Characteristics of German Real Estate Return Distributions: Evidence from Germany and Comparison to the U.S. and U.K.

Executive Summary. *In contrast to the United States and the United Kingdom, little empirical work exists about the distributional characteristics of appraisal-based real estate returns outside these countries. The purpose of this study is to fill this gap by focusing on Germany. In line with other studies, this paper offers an extensive investigation into the distribution of German real estate returns and compares them with and U.S. and U.K. data in the same period. Furthermore, the co-movements with bonds and stocks are also examined. In the core, the distributional characteristics for German real estate are comparable to that for the U.S. and U.K.*

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Introduction

As empirical research suggests, the characteristics of real estate return distributions are significantly different from those of financial assets, like bonds and stocks (*e.g.*, Sirmans and Sirmans, 1987; Fletcher, 1995; Norman, Sirmans and Benjamin, 1995: Stevenson, 2000; and Benjamin, Sirmans and Zietz, 2001). In general, real estate is seen as an investment vehicle providing a low return variability and downside risk with respect to certain target returns. For example, there is a general belief that real estate is an effective vehicle to protect investors from the risk of inflationary erosion, which is particularly important for long-term pension investments. In addition, there is a clear consensus in the literature that real estate returns exhibit low co-movement and a counter-cyclical performance with bond and stock markets. Furthermore, as Newell and Webb (1996) pointed out, real estate returns exhibit significant positive serial correlation, which is in marked contrast to the generally insignificant autocorrelation structure in the stock and bond markets. Due to these specific risk and return characteristics, property investments were shown to be beneficial in reducing the risk, as well as in diversifying international mixed-asset portfolios.

Most of the empirical work towards the estimation of the return generating process of real estate investments has focused on analyzing time series of return indices for the United States and the

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United Kingdom. In particular, the indices developed by the National Council of Real Estate Investment Fiduciaries (NCREIF) for the U.S., and by the Investment Property Databank (IPD) for the U.K. are used extensively throughout the literature. Both types of indices are constructed by aggregating the return of individual income-producing commercial properties held by institutional investors, such as mutual funds, insurance companies and pension funds. To estimate the capital gains portion of the total return, it is common practice to use appraisal values for individual properties. There is a general belief in the literature that using appraised values in conjunction with, and in aggregation across, a number of properties to construct an index may lead to a smoothing effect, which understates the volatility of the underlying true process of real estate returns (see, among others, Ross and Zisler, 1991; Geltner, 1989, 1993; and Brown and Matysiak, 2000).

In contrast to the U.S. and the U.K., there is comparatively little empirical work on the distributional characteristics of real estate returns outside these countries. This is mainly due to the poor availability of adequate time series. The purpose of this study is to fill this gap by focusing the characteristics of real estate return distributions for Germany. In line with other studies concerning the characteristics of appraisal-based real estate return distributions (*e.g.*, Myer and Webb, 1994; Young, 1994; Young and Graff, 1995; and Graff, Harrington and Young, 1997), this study conduced a rigorous and extensive investigation into the distribution of German commercial real estate returns and compared them with U.K. and U.S. data over the same period. Furthermore, the comovements with return series of financial assets (*i.e.*, bonds and stocks) have also been examined.

This paper is organized into three parts. First there is a discussion of a methodology for generating an un-leveraged appraisal-based real estate index, based on publicly available information about German open-ended real estate funds. Second, univariate and multivariate analyses are discussed for statistical properties of the commercial real estate market's return distributions in the U.K., U.S. and Germany. Finally, the paper presents concluding comments.

Appraisal-based Indices for Germany

In contrast to the U.K. and U.S., appraisal-based indices with a comparably long history are not available for the German market. Alongside some smaller providers, the Deutsche Immobilien Datenbank (DID) was founded in 1998 as a subsidiary of the Investment Property Databank (IPD). The DID mainly collects data from German insurance companies and open-ended real estate investment funds. The main commercial property index of the DID is the 'Deutscher Immobilien Index' (DIX), a value-weighted total return index. According to DID, at the end of 2002 the DIX comprised of 2,380 properties (apartment, retail and office) with an appraised value of approximately ≠35 billion, covering about 30% of the total institutional real estate market in Germany. The major drawback of the DIX is its relatively short index history, going back only to 1996 on a year-to-year basis (*i.e.*, actually eight annual returns). It is obvious that with such a limited database, a time series analysis to diagnose the distributional characteristics of German real estate returns is problematic.

An alternative approach to derive an appraisal-based real estate index for Germany is suggested by Maurer and Stephan (1995) and updated by Maurer, Sebastian and Stephan (2000). This approach suggests the use of publicly available information from German open-ended real estate funds. German open-ended real estate funds are a core group of institutional investors, and have operated for over four decades on the German real estate market for retail and office properties. The funds have to publish daily redemption prices for their shares. Based on the net asset value principle, the redemption price is found by the actual market value of all assets held by the fund, less any fund liability, divided by the number of issued units. Aside from properties, the assets of the funds consist of fixed income instruments (bonds, T-bills and cash). While financial assets are valued according to their current market prices, the market value of the funds' property portfolio relies on appraisals.

Of course, daily appraisals are not available for real estate. Instead, due to legal requirements, the value for a property held by a real estate mutual fund must be reappraised only once a year. The reevaluation of each property must be confirmed by a committee of independent appraisers, which convenes in general two times a year. Frequency and date of the meeting may be different for each fund. Additionally, every six months, aggregated information about the composition of the mutual fund's wealth must be published. The exact publication date depends on the accounting period of the fund, which differs in several cases from the calendar year.[1]

Due to legal requirements, German real estate funds have to invest a minimum of 51% of the wealth under management in properties. In practice, they hold considerable portions of interest bearing assets, such as deposits and bonds in their portfolios. Therefore, the return characteristics of the fund units do not represent a pure property portfolio, but rather a multi-asset portfolio consisting of cash, government bonds with different durations and properties.

Maurer, Sebastian and Stephan (2000) suggest the following methodology to adjust the total return for the portion that is non-real estate induced. Let $r_{i,t}^{\text{fund}} = P_{i,t}/P_{i,t-1} - 1$ be the total return on a unit of fund $i = 1, \ldots, N$ over the period t calculated from the redemption prices (adjusted for dividends, splits and net of management fees) $P_{i,t}$ at time t. Dependent on the remaining time to maturity, three classes of interest-bearing assets are defined: money market deposits (cash), and interest bearing assets with, at most (A1) and more than (A2), four years remaining time to maturity. Assume that the returns over the period t on the predefined interest bearing asset classes held by a fund, $r_{i,t}^{\text{Cash}}$, $r_{i,t}^{A1}$ and $r_{i,t}^{A2}$, are (approximately) equal to the returns on the corresponding money and capital market segments with the same remaining time to maturity.[2] Then, the component of the total return that is attributed to the funds property portfolio can be approximated by:

$$r_{i,t}^{\text{real estate}} = \frac{(r_{i,t}^{\text{fund}} - r_t^{\text{Cash}} \cdot x_{i,t}^{\text{Cash}} - r_t^{A1} \cdot x_{i,t}^{A1} - r_t^{A2} \cdot x_{i,t}^{A2})}{x_{i,t}^{\text{real estate}}}. \quad (1)$$

Here $x_{i,t}^{\text{Cash}}$, $x_{i,t}^{A1}$ and $x_{i,t}^{A2}$ represent the proportion of total wealth of the fund invested in the different interest-bearing asset classes at the beginning of period t, while $x_{i,t}^{\text{real estate}}$ is the weight invested in properties. These investment weights could be received from the semi-annual reports of the various funds. Through the value-weighted aggregation of the calculated appraisal-based returns, over all $i = 1, \ldots, N$ real estate mutual funds under consideration, one arrives at the total return, $r_t^{\text{real estate}}$ of a broad appraisal-based commercial real estate index:

$$r_t^{\text{real estate}} = \frac{\sum_{i=1}^{N} (r_{i,t}^{\text{real estate}} \cdot L_{i,t})}{\sum_{i=1}^{N} L_{i,t}}. \quad (2)$$

In this equation $L_{i,t}$ is the fraction of the aggregated appraisal-based real estate wealth of all companies under consideration, held by fund i at the beginning of period t. By applying this methodology, Maurer, Sebastian and Stephan (2000) generated an (unleveraged) appraisal-based real estate total return index for Germany on a monthly basis, named IMMEX.

As only a part of all properties is reappraised each month, the IMMEX is not a true monthly index—unlike the IPD monthly index for the U.K. In effect, comparable to the NPI for the U.S., the IMMEX represents an annual index that is partly updated monthly. The IMMEX is therefore, similar to the NPI, affected by smoothing problems on different levels. The primary source of smoothing is the appraisal process itself.[3] Geltner (1993a) shows that aggregation in an index leads to further smoothing, in addition to smoothing introduced by the appraisal process. As Fisher, Geltner and Webb (1994) point out for the NPI, the practice of reappraising properties only once a year and maintaining the last determined value each other quarter causes further smoothing. The same effect for monthly frequencies is found for the IMMEX.

The IMMEX covers a time period starting in January 1980, providing a sufficient history for most applications. All open-end funds are included twelve months after their creation with the exception of funds having an investment focus outside Germany. In December 2002, the IMMEX consisted of 17 German real estate investment funds with properties under management of approximately €43 billion, representing about 36% of the estimated value of all real estate held by institutional investors. The major drawback of the IMMEX is that no distinction is possible between property type subgroups (apartment, office and retail properties) or location. As the German real estate investment funds essentially hold commercial properties, the index can be regarded as a representation of an investment in German commercial properties. But despite these imperfections, up until today the IMMEX is the only broad commercial real estate index available for Germany with a sufficiently long history.

Empirical Analyses

Data

For the empirical analyses, the following time series covering the time period January 1987 to December 2002 were used. To represent the stock and bond markets, the MSCI monthly gross indices and the Salmon Brothers Government Bond Indices were employed. All these indices are value-weighted, based on market capitalization and adjusted for capital gains, as well as dividends and coupon payments (on a pre-tax basis). As a proxy for the U.K., U.S. and German real estate market, the IPD monthly index, NPI and IMMEX were used. The main focus is on quarterly and yearly returns, which were calculated from the respective index time series. All index returns were calculated in local currency.[4] To analyze real returns, inflation rates were calculated from the respective national consumer price indices.

Univariate Considerations

Analysis of Nominal Returns. Exhibit 1 displays the quarterly nominal returns for the German, U.S. and U.K. real estate market over the 1987–2002 time period. The German return history is characterized by returns on a relatively high level in the late 1980s until the mid-1990s, followed by returns on a relatively lower level in the recent history. Similar return time-patterns are also evident from the U.S. and U.K. real estate markets. Furthermore, it is also apparent that German real estate returns vary in a considerably smaller range and around a lower mean than the returns from the U.S. and U.K. real estate markets.

Exhibit 2 presents some fundamental distributional statistics of the three real estate markets, on a quarterly basis. As expected, clear differences regarding mean returns and standard deviations from the different real estate markets are observable. While the U.K. real estate market exhibits the highest mean return and standard deviation, for the U.S. real estate market both moments are clearly lower. The German real estate returns show a somewhat lower mean return than the U.S., however the German series exhibits a variability that is much lower than for both other markets.

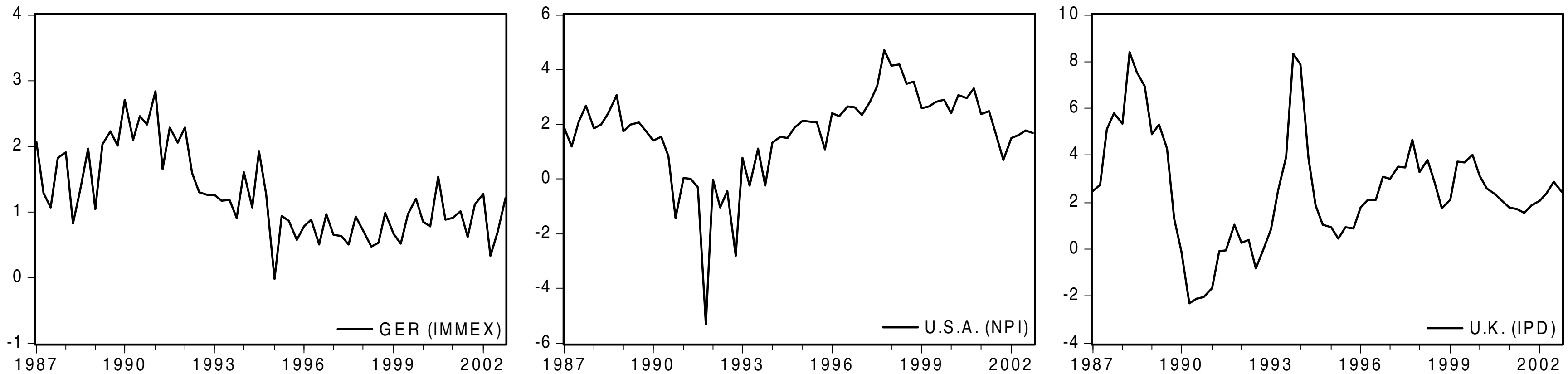
This is also portrayed by the reported coefficients of variation (CV), which provide a standardization of the volatility measure. While the U.S. and U.K. real estate markets provide about 1 unit of standard deviation per unit of mean return, the German market provides only about 0.5 units of standard deviation per unit of mean return. This again highlights the relatively low fluctuations of the German real estate returns.

Considering the shape of the return distributions, the picture for the respective real estate markets is mixed. The U.K. real estate market shows neither significant skewness nor significant excess kurtosis. On the other hand, German real estate returns exhibit a significant positive skewness, indicating a long right tail. Contrastingly, the U.S. real estate market is skewed significantly leftward and considerably leptokurtic, which is in line with the results reported by Myer and Webb (1994). Therefore, at least in the case of German and U.S. real estate, it is questionable if the often made assumption of (symmetrical) normally distributed returns is satisfied.

The question if real estate returns are normally distributed is important for application of modern portfolio theory to real estate investments. For example, the classical mean-variance portfolio analysis of Markowitz requires (inter alii) normal distributed returns to be consistent to rational decision making within the expected utility theory framework. Several studies have addressed this

Exhibit 1

Quarterly Nominal Returns on German, U.S. and U.K. Real Estate Markets (Q1/1987–Q4/2002)



Note: Returns in percentages per three months.

Exhibit 2
Selected Distributional Statistics for Quarterly Nominal Returns on Real Estate Markets (Q1/1987–Q4/2002)

	Mean	Std. Dev.	CV	Width	Skewness	Kurtosis	Normality
GER	1.25	0.64	0.51	2.84	**0.60**	−0.44	*
U.S.	1.67	1.63	0.98	10.03	**−1.60**	**4.51**	*
U.K.	2.53	2.38	0.94	10.72	0.41	0.32	—

Notes: Mean, Std. Dev., CV and Width are the arithmetic mean (in %), the empirical standard deviation (in %), the empirical coefficient of variation and the empirical absolute difference between maximum and minimum return (in % points) for the respective nominal return time series. Skewness and kurtosis denote the empirical skewness and excess kurtosis. Boldface numbers are different from zero at least at the 5% level of significance. For testing the normality assumption for the respective series, Jarque/Bera, Anderson/Darling and Shapiro/Wilk tests were applied. A "*" indicates that at least one of the three tests was able to reject the null of normality at least at the 5% level.

Exhibit 3
Selected Distributional Statistics for Yearly Nominal Returns on Real Estate Markets (1987–2002)

	Mean	Std. Dev.	CV	Width	Skewness	Kurtosis	Normality
GER	5.12	2.34	0.46	7.56	0.68	−0.64	—
U.S.	6.95	5.99	0.86	21.83	−0.71	−0.07	—
U.K.	10.74	8.96	0.83	37.74	0.13	0.37	—

Notes: See Exhibit 2. Significance level for all tests is 10%.

question. For example, Miles and McCue (1984), Hartzell, Hekman and Miles (1986), Myer and Webb (1994), Young and Graff (1995), Byrne and Lee (1997), Graff, Harrington and Young (1997) and Maitland-Smith and Brooks (1999) provide empirical evidence for U.S., U.K. and Australian real estate index returns of being non-normal. To formally test for normality, especially in the German series, three normality tests were applied: the Jarque/Bera test, the Anderson/Darling test and the Shapiro/Wilk test. Therefore, in Exhibit 2, the series in which at least one of these tests could reject the null hypothesis of normality at the 5% level of significance, are marked with a "*". According to these tests, the quarterly return series for the German and U.S. real estate markets differ significantly from normality, yet a rejection of the normality hypothesis at reasonable levels of significance was not possible for quarterly U.K. real estate index returns.

As mentioned in Kallberg, Liu and Greig (1996) quarterly appraisal-based real estate returns and inferences about these returns can be distorted by seasonality introduced by appraisals. Considering annual returns can reduce this problem. To examine the effect of period length on the distributional shape, the annual distributional statistics are presented in Exhibit 3. In contrast to the findings for quarterly returns, none of the annual return time-series shows significant skewness or excess kurtosis. Consequently, the inferences on normality are also altered. The null hypothesis of normality for yearly returns could not be rejected for any of the real estate markets at the 10% significance level.

Exhibit 4 presents autocorrelation coefficients and stationarity tests for the quarterly and yearly time series. Considering quarterly returns, it is remarkable, that there is significant positive autocorrelation for several lags observable for all real estate markets under consideration. This is also confirmed by the Box/Lijung Q-test, through which the rejection of the null hypothesis, with no autocorrelation up to lag 4 could be rejected for all real estate series at the 5% significance level. Interestingly, the U.K. real estate returns exhibit very high autocorrelation at lag 1 and significantly decreasing autocorrelation for higher lags. Conversely, the

Exhibit 4
Further Distributional Statistics and Tests for Quarterly and Yearly Nominal Real Estate Market Returns (Q1/1987–Q4/2002)

	AC 1	AC 2	AC 3	AC 4	Q (p)	ADF (p)	KPSS (q)
Panel A: Quarterly Returns							
GER	**0.64**	**0.61**	**0.70**	**0.60**	112.14 (0.00)	−2.00 (0.59)	0.12 (0.15)
U.S.	**0.69**	**0.71**	**0.60**	**0.71**	126.21 (0.00)	−1.94 (0.62)	0.12 (0.15)
U.K.	**0.86**	**0.64**	**0.40**	0.17	89.91 (0.00)	−2.96 (0.15)	0.08 (0.15)
Panel B: Yearly Returns							
GER	**0.76**	**0.55**	0.34	0.11	19.98 (0.00)	−1.94 (0.59)	0.09 (0.15)
U.S.	**0.78**	0.40	0.03	−0.21	15.09 (0.00)	−3.22 (0.12)	0.09 (0.15)
U.K.	0.35	−0.33	−0.41	−0.21	4.56 (0.10)	—	—

Notes: AC 1-4 is the empirical autocorrelation coefficients for lags 1, 2, 3 and 4. Boldface numbers are significantly different from zero at least at the 5% level. Q denotes the Box/Lijung Q-test statistic up to lag 4 (quarterly returns) and lag 2 (yearly returns), ADF the test statistic from the (augmented) Dickey/Fuller test for the null of non-stationarity of the underlying time-series. p (in parentheses) is the respective marginal significance level. KPSS is the test statistic from the Kwiatkowski/Phillips/Schmidt/Shin test with the null hypothesis of stationarity, and q (in parentheses) is the critical value of the KPSS test for a significance level of 5% (a value of the test statistic greater than q indicates a rejection of the null at the 5% level).

German and U.S. real estate returns show, besides high first-order autocorrelations, also persistent, i.e. non-decreasing autocorrelations for higher lags. For yearly returns, significant first-order autocorrelation for German and U.S. real estate returns is still observable. On the other hand, the U.K. real estate market no longer shows significant autocorrelation.

It should be mentioned that due to the apparent autocorrelation, the inferences about skewness, excess kurtosis and normality for the unconditional distributions presented above should be interpreted carefully.

Given the strong evidence for temporal dependencies in German, U.S. and U.K. real estate returns, the question if these series are stationary arise. For further analysis, two unit root tests for examining whether the series are stationary were applied: an (augmented) Dickey/Fuller (ADF) test, with the null that the series under consideration has a unit root, and a Kwiatkowski/Phillips/Schmidt/Shin (KPSS) test, with the null hypothesis that the series under consideration has no unit root. In each case the applied unit root tests were neither able to reject the null hypothesis of non-stationarity, nor reject the null of stationarity at reasonable significance levels. Although the quarterly German, U.S. and U.K. real estate returns exhibit strong evidence for temporal dependencies, these series appear to be at least stationary.

The apparent autocorrelation in nominal real estate returns is often attributed to smoothing effects in appraisal-based indices, resulting from the appraisal process and temporal aggregation effects in index construction. To address this issue, the next section analyzes unsmoothed real estate returns.

Analysis of Unsmoothed Returns. There is a wide consensus in the literature that returns calculated from appraisal-based real estate indices incorrectly reflect (unobservable) actual returns of the underlying real estate market. The use of previous valuations in generating present valuations (*e.g.*, Geltner, MacGregor and Schwann, 2003) and temporal aggregation of valuations, which occur mostly once a year and for different properties in different months (*e.g.*, Geltner, 1993a) induce autocorrelation and smoothing in the appraisal-based real estate indices. An often-mentioned effect of appraisal smoothing is the underestimation of the true real estate's volatility through the use of an appraisal-based series. Additional evidence is provided by Fisher, Miles and Webb (1999) and Fisher, Gatzlaff, Geltner and Haurin (2003) who find that real estate's volatility, estimated from transaction-based indices, is substantially higher than those estimated from appraisal-based indices.

Blundell and Ward (1987), Firstenberg, Ross and Zisler (1988), Ross and Zisler (1991), Fisher, Geltner and Webb (1994), Geltner (1993b) and Barkham and Geltner (1994), among others suggested different procedures to correct for appraisal smoothing in order to recover "true" real estate market performance.[5] However, the choice of an appropriate unsmoothing procedure is always problematic, due to the assumptions about the appraisal process, index construction process and market (in)efficiency, which the different procedures rely on.

In this section, the Blundell and Ward (1987) and Firstenberg, Ross and Zisler (1988) unsmoothing methodologies, respectively, were applied. Both methodologies are based on the assumption of, at least, weak information efficient real estate markets (*i.e.*, the respective "true" real estate return time series should not be serially correlated). However, the hypothesis of weak-form market efficiency for real estate markets is challenged by more recent research (*e.g.*, Geltner, 1993b). On the other hand, procedures that do not make the assumption of efficient real estate markets need other critical assumptions, like volatility constraints, to be valid (*e.g.*, Lai and Wang, 1998). Furthermore, even if making the assumption of weakly efficient real estate markets, the procedures employed here should be able to correct for a large fraction of appraisal smoothing effects.

Formally, the unsmoothing procedures applied here consist of a linear transformation of the residuals from an AR process that was fitted to the original series. In other words, the procedures are based on a correction of the original real estate series for serial correlation, in order to arrive at the "true," not serial correlated series. For this purpose, a look at the serial correlation structure of the original series is essential. As was shown, quarterly U.K. real estate returns exhibit very high first-order serial correlation, which is evenly decreasing for higher lags, suggesting an AR(1)-structure. Therefore, the method of Blundell and Ward (1987), which is based on an AR(1)-model, was employed for the U.K. In contrast, the German and U.S. real estate markets exhibit persistent serial correlation up to lag 4, suggesting a higher order autoregressive structure. This higher order serial correlation can be the result of seasonality effects (*e.g.*, Geltner, 1993b). Consequently, for Germany and the U.S., the method of Firstenberg, Ross and Zisler (1988), which assumes an AR(1,2,3,4)-process, was applied. Since for yearly returns the predominant autocorrelation is at lag 1, the Blundell and Ward (1987) methodology was used for unsmoothing all yearly series.

Exhibit 5 displays the standard deviations from the unsmoothed and original real estate series. After correcting for smoothing, real estate returns for all three countries exhibit much more volatility than the original series. The standard deviation for unsmoothed quarterly German, U.S. and U.K. real

Exhibit 5

Mean and Standard Deviation for Quarterly and Yearly Unsmoothed Nominal Returns on Real Estate Markets (Q1/1987–Q4/2002)

	Std. Dev. Unsmoothed	Std. Dev. Original	Factor
Panel A: Quarterly Returns			
GER	3.85	0.64	6.02
U.S.	5.59	1.63	3.43
U.K.	7.66	2.38	3.22
Panel B: Yearly Returns			
GER	6.54	2.34	2.79
U.S.	13.36	5.99	2.23
U.K.	13.10	8.96	1.46

Notes: See Exhibit 2. Factor is the ratio between the standard deviation from the unsmoothed series and the original series.

estate returns is about 6.02, 3.43 and 3.22 times higher than for the original series. As in the case of original returns, German quarterly real estate returns display less than half the volatility of the U.S. and U.K. real estate returns. For yearly returns, through unsmoothing, standard deviation grows by a factor of 2.79, 2.23 and 1.46 for Germany, the U.S. and U.K respectively.

As mentioned earlier the Blundell and Ward (1987) and Firstenberg Ross and Zisler (1988) unsmoothing methodologies correct for serial correlation in the original series to extract the "true" not serial correlated returns. Therefore, Exhibit 6 displays serial correlation coefficients for the unsmoothed series. As can be seen after unsmoothing, the quarterly and yearly series exhibit almost no significant serial correlation anymore. Thus, the use of the Firstenberg, Ross and Zisler (1988) method for Germany and the U.S. and the use of the Blundell and Ward (1987) procedure for the U.K. seem to be suitable to recover "true" real estate market returns on the assumption of efficient real estate markets.

From Exhibit 6, it is also evident that the distributional characteristics of the unsmoothed (conditional) series relative to the original (unconditional) series are altered to some extent. While the null of normally distributed German real estate returns could be rejected for the original quarterly nominal returns, this is not possible anymore for unsmoothed returns. The opposite results for the U.K., while for the U.S. (and in line with Myer and Webb, 1994) the null-hypothesis of normality can be rejected for the unconditional as well as the (unsmoothed) conditional series.

Myer and Webb (1994) suggest that the serial correlation in the appraisal-based real estate time series could be a consequence of systematic changing return expectations, due to changes in inflation. Moreover, through inflation-indexed lease contracts, inflation could have a contemporaneous or lagged influence on rents. Because inflation rates are auto-correlated, this could introduce serial correlation into the real estate series. To investigate this item, the next section considers the distributional characteristics of real returns.

Analysis of Real Returns. There is an extensive literature addressing the relationship between inflation and real estate returns. Fama and Schwert (1977) find that U.S. private residential real estate adjusts completely for expected inflation. Hartzell, Hekman and Miles (1987) consider U.S. commercial real estate as a hedge against expected and unexpected inflation. Furthermore, Gatzlaff (1994) investigates excess returns on U.S. residential real estate, and suggests that autocorrelation in residential real estate returns is due to the influence of expected inflation on real estate returns, if adaptive inflation expectations are assumed. According to capital market theory, many studies on the relationship between real estate returns and inflation disaggregate inflation in expected and unexpected inflation. However, the focus here is on actual inflation (*i.e.*, the compounded effect of expected and unexpected inflation). Considering real returns (*i.e.*, nominal returns adjusted for actual inflation) should, at least partly, reduce the effects of inflation on nominal returns.

In Exhibit 7, the contemporaneous and cross-correlations are tabulated between German, U.S. and U.K. real and nominal real estate returns, as well as the corresponding inflation rates. German real estate returns exhibit clear positive contemporaneous and cross correlations with German inflation rates. As mentioned earlier, this could be an effect of inflation-indexed lease contracts. The use of such contracts for commercial properties is common practice in Germany. Conversely, for the U.K. and U.S. real estate markets, no significant contemporaneous correlations with actual inflation rates were found. However, U.K. real estate shows significant but negative cross-correlations with the inflation rate three and four quarters before.

On the other hand, after deflating, a significant negative contemporaneous relationship between the return series and inflation for all countries appears to exist. It seems that there is, at least, no strong contemporaneous effect of aggregated expected and unexpected inflation on nominal U.K. and U.S. real estate returns. This also explains the significant (negative) correlation for these two real estate markets after deflating, which is also apparent for some of the cross-correlation coefficients.[6] Nonetheless, it should be emphasized

Exhibit 6
Distributional Statistics and Tests for Unsmoothed Quarterly and Yearly Nominal Returns on Real Estate (Q1/1987–4/2002)

	Skewness	Kurtosis	Normality	AC 1	AC 2	AC 3	AC 4	Q (p)	ADF (p)	KPSS (5%)
Panel A: Quarterly Returns										
GER	−0.19	0.68	—	0.00	0.10	0.05	0.07	1.11 (0.89)	−7.64 (0.00)	0.21 (0.46)
U.S.	**−2.28**	**9.23**	*	0.20	0.16	0.19	**0.37**	16.12 (0.00)	−6.19 (0.00)	0.21 (0.46)
U.K.	**0.69**	**3.59**	*	0.27	0.11	−0.14	−0.10	8.24 (0.08)	−5.57 (0.00)	0.07 (0.46)
Panel B: Yearly Returns										
GER	−0.02	0.73	—	0.02	0.01	−0.10	−0.01	0.23 (0.99)	—	0.18 (0.46)
U.S.	−0.88	0.25	—	0.45	0.08	−0.22	−0.14	5.52 (0.24)	—	0.14 (0.46)
U.K.	0.01	0.92	—	0.06	−0.42	−0.20	−0.14	4.74 (0.32)	—	0.29 (0.46)

Notes: See Exhibits 3 and 4.

Exhibit 7
Contemporaneous and Cross-Correlation between Quarterly Real Estate Returns and Inflation (Q1/1987–Q4/2002)

	Inflation Rates				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Panel A: Nominal Returns					
GER	**0.39**	**0.25**	**0.25**	0.22	0.11
U.S.	−0.05	−0.14	−0.12	−0.24	−0.19
U.K.	−0.02	−0.14	−0.21	**−0.29**	**−0.32**
Panel B: Real Return					
GER	**−0.43**	0.02	0.20	0.03	**−0.32**
U.S.	**−0.35**	−0.13	−0.17	−0.24	**−0.32**
U.K.	**−0.35**	−0.24	−0.24	**−0.35**	**−0.50**

Notes: Correlation coefficients that proved to be different from zero, at least at the 5% level, are in boldface types.

again that a significant interrelationship between inflation and German nominal real estate returns appears.

These findings are also confirmed through the distributional statistics as presented in Exhibit 8. There are mostly only small differences between skewness, excess kurtosis, stationarity inferences, and especially autocorrelation structure for real returns and nominal returns for the U.S. and U.K. These results are in line with the findings by Myer and Webb (1994) for the U.S. real estate market. However, considerable changes—especially in the autocorrelation structure—appear for the German real estate market.

As shown in Exhibit 4, quarterly nominal German real estate returns show highly positive and persistent autocorrelation for at least four lags. According to Exhibit 8, after deflating, the German real estate series still exhibits significant autocorrelation for three lags, however on a considerably lower level. Additionally, contrasting the findings for nominal returns, after deflating, the ADF test was able to reject the null of a unit root approximately at a minimal level of significance for the German and U.S. real estate markets.

Exhibit 8 also includes the already considered statistics on a yearly basis. As in the case of deflated quarterly returns, the results are hardly altered, relative to the yearly nominal returns. Again, the

Exhibit 8
Distributional Statistics and Tests for Quarterly and Yearly Real Returns on Real Estate Markets (Q1/1987–Q4/2002)

	Skewness	Kurtosis	Normality	AC 1	AC 2	AC 3	AC 4	Q (p)	ADF (p)	KPSS (5%)
Panel A: Quarterly Returns										
GER	−0.41	1.14	**—**	**0.24**	0.11	**0.29**	**0.38**	20.54 (0.00)	−6.89 (0.00)	0.18 (0.15)
U.S.	**−1.00**	**2.62**	*	**0.69**	**0.68**	**0.62**	**0.72**	126.18 (0.00)	−2.47 (0.00)	0.12 (0.15)
U.K.	−0.25	**1.43**	*	**0.81**	**0.57**	**0.38**	0.21	79.21 (0.00)	−3.07 (0.12)	0.08 (0.15)
Panel B: Yearly Returns										
GER	0.77	0.21	—	0.38	0.48	0.14	0.16	7.54 (0.02)	—	—
U.S.	−0.42	−0.33	*	**0.81**	0.48	0.16	−0.09	(17.52) (0.00	—	0.09 (0.15)
U.K.	−0.71	0.62	*	0.35	−0.30	−0.41	−0.20	4.24 (1.20)	—	—

Notes: See Exhibits 3 and 4.

exception is the German real estate market, which exhibits a fundamental change in its autocorrelation structure through deflating. After deflating, German yearly real estate returns no longer appear to be correlated in time.

For the purpose of completeness, Exhibit 9 includes mean returns and standard deviations for the deflated quarterly and yearly return series. Comparing these statistics with the corresponding statistics based on nominal returns (Exhibits 2 and 3), there are only slight differences, not surprisingly, with the exception of the mean returns, which are considerably smaller for all series through deflating.

All in all, the analysis suggests that there is little influence of actual inflation on U.S. and U.K. appraisal-based real estate index returns. Contrastingly, German real estate returns show clear interrelationships with actual German inflation rates.

Multivariate Considerations

Contemporaneous Correlations. The presence and structure of return interrelationships between national and international asset markets is of crucial importance regarding asset allocation decisions (*e.g.*, Maurer and Reiner, 2002). The lower the values of the elements in the correlation matrix are,

Exhibit 9
Selected Distributional Statistics for Quarterly and Yearly Real Returns on Real Estate Markets (Q1/1987–Q4/2002)

	Mean	Std. Dev.	CV	Width	Mean	Std. Dev.	CV	Width	SDR
GER	0.69	0.65	0.93	3.70	2.80	1.76	0.63	6.67	2.71
U.S.	0.89	1.72	1.93	10.45	3.73	6.24	1.67	22.81	3.63
U.K.	1.60	2.50	1.56	14.73	6.80	8.81	1.30	37.41	3.52

Notes: See Exhibit 3.

the higher the potential risk diversification benefits in a multi-asset portfolio may be. This and the following section are dedicated to these items. Common wisdom suggests that the higher the integration of international asset markets, the stronger their return co-movements are. One important measure of overall return interdependency is Pearson's Product Moment Correlation Coefficient, which measures the degree of linear interdependency. Exhibit 10 shows the short-term correlation matrix for the considered international asset markets based on quarterly nominal returns.

Not surprisingly, the intra-asset class correlation for the stock and bond markets is highly positive and in each case significantly different from zero.[7] These high correlations can be attributed to the high degree of integration of these major asset markets. Also, the real estate markets show intra-asset class correlation coefficients, which are, in part, significantly different from zero. While the correlation between the U.K. and U.S. real estate markets is considerably positive yet insignificant, the correlation between these two markets versus the German real estate market is considerably negative and, additionally, is insignificant between Germany and the U.S. Different international properties, and thus also international real estate markets, are not close substitutes for each other. This, in turn, suggests that the returns of these asset markets should be independent. However, Goetzmann and Rouwenhorst (1999) show that national real estate returns are related to national GDP and, through the integration of national economies, GDPs are internationally related. They provide empirical evidence that significant correlation among international real estate returns can be at least partly attributed to interrelations between the economic growths (GDP) of different countries.

Inter-asset class correlations between the different real estate markets and the stock markets are, in almost all cases, close to zero and in no case significantly statistically different from zero. The average coefficient of correlation is 0.01. On the other hand, each real estate market mostly exhibits considerably negative correlations with every bond market, even when these correlations are in most cases not significantly different from zero. The average correlation is −0.14.

Exhibit 10
Contemporaneous Correlation Coefficients on a Quarterly Nominal Basis (Q1/1987–Q4/2002)

	Real Estate Markets			Bond Markets			Stock Markets		
	GER	U.S.	U.K.	GER	U.S.	U.K.	GER	U.S.	U.K.
Panel A: Real Estate Markets									
GER	1								
U.S.	**−0.45**	1							
U.K.	−0.27	0.38	1						
Panel B: Bond Markets									
GER	−0.14	−0.21	−0.26	1					
U.S.	−0.02	−0.10	−0.19	**0.64**	1				
U.K.	0.02	−0.15	**−0.25**	**0.76**	**0.56**	1			
Panel C: Stock Markets									
GER	0.02	0.05	0.17	**−0.26**	**−0.38**	−0.16	1		
U.S.	0.08	−0.06	−0.06	−0.03	−0.19	0.13	**0.69**	1	
U.K.	0.05	−0.07	−0.05	−0.04	**−0.28**	0.23	**0.69**	**0.84**	1

Notes: Correlation coefficients that proved to be different from zero at least at the 5% level are in boldface type. *t*-tests have been corrected for the effect of serial correlation using the procedure of *Dawdy* and *Matalas* (1964). Additional tests showed that the effect of non-normality is not crucial here.

To address the intertemporal stability of correlations between real estate and other asset classes, the full time period of the study was divided into two subperiods of equal length. Exhibit 11 shows the results of the subperiod analysis. The correlations between real estate and stock markets exhibit fairly different magnitudes in the two subperiods and in the total period. While these correlation coefficients are mostly negative in subperiod 1, they are mostly positive in subperiod 2. However, none of the coefficients are different from zero at reasonable levels of significance. These findings provide some evidence of linear independence of real estate returns and stock market returns on national and international levels.

Regarding correlations between real estate and bond markets, the differences between the two subperiods are of considerably more extent, especially for German real estate. While in subperiod 1 German real estate returns are positively but insignificantly correlated with all bond markets, the correlations in subperiod 2 are strongly negative and significant. Interestingly, to a lesser extent, nearly the opposite can be observed for U.S. real estate returns. On the other hand, U.K. real estate exhibits correlations with the respective bond markets, with magnitudes of all correlation coefficients about the same in both subperiods and in the total period.

The correlations between the three real estate markets in the two subperiods also exhibit differences. Again, strongly positive correlations could be detected between U.K. and U.S. real estate returns in both subperiods. Contrastingly, the correlations between U.S. and German real estate are close to zero in both subperiods, while being highly negative in the total period. However, this result seems more to be a consequence of estimation problems due to so few observations, rather than being evidence for structural changes. The significant considerably negative correlation in the total period between U.K. and German real estate can also be found in subperiod 1. Conversely, the subperiod 2 correlation is close to zero.

Real estate returns are driven by different factors, particularly rental and appreciation returns. Notionally, short-run real estate returns (*e.g.*, quarterly returns), measured by appraisal-based indices, cannot perfectly reflect both return drivers, especially appreciation returns. On the other hand, this problem should be lowered by considering long run returns. Furthermore, Collett, Lizieri and Ward (2003) point out that correlation estimates for short-term holding periods of real estate with other assets can be severely different from estimates for longer holding periods. Exhibit 12 includes the correlation coefficients on a yearly basis.

Comparing yearly (Exhibit 12) and quarterly returns (Exhibit 10), inter-asset class-correlations between real estate and stock/bond markets are hardly altered in most cases. The yearly correlations are mostly of more magnitude, but never statistically different from zero. The higher magnitude of correlation can also be seen for the real

Exhibit 11

Contemporaneous Correlation Coefficients on a Quarterly Nominal Basis

	Real Estate Markets			Bond Markets			Stock Markets		
	GER	U.S.	U.K.	GER	U.S.	U.K.	GER	U.S.	U.K.
Panel A: Real Estate Markets for Q1/1987–Q4/1994									
GER	1			0.03	0.22	0.10	−0.14	0.08	−0.15
U.S.	−0.08	1		**−0.43**	−0.24	−0.24	0.01	−0.21	−0.12
U.K.	**−0.51**	0.47	1	−0.26	−0.24	−0.30	0.20	−0.12	−0.07
Panel A: Real Estate Markets for Q1/1995–Q4/2002									
GER	1			**−0.46**	**−0.36**	**−0.37**	0.29	0.14	0.20
U.S.	−0.06	1		−0.07	0.02	0.14	0.16	0.15	0.18
U.K.	0.03	0.60	1	−0.36	−0.12	−0.04	0.21	0.02	0.00

Notes: Correlation coefficients that proofed to be different from zero, at least at the 5% level, are in boldface type.

Exhibit 12

Contemporaneous Correlation Coefficients on a Yearly Nominal Basis (1987–2002)

	Real Estate Markets			Bond Markets			Stock Markets		
Real Estate	GER	U.S.	U.K.	GER	U.S.	U.K.	GER	U.S.	U.K.
GER	1			−0.23	0.03	−0.01	−0.17	−0.07	−0.01
U.S.	−0.67	1		−0.32	−0.17	−0.25	0.21	0.07	−0.07
U.K.	−0.29	0.53	1	−0.31	−0.30	−0.23	0.42	0.05	0.15

Notes: Correlation coefficients that proved to be different from zero, at least at the 5% level, are in boldface type.

estate intra-asset class-correlations. U.K. and U.S. real estate returns are again highly positively correlated, while both are each strongly negatively correlated with German real estate returns. Furthermore, applying a modified *t*-test, no significant differences between the magnitude of the respective yearly correlation coefficients and their quarterly counterparts could be detected.

As mentioned earlier, the appraisal smoothing issue can lead to an underestimation of the true volatility. Fisher, Geltner and Webb (1994) mention that the smoothing issue can also lead to biased correlation estimations. Exhibit 13 shows the unsmoothed quarterly correlations between the real estate markets and the other asset markets. Regarding the correlations between real estate and stocks unsmoothing has, by and large, no mentionable effect on the magnitude of these correlations. These findings again suggest (linear) independence of real estate and stock market returns. As suggested by the study of Crogel and deRoos (1999), the effects of unsmoothing on correlations between real estate and bonds are somewhat stronger. Especially in the case of Germany, after unsmoothing significantly negative correlations were observable between real estate and all bond markets, which was not the case for the original returns.

Interestingly, considering intra-asset class-correlations for the real estate markets, the effects of unsmoothing on correlations are drastic. After unsmoothing, the correlations between all real estate markets are clearly much closer to zero than before unsmoothing. None of the coefficients proved to be significantly different from zero after unsmoothing.

Partial Co-Movements. The low return interdependencies between real estate and stock/bond market returns found in the previous section were calculated from the complete bivariate return distributions of the respective assets pairs. However, as Login and Solnik (2001) point out, returns of different assets can exhibit much stronger co-movements in extreme situations (*e.g.*, stock market crashes) than traditional correlation analysis suggests. Therefore, this section investigates return co-movements in the tails of the total bivariate return distributions only. Due to the limited

Exhibit 13

Contemporaneous Correlations for Unsmoothed Real Estate, Bond and Stock Returns on a Quarterly Nominal Basis (Q1/1988–Q4/2002)

	Uns. Real Estate			Bond Markets			Stock Markets		
Uns. Real Estate	GER	U.S.	U.K.	GER	U.S.	U.K.	GER	U.S.	U.K.
GER	1.00			**−0.42**	**−0.25**	**−0.27**	**0.27**	0.13	0.06
U.S.	0.02	1.00		−0.05	−0.21	−0.06	0.11	−0.10	0.01
U.K.	−0.21	0.05	1.00	0.13	−0.05	0.04	0.19	0.03	0.09

Notes: Correlation coefficients that proved to be different from zero, at least at the 5% level, are in boldface type.

data available, the key focus will be on conditional probabilities, rather than on co-movement structures.[8] To measure the co-movement of two random variables in some part of their bivariate distribution, the concept of conditional probability proves useful.

One can define LCP(c): $= P(X \leq x_c | Y \leq y_c)$ as the (conditional) probability that a random variable X (here, real estate returns) has a realization equal to, or below, its c% percentile on the condition that, at the same time, another random variable Y (here stock or bond returns, respectively) has a realization equal to, or below, its c% percentile. UCP: $= P(X \geq x_c | Y \geq y_c)$ can be defined analogously. If X and Y are two independent random variables, the conditional probability LCP(c): $= P(X \leq x_c | Y \leq y_c)$ is equal to the absolute probability $P(X \leq x_c)$ that X has a realization below, or equal to, x_c, and, equivalently, $P(X \geq x_c | Y \geq y_c) = P(X \geq x_c)$. The LCP(c) and UCP(c) do not, per se, allow for inferences in the statistical dependence and independence of two random variables. However, LCP(c) (UCP(c)) are useful measures to quantify the risk (opportunity), for example, given that one asset market is in bad (good) condition, the other is also.

The conditional probabilities, LCP(c) and UCP(c), can be estimated through the corresponding conditional frequencies, eLCP(c) and eUCP(c). It should be mentioned that the eCPs are estimations of the true CPs. Due to the small quarterly database, these estimations have high standard errors, whereby the higher they are, the smaller the percentile considered. So the eCPs should be interpreted carefully.

In Exhibit 14, the (conditional) relative frequencies for the considered real estate market returns are tabulated to be equal to, or lower (higher) than their 10%, 20% and 50% (50%, 80% and 90%) percentile returns, on the condition that the corresponding stock and bond market returns respectively fulfill the same conditions.

As can be seen from Exhibit 14, the eLCP(20) and eLCP(10) for the U.K. and especially the German real estate market are of considerable magnitude, depending on the respective stock market returns.

Exhibit 14

Conditional Relative Frequencies in Several Percentiles of the Quarterly Real Estate Market Return Distributions (Q1/1987–Q4/2002)

Lower Percentiles			Upper Percentiles		
10%	20%	50%	50%	80%	90%
Panel A: Real Estate Returns Dependent on Stock Market Returns					
IMMEX Returns Dependent on MSCI Germany Returns					
16.67	33.33	56.25	56.25	23.08	0.00
NPI Returns Dependent on MSCI U.S. Returns					
0.00	0.00	56.25	56.25	30.77	28.57
IPD Returns Dependent on MSCI U.K. Returns					
16.67	16.67	50.00	50.00	23.08	0.00
Panel B: Real Estate Returns Dependent on Bond Market Returns					
IMMEX Returns Dependent on DS Government Bond Germany Returns					
16.67	8.33	46.88	46.88	7.69	0.00
NPI Returns Dependent on DS Government Bond U.S. Returns					
0.00	16.67	50.00	50.00	15.38	14.29
IPD Returns Dependent on DS Government Bond U.K. Returns					
8.33	8.33	43.75	43.75	15.38	14.29

Notes: Conditional relative frequencies (in %).

In quarters where the U.K./German stock market returns are low to very low, there is also a considerably high probability that the corresponding real estate market returns are also relatively low to very low. In other words, U.K. and German real estate often cannot provide a perfect alternative investment in times of poor stock market performance. On the other hand, the U.S. real estate market does not necessarily tend to put out low to very low returns when this is true for the U.S. stock market.

eUCP(20) and eUCP(10)—the tendency for real estate to have high to very high returns, while the corresponding stock markets perform well to very well—is lower than the corresponding eLCP, or even zero. In other words, in times of high stock market performance, the U.K. and German real estate market do not usually show their best performance. Again, the U.S. real estate market is an exception. Its eUCP(20) and eUCP(10) are relatively high compared to the U.K. and German real estate market.

In quarters when bond market returns are low to very low, real estate markets tend to perform better. In other words, real estate markets, in most cases, seem to be a better alternative investment when bonds are performing weakly. If bond market returns are high, then the eUCPs for U.K. and U.S. real estate markets are high, while those of the German real estate market are low.

As could be seen from the analysis, unsmoothing has a strong effect on volatility and correlations. Exhibit 15 illustrates that unsmoothing also seems to have some effect on LCP. The unsmoothed real estate returns for the U.K. and German real estate markets tend to show in tendency higher LCP(20)s and LCP(10)s, dependent on the stock and bond market returns. The effects of unsmoothing on the UCPs dependent on the stock market returns are more drastic, than relative to the bond market returns. After unsmoothing, the eUCP(20)s and eUCP(10)s are clearly higher in the German case and lower in the U.S. case. On the other hand, the eUCPs dependent on the bond market returns are not, or only slightly, altered.

Exhibit 15
Conditional Relative Frequencies in Several Percentiles of the Unsmoothed Quarterly Real Estate Return Distributions (Q1/1988–Q4/2002)

Lower Percentiles			Upper Percentiles		
10%	20%	50%	50%	80%	90%
Panel A: Real Estate Returns Dependent on Stock Market Returns					
IMMEX Returns Dependent on MSCI Germany Returns					
33.33	33.33	63.33	63.33	33.33	16.67
NPI Returns Dependent on MSCI U.S. Returns					
16.67	16.67	43.33	43.33	8.33	0.00
IPD Returns Dependent on MSCI U.K. Returns					
0.00	25.00	50.00	50.00	8.33	16.67
Panel B: Real Estate Returns Dependent on Bond Market Returns					
IMMEX Returns Dependent on DS Government Bond Germany Returns					
16.67	16.67	43.33	8.33	0.00	
NPI Returns Dependent on DS Government Bond U.S. Returns					
16.67	25.00	50.00	50.00	0.00	0.00
IPD Returns Dependent on DS Government Bond U.K. Returns					
33.33	16.67	43.33	43.33	16.67	16.67

Notes: Conditional relative frequencies (in %).

Conclusion

The purpose of this paper was to extend previous research on international real estate returns by focusing on the German real estate market. As there is no adequate real estate index for Germany available so far, a methodology for generating an un-leveraged appraisal-based real estate index (IMMEX), based on publicly available information about German open-ended real estate funds, was demonstrated and applied.

Using this index for Germany, as well as the NPI and IPD index for the U.S. and U.K., respectively, quarterly and yearly analyses in univariate and multivariate settings for the time period 1987 to 2002 were conducted. In the core, German real estate returns exhibit time-series features that are comparable to that of the U.K. and U.S. property market. However, there are also clear differences observable.

Univariate analyses revealed that, even after correcting for appraisal smoothing, German real estate exhibits lower mean returns and clearly lower volatility than U.S. and U.K. real estate. Additionally, some evidence for German real estate returns to be not normally distributed were found.

All real estate markets showed significant serial correlation in returns. An analysis of real returns uncovered that serial correlation in German real estate returns is partially attributable to serial correlation in actual inflation rates. However, no influence of actual inflation on U.K. and U.S. real estate returns could be detected.

Multivariate analyses revealed that, like the U.S. and U.K. real estate, German real estate exhibits zero or negative correlations with the stock and bond markets, respectively. Furthermore, while U.K. and U.S. real estate markets show considerable positive correlation with each other, German real estate returns tend to be significantly negatively correlated with U.S. and especially with U.K. real estate. However, after correcting for appraisal smoothing effects, the different real estate markets tended to be uncorrelated.

Analyses of extreme co-movements showed that German, U.S. and U.K. and real estate markets exhibit relations to stock and bond markets in extreme situations.

Endnotes

1. See also Maurer and Sebastian (2002) for further details of the regulation of German open-ended real estate investment funds.
2. Monthly returns of the REXP1 and the REXP4 are used as proxies for the bond returns. Both indices represent a portfolio of German government bonds with one and four years to maturity, respectively. Both indices are value-weighted, based on market capitalization and adjusted for capital gains, as well as coupon payments (on a pre-tax basis). As a proxy for the funds cash return, the one-month interest rates provided by the Deutsche Bundesbank (European Central Bank, respectively) are used.
3. Appraisal rules in Germany are based on the same principals as those in the U.S. and U.K. Small differences exist, for example, in value definitions or the treatment of rents above and under market level, respectively. See Thomas (1995) for a comparison of the British and German appraisal system and Downie, Schulte and Thomas (1996) for a detailed description of the German appraisal system.
4. All analyses in the following sections are done on the basis of national (local) returns, i.e., the interrelationships between different national asset markets are investigated assuming a perfect (currency) hedge (e.g., Eun and Resnick 1988, 1994). Through this assumption, the results derived are independent of the reference currency of the investor and thus they hold for every (perfectly hedged) investor independent of the investor's nationality.
5. For a critical view regarding correcting for appraisal smoothing, see Lai and Wang (1998). However, it should also be mentioned that Geltner (1999) points out that this study could be seriously misleading due to certain errors of application and interpretation.
6. To see this, suppose that the nominal real estate return R and the discrete inflation rate I are independent random variables. Through deflating R with I one obtains the real return $r = ((1 + R)/(1 + I)) - 1$, which is also a random variable. Because r is a function of I, independence between the deflated return r and the inflation rate I is unlikely.
7. The analyses in the previous sections showed that some of the time series used in this study are non-normal distributed and/or auto-correlated. In such cases the use of a standard t-test for testing the hypothesis that a correlation coefficient is different from zero, is critical. Non-normality leads to an unknown distribution of the t-test statistic. To address this item, each correlation coefficient for which both of the underlying series proved to be non-normal, was tested with a simple t-test and additionally via a bootstrap BCa confidence interval with 10,000 bootstrap replications. In almost all cases, both test-procedures provided the same conclusions regarding the rejection of the null, leading to the presumption that non-normality in the time-series used here is less problematic for applying the usual t-test. The serial correlation in one or both of the underlying time-series leads to a reduction in the degrees of freedom of the t-tests' t-distribution. To address the item of autocorrelation, especially in the real estate series, a correction for the t-test suggest by Dawdy and Matalas (1964:8/87) was applied, which at least allows to control for first-order autocorrelation. This correction is applied by adjusting the t-tests' t-Statistic and the degrees of freedom of the t-test statistics' t-distribution.
8. Measuring the structure of dependencies in the tails of a bivariate distribution requires higher frequency data than available here. For structural measures of extreme dependencies, see Malevergne and Sornette (2002).

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