strategies, the role of real estate is more muted and varies over time. Holding real estate is found to be most beneficial during the first two decades of the 21st century. Consistent with our intuition, multi-family property returns are found to be positively related to wage growth, whereas the relationship is negative for stocks and bonds. We also find that wage growth Granger-causes net operating income (NOI) growth, but not the dividend yield. Hence, the underlying economic mechanisms corroborate the positive role found for real estate in pension portfolios.

The remainder of the paper is structured as follows. The next section presents some key findings from the literature, while the following section highlights salient features of the residential rental market in Sweden from a historical perspective. We then discuss our data, before presenting the methods. The following section discusses our results, while the final section contains concluding remarks.

Literature Review

Real estate has been found to lower portfolio risk for a given return, particularly in low-risk portfolios, and its optimal allocation is about 20%. Studies have either relied on modern portfolio theory (Hoesli *et al.*, 2004; Lekander, 2015) or used the Campbell and Viceira (2002,

2004) framework which recognizes that expected return and risk change over time (MacKinnon and Al Zaman, 2009; Rehring, 2012). An advantage of the latter framework is that the effects of the time horizon on diversification benefits can be gauged.

Focusing on the diversification benefits only is not sufficient for institutional investors as their primary objective is to minimisze the risk of not being able to meet their future liabilities, notably retirement annuities for pension funds. Several studies have assessed the role of real estate in an asset-liability management context (Chun *et al.*, 2000; Craft, 2005; Brounen *et al.*, 2010). They confirm the positive impact of holding real estate in a portfolio. The optimal allocation to real estate, however, is lower than when alternative models are considered and thus more in line with the actual allocations to real estate by institutional investors (Hoesli and Lekander, 2005).

The relationship between asset returns and macroeconomic factors is crucial when constructing a mixed-asset portfolio. While asset-only allocations rely on the idea that the exposure to the various risk factors should be diversified, an asset-liability approach requires that the asset risk factor exposures be aligned with those of liabilities. Ling and Naranjo (1997) find that real estate returns in the U.S. are positively related to the growth rate of consumption, while they are negatively related to the real T-Bill rate, the term spread, and unexpected inflation. In line with those results, Delfim and Hoesli (2019b) report that real estate returns are positively linked to real GDP growth, expected inflation, construction costs, money supply, and a leading economic indicator, while they are negatively impacted by the inflation surprise, and the term and credit spreads. Ho *et al.* (2015) investigate the drivers of real estate returns for 16 Asian cities and the U.S. and find that macroeconomic variables are more useful to predict the returns for the office and retail sectors, than for the residential sector. Overall, their results suggest a positive impact of GDP and interest rates. Hoesli *et al.* (2008) find that real estate returns in the U.S. and U.K. are positively related with anticipated and unanticipated inflation over the long-run. Finally, Hardin *et al.* (2017) study inflation illusion and conclude that real estate is a suitable hedge against inflation.

For financial assets, the literature on the macroeconomic determinants of returns has mainly focused on stocks. Chen *et al.* (1986) find that stock returns are positively related to industrial production and the anticipated change in the credit spread, while they are negatively associated with the change in expected inflation, unexpected inflation, and the change in the term spread. Using data spanning a century (1889-1988), Schwert (1990) finds that the future growth rate in production is tightly related to stock returns (see also Binswanger, 2000; and Beaudry and Portier, 2006). Stocks have been found to be a hedge against inflation over long horizons, while they are poor hedges in the short term (Arnold and Auer, 2015). For bills and bonds with fixed principal or coupon payments, returns are negatively correlated with inflation in the short run, while they should provide at least a partial hedge in the long run (Arnold and Auer, 2015). All else being equal, the more frequently the fixed rate is reset to market conditions, the better the inflation-hedging ability; hence, bills should be superior hedges than bonds.

Background on the Swedish Residential Rental Market

The residential rental market has been a central component of the Swedish welfare system (Lundberg and Åmark, 2001; Holmqvist and Magnusson Turner, 2014). Over our study period, the market has experienced periods of mild and tighter regulation. Even in periods of tighter regulation, the central role that bargaining plays in the Swedish residential market has resulted in a hybrid system between strict regulation and free market (Kettunen and

Ruonavaara, 2021). We highlight below some salient features of the rental market and some changes that have occurred during the period under investigation.

Prior to the second World War, the residential rental market in Sweden was lightly regulated. Rental regulation was introduced in 1942 to protect tenants against abusive increases in rents (Wilhelmsson *et al.*, 2011). Such regulation formed the basis for the introduction, in 1969, of the "use-value system" to strengthen tenant rights, by balancing demand and supply, and promoting social integration. The fundamental ideas are that the rent should be in line with the long-run equilibrium rent level (Kettunen and Ruonavaara, 2021) and that two units of similar quality should have equal rent irrespective of the owner (private or public).[2] Under this system, rents are set through collective bargaining between landlords' and tenants' associations. The long-run rent level was kept low through the encouragement and subsidizing of new construction. This was mainly achieved through the so-called million programme, which led to the construction of over one million housing units from 1965 to 1974 (Hall and Vidén, 2005; Verkasalo and Hirvonen, 2017). The purpose of the programme was to reduce the housing shortage and increase general housing standards, while concurrently increasing social integration. The programme, however, led to an oversupply in the housing market and capital starvation in other sectors of the economy. This resulted in the programme being gradually phased out during the latter part of the 1970s.

In 1974, the use-value system changed to one in which the municipally-owned housing companies were rent setters, and private landlords had to adapt rents to the levels set by these companies (Atterhög, 2005). This caused an unfair balance between municipal and

[2] In practice, the use-value system allowed for some discrepancy in rents between units owned by private investors and those held by municipalities through housing companies (Svensson, 1998).

private landlords, as municipal housing companies had other objectives than just generating profit (e.g., social integration and coherence) and received financial subsidies from the central government. This was offset in part by the period of high inflation following the first oil crisis. Since 2011, municipal housing companies are no longer rent setters; however, a landlord must still be able to prove that the level of rent asked is comparable to that of other apartments in the same location and of similar quality.

Following the deregulation of the capital market in Sweden in the 1980s and early 1990s, investors, including pension funds, were granted the ability to invest internationally at the same time as the requirement for them to invest in housing mortgages was ended. As this requirement was instrumental in funding the multi-family housing residential market, its termination effectively impaired the government's ability to pursue large scale housing policy. This resulted in the residential stock in many urban areas being privatized, either through the sale of units to the tenants or the sale of the building to a private investor (Atterhög, 2005; Lind, 2015). Another important driver of this change was that rental levels did not permit to meet the required return to produce new residential stock, which resulted in a shortage of rental apartments in attractive urban locations (Wilhelmsson *et al.*, 2011). Many households hence decided to buy, instead of renting, leading to significant price increases for condominiums.

Data

Our analyses cover the period 1875-2020. For residential properties, we use data for Stockholm and Gothenburg sourced from Söderberg *et al.* (2014) and Bohlin (2014), respectively, for the period from 1875 to 1957. The data from 1957 to 2012 are from Statistics Sweden and are contained in the online supplement of the paper by Söderberg *et al.* (2014).

The indexes pertain to multi-family properties and are price indexes constructed using the sale price to appraisal ratio (SPAR) method.[3] From 2013 to 2020, we use capital returns from MSCI for residential properties in Stockholm and Gothenburg, respectively. Given that the MSCI returns are based on appraisals, they suffer from smoothing (Geltner, 1993). Desmoothing is undertaken using an alpha of 0.5 in the reverse filter formula (Hoesli *et al.*, 2004). Our capital return series for residential real estate are obtained by weighting the Gothenburg and Stockholm figures by 30% and 70%, respectively, reflecting the relative economic importance of these markets. Properties that form the basis for the indexes are privately owned and the SPAR method relies on arm's length transactions,[4] although values are affected by the specificities of the Swedish rental market. For instance, apartment building prices have risen more slowly than those of houses due to the rental system that was instituted in 1942 (Bohlin, 2014).

Income returns for multi-family properties are available from MSCI for 1996-2020 only, but Jordà *et al.* (2019) provide time series of prices (for 1875-2017) and rent-to-price ratios (for 1883-2015) for single-family properties in Sweden. We assume that the rent-to-price ratio for apartment buildings moves in line with the ratio for houses and infer a rent index for apartment buildings. This permits us to construct an income return series for apartment buildings. For this, we rely on a benchmark income return from MSCI and backtrack that return using the rent and price indexes. This is undertaken separately for Gothenburg and Stockholm. Analysis suggests that the backtracking of income returns is sensitive to the benchmarking year being considered. Hence, for each year from 1875 to 1995, we select the median income return from the distribution of returns generated from all the benchmark

[3] For details of the method, see Bourassa *et al.* (2006).
[4] Prior to the 1950s, there were very few municipally-owned properties. Municipalities then entered the market either by building or purchasing properties at market value from private investors.

years (1996-2015).[5] As backtracking was only possible until 1883, we infer income returns for 1876-1882 by assuming that rents follow the same path as inflation. Finally, for the period 1996-2020, we use the MSCI income returns.

Income returns are net of operating expenses, but not of capital expenditures, and hence the figures are adjusted using capital expenditures of 30% of net rental income (corresponding to about 25% of gross rent or 1.5% of property value). Income returns net of capital expenditures are obtained by weighting the Gothenburg and Stockholm figures by 30% and 70%, respectively. Total returns are the sum of capital returns and income returns net of capital expenditures.

–Two caveats concerning the data are warranted. Firstly, the usual caveat pertaining to using index-level returns to proxy for portfolio returns applies. Hence, results are mainly representative for large investors who can diversify away idiosyncratic risk in their real estate portfolio. Secondly, as with all studies that consider long-run data, measurement error is likely to increase for data further back in the past. However, great caution was exercised in reviewing and combining data sources to minimise the potential impact of this pitfall on our study.

Stock returns for 1875-2012 are from Waldenström (2014) and are sourced from MSCI for 2013-2020. Long-term government bond, short-term government bill and consumer price index (CPI) data are also from Waldenström (2014).[6] The term spread is computed as the difference between the yield on long- and short-term government debt. All asset series are total return indexes. Gross domestic product (GDP) data are from Edvinsson (2014) for 1875-2014 and Statistics Sweden for 2015-2020. The wage index is constructed from the hourly

[5] The period corresponds to the overlap of the periods for the MSCI returns and the rent-to-price data.
[6] Daniel Waldenström kindly provided the data for 2013-2020.

earnings series of Prado (2010) for 1875-2013 and the average monthly salary from Statistics Sweden for 2014-2020.[7]

Table 1, Panel A contains summary statistics for asset returns and selected macroeconomic variables. The returns for the three main asset classes confirm prior evidence that real estate's return (7.4%) is in between that of stocks (9.0%) and bonds (5.5%). The return on real estate breaks down in a return of 3.8% for capital and 3.5% for income, but the latter is substantially more stable than the former (figures not reported in the table). The standard deviations of apartment building returns when Gothenburg and Stockholm are considered separately are slightly higher than that of bonds. However, the standard deviation of the aggregated real estate index is lower than the standard deviation of bonds due to diversification effects, but significantly higher than that of bills. The return on government bills equals that of wages, while government bonds, real estate, and stocks command a premium of 60 bps, 250 bps, and 410 bps, respectively. The return on all asset classes exceeds inflation. Real economic growth during the period was 2.6%.

[Table 1 approximately here]

Table 1, Panel B contains the correlation coefficients of asset returns and macroeconomic variables. Apartment building returns are lowly correlated with the returns of both stocks and government bonds. All asset classes are lowly correlated with inflation, while economic activity is tightly related to inflation. As expected, GDP changes are also highly correlated with wage changes.

Returns net of wage growth can be analysed on the basis of the statistics appearing at the bottom of Table 1, Panel A and of Figure 1 which displays the real total return indexes for

[7] For 1875-1921, we use the male hourly series as female wages are not available. For 1922-2013, we use the average of male and female hourly earnings.

the four asset classes as well as the real wage growth index. Over the whole period, real estate and to a greater extent stocks have a return that is clearly in excess of wage growth (2.2% vs. 3.5%). However, real estate's tracking error is much lower than that of stocks (8.6% vs. 20.3%), leading to a higher information ratio (0.25 vs. 0.17). Bond and bill returns are roughly in line with wage growth, with a significant period of underperformance from the 1960s to the mid-1990s. There are two periods during which real estate had material drawdowns in real terms. The first one concurs with the massive declines across asset classes that occurred during the first World War. During that period, real estate prices dropped by 53% in real terms. The second drawdown occurred during the banking crisis of the early 1990s when real estate prices declined by 41% in real terms.

[Figure 1 approximately here]

Methods

We assess the capability of a portfolio to hedge wage inflation risk, and in turn pension liabilities, by considering returns net of wage increases. Hence, we do not make any actuarial assumptions, for instance regarding life expectancy, and assume that liabilities grow at the same rate as wages. While we acknowledge that this is a simplified case, a more comprehensive approach would require making various arbitrary assumptions. Moreover, the results from such an approach would be less generalisable than the ones we report.

Portfolios are constructed by combining a core portfolio of financial assets with a fixed allocation to real estate of 20%, reflecting research on the optimal allocation to real estate (e.g., Hoesli *et al.*, 2004). The advantage of considering a fixed allocation is that the incremental performance resulting from the inclusion of real estate is attributable to the asset class return and risk characteristics only and not to its varying portfolio weight. Furthermore, asset class weights derived by optimis~~z~~ation tend to shift abruptly which is problematic for illiquid asset classes such as real estate.[8]

To construct the core portfolios, we consider four allocation strategies. When an allocation strategy requires optimis~~z~~ation, we rely on 30-year windows, rolling that window by one year at a time. This yields a time series of 116 portfolio weights per strategy. For the first strategy, we use the conventional allocation of 60% to stocks and 40% to fixed-income securities (60/40 allocation) and consider for the latter a breakdown of 35% for bonds and 5% for bills. The second approach consists in selecting the portfolio that maximis~~z~~es the ratio between return and standard deviation. Given that returns are net of wages, this corresponds to maximis~~z~~ing the portfolio's information ratio ($IR_{p,t}$) over the optimis~~z~~ation period ending at time t:

$$IR_{p,t} = \frac{Return_{p,t} - WageGrowth_t}{\sigma_t(Return_p - WageGrowth)} \quad (1)$$

where $Return_{p,t}$ is the portfolio p annualised compound return over the period ending at time t, $WageGrowth_t$ is the yearly wage growth over the period ending at time t and σ_t $(Return_p - WageGrowth)$ is the tracking error of the portfolio p returns with respect to wage growth over the period ending at time t.

While the first two strategies generate high risk portfolios, the other two approaches are designed to control for portfolio risk. The third method is akin to a minimum variance approach and minimis~~z~~es portfolio risk as measured by the tracking error, i.e., the denominator of the information ratio. Our final approach is risk parity, i.e., we consider the allocation where each of the three asset classes (stocks, bonds, and bills) contributes equally to portfolio tracking error.

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[8] This was confirmed when we performed optimis~~z~~ations on all four asset classes rather than on financial assets only.

For the second and third approaches, the optimiszation setting constrains real estate's weight to 20%. Hence, the impact of the real estate allocation on portfolio risk and return are taken into account for the estimation of the other asset class weights. Optimiszations rely on a random search approach within a sample of 200,000 portfolio allocations. Analyses are performed without and with the investment limits of the Swedish public pension funds' act which states that at least 20% should be allocated to investment-grade fixed-income securities. This rule translates into a maximum allocation of 60% to stocks given the 20% real estate pocket.

For each strategy, we calculate out-of-sample portfolio returns from 1905 to 2020 both for portfolios without and with real estate. To avoid look-ahead bias, portfolio compositions are determined using only information available at the time. Portfolios are rebalanced every three years using the following transaction costs at purchase: 125 bps for real estate, 20 bps for stocks, and 5 bps for bonds and bills. The same transaction costs are used at portfolio inception. Swedish pension funds do not pay income nor capital gains taxes, but they are subject to a wealth tax. As this tax does not depend on portfolio composition, it does not distort the analysis of the impact of adding real estate to a portfolio. Hence, for simplification purposes, we ignore taxes. Using out-of-sample portfolio returns, we compute each strategy's information ratio over 30-year rolling windows. The rationale is that the higher the information ratio, the better is a strategy at hedging wage growth (i.e., it has a higher excess return and/or a lower tracking error). Given that differences in information ratios are difficult to interpret, we compute the risk-adjusted excess return that results from holding real estate in a portfolio:

$$RAER_t = (IR_{RE,t} - IR_{NRE,t}) \cdot TE_{NRE,t} \qquad (2)$$

where $RAER_t$ is the risk-adjusted excess return per annum for the 30-year period ending in t, $IR_{RE,\,t}$ and $IR_{NRE,\,t}$ is the information ratio of a portfolio with and without real estate, respectively, for period ending in t, and $TE_{NRE,t}$ is the tracking error of a portfolio without real estate for the period ending in t. If holding real estate in a portfolio is beneficial, we expect risk-adjusted excess returns for most of the rolling windows to be positive.

We test whether risk-adjusted excess returns are significantly positive using ARMA models. Model specification for each strategy is determined as the ARMA model with the lowest Akaike information criterion (AIC), considering up to 10 lags for the autoregressive (AR) and moving average (MA) terms. An intercept significantly greater (lower) than zero indicates that real estate contributes positively (negatively) to portfolio returns after accounting for tracking error.

To examine the sensitivity of our results to the key assumptions being made, ~~W~~we consider three sets of robustness checks. Firstly, we use a real estate allocation of 10% and 30%, respectively, rather than 20% as in the main analyses. Secondly, we consider an investment horizon of 20 and 40 years, respectively, rather than the base case horizon of 30 years. Finally, portfolio weights are rebalanced every year and after five years, respectively, rather than every three years.

We then regress real returns for each asset class on real wage growth and a set of macroeconomic variables comprising real GDP growth, inflation, and the change in the term spread. We use an autoregressive integrated moving average model with exogenous variables (ARIMAX) where the numbers of AR and MA terms are selected based on the AIC. We limit the AR and MA part of the model to a maximum of three lags as it seems unlikely that the time series have a longer memory than three years. The model is:

$$Ret_t = \mu + \sum_{m=1}^{p} \gamma_m Ret_{t-m} + \sum_{n=1}^{q} \theta_n \varepsilon_{t-n} + \sum_{o=0}^{r} \beta_o y_{t-o} + \varepsilon_t \quad (3)$$

where Ret_t is the real return for a given asset class for period t, Ret_{t-m} is the response variable lagged by m periods, ε_{t-n} is the MA term at lag n, y_{t-o} is the vector of macroeconomic variables lagged by o periods, and μ, γ, θ, and β are estimated parameters.

We refine our analysis of the impact of inflation on asset returns by considering separately the expected and unexpected components. For parsimony, expected inflation is estimated using an AR(1) model over the previous 30 years.[9] The correlation between expected and realised inflation is 0.57, suggesting that the model provides reliable forecasts. Unexpected inflation is calculated as the difference between realised and expected inflation. Following Chen *et al.* (1986), we include the changes in expected inflation (and not expected inflation per se) in our models, as a constant rate of expected inflation should not affect returns. Consistent with economic intuition, real wage growth exhibits a strong negative relationship with unexpected inflation (correlation of -0.57).[10] Consequently, our model includes only changes in expected inflation in addition to the other macroeconomic variables.[11]

We check for stationarity using Ljung-Box (autocorrelation), Augmented Dickey-Fuller (unit root), and Kwiatkowski-Phillips-Schmidt-Shin (stationary around a deterministic trend) tests. We consider a variable to be stationary if at least two tests indicate so. Only the term spread variable is non-stationary; hence, we differentiate this variable to make it stationary.

[9] An ARMA(1,1) yielded similar results.

[10] Over long time periods, nominal wage growth should be tightly related to expected inflation. This is supported by the correlation of 0.74 in our data. The resulting effect is a negative correlation between *real* wage growth and unexpected inflation.

[11] As inflation rate data start in 1871 and our AR(1) model is fitted over 30 years, our first estimate of expected inflation is for 1901 and the first change in expected inflation for 1902. Given that the models allow for three lags, the ARIMAX regressions are estimated over 116 years (1905-2020), instead of 145 years as in the base case.

In addition, no collinearity issue was detected using the Variance Inflation Factor (VIF). The residual analysis indicates no violation of the distributional assumptions.

Finally, we examineverify our assumption concerning the transmission channel from wages to asset returns using a Granger causality test. Our assumption is that the real NOI of multi-family properties should be positively correlated to real wage growth as higher wages permit households to afford higher rents (Albouy, 2008; Davis and Ortalo-Magné, 2011). All else being equal, higher NOI growth will positively impact upon both income and capital returns. In contrast, we are agnostic as to the impact of higher wage growth on company profitability and hence stock returns. To test our hypothesisMore specifically, we examinetest whether real wage growth Granger-causes increases in real NOI growth. We perform the same test for stocks by substituting real dividend growth for real NOI growth.[12]

Results

In the context of hedging liabilities, it is desirable that asset returns exhibit strong and stable positive correlations with liabilities. Figure 2 shows the 30-year rolling correlations between asset returns and wage growth. Stock returns are in most cases negatively related to wage changes. The correlation between bond returns and wage growth increases over time, as it goes from being strongly negative to being close to zero. Bill returns are positively associated with wage changes, except during the aftermath of the second World War and during the 1980s. The result for the latter period is likely due to the different behaviour of wages and bills during periods of high inflation. The correlation between real estate returns and wage changes exhibits a similar pattern to that between bill returns and wage growth, albeit more

[12] Dividend is used as a proxy for company earnings which are not available. This assumes a constant dividend payout ratio over time.

muted. As a result, the correlation is virtually always positive. The correlation between real estate returns and wage growth declines at the onset of the one million programme, highlighting the negative impact that increased supply had on real estate returns. In sum, correlations suggest that real estate and bills should be the most useful assets to hedge pension liabilities.

[Figure 2 approximately here]

Turning to portfolio allocations, stocks and bills play an important role in the maximum information ratio strategy (Figure 3). The allocation to stocks is substantial right after the first World War and from the end of the second World War to the mid-1990s. The weight of bills is large during the first 35 years of the 20th century, apart from the aftermath of the first World War when stocks dominate, and from the mid-1990s to the mid-2010s. Bonds only constitute a significant share of the portfolio from the mid-1930s to 1950 and, to a lesser extent, during the last 20 years of the period. On average, the allocations are 38% for stocks, 30% for bills, 12% for bonds, and (by construction) 20% for real estate. In contrast to the maximum information ratio strategy, the allocations for the risk parity approach are more stable, given that tracking errors exhibit less variability than returns over time (Figure 4). Given their low tracking error, bills have the largest average allocation (44%). Bonds account on average for 22% of portfolios, whereas a relatively low weight is allocated to stocks (14%). The allocation to bills increases over time, whereas that of stocks declines. For the minimum tracking error strategy, the core portfolio contains almost exclusively government bills (the results are hence not displayed).[13]

[Figures 3 and 4 approximately here]

[13] Portfolio compositions for the 60/40 strategy are not displayed either given that weights are constant over time.

Figure 5 displays the annualised 30-year risk-adjusted excess returns of the various strategies for all 30-year periods. A real estate allocation is particularly useful with low-risk allocation approaches, i.e., minimum tracking error and, to a lesser extent, risk parity. For higher risk strategies, the excess returns from adding real estate are more volatile, with periods of positive and negative returns.

[Figure 5 approximately here]

The minimum tracking error strategy is the only strategy that consistently yields a positive risk-adjusted excess return when adding real estate to a portfolio. This translates into an excess return of 77 bps (significant at the 1% level). Over time, the excess return varies between 12 and 204 bps. It only exceeds a level of 100 bps from the mid-2000s, reflecting the capitalisation rate compression toward the end of the period. The risk parity strategy has the second highest excess return at 53 bps (significant at the 5% level), and the excess return is only negative during 11 periods. This strategy, however, has a significantly lower excess return than the minimum tracking error strategy from the 1950s to the 1980s. Again, the compression in capitalisation rates at the end of the period leads to substantially higher excess returns.

The excess return is 39 bps for both the maximum information ratio and 60/40 strategies (both significant at the 1% level). Out of the 86 periods, the excess return was negative during 17 periods (maximum information ratio) and 24 periods (60/40 strategy), suggesting that caution should be exercised when including real estate in a portfolio with riskier strategies. The worst period saw a negative excess return of 55 and 63 bps, respectively, which translates into a negative return exceeding 15% over the 30-year period. This compares with a negative return of only 3.5% for the risk parity strategy over the investment horizon.

To understand why low-risk strategies benefit more from the inclusion of real estate than high-risk strategies, it is important to apprehend how portfolio compositions change when the asset class is added. For the minimum tracking error strategy, in which bills dominate the allocation, real estate mainly replaces bills. As real estate has a tracking error in line with that of bills, but a higher return in excess of wage growth, the portfolio containing real estate maintains its ability to track wages while improving the excess return. This leads to positive risk-adjusted excess returns. The same reasoning applies to the risk parity strategy, albeit the substitution effect and performance improvement are more muted given that the initial allocation is more balanced across asset classes. In the case of the high-risk strategies, the initial portfolios are heavily allocated to stocks and bonds. As a result, real estate substitutes for stocks and to a lesser extent bonds and bills. Although the information ratio of real estate is higher than that of bonds and bills, it is only marginally higher than that of stocks, and hence adding real estate results in a moderate risk-adjusted excess return.

To quantify the influence of the significant capitalisation rate compression at the end of our period, we discarded the years 2000-2020 from the analysis. This leads to the risk-adjusted excess returns being 21 to 33 bps lower across the four strategies. Hence, results of studies on the role of real estate in mixed-asset portfolios that have relied on data for the recent decades should not be naively extrapolated for future periods, especially if capitalisation rates are set to increase going forward.

Considering the minimum allocation of 20% to fixed-income securities does not lead to material differences in excess returns for the minimum tracking error strategy. This is expected as the allocation already comprises mainly of bills. For the maximum information ratio strategy, the risk-adjusted excess return is amplified both on the upside and downside.

The estimated risk-adjusted excess return is 11 bps lower than in the unconstrained case, but the worst period saw a 30-year excess return of approximately -25%.

Our robustness checks involve considering a different real estate allocation, changing the investment horizon, and using an alternative rebalancing period. Appendix A1 and A2 contain the risk-adjusted excess returns when 10% and 30% is invested in real estate, respectively. An allocation of 10% is more in line with the figures that have been reported in studies using an asset-liability framework. On the other hand, a weight of 30% is consistent with studies that have reported higher optimal allocations for real estate. Overall, the patterns of excess returns do not change substantially. However, the magnitudes of excess returns change materially, with excess returns being much more muted when 10% is invested in real estate and exacerbated for a 30% allocation. For the latter allocation to real estate, the risk parity strategy only yields a negative excess return during six periods. As expected, the impact of the compression in capitalisation rates are more pronounced during the last 20 years of the period with a 30% real estate allocation. For the other two robustness checks, i.e., when we change the investment horizon from 30 years to either 20 or 40 years or when we consider one-year and five-year rebalancing periods rather than three years, the results are by and large unchanged and hence not reported.

We next discuss the regression results to identify the macroeconomic drivers of asset class returns (Table 2). Focusing first on the main variable of interest, i.e., real wage growth, only real estate returns have a positive association with this variable, supporting our assumption that real estate should benefit from increased household income. In contrast, stocks are negatively related to wage growth, which is consistent with higher wages (and hence labour costs) negatively impacting returns. The relation between bond returns and wage growth is weakly negative, while for bills the linkages are insignificant. Overall, these results are consistent with the reported positive impact of including real estate in a pension portfolio.

[Table 2 approximately here]

Consistent with previous literature, real estate and stock returns are positively associated with real economic growth, with a stronger effect for stocks. In contrast, fixed-income security returns are negatively related to real GDP growth. Real returns for all assets are negatively related to contemporaneous changes in the CPI. However, the various asset classes exhibit varying responses when lags of CPI changes are considered, with real estate and bills displaying better inflation-hedging capabilities than stocks and bonds. The change in the term spread, which can be interpreted as a leading indicator of economic activity, positively impacts stocks, real estate, and bonds, whereas the response is negative for bills.

Table 3 contains the regression results when the change in expected inflation is considered rather than the rate of inflation (Panel A).[14] For comparison purposes, we also report the regression results for the base model estimated over the same period, 1905-2020 (Panel B). The results are generally in line with those in Table 2. Substituting the change in expected inflation for inflation results in wage growth being more positively (or less negatively) related to asset returns. Real estate returns are again positively associated with wage growth, but the relationship is stronger. Bills are now also positively related to wage growth, while the association is insignificant for bonds. For stocks, the relationship is still negative, albeit weaker. Real bill returns are positively related to real GDP and the relation

[14] As mentioned above, unexpected inflation is not included in the regressions as it presents a strong negative correlation with wage growth.

for stocks is stronger than in the base case. The returns on all asset classes are negatively associated with changes in expected inflation. This is in line with the intuition that a change in expected inflation should lead to a repricing of assets which will negatively affect returns.

[Table 3 approximately here]

Finally, we test for a causal relationship between real wage and real NOI growth using a Granger causality test. The results indicate that the previous period real wage growth Granger-causes real NOI growth (p-value of 0.092),[15] which confirms our hypothesis that real estate returns are positively associated with wage growth through NOI (and rent) growth. For stocks, we fail to identify predictive causality between wage and dividend real growth.

Conclusions

This paper examines the role of multi-family properties in mixed-asset portfolios to hedge against wage inflation risk. Beyond the availability of long time series of data, the case of Sweden is interesting as its economy is integrated with that of other developed countries, and hence experienced similar shocks and crises. This, together with the hybrid nature of the Swedish rental market that also prevails ~~Consequently, the conclusions of this study should apply to other countries.~~ in other developed countries, indicates that the conclusions of this study should be relevant to institutional investors in other countries~~Moreover, Sweden is quite unique in that it was close to the epicentre of the two World Wars but did not experience major destruction of properties~~.

In contrast to much of the literature on the role of real estate in a portfolio, which has focused on a single period of two or three decades, we investigate the benefits associated

[15] The reverse test has a p-value of 0.424, indicating that the causal relationship is indeed from wage growth to NOI growth.

with holding real estate across several periods of similar length. The benefits are the greatest for portfolios that target low-risk allocation approaches; for riskier strategies, the role of real estate is more muted and varies over time. Holding real estate is found to be most beneficial during the first two decades of the 21st century. Our results are robust when considering alternative real estate weights, investment horizons, and rebalancing frequencies.

Multi-family property returns are positively related to wage growth, whereas the relationship is negative for stocks and bonds. Stocks and to a lesser extent real estate are positively related to economic growth, whereas the relationship is negative for fixed-income securities. Real estate provides better inflation-hedging capabilities than stocks and bonds. Finally, we find that wage growth Granger-causes NOI growth, but not the dividend yield, corroborating the positive role found for real estate in pension portfolios.

Using long term data makes it possible to use a rolling windows approach and hence to consider multiple outcomes for an allocation strategy over a typical investment horizon. Our study demonstrates the importance of doing this, as our results show that the conclusions that would be drawn from looking at the past two or three decades of data differ substantially from those for earlier time periods. The current context of high inflation and rising interest rates, and the resulting uncertainties concerning the pricing of real estate assets speak to the importance of understanding the dynamics of real estate returns in various environments. The development of long run time series of commercial real estate returns for other countries and spanning the various property sectors should improve such understanding.

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Table 1. Summary Statistics and Correlations

Panel A. Summary Statistics

	RE Stockholm	RE Gothenburg	RE Weighted Average	Stocks	Gov. Bonds	Gov. Bills	GDP	Inflation	Wages	Term Spread
Geo. Mean	7.2%	7.5%	7.4%	9.0%	5.5%	4.9%	5.4%	2.8%	5.1%	0.3%
Std Dev.	8.7%	9.5%	7.6%	19.8%	8.6%	2.9%	6.4%	6.5%	6.9%	1.2%
Min.	-17.0%	-26.8%	-11.0%	-39.3%	-32.5%	-0.7%	-25.1%	-18.5%	-25.8%	-3.3%
Max.	43.3%	60.0%	36.4%	69.8%	29.6%	15.4%	38.0%	47.0%	43.7%	3.2%
Excess Return	2.0%	2.3%	2.2%	3.5%	0.3%	-0.3%	-	-	-	-
Tracking Error	9.5%	10.0%	8.6%	20.3%	11.7%	6.5%	-	-	-	-
Info. Ratio	0.21	0.23	0.25	0.17	0.02	-0.04	-	-	-	-

Notes: annual data for 1876-2020. Excess returns, tracking errors, and information ratios are geometric means, standard deviations, and return-to-volatility ratios, respectively, using returns in excess of wage growth rather than returns.

Panel B. Correlation Coefficients

	Apart. Buildings Stockholm	Apart. Buildings Gothenburg	Apart. Buildings Weighted Average	Stocks	Gov. Bonds	Gov. Bills	GDP	Inflation	Wages	Term Spread
A. B. STH	1.00	0.38	0.94	0.01	-0.09	0.23	0.19	0.13	0.18	0.28
A. B. GBG		1.00	0.67	0.00	0.01	0.17	0.21	0.18	0.20	0.20
A. B. W. Av.			1.00	0.01	-0.07	0.24	0.22	0.17	0.22	0.30
Stocks				1.00	0.13	0.06	0.11	0.06	-0.07	0.19
Gov. Bonds					1.00	0.27	-0.17	-0.08	-0.17	0.11
Gov. Bills						1.00	0.22	0.29	0.24	-0.05
GDP							1.00	0.87	0.73	0.25
Inflation								1.00	0.80	0.19
Wages									1.00	0.16
Term Spread										1.00

Note: annual data for 1876-2020.

Table 2. Results for Baseline Regression Models

Variables	Real Estate		Stocks		Bonds		Bills	
Real GDP Growth	0.134		1.034	**	(0.199)		(0.104)	***
Real GDP Growth (-1)	0.376	**	(0.337)		(0.667)	***	(0.070)	**
Real GDP Growth (-2)	(0.389)	**	0.803		(0.057)		0.028	
Real GDP Growth (-3)	0.358	**	(0.215)		(0.299)		(0.012)	
Inflation	(0.787)	***	(1.360)	***	(1.099)	***	(0.829)	***
Inflation (-1)	0.259	*	0.019		0.119		(0.059)	
Inflation (-2)	(0.301)	**	0.394		(0.377)		(0.015)	
Inflation (-3)	0.232	*	0.567		0.285		0.147	***
Real Wage Growth	0.047		(1.142)	**	(0.249)		0.007	
Real Wage Growth (-1)	0.412	**	(1.088)	*	0.092		(0.011)	
Real Wage Growth (-2)	(0.254)		(0.637)		(0.015)		(0.026)	
Real Wage Growth (-3)	0.080		(0.029)		(0.339)	**	0.029	
Term Spread Difference	1.141	*	0.040		(0.764)		(0.616)	***
Term Spread Difference (-1)	(0.050)		3.893	*	2.386	***	(0.400)	***
Term Spread Difference (-2)	2.612	***	2.681		(1.149)		0.187	
Term Spread Difference (-3)	0.704		0.925		1.175		0.035	
R-Squared	**0.52**		**0.25**		**0.62**		**0.96**	

Notes: annual data for 1876-2020; (-1), (-2) or (-3) in a variable name indicates that the variable is lagged by 1, 2, or 3 years, respectively; *, ** and *** indicates significance at the 10%, 5%, 1% level, respectively; coefficients for the AR and MA terms are not shown in the table as they are not interpretable.

Table 3. Results for Regression Models with Expected Inflation and Baseline Models for Restricted Period

Panel A. Models with Expected Inflation Change

Variables	Real Estate		Stocks		Bonds		Bills	
Real GDP Growth	0.422	*	2.181	***	0.211		0.234	***
Real GDP Growth (-1)	0.281		(0.848)		(0.970)	***	(0.044)	
Real GDP Growth (-2)	(0.422)	*	1.176	*	(0.097)		(0.040)	
Real GDP Growth (-3)	0.471	**	(0.092)		(0.309)		0.120	
Expected Inflation Change	(0.267)		(1.479)	**	(0.881)	***	0.021	
Expected Inflation Change (-1)	(0.673)	***	(1.637)	***	(0.962)	***	(0.355)	***
Expected Inflation Change (-2)	(0.609)	***	(0.469)		(0.425)	*	(0.299)	***
Expected Inflation Change (-3)	(0.110)		(0.698)		0.050		(0.019)	
Real Wage Growth	0.759	***	(0.169)		0.244		0.736	***
Real Wage Growth (-1)	0.325		(1.208)		(0.259)		0.387	***
Real Wage Growth (-2)	(0.134)		(1.154)	*	0.270		0.194	
Real Wage Growth (-3)	(0.221)		(0.599)		(0.330)		0.148	*
Term Spread Difference	0.103		(0.049)		(1.517)	*	0.125	
Term Spread Difference (-1)	(0.950)		2.920		2.085	**	(0.638)	
Term Spread Difference (-2)	1.809	**	2.198		(0.952)		(0.556)	
Term Spread Difference (-3)	0.141		(0.705)		1.426	*	(0.451)	
R-Squared	**0.45**		**0.26**		**0.54**		**0.81**	

Panel B. Baseline Models (estimated over 1905-2020)

Variables	Real Estate		Stocks		Bonds		Bills	
Real GDP Growth	0.151		0.880		(0.172)		(0.085)	**
Real GDP Growth (-1)	0.296		0.025		(0.639)	**	(0.080)	**
Real GDP Growth (-2)	(0.444)	*	0.557		(0.118)		0.026	
Real GDP Growth (-3)	0.396	*	(0.654)		(0.317)		(0.013)	
Inflation	(0.761)	***	(1.261)	***	(1.225)	***	(0.801)	***
Inflation (-1)	0.206		0.313		0.276		(0.064)	
Inflation (-2)	(0.344)	**	(0.145)		(0.463)		(0.041)	
Inflation (-3)	0.252		0.648		0.343	*	0.176	***
Real Wage Growth	0.090		(1.694)	***	(0.427)		0.010	
Real Wage Growth (-1)	0.431	**	(0.440)		0.169		(0.005)	
Real Wage Growth (-2)	(0.251)		(0.633)		(0.058)		(0.034)	
Real Wage Growth (-3)	(0.026)		(0.342)		(0.312)		0.037	
Term Spread Difference	0.928		0.815		(1.111)		(0.612)	***
Term Spread Difference (-1)	0.089		1.775		2.716	***	(0.427)	***
Term Spread Difference (-2)	2.657	***	1.095		(1.111)		0.193	
Term Spread Difference (-3)	0.676		(0.167)		1.591	**	0.064	
R-Squared	**0.53**		**0.30**		**0.64**		**0.96**	

Notes: annual data for 1905-2020; (-1), (-2) or (-3) in a variable name indicates that the variable is lagged by 1, 2, or 3 years, respectively; *, ** and *** indicates significance at the 10%, 5%, 1% level, respectively; coefficients for the AR and MA terms are not shown in the table as they are not interpretable.

Figure 1. Real Total Return and Wage Growth Indexes (in logarithms), 1875-2020

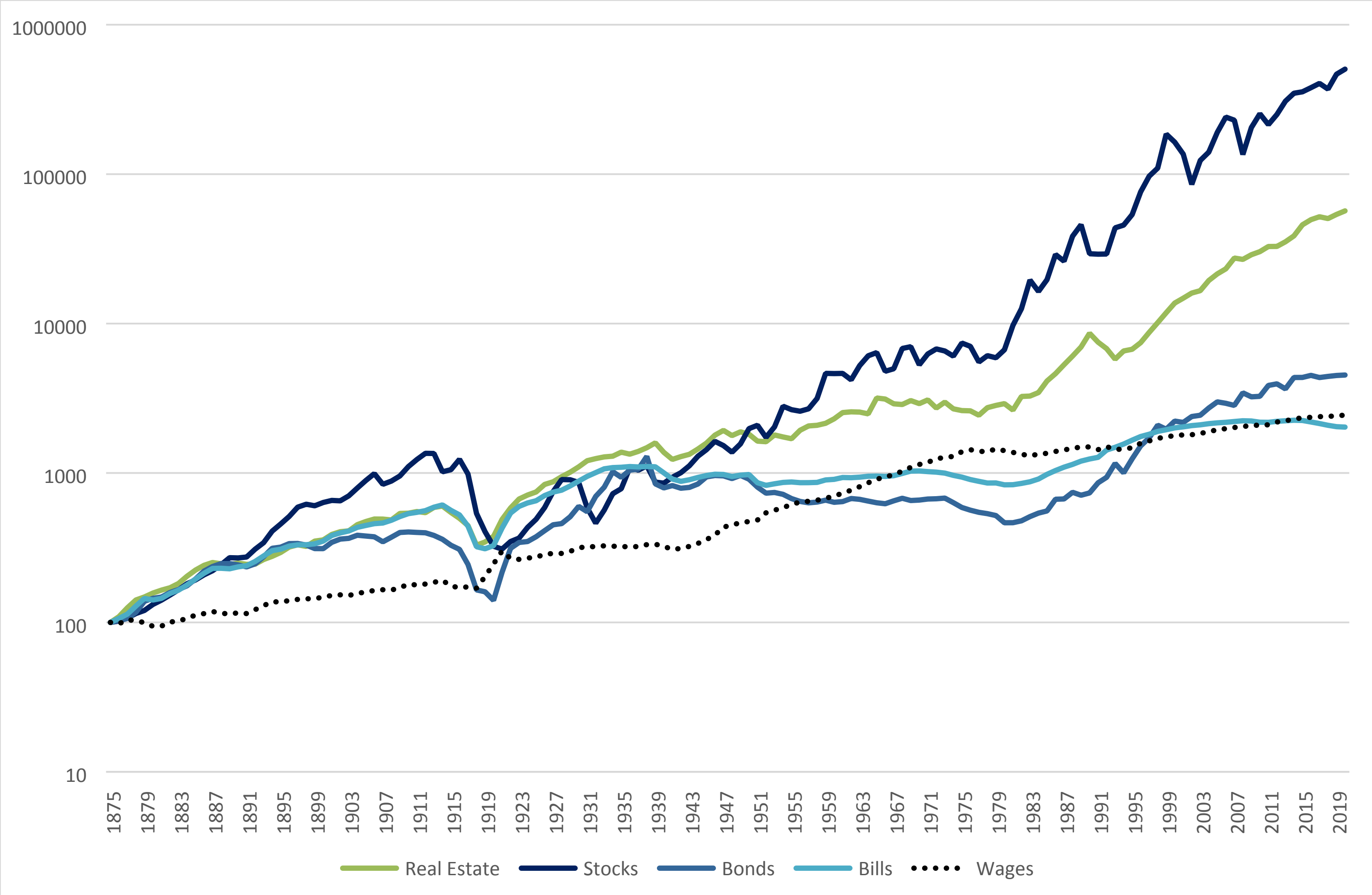
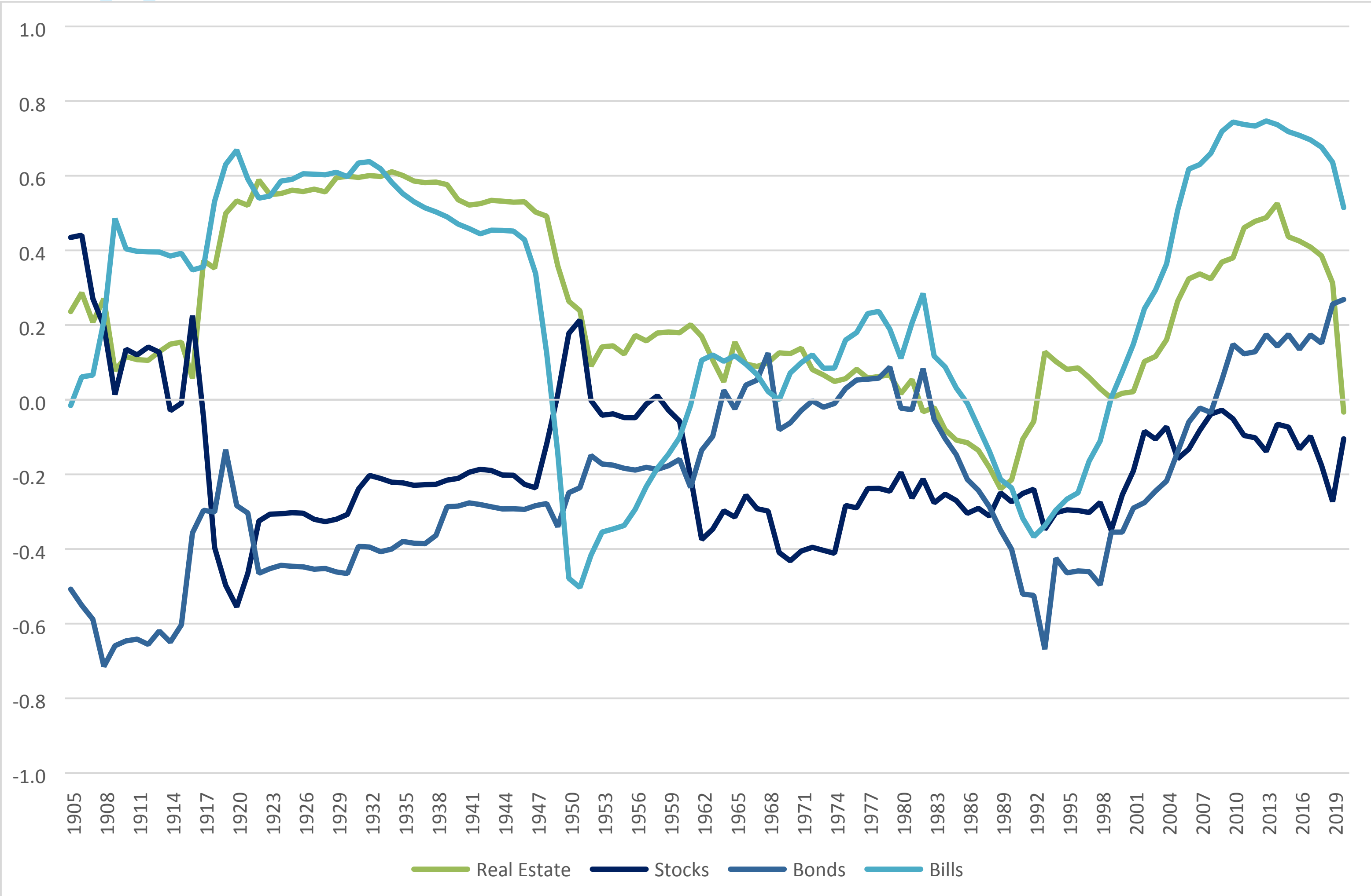
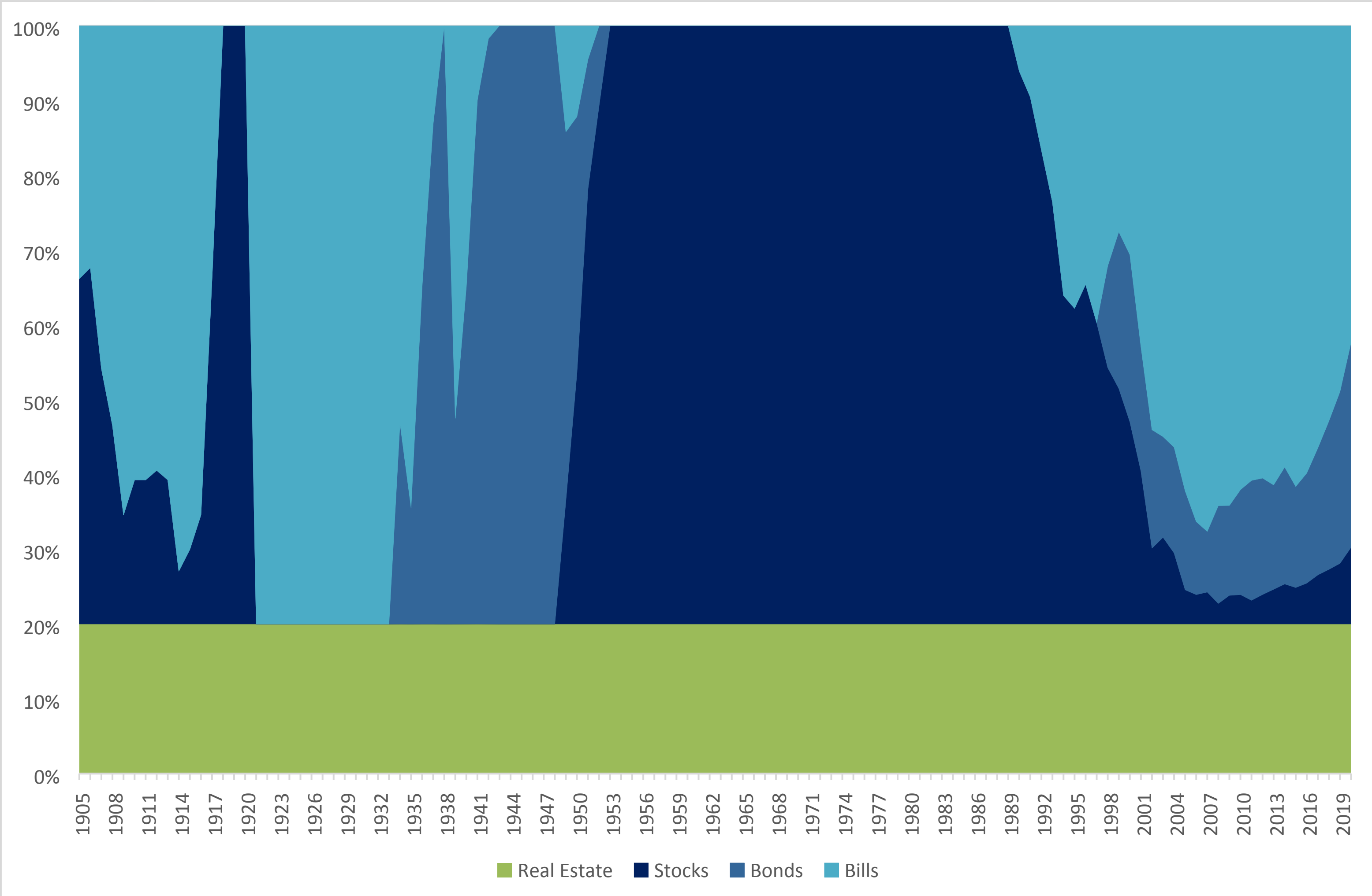


Figure 2. Rolling Correlations Between Asset Returns and Wage Growth



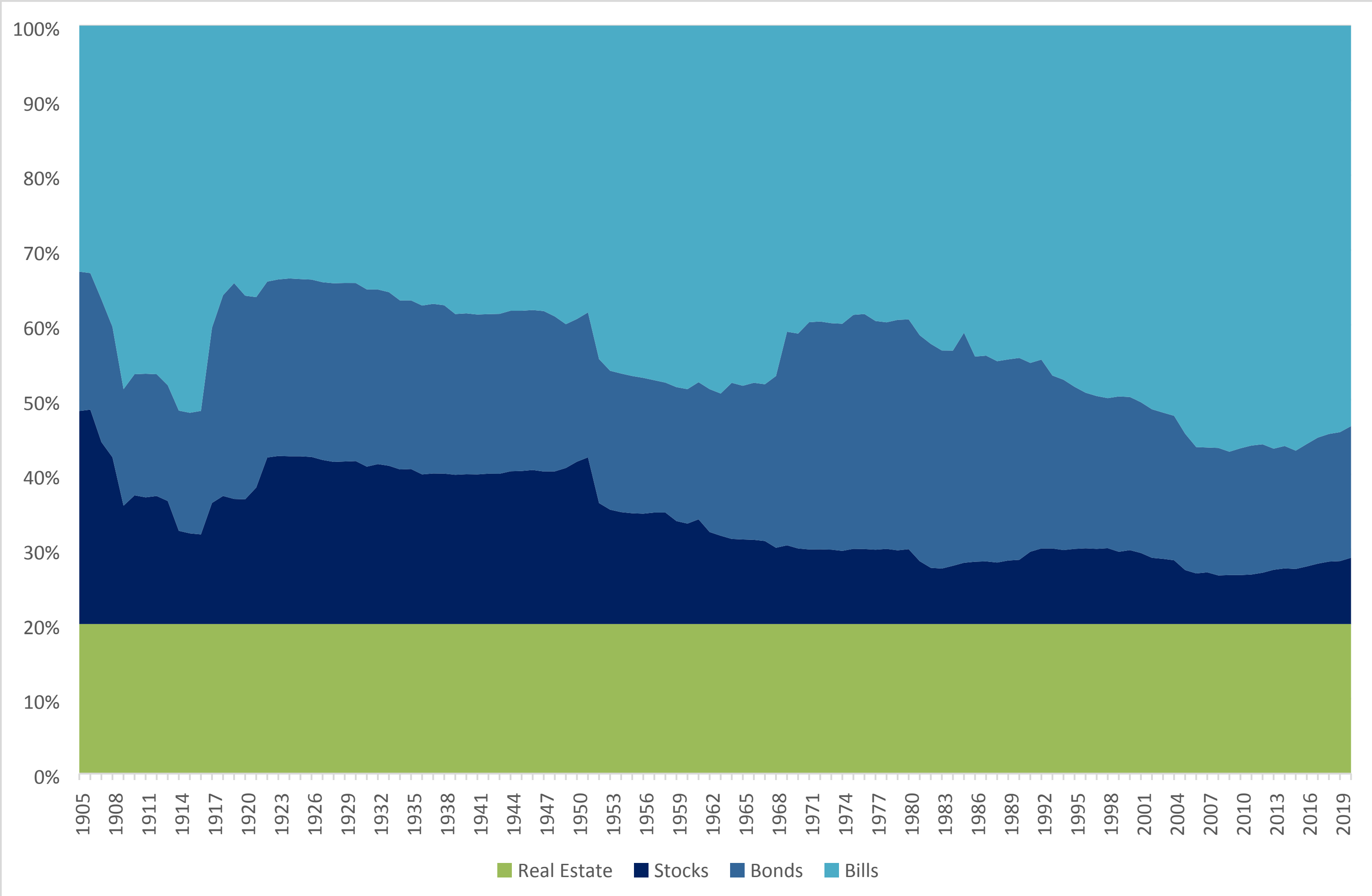
Note: the dates on the x axis refer to the final year of each of the 30-year windows. For instance, correlations for 1905 are computed using data for the period 1876-1905.

Figure 3. Portfolio Weights for the Maximum Information Ratio Strategy



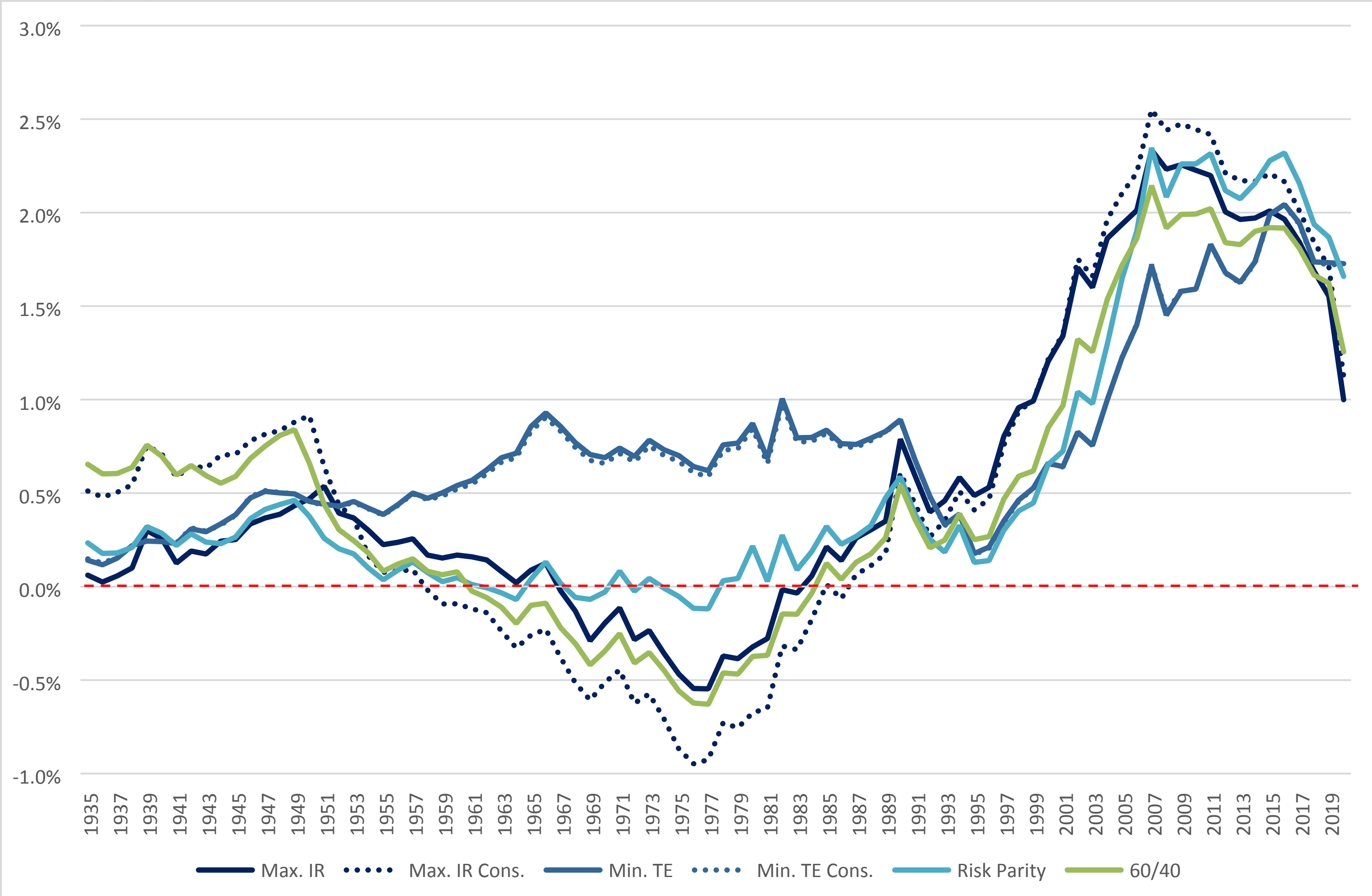
Notes: the dates on the x axis refer to the final year of each of the 30-year windows. For instance, weights for 1905 are the optimal weights calculated for the period 1876-1905. Realiszed weights can deviate slightly from optimal weights between portfolio rebalancing dates.

Figure 4. Portfolio Weights for the Risk Parity Strategy



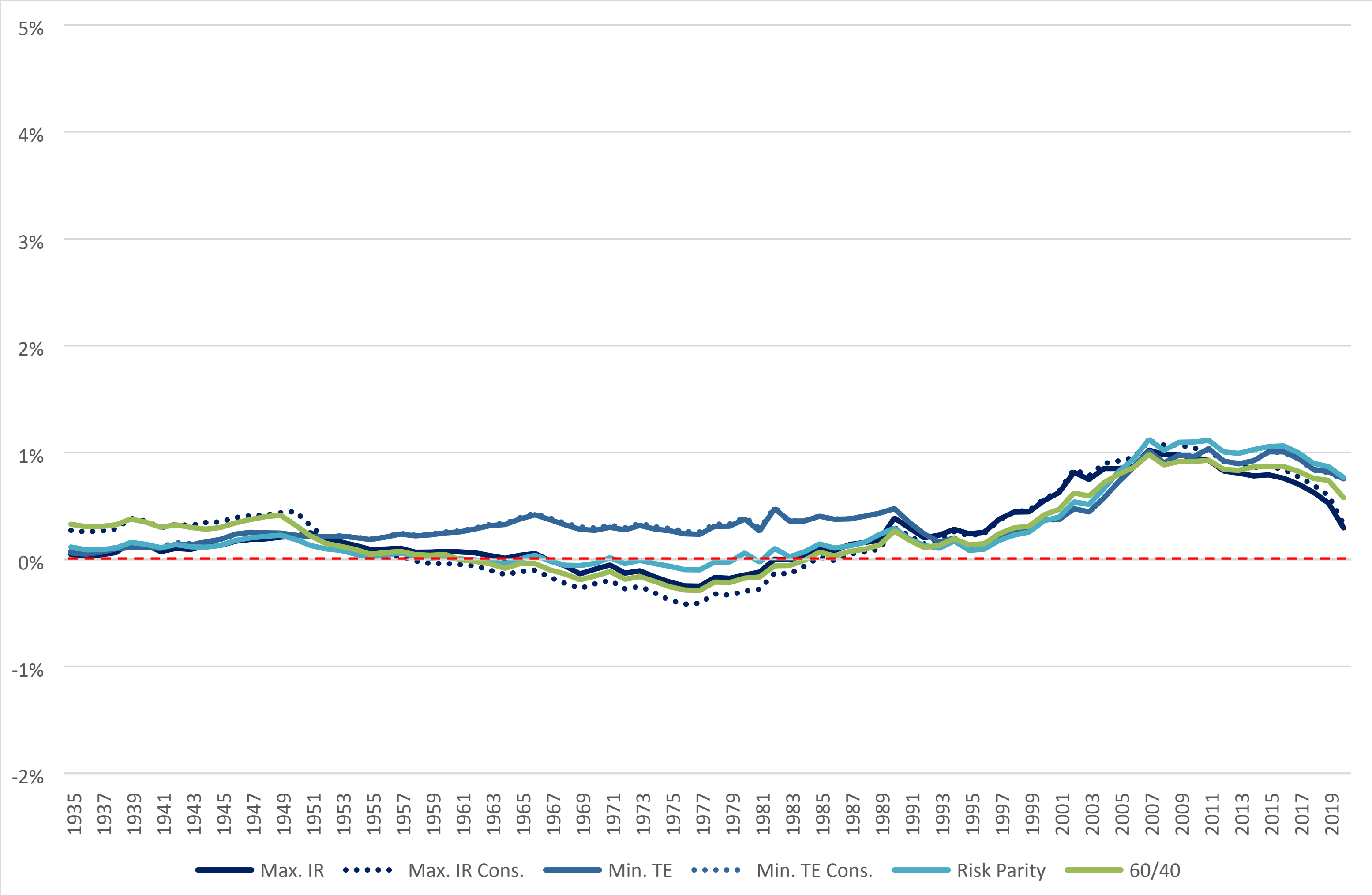
Note: the dates on the x axis refer to the final year of each of the 30-year windows. For instance, weights for 1905 are the optimal weights calculated for the period 1876-1905. Realiszed weights can deviate slightly from optimal weights between portfolio rebalancing dates.

Figure 5. Risk-Adjusted Excess Returns Provided by Real Estate



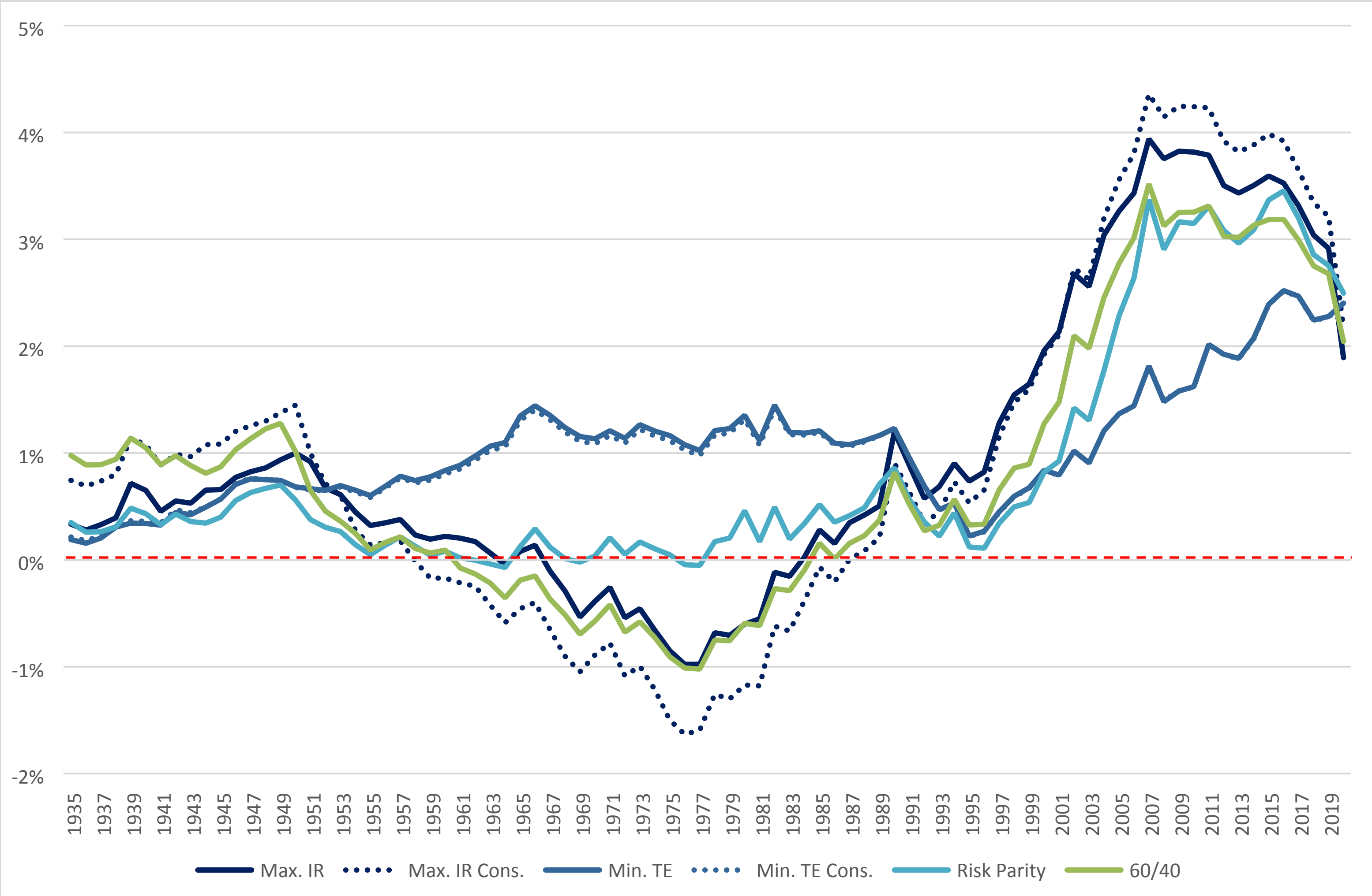
Notes: Each data point shows the annualised 30-year risk-adjusted return for the period ending at the date appearing on the horizontal axis. "Cons." refers to a strategy that is constrained to allocate a minimum of 20% to fixed-income securities.

Appendix A1. Risk-Adjusted Excess Returns Provided by Real Estate (10% Allocation)



Note: Each data point shows the annualised 30-year risk-adjusted return for the period ending at the date appearing on the horizontal axis. "Cons." refers to a strategy that is constrained to allocate a minimum of 20% to fixed-income securities.

Appendix A2. Risk-Adjusted Excess Returns Provided by Real Estate (30% Allocation)



Note: Each data point shows the annualised 30-year risk-adjusted return for the period ending at the date appearing on the horizontal axis. "Cons." refers to a strategy that is constrained to allocate a minimum of 20% to fixed-income securities.