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Discussion note

Drivers of listed and unlisted real estate returns

We analyse the exposures of real estate to fundamental return drivers: expected cash flows, inflation, real interest rates, and risk premiums. We find that listed and unlisted real estate provide protection against inflation risk.

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Summary

- We analyse the drivers of real estate returns, and evaluate real estate exposures in the context of a diversified equity and fixed income portfolio. We focus on US real estate, analysing both listed and unlisted assets.
- A common approach to analysing real estate is to regress its returns on equity and fixed income returns. This 'spanning' regression approach explains listed real estate returns relatively well, but only captures a small proportion of the variation in de-smoothed unlisted real estate returns. We argue, however, that the apparent divergence between listed and unlisted real estate is overstated by this regression approach.
- The differences between listed and unlisted real estate appear to reduce over the longer term, where the return correlations between the two segments increases with horizon. In addition, the correlations with the broader equity market are lower at longer horizons for both real estate segments. These correlation patterns suggest that differences between listed and unlisted real estate returns are short-term and largely driven by transitory factors.
- We estimate the exposures of real estate to fundamental return drivers: expected cash flows, inflation, real interest rates and risk premiums. We find that both segments of real estate hedge inflation risk more than the aggregate equity market, and that listed real estate has a high exposure to transitory risk premium shocks. The inflation and risk premium exposures help to reconcile the spanning regression results and patterns of real estate correlations across different horizons.
- We estimate exposures and correlations for other equity sectors, and find patterns that support our analysis for real estate. In addition, when allowing for inflation exposures in spanning regression models, we better explain unlisted real estate returns, accounting for levels of variation comparable to listed real estate.

1. Introduction

The Government Pension Fund Global invests in listed and unlisted real estate assets within several countries across the world.[1] It is important to understand the drivers of real estate returns, and how real estate relates to other asset classes. In this note, we analyse the drivers of US listed and unlisted real estate returns, and evaluate real estate exposures in the context of a diversified equity and fixed income portfolio.

A common approach to benchmarking real estate returns is to use 'spanning' regressions.[2] This approach regresses real estate returns on equity and fixed income returns, and indicates whether real estate can improve the risk-return properties relative to diversified equity and fixed income portfolios. This regression approach explains listed real estate returns relatively well, however it explains only a small proportion of the variation in unlisted real estate returns. While this could indicate differences between listed and unlisted real estate, we argue that any differences seem to be concentrated in the short-term, and are therefore overstated by this standard regression approach.

We show that listed and unlisted real estate returns are more similar at longer horizons. The correlation between listed and unlisted real estate returns increases with return horizon, and their correlations with the broad equity market also converge at longer horizons. This suggests that transitory factors can account for differences between listed and unlisted real estate in the spanning regressions.

We attempt to reconcile the spanning regression results and real estate correlations over different horizons. We do this by estimating the exposures of real estate to fundamental drivers of equity and fixed income returns. These drivers are components of returns related to cash flows, inflation, real interest rates and risk premiums, described in detail in NBIM (2021). We show that the spanning regression approach imposes restrictions on the exposures of real estate to different return drivers, and assume that the exposures to equity and fixed income drivers are the same for all drivers. Empirically, this is not the case, where we find that both segments of the real estate market hedge inflation risk more than the aggregate equity market. Real estate also shares some characteristics with bonds, which makes it sensitive to changes in term premiums. The fundamental driver regressions highlight similarities between listed and unlisted real estate compared to the earlier regressions. Using the fundamental drivers, we are able to explain a much larger proportion of the variation in unlisted real estate returns.

The exposures to fundamental drivers help us to understand why real estate correlations change over different return horizons. We estimate a higher exposure of listed real estate to transitory risk premium shocks, which can account for its

[1] The global market for real estate is estimated to be over $10 trillion US dollars, and it is well-documented that these assets constitute a significant part of the global market portfolio. For a detailed breakdown, see discussion and references in Ganesan, Patkar, and Neshat (2022), Van Nieuwerburgh, Stanton, and de Bever (2015) and NBIM (2015).

[2] The academic literature on modelling real estate returns is relatively small. Older studies, such as Peterson and Hsieh (1997) and Ling and Naranjo (2003), use traditional asset pricing tools to examine real estate returns. More recent examples include Van Nieuwerburgh (2019) and Andrews and Goncalves (2020), who use a present-value approach to model real estate returns.

high correlation with the equity market. As the horizon extends, persistent effects of inflation grow in importance relative to risk premium shocks. This is consistent with the declining correlation between listed real estate and the equity market, and the increasing correlation between listed and unlisted real estate. We estimate the exposures of other equity sectors to fundamental drivers and the correlations of sector returns with the equity market. Most sectors share similar exposures to the overall equity market. One exception is the energy sector, which also provides some inflation protection, and also has a lower correlation with the equity market over the longer term.

We revisit the spanning regressions in light of the estimated exposures to fundamental drivers. Specifically, we add TIPS and inflation swap returns into the regressions, as a way to separate real rate and inflation exposures within fixed income returns. This additional granularity in the set of assets allows us to explain a higher proportion of the variation in real estate returns.

Our analysis shows that the exposures of real estate to fundamental drivers are distinct from the exposures of diversified equity and fixed income portfolios. In particular, both segments of real estate hedge inflation risk, while equity and fixed income portfolios tend to be more exposed to this risk. The ability to protect against inflation shocks distinguishes real estate from other equity sectors, and this property is likely to be attractive to a long-term investor.

2. Real estate spanning regressions

In this section, we estimate regressions that relate listed and unlisted real estate returns to combinations of equity and fixed income returns. This approach takes the perspective of an investor holding diversified equity and fixed income assets, and evaluates alternative asset classes relative to these assets. Ang, Brandt, and Denison (2014), Van Nieuwerburgh, Stanton, and de Bever (2015), and Van Nieuwerburgh (2019) estimate similar models for listed and unlisted real estate returns.

The spanning regression approach evaluates alternative strategies or assets relative to a benchmark as follows:

$$r_t^i = \alpha + \beta^B r_t^B + \varepsilon_t, \tag{1}$$

where r_t^i is the return on asset i, and r_t^B is the return on a benchmark portfolio, which we set equal to a 70%-30% portfolio of equities and fixed income. When evaluating alternative strategies or assets relative to this benchmark, an alpha value greater than zero indicates that an asset provides additional diversification benefits. This approach evaluates the alternative asset from a mean-variance perspective, where a positive value of alpha is equivalent to achieving a higher Sharpe ratio when including the alternative asset. We also estimate the following regression:

$$r_t^i = \alpha + \beta^{EQ} r_t^{EQ} + \beta^{FI} r_t^{FI} + \varepsilon_t, \tag{2}$$

where r^{EQ} and r^{FI} are the equity and fixed income return series, respectively. This specification allows for unrestricted weights on the equity and fixed income assets. This regression tests whether asset i provides diversification benefits relative to optimal mean-variance combinations of the equity and fixed income portfolios.[3]

For our analysis, we use returns for the broad real estate asset class, for which we distinguish between listed and unlisted investments. We focus on the US real estate market, where a significant proportion of the fund's investments are located, and which is the largest market in the global context. We use the NCREIF index to represent the private real estate market in the US, where the index is available at a quarterly frequency, and represent listed real estate using an index consisting of selected Real Estate Investment Trusts (REITs). In Appendix A, we provide more details on real estate returns and their properties, and de-smoothing of unlisted real estate returns.

We use total returns on the Russell 1000 index as a proxy for the US equity portfolio, and total returns on the Bloomberg US Treasury index for US fixed income. Both series are denominated in US dollars, and we use quarterly returns aligned with the frequency of real estate return data. Table 1 shows the regression results for both models, for listed and unlisted real estate, including standard errors for each estimated coefficient.

TABLE 1 Mean-variance spanning regressions for listed and unlisted real estate

	Unlisted (1)	Unlisted (2)	Listed (1)	Listed (2)
α	0.01 *	0.02 *	−0.01	−0.01
	(0.005)	(0.01)	(0.01)	(0.01)
β^B	0.16		1.23 *	
	(0.09)		(0.11)	
β^{EQ}		0.11		0.86 *
		(0.06)		(0.08)
β^{FI}		−0.25		0.21
		(0.18)		(0.23)
N	154	154	154	154
Adj. R^2	0.02	0.03	0.44	0.44

NOTE: Columns 1 and 2 shows regression of returns on the NCREIF index on equity and fixed income returns. Columns 3 and 4 show results for returns on REIT portfolios. Model (1) includes a 70-30% equity and fixed income portfolio as the independent variable. Model (2) includes equity and fixed income returns separately as independent variables. Standard errors are shown in parentheses. Sample period is from Q4 1984 to Q1 2023. Start of the sample period is determined by the data availability for listed real estate. * indicates significance at $p < 0.05$.

In the first column, we show returns for unlisted real estate returns relative to the 70%-30% benchmark. The alpha coefficient is positive and statistically significant

[3]The estimated coefficients in Ang et al. (2014) differ as they include corporate bond returns alongside equity returns as independent variables. In addition, they constrain the beta coefficients to sum to one. Their modelling choices lead to a negative alpha coefficient in their regression tests.

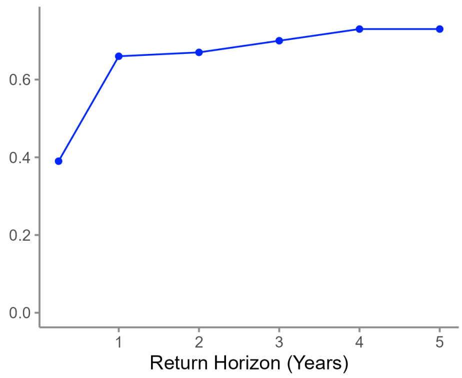
implying that, based on historical data, adding unlisted real estate to the benchmark generates Sharpe ratio improvements. In the second column, for the regression of unlisted real estate on equity and fixed income, the alpha coefficient remains positive.[4] The R^2 values are very low, at 2% to 3%, implying that the majority of return variation is unexplained by equity and fixed income returns. One possible interpretation of this finding is that unlisted real returns contain a large idiosyncratic component specific to this segment of the real estate market. Later in the note, we show that the low R^2 is partly the result of these regressions being restrictive in terms of the exposures to different return drivers that make up equity and fixed income returns.

The third and fourth columns of Table 1 show the regression results for listed real estate returns. The R^2 values are significantly higher for listed real estate, which at first glance could indicate that the listed portion of real estate market is fundamentally different from the unlisted portion.[5]

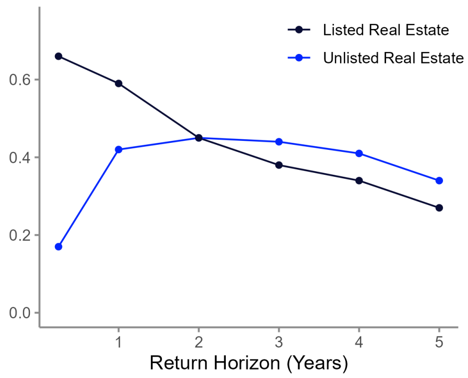
For both models, the alpha coefficient is near to zero and statistically insignificant. On this basis, adding listed real estate to diversified equity and fixed income assets does not lead to a Sharpe ratio improvement.[6] The regression analysis is based on short-horizon returns, however, and differences in the properties of listed and unlisted real estate might not persist. There is evidence to suggest that these two asset classes are more similar when viewed over longer horizons. Figure 1 Panel (a) shows the correlation between listed and unlisted real estate returns, when returns are measured over horizons up to five years.

FIGURE 1 Real estate correlations at different return horizons

(A) Correlations between listed and unlisted real estate returns by horizon



(B) Correlations between real estate and equity market returns by horizon



NOTE: Panel (a) shows the correlation of listed and unlisted real estate returns across horizons. Panel (b) shows the correlation of listed and unlisted real estate returns with the broad equity market. Sample period is Q4 1984 to Q1 2023, quarterly data.

[4] The estimated parameters may vary over time. To explore this, Appendix B estimates each model based on different sub-samples. These results are similar to the findings in Van Nieuwerburgh, Stanton, and de Bever (2015), who explore the risk factor exposures of listed real estate only.

[5] One can further increase the R^2 in the spanning regressions for listed real estate by including additional factors such as value, momentum or size, see e.g., Van Nieuwerburgh, Stanton, and de Bever (2015). Our focus is less on maximising the explained variation and more on relating real estate returns to economically interpretable drivers.

[6] These conclusions do not change if the regression is estimated using returns that are adjusted for leverage.

The correlation between listed and unlisted real estate returns increases from 0.39 at the quarterly horizon to 0.73 at a 5-year horizon, suggesting that the short-term differences are driven by transitory factors. Relatedly, the relationship between real estate returns and other asset classes may also change depending on the return horizon. Figure 1 Panel (b) shows the correlation between real estate returns and the aggregate equity market over different return horizons. At the 1-quarter horizon, listed real estate is much more highly correlated with equities compared to unlisted real estate. The correlation declines with horizon for listed real estate, however. At the 5-year horizons, listed and unlisted real estate have similar correlations with equities.[7]

The correlations across horizons show that the dynamics of returns change over the longer-term. Ideally, we would account for these changes by analysing long-horizon returns directly. Due to the relatively short samples of real estate data, however, it is problematic to run long-horizon return regressions. In the next section, we explore the factors that might be causing differences in results for listed and unlisted real estate returns at shorter horizons. Our analysis helps understand longer-term correlations by estimating exposures of real estate returns to fundamental drivers that differ in terms of their persistence.

3. Real estate exposures to fundamental return drivers

We expand on the analysis in the previous section to better understand the exposures of listed and unlisted real estate. We estimate the exposure of real estate to 'fundamental' drivers of equity and fixed income returns. As outlined in detail in NBIM (2021), equity and fixed income returns can be decomposed into drivers related to expected cash flows, inflation, real interest rates, and risk premiums. Specifically, returns can be expressed in terms of changes in market expectations, often referred to as 'news' terms. For fixed income returns, the continuously compounded return, r_t^{FI}, on a bond with maturity n, can be written as follows:

$$r_t^{FI} = E_{t-1}\left(r_t^{FI}\right) - N_{\pi,t}^{(n)} - N_{r^*,t}^{(n)} - N_{rr^c,t}^{(n)} - N_{tp,t}^{(n)}. \tag{3}$$

This equation decomposes returns into the expected return, $E_{t-1}\left(r_t^{FI}\right)$, and unexpected or news components. The components of the unexpected return are changes in expectations of inflation, $N_{\pi,t}^{(n)}$, and expected equilibrium and cyclical real interest rates, $N_{r^*,t}^{(n)}$ and $N_{rr^c,t}^{(n)}$, respectively. In addition, variation in term premium news, $N_{tp,t}^{(n)}$ is a driver of bond returns.

Similarly, equity returns can be expressed as a function of news terms:

$$r_t^{EQ} = E_{t-1}\left(r_t^{EQ}\right) + N_t^d - N_{r^*,t} - N_{rr^c,t} - N_{e,t}. \tag{4}$$

The drivers of equity returns include changes in expected cash flows, N_t^d, and changes in expected real interest rates, $N_{r^*,t}$ and $N_{rr^c,t}$, similar to fixed income returns. These real rate news terms differ from fixed income as equities do not

[7] The correlation patterns we document for the US market hold across developed markets, see e.g., Hoesli and Oikarinen (2021).

have a fixed maturity and the news terms for equities refer to changes in expectations over infinite horizons. Finally, returns can be attributed to changes in expected excess equity returns, or equity risk premiums, $N_{e,t}$.

These drivers capture intuitions of a present-value approach to pricing equities and bonds. For example, all else equal, higher discount rates through higher real interest rates or risk premiums will lead to negative realised equity and bond returns. In NBIM (2021), we construct proxies for news terms, and show that they are able to explain a significant amount of variation in equity and fixed income returns.

We use these news term proxies to better understand real estate return variation. The news terms differ in terms of their persistence: we tend to think of inflation and cash flow news as highly persistent drivers, while cyclical interest rate and risk premiums are more transitory. We can exploit differences in exposures to persistent and transitory drivers over the shorter-term to infer return properties over the longer term.

Equations (3) and (4) can also be related to the spanning regressions presented in Section 2, and highlight some of the limitations of that analysis. Specifically, the model outlined in equation (2) is equivalent to assuming a certain combination of exposures to each of the fundamental drivers of equity and fixed income returns. By combining equation (2) with the expressions for fixed income an equity returns in equations (3) and (4), the previous model is equivalent to assuming the following:

$$r_t^i = \alpha + \beta^{EQ} \begin{bmatrix} E_{t-1}\left(r_t^{EQ}\right) \\ N_t^d \\ -N_{r^*,t} \\ -N_{rr^c,t} \\ -N_{e,t} \end{bmatrix} + \beta^{FI} \begin{bmatrix} E_{t-1}\left(r_t^{FI}\right) \\ -N_{\pi,t}^{(n)} \\ -N_{r^*,t}^{(n)} \\ -N_{rr^c,t}^{(n)} \\ -N_{tp,t}^{(n)} \end{bmatrix} + \varepsilon_t. \tag{5}$$

This expression shows that the spanning regressions implicitly impose the restriction that the exposures are constant across the fundamental drivers. The regression ensured that the exposure is equal to β^{EQ} for all equity drivers and equal to β^{FI} for all fixed income drivers.[8] To the extent this assumption is too strict, this could explain the low explanatory power of the spanning regressions. Next, we estimate a less restricted version of this regression to understand the extent to which the coefficient restrictions are problematic.

[8] As described later, the fundamental drivers are unobserved and equity and fixed income returns have exposures to these proxies that are not equal to 1 and -1. The restrictions in the spanning regression can still be problematic when there are not unit exposures, however.

We regress returns for asset i on the set of fundamental drivers in the following model:

$$r_t^i = \beta^{er} E_{t-1}(r_t^i) + \begin{bmatrix} \beta^d \\ \beta^\pi \\ \beta^{r^*} \\ \beta^{rr^c} \\ \beta^e \\ \beta^{tp} \end{bmatrix}' \begin{bmatrix} N_t^d \\ N_{\pi,t}^{(n)} \\ N_{r^*,t} \\ N_{rr^c,t} \\ N_{e,t} \\ N_{tp,t}^{(n)} \end{bmatrix} + \varepsilon_t. \quad (6)$$

We are interested in the exposures of listed and unlisted real estate, and this regression model removes the restrictions described in equation (5). We use the news terms for the equilibrium and cyclical real rates from the equity decomposition, $N_{r^*,t}$ and $N_{rr^c,t}$, which reduces the number of factors in the regression. These equity news terms are highly correlated with their fixed-maturity counterparts for long-term bonds, so this choice does not materially impact our analysis. For inflation and term premium news, we use the news terms based on a bond maturity of ten years.[9,10]

We also estimate the model in equation (6) with equity and fixed income returns as the dependent variable. As discussed in NBIM (2021), we do not observe drivers directly and therefore need to build proxies for them. Based on the return identities in equations (3) and (4), if we were able to construct perfect proxies, we would obtain an R^2 equal to one and betas either equal to +1 or -1 in these regressions. Given the imperfect news proxies, the estimated coefficients for equity and fixed income assets serve as a benchmark for assessing the exposures of real estate. Equation (6) also differs from equation (4) in that we include inflation and term premium shocks to equity drivers.[11] Finally, we include the cash flow and risk premium drivers for equities in the fixed income regressions.

The results for the regression in equation (6) are shown in Table 2.[12] For this regression analysis, the sample period covers Q1 1996 to Q1 2023, based on the availability of the fundamental return drivers. In addition to the results for listed and unlisted real estate returns, we report the results for equity, nominal government bonds, and inflation-protected bonds (TIPS). Including these assets helps us to benchmark the regression coefficients for real estate returns.

The estimated exposures for equity and fixed income are in line with the estimates in NBIM (2021), and can be used to benchmark the results for real estate. One difference relative to the previous results is that the model for equities includes

[9] We include both equity and fixed income news terms in the regression for real estate returns. This choice is motivated by the fact that real estate shares some characteristics of both asset classes.
[10] For an alternative decomposition of returns on listed real estate, see Van Nieuwerburgh (2019).
[11] Inflation shocks were excluded from the original specification in equation (4) by assuming that equities are real assets, which would imply that the loading on inflation is zero.
[12] We estimate the regressions using Bayesian methods as outlined in NBIM (2021). The priors are centered around the theoretical values implied by equations (3) and (4). For real estate, we use priors implied by the decomposition for equities. For drivers that are not included in equations (3) and (4) we assume an uninformative prior centered around zero. For example, this applies to including inflation shocks in the regression for equities and real estate.

TABLE 2 Exposures of equity, fixed income and real estate returns to fundamental return drivers, US data

	EQ	FI	TIPS	Unlisted RE	Listed RE
Expected return	1.14 *	0.39 *	0.72 *	0.76 *	0.78
	(0.36)	(0.09)	(0.15)	(0.33)	(0.42)
Expected cash flows	0.77 *	0.02	0.11	0.48 *	0.96 *
	(0.15)	(0.04)	(0.06)	(0.13)	(0.16)
Expected inflation	−0.89 *	−0.23 *	0.07	0.73 *	0.57
	(0.29)	(0.05)	(0.09)	(0.24)	(0.38)
Monetary policy	−0.52 *	−0.17 *	−0.14 *	−0.42 *	−0.68 *
	(0.11)	(0.02)	(0.04)	(0.09)	(0.12)
Equilibrium real rate	−0.46 *	−0.19 *	−0.16 *	−0.38 *	−0.67 *
	(0.14)	(0.03)	(0.05)	(0.13)	(0.16)
Equity risk premium	−1.23 *	0.04	−0.23 *	−0.5*	−1.2*
	(0.13)	(0.03)	(0.05)	(0.12)	(0.15)
Term premium	0.21	−0.44 *	−0.51 *	−0.37 *	−0.37
	(0.18)	(0.03)	(0.05)	(0.14)	(0.23)
N	108	108	104	108	108
adj. R^2	0.54	0.8	0.57	0.48	0.48

NOTE: The estimates are obtained using a Bayesian estimation. Data are quarterly, and the sample period is Q1 1996 through Q1 2023 for all regressions except TIPS, for which the sample period starts in Q1 1997 due to the availability of TIPS data. "Monetary policy" represents transitory variation in the ex-ante real rate. * indicates significance at $p < 0.05$.

inflation and term premium components. The results indicate that, in our sample period, equities are negatively exposed to inflation shocks, implying that they do not behave as a real asset. A negative exposure to inflation shocks describes an asset that tends to perform poorly in an inflationary environment.[13]

This contrasts with the estimated coefficients on inflation news for real estate. Both real estate segments have a positive exposure to inflation shocks, indicating that these assets provide protection against inflation. In the case of listed real estate, the estimated positive coefficient is not statistically significant. A zero coefficient also describes the behaviour of real assets, however. As a benchmark, the expected inflation coefficient of TIPS is estimated to be close to zero. Listed real estate can be thought of providing inflation protection in a similar manner to TIPS. The positive exposure of unlisted real estate to inflation shocks indicates that this segment provides inflation hedging effects. For both listed and unlisted real estate segments, the degree of inflation protection is substantially higher compared to equities and nominal bonds.[14] Both segments of real estate are more exposed than the equity market to bond-specific drivers, in particular term premium news. Real estate therefore shares similarities with the exposures of TIPS, which are mainly exposed to the real interest rate and term premium news.

The fundamental drivers explain almost half of the quarterly variation in returns on

[13] The negative exposure of equities to inflation is well documented, see e.g. Boudoukh and Richardson (1993); Bekaert and Wang (2010); Katz, Lustig, and Nielsen (2017); Fang, Liu, and Roussanov (2022). Some papers argue that the negative exposure of equities to inflation disappears at long horizons, see e.g. Boudoukh and Richardson (1993).

[14] The literature on inflation-hedging properties of real estate largely concludes that real estate is a better inflation hedge than equities, see e.g. Hoesli, Lizieri, and MacGregor (2008); Muckenhaupt, Hoesli, and Zhu (2023).

unlisted real estate. This is significantly higher than the variation explained by equity and fixed income returns, reported earlier in Table 1.[15] The magnitudes of exposures to cash flows, monetary policy, equilibrium rates and equity risk premiums, are smaller for unlisted real estate relative to the equity market. These coefficients are not highly dispersed, which could imply that constant exposures in the spanning regressions would not be problematic.

Relative to equities and fixed income, however, listed and unlisted real estate have a very different loading on expected inflation. The inflation-hedging properties are more pronounced for unlisted real estate, and imply that the assumption of constant exposures to the fundamental drivers can account for the low R^2 in the spanning regressions for unlisted real estate we saw earlier.[16]

The increase in R^2 is smaller for listed real estate.[17] When regressing listed real estate returns on equity and fixed income returns in the spanning regressions, the equity return variable is highly significant and accounts for essentially all of the explanatory power of the model. As a result, the separation of return drivers on the equity side adds less to the R^2 value.

When separating the different equity and fixed income drivers, we observe fewer differences between listed and unlisted real estate compared to the earlier spanning regressions. The coefficients have the same sign for both real estate segments, and the regressions have similar explanatory power.[18] The returns we use for listed real estate are not adjusted for leverage. Adjusting for leverage leads to marginally lower exposures to equity-related return drivers, and reduce the inflation coefficient of listed real estate closer to zero. The main conclusions from the analysis therefore remain unchanged in this case.

4. Real estate correlations and equity sector exposures

Next, we discuss how our estimates of fundamental driver exposures relate to the real estate return correlations shown earlier in Figure 1. Earlier, we documented an increasing correlation between listed and unlisted real estate as the return horizon increased. The higher exposure of listed real estate to the equity risk premium driver may help to understand this correlation pattern. If risk premium shocks tend to be transitory in nature, the exposure of real estate to this return driver becomes less relevant as the horizon increases. At longer horizons, the common exposures across listed and unlisted real estate are more important drivers of their correlation. As the horizon extends, persistent effects of inflation grow in importance relative to risk premium shocks.

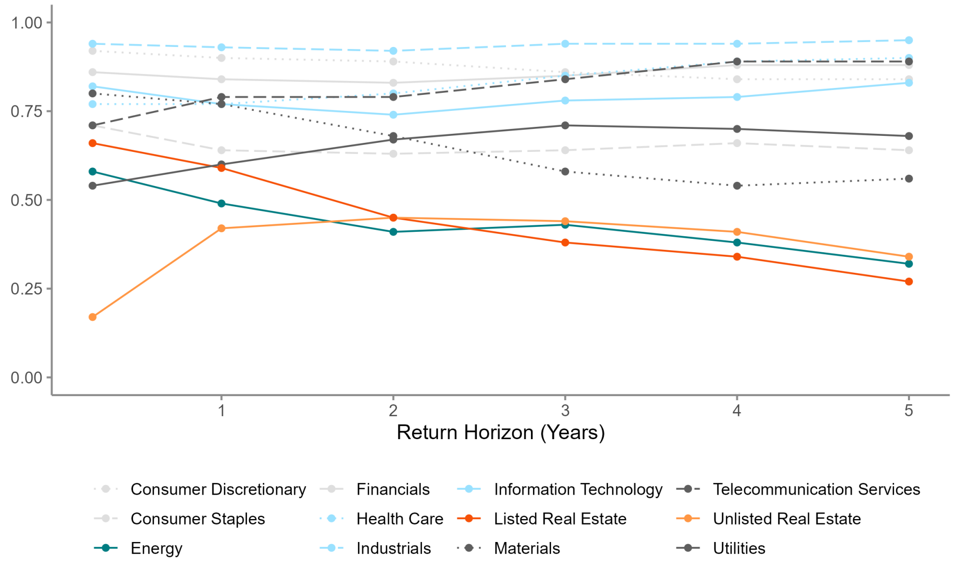
An analogous intuition applies to the higher exposure of listed real estate to monetary policy shocks, which are also more transitory. Similarly, these

[15] This is also the case when aligning the sample period for the spanning regression, which gives an adjusted R^2 value of 0.08 when regressing unlisted real estate on equity and fixed income assets.
[16] In addition, this differential exposure can account for an estimated negative exposure to fixed income returns in the spanning regressions.
[17] When aligning the sample period for the spanning regression, the R^2 value is 0.42.
[18] On a related note, an investor does not need to own the entire real estate index to reap the diversification benefits that real estate provides. This is because the diversification benefits come in the form of inflation hedging properties that are an inherent feature of real estate even at a property level.

mechanisms can explain the high correlation between listed real estate returns and the equity market that declines as the horizon extends. At longer horizons, the differences in exposures to persistent drivers between real estate and the equity market - most notably to inflation news - lead to a lower long-term correlation.

We further explore the patterns of fundamental driver exposures and horizon correlations by extending our analysis to other equity sectors. Figure 2 shows the correlations across horizons between different equity sectors and the overall equity market.

FIGURE 2 Correlations of real estate and equity sectors with equity returns across horizons, US data



NOTE: The chart shows the correlations of returns on listed and unlisted real estate, and equity sector returns with the returns on a broad equity market across horizons. Sample period is Q4 1984 to Q1 2023. Data are at a quarterly frequency.

Unlike real estate, the correlation of most other equity sectors with the broader market tends to be stable across horizons. One exception is the energy sector, where correlation with the equity market declines as the horizon increases, reaching levels similar to listed and unlisted real estate at longer horizons.

For further context, we estimate exposures of equity sectors to fundamental drivers, included in Appendix C. Almost all the other equity sectors have similar fundamental driver exposures to the overall equity market. This is consistent with the relatively stable correlations with sector and market returns over longer horizons. Real estate stands out from equity sectors in terms of its inflation-hedging properties. With a less negative and insignificant beta to inflation shocks, the energy sector also stands out compared to equity sectors, which have exposures to inflation similar to the broader market.

Consistent with our discussion of real estate exposures and correlation patterns, the lower longer-term correlation for the energy sector can also reflect the different exposure to persistent inflation news. It also appears that real estate is more sensitive to term premium news than other sectors, with the exception of utilities. To the extent the exposure to inflation is the key distinguishing feature of real estate and energy sectors relative to other equity sectors, this may account for the low correlation of these sectors with the broad equity market at longer horizons. This would be consistent with the observation that variation in discount rates that is shared across all equity sectors dominates returns at shorter horizons. Variation in returns generated by revisions to expected cash flows, such as inflation, tends to be more permanent and thus more prominent at longer horizons.

5. Revisiting unlisted real estate spanning regressions

In light of our findings for real estate exposures, we next revisit the spanning regressions presented earlier in the note. The above analysis indicates that exposure to expected inflation is likely to be a confounding factor in these regressions, and can account for the low explanatory power for unlisted real estate.

In order to incorporate the different exposures of real estate, we expand the set of assets in the regressions. For spanning regressions, we need to use tradeable assets in our tests so that alpha coefficients can be interpreted as outperformance. Given that returns on nominal government bonds can be attributed to real returns and inflation shocks, we replace the return on nominal government bonds in equation (2) with returns on TIPS and different proxies for inflation. As shown earlier, TIPS returns are not exposed to inflation news, and are therefore useful for testing the diversification potential of real estate. For a direct measure of returns closely related to inflation, we use the Bloomberg 2-year inflation swap index return. Returns on this index have a correlation of 0.70 with the inflation news series, $N_{\pi,t}^{(n)}$, presented earlier. The index series is only available from 2006, however, which shortens the sample period for the regression analysis. Table 3 shows the results for different regression models for unlisted real estate returns.

Column (1) shows the spanning regression model from Section 2, which relates real estate returns to equity and nominal fixed income returns. With a sample period starting in 2006, the estimated coefficients are similar, with a negative fixed income coefficient, and the R^2 is relatively low at 0.13. In column (2), we replace the nominal fixed income variable with returns on TIPS and the inflation swap return measure. This separation improves the fit of the model, where the R^2 increases to 0.23. In line with the findings in the previous section, real estate returns have a significant positive exposure to the inflation swap strategy. The TIPS return coefficient is positive, capturing the real rate and term premium exposures of real estate. The alpha coefficient is lower than the previous spanning regressions, though remains positive. Both the alpha and TIPS coefficients are imprecisely estimated, which is likely attributable to the short sample period.

In column (4), we repeat the regression analysis using a longer sample and a different inflation proxy. We regress unlisted return estate returns on equity and TIPS returns, and the inflation news term $N_{\pi,t}^{(n)}$ from earlier. The inflation news term can be thought of as a crude proxy for an inflation swap strategy available over a

TABLE 3 Mean-variance spanning regressions for unlisted real estate

	(1)	(2)	(3)	(4)
α	0.01	0.01	0.02 *	0.01 *
	(0.01)	(0.01)	(0.01)	(0.005)
β^{EQ}	0.28 *	0.12	0.21 *	0.15 *
	(0.10)	(0.10)	(0.07)	(0.05)
β^{FI}	−0.25		−0.02	
	(0.33)		(0.24)	
β^{TIPS}		0.24		0.31
		(0.30)		(0.18)
β^{SWAP}		1.77 *		
		(0.61)		
β^{INF}				1.23 *
				(0.19)
N	66	66	104	104
Adj. R^2	0.13	0.23	0.08	0.38
Sample Period	2006 - 2023	2006 - 2023	1997 - 2023	1997 - 2023

NOTE: Table shows regressions of de-smoothed NCREIF index returns on different variables. (1) and (3) include equity and nominal fixed income returns separately as independent variables. (2) and (4) include equity, inflation-protected bonds (TIPS) and inflation return proxies. (2) uses the Bloomberg 2-year inflation swap index return series, and (4) uses the inflation news series, $N^{(n)}_{\pi,t}$. Regressions are estimated via OLS. Standard errors are shown in parentheses.* indicates significance at p < 0.05.

longer period, though it is not a tradeable asset. We include this regression to add some indicative additional evidence that isolating the inflation exposure of real estate is useful over a longer sample. In column (3) we again include the results for the regression on equities and nominal Treasuries, to benchmark our findings. The alpha coefficient is lower than the estimate in column (3), though remains statistically different from zero. The estimated coefficients in column (4) are similar to column (2), suggesting the short sample evidence is relevant over a longer sample period. The R^2 increases substantially, however, to 0.38. Again, separating out inflation shocks from fixed income returns leads to a significant improvement in the explanatory power of the regression. This result reinforces the point that real estate is an inflation-hedging asset, which is a key distinguishing feature relative to equities and fixed income.

6. Summary and further discussion

Our analysis indicates that the exposures of real estate to fundamental drivers are distinct from the exposures of diversified equity and fixed income portfolios. Most notably, both segments of real estate hedge inflation risk, while equity and fixed income portfolios are exposed to this risk. Any ability of real estate to protect against inflation shocks is likely to be attractive to a long-term investor. This hedging behaviour supports a case for a strategic allocation to real estate for an investor holding a diversified equity and fixed income portfolio.

Similar to other funds, the Government Pension Fund Global has a delegated mandate that specifies a benchmark index for the fund's investment portfolio. The mandate allows for deviations between the investment portfolio and the benchmark, subject to a tracking error limit, which is currently set at 1.25 percentage points. Tracking error is a measure of risk based on returns relative to the benchmark, and can implicitly encourage a relative return perspective for investment decisions.

Our analysis of real estate returns has taken a total return perspective when evaluating its addition to an equity and fixed income portfolio. The addition of this asset class implicitly requires reductions in the equity or fixed income benchmark weights, often referred to as the 'funding' of the real estate allocation. As discussed in NBIM (2020), the choice of funding can change depending on whether the portfolio problem is viewed from a total or relative return perspective. For example, the optimal funding of real estate that increases the Sharpe ratio of the portfolio could involve reducing both equity and fixed income portfolio weights. NBIM (2020) illustrates that when a manager is evaluated in terms of returns relative to a benchmark, the benchmark portfolio acts as a risk-free asset from which they optimise relative returns and risk. From this perspective, the chosen funding mix for real estate may involve greater risk-taking, for example by only reducing fixed income weights to fund real estate investments.

In general, the allocation and funding of a diversifying asset class should reflect total portfolio considerations. This implies, however, that the tracking error budget will be utilised by a strategy that is not optimised based on relative returns. In these circumstances, there are conflicting incentives when using relative return and risk metrics for a total return-enhancing strategy. This can be thought of as accepting a lower *Information ratio* for relative returns, when aiming for a higher *Sharpe ratio*.

One measure for reducing this conflict between total and relative return perspectives could be to separate real estate assets from tracking error calculations. Since tracking error limits are in place to prevent excessive risk-taking, additional measures would need to be considered for risk management of the real estate portfolio, with the aim of limiting the contribution of real estate to total portfolio risk. As discussed in NBIM (2020), an explicit constraint could be defined when evaluating contributions to total risk. This could also be useful for aligning incentives to the extent that a manager cares about relative returns of real estate beyond its tracking error contribution. Additional measures could include setting ranges for the allocation to real estate, setting targets for the geographic and sectoral diversification, and restricting the debt ratio of the real estate portfolio.

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Appendix A: Data

We use the NCREIF index to represent the private real estate market in the US. The index starts in 1978 and is available at a quarterly frequency. One problem with unlisted real estate returns is that they contain biases resulting from infrequent valuations, smoothing, and appraisals. In addition, any analysis of returns encounters data limitations in terms of relatively short sample histories, combined with limited coverage across geographies or sectors.

To address measurement issues in unlisted real estate market, we de-smooth reported returns following the methodology outlined in Geltner (1991) and Ross and Zisler (1991). The basic idea behind return de-smoothing techniques is to assume that observed returns are weighted averages of current and past actual returns. These techniques estimate these weights and use them to recover actual return estimates, which are otherwise unobservable. We assume that the reported returns, r_t^{rep}, relate to the actual return, r_t, as follows:

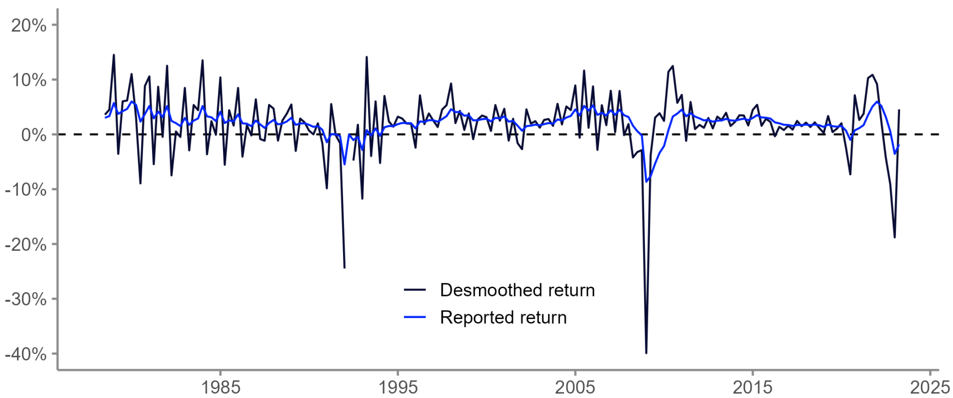
$$r_t^{rep} = (1-\beta)\,r_t + \beta r_{t-1}^{rep}, \tag{7}$$

where β is the smoothing parameter. Assuming that the smoothing parameter is observable, the actual return can be rewritten as a function of reported returns as follows:

$$r_t = \frac{1}{1-\beta} r_t^{rep} + \frac{\beta}{1-\beta} r_{t-1}^{rep} \tag{8}$$

The actual return is a function of the current and the lagged reported return.[19] Using the sample estimate of $\beta = 0.78$, we obtain de-smoothed returns on unlisted real estate which we report in Figure 3. The reported return shows a high degree

FIGURE 3 Reported and de-smoothed returns on unlisted real estate, US data



NOTE: The chart shows reported and de-smoothed returns on unlisted real estate in the US. The US market is represented by the NCREIF index comprising all segments of private real estate. The sample period is Q1 1978 through Q1 2023, quarterly data.

[19] Such a model is referred to as "one-step" de-smoothing. More recent models seek to improve on this simple de-smoothing model, see e.g., Chen and Greenberg (2017); Couts, Goncalves, and Rossi (2020). The improvements tend to be marginal, however.

of persistence, which is removed for the de-smoothed return series.

We represent the listed real estate returns through a tailored index consisting of selected Real Estate Investment Trusts (REITs). The selection of REITs is aimed at representing segments of the real estate market relevant for the Government Pension Fund Global. The REITs universe is built on FactSet security-level data that have broad coverage and long history. For most regions, we are able to construct REIT universe going back to late 1980s. In the case of US REITs, the sample period starts in Q4 1984. The correlation between this return series and the FTSE US NAREIT index is 0.98. In our analysis, we use listed real estate returns that are not adjusted for leverage. As we discuss in the note, adjusting for leverage does not meaningfully change our conclusions. In Table 4, we report descriptive statistics for listed and unlisted real estate returns. For comparability, we consider unlisted real estate returns starting from Q4 1984.

TABLE 4 Returns on unlisted and listed real estate, descriptive statistics

	Unlisted RE	Listed RE
Mean (%, annualised)	7.2	9.0
Volatility (%, annualised)	12.2	21.1
Autocorrelation	−0.02	0.13

NOTE: The table reports the properties of de-smoothed returns on unlisted real estate along-side returns on listed real estate. Sample period is from Q4 1984 to Q1 2023. Start of the sample period is determined by the data availability for listed real estate.

Returns on unlisted real estate are imperfectly correlated with returns on listed real estate in the short run, as shown in Table 5. Over the longer run, however, the correlation increases substantially, reaching over 0.70 at 5-year horizons.

TABLE 5 Correlation of returns on listed and unlisted real estate across horizons

Horizon (quarters)	Unlisted vs. Listed RE	Unlisted RE vs. EQ	Listed RE vs. EQ
1	0.39	0.17	0.66
4	0.66	0.42	0.59
8	0.67	0.45	0.45
12	0.70	0.44	0.38
16	0.73	0.41	0.34
20	0.73	0.34	0.27

NOTE: The table reports the correlation of de-smoothed returns on unlisted real estate with the returns on listed real estate across different horizons. Sample period is from Q4 1984 to Q1 2023.

Appendix B: Spanning Regressions - Sub-samples

Below, we provide regression results for the models presented in Section 2 based on first and second halves of the sample.

TABLE 6 Mean-variance spanning regressions - unlisted real estate

	(1) Early	(2) Early	(1) Late	(1) Late
α	0.02 *	0.02 *	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
β^{B}	−0.07		0.43 *	
	(0.11)		(0.13)	
β^{EQ}		−0.04		0.28 *
		(0.07)		(0.10)
β^{FI}		−0.23		−0.16
		(0.23)		(0.30)
N	77	77	77	77
Adj. R^2	0.00	0.00	0.11	0.11

NOTE: Table shows regressions of de-smoothed returns on the NCREIF index on 70-30 benchmark returns. Model (1) includes a 70-30% equity and fixed income portfolio as the independent variable. Model (2) includes equity and fixed income returns separately as independent variables. Standard errors are shown in parentheses. Sample period is from Q4 1984 to Q4 2003 for 'Early' sample and from Q1 2004 to Q1 2023 for 'Late' sample. * indicates significance at $p < 0.05$.

TABLE 7 Mean-variance spanning regressions - listed real estate

	(1) Early	(2) Early	(1) Late	(1) Late
α	0.01	0.01	−0.02*	−0.02
	(0.01)	(0.01)	(0.01)	(0.01)
β^{B}	0.72 *		1.82 *	
	(0.12)		(0.17)	
β^{EQ}		0.50 *		1.27 *
		(0.08)		(0.13)
β^{FI}		0.33		0.44
		(0.26)		(0.39)
N	77	77	77	77
Adj. R^2	0.32	0.31	0.59	0.59

NOTE: Table shows regressions of returns on REIT portfolio on equity and fixed income assets. Model (1) includes a 70-30% equity and fixed income portfolio as the independent variable. Model (2) includes equity and fixed income returns separately as independent variables. Standard errors are shown in parentheses. Sample period is from Q4 1984 to Q4 2003 for 'Early' sample and from Q1 2004 to Q3 2022 for 'Late' sample. * indicates significance at $p < 0.05$.

Appendix C: Fundamental Drivers - Equity Sectors

TABLE 8 Exposures of equity sectors and real estate returns to fundamental return drivers

	Cons. Discr.	Cons. Staples	Energy	Financials	Health Care	Industrials	Info. tech	Materials	Telco Serv.	Utilities	Unlisted RE	Listed RE
Expected return	1.36 *	1.04 *	1.13 *	0.92 *	1.18 *	1.12 *	1.4*	1.13 *	0.95 *	0.92 *	0.76 *	0.78
	(0.41)	(0.38)	(0.45)	(0.41)	(0.37)	(0.40)	(0.45)	(0.42)	(0.43)	(0.39)	(0.33)	(0.42)
Expected cash flows	0.91 *	0.66 *	0.86 *	0.97 *	0.72 *	0.86 *	0.92 *	0.88 *	0.88 *	0.67 *	0.48 *	0.96 *
	(0.16)	(0.15)	(0.17)	(0.16)	(0.15)	(0.15)	(0.18)	(0.16)	(0.17)	(0.16)	(0.13)	(0.16)
Expected inflation	−1.26 *	−0.65 *	−0.17	−0.36	−0.79 *	−0.76 *	−1.47 *	−0.74 *	−1.54 *	−0.56	0.73 *	0.57
	(0.37)	(0.31)	(0.49)	(0.39)	(0.32)	(0.34)	(0.50)	(0.37)	(0.45)	(0.36)	(0.24)	(0.38)
Monetary policy	−0.63 *	−0.55 *	−0.47 *	−0.54 *	−0.53 *	−0.51 *	−0.85 *	−0.56 *	−0.69 *	−0.67 *	−0.42 *	−0.68 *
	(0.12)	(0.11)	(0.15)	(0.13)	(0.11)	(0.12)	(0.14)	(0.13)	(0.14)	(0.12)	(0.09)	(0.12)
Equilibrium real rate	−0.61 *	−0.57 *	−0.79 *	−0.73 *	−0.59 *	−0.56 *	−0.68 *	−0.63 *	−0.79 *	−0.69 *	−0.38 *	−0.67 *
	(0.15)	(0.15)	(0.17)	(0.15)	(0.14)	(0.15)	(0.17)	(0.15)	(0.16)	(0.15)	(0.13)	(0.16)
Equity risk premium	−1.34 *	−0.86 *	−1.1*	−1.28 *	−0.94 *	−1.26 *	−1.27 *	−1.29 *	−1.08 *	−0.86 *	−0.5*	−1.2*
	(0.15)	(0.14)	(0.17)	(0.15)	(0.14)	(0.14)	(0.17)	(0.15)	(0.16)	(0.15)	(0.12)	(0.15)
Term premium	0.32	−0.14	0.52	0.36	−0.04	0.39	0.48	0.48 *	−0.09	−0.45 *	−0.37 *	−0.37
	(0.22)	(0.19)	(0.28)	(0.22)	(0.20)	(0.21)	(0.28)	(0.23)	(0.25)	(0.21)	(0.14)	(0.23)
N	108	108	108	108	108	108	108	108	108	108	108	108
adj. R^2	0.47	0.36	0.31	0.46	0.38	0.49	0.32	0.47	0.29	0.32	0.48	0.48

NOTE: We construct returns on equity sectors bottom-up using stocks includes in the MSCI USA index classified as large- and mid-cap. The estimates are obtained using a Bayesian estimation. The sample period is Q1 1996 through Q1 2023. “Monetary policy” represents transitory variation in the ex-ante real rate. * indicates significance at $p < 0.05$.