TOWARDS A PAN-EUROPEAN PROPERTY INDEX: METHODOLOGICAL OPPORTUNITIES

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ABSTRACT

This study examines the methodological opportunities of index construction for the Pan-European property index, whose release is planned by the company Investment Property Databank (IPD). To address the question of temporal aggregation in appraisal indices, three index construction methods, namely "Stale Appraisal", "Linear Interpolation", and "Repeated Measures Regression", are tested for their accuracy in dealing with infrequent appraisals. Our model is based on a simulation approach, calculating appraised indices from a simulated "true index" of randomly generated returns, and directly comparing the statistical characteristics of these index returns to the true return.

As broader context, this paper also gives an overview of the current theories in respect to general valuation issues on a disaggregate, aggregate and international level. We also investigate the European real estate market regarding currently applied market size measuring, structure and country performance. In particular, we explore crucial valuation issues that are relevant for the planned Pan-European property index to obtain the respect of the international investment community.

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We would like to point out that neither any position nor the final recommendations are necessarily shared by the contributors noted above.

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1. INTRODUCTION

1.1. Towards a Pan-European Property Index

Investment Property Databank Ltd. (IPD) is an independent property information service company located in London and leading supplier of European property-level investment return data. The company produces and publishes appraisal-based property indices similar to the NCREIF Property Index (NPI) in the US for many European countries in collaboration with national partners. In August 2004, IPD plans to release a Pan-European consultation index that represents an aggregation of eleven of its national property indices.[1]

In the face of disappearing borders between European countries and a growing internationalization of commercial property investments, the establishment of a Pan-European property index is welcomed and well-needed by the investment community. Reliable performance information for European real estate will not only serve the existing European investment industry but also attract more international investors (e.g. from the US), who are currently deterred by the lack of transparency and data in the European property market.

The Pan-European Index is one of the first multi-national indices to be established, which adds substantially to the complexity of index construction. This thesis summarizes and reflects insights we gained regarding some of the major questions and issues IPD is currently facing in constructing this new index. In detail, we considered the following principal questions in this thesis:

- How to generally deal with the heterogeneity of the European markets, addressing the fundamentally differing nature of these markets and their appraisal methods.

- How to weigh the current country indices on an aggregate level, as each country index represents a different share of its total real estate market, and how to define the term total real estate market at all.

- What index construction method to use for a most accurate and efficient interpolation of infrequent appraisal data, in order to adapt to changing currency rates and to eventually publish quarterly or monthly indices.

The first question especially relates to the difference between Anglo-Saxon and non Anglo-Saxon countries and their potential impact in a Pan-European Index. Germany is an often cited example in the currently ongoing discussion about the source and magnitude of the differences. These differences range from the understanding of the asset class real estate over the functioning of the real estate market to cus-

[1] A full-published Pan-European Index is supposed to be established by June 2005.

tomary performance measuring procedures. A number of challenging and exciting issues regarding how to integrate these types of markets into a single European market are explored and summarized.

Question two is currently the most relevant for the Pan-European Index, as significant changes in the market weights have the highest impact on the index and return levels. This issue, however, is intimately related to the intended use of the index. We raise some specific considerations that seem important to us in this process of index weighting, and we suggest some guidelines that we hope will help IPD to move forward regarding this issue. We show the current approach of measuring different private real estate market sizes in the European countries and relate the underlying theory to the potential use of the Pan-European Index.

Although considered as very important and further discussed in the following chapters, the first two questions are not the primary focus of this thesis. Instead, we emphasize the third question. We test in depth the construction of appraisal based indices of the private real estate market returns. Precisely, we compare the often criticized “Stale Appraisal” method, the Linear Interpolation method, which is currently used by IPD, and an advanced econometric technique, known as Repeated Measures Regression (RMR). Based on computed statistical properties we outline the ideal application of these methods, making most out of the underlying appraisal information.

In summary, private real estate performance indices serve a broad range of usages, which imply different construction methods as well as various requirements to the index quality. This report serves as guidance and inspiration for IPD to develop further policies for the planned Pan-European Index. The surveyed information and tested methods should also help the European real estate community address the indexing question from a European perspective in an international and informed manner.

1.2. Scope of Study

The report is structured around three principle parts. Chapter 2 gives a theoretical overview of the current theories regarding the valuation and indexing of private real estate; in chapter 3 we briefly explore the European markets and the current involvement and activities of IPD; chapter 4 finally compares specific index construction methods on a quantitative level. The bodies of text are interrelated but can also stand on their own as individual parts of the study.

Theoretical Overview

Valuation issues of the private real estate market are well documented and discussed in the literature. However, the appropriate use of private real estate valuation and return indices is still a key issue of real estate investment. The theoretical framework and the instruments may be different than the ones applied in the security markets and may generally be trickier than anticipated. Several unique aspects of the real estate market distinguish this asset class from its peers and need further investigation.

The basic challenge of the private real estate indices starts with the way returns and values are measured on a disaggregate level. Real estate transactions occur only infrequently and transaction prices are available for only a small fraction of the stock of real estate. The nature of markets can therefore be considered inefficient and the values and returns are rather estimated than precisely measured. Like all estimation of real asset values, the appraisals of the private real estate are not based on a unique method and contain a substantial amount of random noise and systematic bias.

The process of information aggregation to create private real estate market indices is also subject of increased attention in the real estate research. Real estate values are generally derived from infrequent reappraisals, and the aggregated real estate index is essentially engineered from these sporadic value observations or estimations staggered across time. This lack of information in the underlying property values abounds at the index level in the form of lagged and smoothed returns. Up to date, no standardized methods are applied to deal with this issue.

Finally, at the level of an international index, the aggregation of individual country indices into a whole European index is a challenging topic. The private real estate market is far more diverse than the security markets. Differences may exist between countries regarding the functioning of the real estate market and even the perception of real estate as an asset class, and the real estate indices may reflect these differences. A specific issue is the weight that each country is assigned in the international index, as the size of the whole real estate market, as well as of the different sectors, is difficult to define and is affected by changing currency rates.

IPD and the European Real Estate Market

Until the final release of the Pan-European Index, a number of key issues have to be addressed, including

1) the difference in valuation practices across the countries represented in the index,
2) IPD's market coverage and even more important the market size of the countries represented in the index,
3) the specific use of the Pan-European Index, and
4) the currency issue of countries that do not use the common currency EURO.

These issues need to be addressed or else they may threaten the significance and usability of the Pan-European Index.

The index will be based on 11 European countries. Given the diversity of the these European countries regarding the cultural, legal, and economical environment, it is difficult to talk about "one" European real estate market; it would probably be more appropriate to talk about a combined European real estate market. This combination of real estate markets is clearly characterized by its heterogeneity, its lack of transparency, as well as its missing standardized measurement procedures.

Compared to the US, the European real estate market is in many areas less developed and in certain aspects less studied. Therefore, in terms of a place to invest, the European real estate market is perceived especially by US investors as rather unfamiliar, partially illiquid and just simply risky. Under this perspective, and based on the data which is currently provided by IPD, we discuss the European real estate market regarding country and sector performance to investigate the heterogeneity of the different markets.

Simulation of Index Construction Methods

The valuation issues regarding the planned Pan-European Index are complex and only partly quantifiable. In this chapter we therefore specialize on a single but quantifiable issue that does not deal with individual appraisal procedures, but only with the aggregation of these values at the index level. The statistical quality of these index returns can be quantified through time-series statistics that can be derived from the index at each period. Accordingly, we test these statistical qualities on an aggregate level to derive insights about methodological potential and ideal index application.

The issue of "temporal aggregation" in an index is observable when the index is reported more frequently than the properties are appraised (the quarterly US NPI index is for example based on mostly annual appraisals), or when the dates of appraisals are different than the closing date of the index (many German funds for example end their financial year in September and reappraise their properties by then, whereas the German Property Index is produced as of December). This leads to the database containing "stale" appraisals that significantly alter the statistical characteristics of the index (commonly known as smoothing and lagging), even if the appraised value doesn't contain any error.

In order to deal with the need of converting the indices to different currencies and to homogenize their country indices, IPD decided to change the index construction method for their annual indices from calculating annual total returns to calculating monthly total (currency-adjusted) returns and time-weighting them back to aggregated annual returns. To get monthly property values out of the mostly annual reappraisals, the appraised values are linearly interpolated.

In our analysis we compare three construction methods. First, the so called "Stale Appraisals" method, where the reported value remains as constant in the database until the next reappraisal; second, the "Linear Interpolation", where the periodic appreciation is simulated by linear interpolation between each reappraisals; and third the "Repeated Measures Regression" (RMR), where more frequently available data of smaller samples is used to compute representative periodic changes of the reported index return each period.

To test and quantify the difference between the methods, we use a simulation analysis rather than real index histories. By simulating a "true index" out of randomly generated returns and applying the index construction methods to it, the true and appraised indices can be directly compared. Consequently, the comparison of defining statistical index properties (esp. mean, standard deviation, serial autocorrelation, and cross correlation) reveals the potential applications of these methods for the intended uses.

2. CURRENT THEORIES

This chapter explores the current theoretical discussion on valuation and index issues. The relevance of these theories is given by the fact that the value of real estate is generally estimated with error, which derives from the unique characteristics of buildings that can not be replicated by comparable assets.[2] To internalize the behavior and attributes of real estate indexing methodologies one has to become acquainted with the properties of the private real estate market, the valuation theories on a disaggregate level, the data aggregation methodologies, and finally the specific index features.

2.1. The Private Real Estate Market

2.1.1. Price Formation in the Private Real Estate Market

A fundamental role of any market is to provide price information to participants. In certain markets like in the private real estate market (as well as in other private asset markets) this flow of reliable price information may be reduced or even absent. The lack of information may be caused by low liquidity, infrequent trades, and confidentiality. Such information imperfection and the thereby evolving differing price expectation and price dispersion in the short run equilibrium are typical characteristics of the private real estate investment market.

In such market environments, the market participants face the challenge of appointing the market value of an asset. Due to the inefficiency of the market, this price determination process represents a significant departure from the traditional auction model, i.e. the observation of the transaction price does not fully reveal the equilibrium value or market price; it rather describes a range around the likely equilibrium value. Accordingly, the market value may depart from the fundamental asset value as well as from the empirically observed transaction price.[3]

This notion is also addressed in the definition of the International Valuation Standards Committee (IVS, 2003, p. 96) which defines the market value of a property in the private real estate market as *"…the estimated amount for which a property should exchange on the date of valuation between a willing buyer and*

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[2] When these characteristics are priced the information will also be difficult to be replicate for non traded assets, thereby resulting in an estimation error.

[3] Geltner & Miller (2001) further distinguish the notion of asset value or price of a property in the private real estate market into:

1. Inherent Value, which represents the maximum amount a given person would be willing to pay for a good if he had to.
2. Investment Value, which represents the Inherent Value of a property for a non user namely an investor.
3. Reservation Price, which represents the price at which a seller or buyer will stop searching for other opportunities and would agree to trade.

Quan and Quigley (1989) in addition use the notion of a Threshold Price, which stands for the expected true price based on the information given at that point to the buyer.

a willing seller in an arm's length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion".

The reasons for the spread between market value and transaction price are inherent in the way the private real estate market functions, and were further identified by Quan and Quigley (1989, p. 221-2) as:

- The costly search process related to the acquisition of real property. Resulting significant transaction cost will affect the transaction price.
- Uncertainty and incomplete information of the market participants, especially prevalent in the real estate market that is characterized by segmentation, uniqueness and infrequent trading.
- Imperfect competition, exhibited by the thinness of some markets, or the distress of one of the parties.

Looking at the statistical properties, the real estate transaction prices can further be described as noisy signals of the underlying true market values. As Quan and Quigley (1991) show, this noise may not only be idiosyncratic but also systematic. They show evidence that this "market wide noise" will not diversify away when prices are aggregated. Accordingly, a consensus that also emerges from Giaccotto and Clapp (1992) is that the unconditional mean of the transaction prices will not reflect the true market value but will be biased depending on the trend of the economic period.

If the price information flow in a market becomes more efficient and the market participants get generally better informed about the market conditions, the overall deviation of transaction prices from the true market value is expected to decline. The range of the transaction prices tightens around the equilibrium and the described noise or error finally disappears. The economic literature calls this process when "the market is learning from itself" price discovery.[4]

2.1.2. Common Valuation Methods in the Private Real Estate Market

Most appraisal standards like the International Valuation Standards (IVS, 2003) acknowledge three approaches to estimate the market value of a property: the cost approach, the sales comparison approach, and the income capitalization approach (including direct capitalization and discounted cash flow method).

These three approaches are considered equally valid to come up with an estimate of market value, although it is recommended to apply "*valuation methods and procedures that reflect the nature of property and the circumstances under which given property would most likely trade in the (open) market*" (International Valuation Standards, 2003, p. 95). For example, if recent sales comparables of similar properties are available, e.g. in the residential market, the appropriate method would be the sales comparison ap-

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[4] The more informational efficient a market is the faster it is learning from itself (Geltner & Miller, 2001). The information aggregation needed for price discovery may also include exogenous variables such as economic growth, inflation etc. Also the public real estate market vehicles like REITs can further inform the price discovery in the private market. Even though the assets are traded in different markets their values are related and relevant price information from the public market can be transmitted into the private one (and vice versa) (Barkham & Geltner, 1995, Geltner et al., 2003). This kind of price discovery was further studied by Geltner, McGregor & Schwann (2003) especially regarding the Granger causality.

proach. For mainly income-producing properties the income approach should be taken, whereas very unique, stable, and infrequently traded assets best be valued by the cost approach.

Appropriately applied, all three methods should lead to a "*common expression of market value when based on market-derived data*" (International Valuation Standards, 2003, p. 95). In practice, however, one would generally expect to get different results with each different method. This would not be of much concern if these different valuations reflect a purely random deviation from true market value. The relevant question is therefore, if one of these valuation methods introduces a systematic bias that doesn't diversify away and thus affects an index or portfolio return at an aggregate level.

Income vs. Sales Approach

Comparing the income approach and the sales comparison approach, the former is based on the relation between expected income and current value,[5] whereas the latter purely relies on market information. In the income approach, the current market condition is reflected by estimating current rent and expense levels and appropriate discount or capitalization rates that are generally retrieved by market observation.[6] Depending on how far back in history the market observation is reaching, both methods could introduce a systematic lag bias in the valuation. The sales comparison approach could also be susceptible to a transaction bias, as the properties sold may not be representative of the universe.[7] However, there seems to be no significant, systematic difference between these two models.[8]

The Cost Approach

The cost approach is justified by the microeconomic theory that in market equilibrium prices will equal marginal cost. If the price is higher than the cost of a good, this will lead to increased supply, which will lower the price until the equilibrium situation is reached again. So in the long run, we should not see prices of properties significantly deviating from their replacement cost. However, this theory assumes efficient markets, and as described in chapter 2.1.1 the real estate market has proven to include all kinds of inefficiencies.

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[5] The fundamental assumption underlying the income approach is that current values reflect expectations of future income. This theory is widely applied for the valuation of various financial assets like stocks and bonds as well as companies (see for example Brealey & Meyers, 2003) and should also hold for owner-occupied property, as the owner incurs opportunity cost and could always choose to rent instead.

[6] According to Hamilton and Clayton (1999) the direct capitalization approach of the income method of appraisals is the most widely applied one (the sample was taken in Canada).

[7] This would also affect the direct capitalization method and the discounted cash flow method to the extent that the discount rate is based on current cap rate observations.

[8] The direct capitalization method has been much criticized for its simplicity and therefore failure to account for specific property characteristics. The more sophisticated discounted cash flow method has been introduced as the main recommended method to evaluate investment property. Cutting edge research focuses on the option value in properties that is not captured by the discounted cash flow analysis (see for example, Geltner & Miller, 2001). Significant option value, however, is assumed to exist mainly in vacant land. Stabilized properties may still be properly appraised by the discounted cash flow analysis.

For example, as new supply is often lagged by many years due to the planning, permit, and construction process, significant price differences between market value and replacement cost (one definition of market "bubbles") could prevail for many years. Replacement costs are only affected by current market conditions in that construction cost are expected to be influenced by market conditions due to labor cost or shortage of material. These cost differences will, however, also lag and never be as big as changes in market value. In comparison to the income and cost comparison approaches, the cost approach will therefore systematically result in less volatile and more temporally lagged appraisals.

2.2. Appraisal Behavior at the Disaggregate Level

2.2.1. Modeling Rational Appraisal Behavior: The "Noise-Lag" Tradeoff

As real estate transactions occur only infrequently, transaction prices are available for only a small fraction of the stock of real estate. To overcome this scarcity of reliable information, the private property market usually resorts to appraisals in order to estimate market value. In such an inefficient market, with only little information about transaction prices (which contain noisy and misleading signals), the estimation of the true market value of a single property as of a certain point in time is challenging.

Independent from the specific method used, an estimation of the market value will be based on information of comparable properties that are not identical with the given subject property.[9] Appraisers receive information about transaction prices (e.g. capitalization or discount rates are derived from market sales), which statistically speaking represents a noisy signal out of which they extract an estimate of the true market value of a subject property.[10]

To adjust or "diversify away" these differences, appraisers look for as many similar properties as possible as reference for their estimation. Hereby they face a sample selection bias and a fundamental tradeoff between two possible sources of error:

- *Cross Sectional Noise*, the effect of insufficient current information, e.g. if they have only a few transaction prices to compare the subject property, the similarity may be rather small.

- *Temporal Lag*, the effect of the inclusion of older transaction prices e.g. the subject property will be represented better by a wider range of comparables, but the transactions may date back in time.

[9] One can distinguish between two kinds of differences between any given subject property and its relevant comparables: Cross sectional differences and temporal differences (Geltner & Miller, 2001). Also one can note that exact comparability can never be obtained, if only because of the differences in the fixed geographical location of a property (Quan & Quigley, 1989).

[10] Each real asset valuation typically contains error, simply because they have unique locational, physical, and contractual-relational characteristics that can not be replicated (Childs, Ott, Riddiough, 2002).

Conceptually this tradeoff was widely studied in the literature[11] out of which we will further examine the approach of Quan and Quigley (1989, 1991) who modeled the appraiser's dilemma of weighting information from past transaction and the one of the current market. Based on a linear updating process[12] they identified the optimal behavior of an appraiser predicting the current value of a property and formalized it as follows[13]:

$$P^*t = KP_t^T + (1-K)P^*{}_{t-1} \qquad (1)$$

K ....Weight on current information

P^*t ....Appraised value at time t

P_t^T .....Additional price information at time t

With K defined as:

$$K = \frac{\sigma_\eta^2}{\sigma_\eta^2 + \sigma_\nu^2} \qquad (2)$$

σ_η^2 ......Market-wide noise, variance in macroeconomic conditions

σ_ν^2 ......Idiosyncratic transaction noise

Hereby, the weights depend on the second moments of the errors distribution, e.g. the weight on current information, K, depends on the relative insecurity in the value of the individual property (idiosyncratic noise, the variance in P^T_t, the available additional information) compared to the market-wide noise, i.e. the variance in overall macroeconomic conditions. The bigger the idiosyncratic noise, the smaller K and therefore the more weight is put on past information.

Figure 1 displays the noise-lag tradeoff along the line T_{Dis} for an individual appraisal. In order to maximize the usefulness of the appraisal, the appraiser "picks" the optimal noise-lag balance at point A, which denotes the point that touches the highest usefulness indifference curve U_0. This optimal balance will differ at one point in time across properties, property types or geographic regions (see Chaplin, 1997, Chinloy et al., 1997). It may also differ for the same property for different points in time, e.g. due to different levels of liquidity (see Matysiak & Wang, 1995, Childs et al., 2002).

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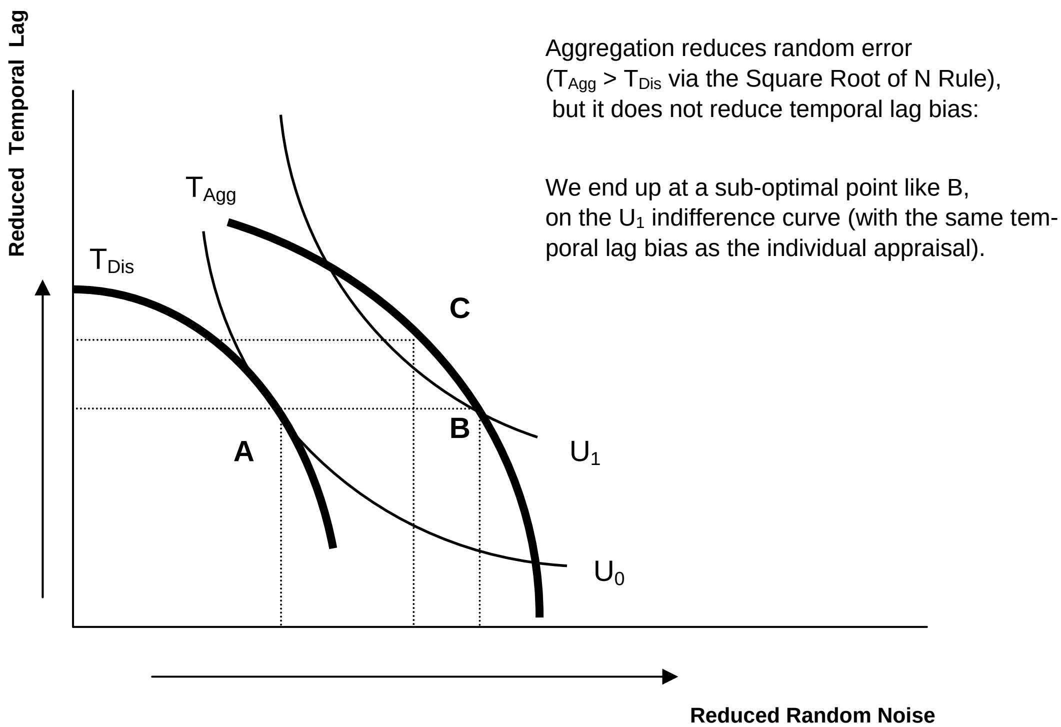
[11] The empirical studies of Miles et al. (1990) and Webb (1992) in which transaction prices are compared to recent appraised values for a sample of sold properties show an average absolute difference between appraised value and transaction price of approx. 10% (Geltner, Graff & Young, 1994).

[12] One may note that Quan and Quigley based their model on the assumption that the mean adjusted true price at time t follows a random walk, as would be suggested by efficient market theory. Geltner (2001) further refined this approach without assuming a priori that the true market returns are uncorrelated or unpredictable.

[13] Mathematically this formula is a first order auto regression model, basically derived from an infinite moving average of present and past values with exponential declining weights, ($r^*_t = w_0 r_t + w_1 r_{t-1} + w_2 r_{t-2} + \ldots$).

Figure 1: Optimal Noise-Lag Balance for Disaggregate Appraisals and Aggregate Indices



Source: Geltner, D. and D. Ling. 2001. Ideal research and Benchmark Indexes in Private Real Estate: Some Conclusions from the RERI/PREA Technical Report. Real Estate Finance 17(4), p. 27.

Figure 1 also shows that when individual property valuations are aggregated to a portfolio or property index, the optimal noise-lag balance at the disaggregate level, A, will be suboptimal. Since idiosyncratic transaction noise is a random component in the valuation it therefore underlies the "square root of n" rule, i.e. it tends to diversify away on the aggregate level provided a sufficient number of properties. As one source of error is reduced, the tradeoff frontier moves "east" to T_{Agg}. Along the line T_{Agg}, the optimal balance would be in point C, whereas the aggregate individual appraisals lead to the suboptimal tradeoff in point B. For aggregate purposes, the appraiser should therefore rely on more current information than is optimal for the individual appraisal.

This tendency of appraised values to lag behind the true market movements is known as "appraisal smoothing", as it results in an "artificially" smooth index on an aggregate level[14]. The final effect of any appraisal smoothing is a reduced volatility and an increased autocorrelation in index return series. This

[14] One can note that Lai and Wang (1998) demonstrate that the use of appraisal based data can theoretically also increase the volatility of a time series and that presented theories only function with the prior assumption that "smoothing" as such exists. They also show observations where the volatility of the appraised returns are not less volatile than the underlying true return.

effect at the disaggregate property level is further compounded at an aggregate level (which will be further explained in chapter 2.3).

2.2.2. Reverse-Engineering Rational Appraisal Behavior

If one can understand appraisal based returns as essentially being value constructs that are engineered from raw material consisting of empirically observable transaction prices (the comps used by the appraisers), one should be able to reverse-engineer the appraisals to recover the underlying contemporaneous transaction price evidence. Fisher and Geltner (2000) conceptually explain that the appraisal process starts out with comps and ends up with producing appraisals, whereas the reverse-engineering process starts out with appraisals and ends up producing comps.

They further suggested a three step process to reverse engineer an appraisal based index:

- Step 1: Posit a model of appraiser behavior at the disaggregate (individual property) level: Appraised value as a function of empirically observable market transaction prices.

- Step 2: Calibrate the appraiser model using empirical observation of the typical appraisal lag in the index, based on a comparison of actual transaction prices versus the contemporaneous appraised values of all properties sold from the index.

- Step 3: Invert the appraiser behavior model (i.e., “reverse-engineer” the appraisals, to “back out” implied transaction prices from observed appraised values), and apply this reverse model the value-index to derive implied transactions-based appreciation returns for the index.[15]

If we now use Equation (1) as our basic appraiser behavior model we can solve for the true underlying value, as follows:

$$P_t = \frac{P_t^* - (1-K)P_{t-1}^*}{K} \qquad (1a)$$

This simple method to unsmooth or to “delag” time series of property valuations depends sensitively on the correct value of K and additionally, it can not escape the noise-lag trade-off.[16] However, among the

[15] Fu & Ng (2001) argue that this method of reverse-engineering does not recover real information. They further suggest an approach using the public real estate market to reconstruct the market value of the private real estate property market (cp. Footnote 4).

[16] As further caveat, one can mention that this reversed engineering model can only be used to estimate appreciation returns and not total returns. Nevertheless, as most people are concerned about the periodic changes in the appreciation components when addressing the temporal lag bias the model finds acceptance in the related industry.

various methods of reverse engineering[17] this model is a handy tool to reengineer underlying market returns and to unsmooth indices and is currently the most widely accepted approach.[18]

Calibrating the Rational Appraisal Behavior Model

Obviously, after establishing a model that describes the rational appraisal behavior, the more difficult part is to quantify or what Geltner and Miller (2001, p. 682) call "calibrating" the appraiser behavior model.

The calibration of the model is normally based on empirical evidence regarding the length of the average appraisal lag. If there is empirical data on micro level appraisal behavior (procedures) available one may estimate for example the confidence factor K and the smoothing or stickiness factor 1-K to further calibrate the appraiser behavior model. If there is a transaction based index available the difference between the transaction prices and the contemporaneous appraised values of the properties can also inform about the appraisal behavior, indicating the average length of temporal lag between transaction prices and appraised values.

As many markets do not provide this empirical data, further techniques were developed to recover the true underlying property returns, i.e. the time series second moments of these returns. Blundell and Ward's first attempt 1987 was based on the assumption that the underlying true returns were unpredictable across time (as reported by Geltner et al., 1994); an assumption that we know from the random walk of a perfectly efficient market. Accordingly, the level of autocorrelation can also be used as a tool to make further assumptions about the appraisal lag.

2.2.3. Behavioral Sources of Deviations from the True Market Value

Apart from the rational appraisal behavior mentioned above, the literature also recognizes several behavioral issues that may be perfectly rational to the appraiser in the current situation, but may cause a deviation from the "best estimate" of true market value:

- Changes in the underlying fundamentals may be considered too small in order to result in a change in value, the valuation therefore remains constant until a certain threshold is reached and then steps up to finally represent the newly arrived information (Brown & Ong, 2001).
- Conversely, large changes in value, particularly in a very volatile market, may not be appreciated by the clients, whose balance-sheets and income-statements could be significantly affected if all their

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[17] A further example, Fu (2003) developed a "state-space" model with which is capable to incorporate also exogenous variables such as real estate income return and short term interest rates.

[18] Also to further demonstrate the simplification, Chaplin (1997) points out there is a very real possibility that the ratio between valuation and market noise being non-constant, what would be a potential flaw in this model.

property is marked to market. Facing this pressure, appraisers tend to only gradually adjust the appraised values to market conditions (Brown & Ong, 2001).[19]

- Chinloy et al. (1997) find in an analysis of US housing data that appraisals are systematically higher than purchase prices. They argue that if an appraisal is made in order to obtain or justify a mortgage, an appraisal below the suggested purchase price results in higher costs to the appraiser for validation and documentation and that the appraiser therefore faces a "*transaction incentive to over-appraise*" (Chinloy et al., 1997).

- Studies of Diaz and Wolverton (1998) showed that appraisers are significantly influenced by their own previous appraisals, which implies an anchoring impact of self generated initial value conclusion. In other words, compared to external appraises who appraise a property the first time, appraiser who internally reappraise a property put relatively more weight on their previous appraisal and less weight on market information compared to what external appraisers would do.

- Clayton, Geltner and Hamilton (2001) found evidence which suggests that there is an additional behavioral component to appraisal lagging if appraisers value the same property in consecutive periods. They appear to place higher weight on their past appraisals than on new market information.[20]

All these situations describe potential sources of systematic valuation bias that would also be apparent on an aggregate level. However, the existence and magnitude of the described behaviors will be almost impossible to estimate.

2.3. Reporting Issues at an Aggregate Level

2.3.1. General Reporting Issues

Total Return

An index reports data of an underlying market on a simple holding period return (HPR). Mainly based on the considerable use there is a wide range of information an index can potentially report. For most investors the information about the total return of a property is the most fundamental statistic. This periodic return includes both the change of the capital value (appreciation return, capital gain, growth, etc.) of an asset as well the income earned (income return, current yield, etc.) during a specific period.

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[19] Fisher, Miles & Webb (1999) also showed evidence that the absolute appraisal value error peaked in 1991 and 1992 in the US commercial real estate market when this one was under depth and credit crunch.

[20] They therefore support the policy suggestion of Graff and Young (1999) that the appraisers should rotate, i.e. not consecutively reappraise the same property. This would of course result in more idiosyncratic noise in the reappraisals (as reported by Clayton, Geltner and Hamilton, 2001).

To measure the income is a straightforward task, since it is normally observable on the rent roll on a monthly basis. The gain in capital value though needs to be appraised or computed statistically using transaction prices, which normally does not happen in the same frequency as when the income is observable. The specific form of use (for example, how to count for capital expenditures), as well as the form of adding up the income and capital returns, can vary and mostly depends on basic accounting principles and regulations.[21]

Reporting Frequency

The reporting frequency can be depicted as one of the key characteristics of any index. In the case of the private real estate market one finds monthly, quarterly, and annually reported indices. Depending either on the use of the index or on the availability of the underlying data, a certain frequency may be preferred over another one.

It is important to note that in the private real estate market greater frequency does not necessary imply a more useful index. Geltner and Ling (2001) describe a fundamental tradeoff between frequency and accuracy. They state that for any given level of underlying empirical valuation data collection, greater frequency of index reporting tends to result in more temporal lag and random error per period.

In their technical report, Geltner and Ling further explain that the only way to increase frequency without increasing either noise or lag is to improve the underlying property level valuation.[22] Also the underlying sluggishness in private real estate asset markets reduces the incremental benefits of greater frequency, as the underlying prices are already influenced by previous periods, and more frequent appraisals don't reveal much new information.[23]

2.3.2. The Effect of Temporal Aggregation

In addition to the issues in regards to the individual property level discussed in chapter 2.2, one also can find another systematic bias on the index level due to temporal aggregation. At the aggregate level, the properties are often neither reappraised at the same point in time nor with the same frequency. If proper-

[21] Geltner and Ling (2001) identify following information which be ideally included in an index representing the private real estate market:

1. Asset market prices: Both the levels and changes in property asset prices.
2. Asset market activity: The nature and volume of transactions & capital flow.
3. Investment cash flows: Net operating income and capital expenditures, including breakdowns by sources.
4. Space market prices; Rents & leasing activities.
5. Development industry information: Construction costs & activity levels, land & location values.

[22] One can note that a higher frequency of appraising is very costly and therefore the reappraised values are often based on a desktop valuation and not on a refined estimate.

[23] This effect increases with shorter observation periods. Current statistical procedures actually allow that properties can be reappraised less frequently than the return frequency of the index.

ties are not appraised in the same month or quarter their most recent values appear in the index as if they were the actual ones ("stale appraisal" effect).[24] This situation especially exists if the values get reported more often than the properties are appraised.

Geltner and Miller (2001, p. 675) outline that the temporal effect of such a lag bias does not change the long-run (unconditional) expected value of the periodic return. The direction of the bias depends on the direction of the trend of the underlying true returns, meaning the valuation at any given point in time may be biased conditional on the past history of the market prices at that point in time. This so called "conditional" bias can be described as a moving average of the true returns.[25] It reduces the volatility of the observable real estate returns compared to non lagged benchmarks and accordingly affects the second moment statistics (reduces the beta, the systematic risk) of the measured real estate returns.[26]

The impact of the temporal aggregation or stale appraisal effect also depends on the reporting frequency. The effect gets bigger the higher the reporting frequency. Also based on the valuation frequency, the stale appraisal effect can cause an artificial seasonality with spikes at the quarter or month when most properties were reappraised (Especially, if there is a clear market direction, Fischer & Geltner, 2000).[27]

To model the temporal aggregation is more complicated than to model the rational appraisal behavior, since the weighting of the past observation can not be assumed infinitely declining. It is difficult to observe how much weight was given to past observations. Also from a statistical perspective to average across spikes (when the properties where reappraised), is also not the most efficient way to come up with a solid and useful approximation of the underlying return. Currently the strongest method to deal with temporal aggregation and to get rid of stale appraisal is the Repeated Measures Regression model, which is further explained in the following chapter.

2.3.3. Regression-Based Indices

The "missing value problem" can be found in indices created from appraisals as well as from transaction data. In general one can say that both transaction based as well as appraisal based indices contain noise or "errors".[28] But there tend to be differences between the transaction prices and appraised values in the na-

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[24] Conceptually, this problem can be viewed as a missing valuation observation problem. The same problem can be found in the attempt of constructing transaction price based indices of real estate.

[25] The general moving average model can be represented mathematically as: $r^*_t = w_0 r_t + w_1 r_{t-1} + w_2 r_{t-2} + \ldots$

[26] Geltner and Miller (2001, p 661) also point out that the pure effect of temporal lag bias will be on the lower side with respect to another similarly lagged series. The underlying true returns are likely to be autocorrelated and to contain lagged cross-correlation terms.

[27] Geltner (1989) reveals that internal appraisers normally strongly rely on the valuation of external appraisers which estimate property values in a lower frequency (mostly yearly). Therefore seasonality can also be found in frequent (monthly, quarterly) property valuations.

[28] McAllister, Baum, Crosby, Gallimore and Gray (2003) interestingly observed in the UK that the transaction prices tend to be also smoothed similar to the appraisal valuation since transactions are normally based on appraisals of the property of interest that are used as reservation price of the parties involved in the transaction.

ture of the error (Geltner & Ling, 2001).[29] However, similar statistical methods were developed to deal with both kinds of indices.

We already touched on the kinds of appraisal errors, which can basically be described on an idiosyncratic level as the pure difference between the market value and the appraised value of a given property, and on a systematic level as a temporal lag or bias. In contrast, the error of the transaction price is based on a rather cross sectional dispersion, since the transacted property is compared to other properties (with different characteristics) which are transacted at different points of interest.[30]

Regression Analysis

Currently two methods for price index estimation are established, the hedonic regression and the repeated sales regression (RSR). The hedonic regression method (HVM) basically models the relationship between the heterogeneous property characteristic and the market value of the individual properties.[31] The impact of property characteristics (the hedonic variables) on the sales price can be quantified by using the statistical device known as regression analysis.

The HVM requires a substantial amount of property characteristics to be identified, in order to construct a reliable price/rent index. But, if these characteristics are known the method allows quantifying the value of cross-sectional or temporal differences in samples. Since residential tax and mortgage assessments provide a huge database the hedonic regression method is mainly used for residential properties.

Also, if a lot of simultaneous and cross sectional information about property values (specific quantifiable characteristics of property on which one can base a value estimate) is available the appraisers can take advantage of this so called mass appraisal.[32] Especially institutions that must appraise a large amount of properties on a regular basis take advantage of this economies of scale, mainly by reducing the cost of appraising.

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[29] Also, Webb, Miles and Guilkey (1992) showed empirical evidence that transaction based indices are slightly more volatile than appraisal based ones.

[30] Fisher, Geltner and Webb (1994) raise another important point, namely the dependence of the transaction price indices on the liquidity, which will also be reflected in the transaction price based index.

[31] The hedonic regression was developed/introduced by Court (1939) to measure car price changes and further refined by Tinberg (1959) and Rosen (1974), (as reported by Hoesli et al, 1997).

[32] Information can also be shared over time, in this case the literature talks about “longitudinal” scale economics (Geltner & Miller, 2001).

Repeated Sales/Measures Regression

The other kind of regression model, the repeat-sales method, uses sales prices of the same property at different points in time, provided that the property characteristic does not change between the two sales.[33] This same method can easily be applied to appraisal instead of sales data, only the name of the regression changes from RSR to Repeated Measures Regression (RMR). The big advantage of this econometric technique is that it allows a more efficient use of empirical observable data, namely the construction of an index (of capital returns)[34] at a greater frequency than the properties are reappraised, under the condition that the reappraisals are staggered over time (Geltner, 1996).[35]

The number of transactions is critical for the RSR procedure, because it can only be applied if the data covers more than one transaction of the same property.[36] This restriction requires a sufficient property turnover rate to be successfully applied which may not be available. Also the differentiation between substantial property modification and regular renovation may be challenging and may bias the sample selection. Clapp and Giaccotto (1992) also showed that those properties selling repeatedly may not be a representative sample of the population of all properties.[37]

Nevertheless, in their recent studies Gatzlaff and Geltner (1998) developed the first repeated sales transaction-based index of commercial properties for the state of Florida, based on Florida's Department of Revenue data on properties that sold twice during two decades. Their results showed the feasibility of this method, which seems to filter out transaction noise. They further examined the difference between the RSR method and the appraisal based NCREIF of Florida. Surprisingly the two indices differ little in terms of overall performance and annul volatility but the RSR index may slightly lead the NCREIF index in time and may also register price movements that the NCREIF index does not exhibit.

The RMR usually doesn't lack repeated appraisal information about one property, however, the appraised values will be affected by idiosyncratic appraisal error (as discussed in chapter 2.2), which can add additional heterogeneity on the property level. To cope with the heterogeneity of the property data, advanced regression techniques like the Ridge Regression were developed (Geltner & Miller, 2001, cp. chapter 4).

[33] The regression method (RSR) was first proposed by Bailey Muth and Nourse (1963) as a procedure for developing real estate price indices. The technique was refined by Case-Shiller (1989), Clapp-Giaccotto (1992), Gatzlaff-Haurin (1997), Goetzmann (1992), and others (as reported by Clapp & Giaccotto, 2001).

[34] Geltner (1996) describes the biggest advantage of the RMR method to be used as a leading capital gain indicator mainly for commercial properties. (Housing indices normally already use HVM methods.)

[35] As the RSR/RMR assumes that the object acquired and sold is the same, properties that have changed substantially during the two sales due to addition or modification need to be screened out of the sample.

[36] Clapp and Giaccotto (2002) showed that this restriction can reduce the sample size up to 97%.

[37] Clapp and Giaccotto (2002) describe the "lemon" phenomena, where they establish a relation of the properties attractiveness and the frequency they are sold. In general they observe unattractive properties sell more often than attractive ones.

2.3.4. Synthetic Indices

Synthesizing and Forecasting

As discussed in previous chapters, independent of the index construction method applied, the availability of real estate transaction data is key. If such data is not sufficiently available, what may often be the case due to the general lack of long term data especially in Europe, an index can also to be "synthesized", i.e. derived from private real estate market related data.

In the case of Europe, Chaplin (2004) outlines the following three conditions of real estate market related data necessary to create an index:

- A reasonably long series of data for various market indicators by country and sector.
- A set of data that is consistent (e.g. availability of a market rental value measure for each country).
- A set of data that aims to represent the market movements in each of the countries.

The problems of the availability and also reliability of measures of the direct real estate market severely limit the analysis of international real estate markets and may force the use of alternative measures of these markets. The use of any synthetic approach therefore provides clear advantages. First, international coverage can be greatly expanded to include markets that have limited direct market data. Second, the historical coverage and frequency of the data can be greatly expanded. Nevertheless, it is clear that the quantification of any step used to transform related data into a real estate index may be another source of misleading assumptions.

Examples of Additional Data Sources

One source of information which is normally provided for any bigger city in Europe is prime rent which can normally be obtained from various real estate agents and consultants. Based on the high correlation between this prime rental growth and the portfolio rental growth, Chaplin (2004) demonstrated a way to translate the characteristic of the prime rent into synthetic portfolio rent which again can be used to generate a total return index by countries and segments.

As other example, one can mention Stevenson (2000) who uses the indirect real estate security (REIT) index to synthesize a direct real estate index. He uses a hedge method proposed by Giliberto (1993) which utilizes the more comprehensive data available for indirect real estate securities to obtain a proxy of the direct market by removing the influence of the general equity market on the real estate security series (as reported by Stevenson, 2000).[38]

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[38] As the relationship between the indirect real estate vehicles and the general equity market may not be stable, the hedge indices used by Stevenson are calculated on a forty-eight month rolling basis as in Giliberto (1993) and Liang and Webb (1996), (as reported by Stevenson, 2000).

Fu and Ng (2001) investigate in the price adjustment process of the private and the public indirect real estate market as well as in the level of autocorrelation of these time series. Similarly, Geltner and Miller (2001) examine the relation between the returns of NCREIF and REITs. Even though this studies target only the characteristics of the returns of the private real estate markets regarding efficiency, volatility, and smoothing, such approach could also be used to reconstruct an entire time series of a not observable private real estate market based on publicly traded securities.

2.4. Index Issues on an International Level

2.4.1. Index Use and Statistical Method

Especially at the level of an international index, the question of the statistical method used to create and to conjoin indices needs to be further explored. According to Geltner and Ling (2001), the purpose and specific use of an index informs this statistical method. They further establish two categories of use and distinguish two types of index products in the private real estate investment industry, namely a benchmark index[39] and a research index.

A benchmark index is used as reference point or standard to measure the relative performance of a specific portfolio or of a specific investment manager. In this case, a manager is mainly interested in the performance of a market (or a market sector) which is comparable to the portfolio under his survey.[40] For such a purpose a large fraction of the population of the possible peer universe should be included to minimize the bias in the benchmark index. (Smaller samples are often not random and do not represent the entire peer universe, Geltner & Ling, 2001).[41]

Traditionally it is suggested to base an index with such use as close as possible to the census population rather than to base it on a merely acceptable sample size. Also often evaluation benchmarking requires the comparison of a time-weighted average return over a given period. The calculation of the managers

[39] Geltner and Ling (2001) further describe two different types of benchmark index used in the public securities investment industries: first, a peer universe index, which reflects the performance of all managers that are effectively competitors of the subject manager. Second, a passive market index, which represents the performance of all assets in the given market segment or also group segment.

[40] For example, if it is used as a benchmark for institutional investors it should only include properties in which such institutions can invest in. Otherwise, one will not compare apples vs. apples.

[41] Geltner and Ling (2001) also establish fundamental criteria for an ideal performance evaluation benchmark:

1. The benchmark's return can be calculated over the time span of the investment management contract.
2. The investor can invest directly in the benchmark index as an alternative to hiring the investment manager.
3. The investment manager will therefore never be forced to place a bid against the benchmark index
4. The benchmark should reflect the investment style or specialization of the manager.
5. The manager should not be able to directly influence the performance of the benchmark to any significant degree.
6. The benchmark should be mutually agreed upon by the investor and manager at the outset of the investment management contract.

(agents) time weighted return is normally appraisal based[42] and accordingly it is legitimate to also use an appraisal based rather than a pure transaction based index as benchmark. (Geltner & Ling, 2001)

In the case of a research index, the claim of consensus is normally too ambitious. The population and the heterogeneity of the single assets may be a good deal bigger. Accordingly, the traditional sample method is appropriate to reflect the entire population of the universe of interest. Generally, most of the indices are sample based, i.e. the entire market gets represented by a sample of the population. Also in the public security markets sample based indexes are common.[43]

Depending on whether the index is viewed as statistical sample or population census the properties should be weighted equally in case of the sample[44] and value weighted in the case of population census (Geltner & Ling, 2001). Also, the usefulness of a sample drawn from a large population is a function of three characteristics:

- How much random dispersion exists in the underlying population.
- The absolute size of the sample.
- The representativeness of the sample.

Generally speaking, the effect of the absolute size of a sample is a function of the square root of the number of independent observations in a sample[45], meaning that the increment of the sample size does not equally affect the quality of the observation. In a diverse or complex population like in the private real estate market it may be more efficient to stratify the sample for the purpose of increasing the confidence factor.[46]

2.4.2. Market Size and Weight

Combining indices of different segments, sectors or countries requires the knowledge about the weight or the size of the parts which will be combined. In the private real estate market the size of the population as well as the size of the sectors is difficult to define. For example, it may be challenging to position to owner occupied real estate, mixed use projects, or also developments.

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[42] An individual portfolio of a single agent is likely to contain a relatively small number of properties (small sample) where purely random valuation noise tends to present the most serious problem. Valuation techniques that minimize the purely random error are therefore the appropriate methods in respect to the agent's portfolio.

[43] For example, the S&P 500 is a passive market index whose use is widely accepted both for evaluation and benchmarking and for broader research purposes in the public securities market (Geltner & Ling, 2001).

[44] This argument holds, unless the sample is stratified and would represent disproportionate shares of the underlying population.

[45] According to the square root rule in statistic theory a sample that is four times larger tends to only double the statistic accuracy e.g. half of the typical estimation error magnitude or range in a given confidence bound.

[46] Sample stratification refers to the identification of the "strata" (cells) which consist of subpopulations (or segments of the total population) that are relatively homogeneous within each cell.

However, the size of the private real estate market has been studied in the US as well as in Europe by investment banks and professional research companies.[47] There are many approaches to estimate a market size and accordingly there is a diversity in interpretation and practice. Due to the “alarming” difference of the estimates, the question of the precise size of the population of the private real estate market can be considered ”unsolved”. The current practice in Europe is to stratify the universe in order to survey the market, namely the distinction in the investible and the invested real estate market (IPD’s use of these terms is further explained in chapter 3.2.1).

To estimate the size of the investible market one can follow the approach of Liang and McIntosh (2004) who basically establish a ratio between the GDP, the GDP per capita, and the investible real estate market in a country with a refined surveying industry. In a second step they apply this relationship as base to estimate the size of other private real estate markets in countries which are surveyed to a lesser extend (as reported by Hordijk, 2004).

It is obvious that this approach is just the “best estimate” and is based on the assumption that the relation between a private real estate market and underlying economic data as well as the relation between the different real estate sectors within the market are consistent in all countries of observation. Since the country specific laws and regulation, like social housing policies, tax policy, corporate real estate ownership etc. are seldom identical for different countries, the pitfalls of this approach have to be recognized. (Hordijk, 2004)

An easier and more applicable approach may therefore be to estimate the invested market. Especially if an index is used as benchmark, the market of interest is the one where participants with the same asset allocation agenda are currently investing. Accordingly, instead of the properties, one counts the companies and the value of their assets. Obviously this approach is easier to be applied in practice than the one prior described, and finds therefore currently a high level of acceptance in the valuation industry.

2.4.3. Currency Issues

To combine or group national indices of real estate markets in countries with an independent currency ads complexity. Next to the movements of the market one also has to deal with different currencies. Since currencies generally move much faster than the real estate markets, any observable change may be primarily based on a change in the currency. However, the currency market is considered rather efficient and is well observed, so index movements based on currency market can be easily isolated.

Currency rates change and are reported in a much higher frequency than property values and indices. The currency rate at the specific index reporting date may not be representative of the currency movement of

[47] In the US, Mike Miles (1997) as well as David Harzell (1994) have studied this field several times. Harzell used local property tax records by Real Estate Data for his estimates, Miles also calculated the value growth factor based on the NCREIF index. In Europe, the main studies where done in the UK by Bootle (2002) who estimated the size of the stock based on the property related activities compared to the GDP (as reported by Hordijk, 2004).

the previous period. Consequently, the property income and appreciation during that period will be distorted if they are converted by this single currency rate. This influence can be mitigated by a more frequent reporting and conversion of property income and value.

Also, currency movements will have a strong influence on the weight of a single country in an international index. Let's assume a real estate market of a specific country outperforms other ones but the currency of this country devaluates and diminishes the size of the market weight in the international index. In this case would the performance of the marked be reflected correctly in the international index?

There are different arguments to be made how to deal with currency movements in an international index and the issue is widely discussed in the literature. What finds common ground is the fact that the reporting frequency of the index is of importance, meaning, the higher the frequency the less noise or error is added to the returns through currency movements.

3. THE IPD INDICES AND THE EUROPEAN REAL ESTATE MARKETS

In this chapter we would first like to give a brief overview of the coverage and characteristics of the Pan-European Index whose consultation release is planned for August 2004. Second, based on the data which is currently provided by IPD we will discuss the European real estate market regarding country and sector performance. Third, we will address key areas regarding European appraisal issues that are generally relevant for a successful implementation and credibility of the Pan-European Index.

Looking at the indices currently provided in western Europe, Geltner and Ling (2001) distinguish among three main types of data streams reported with regular frequency: There are property level indices, produced by individual firms or agents which are directly involved in transactions and portfolio management (for example, CBRE , and JLL, that base their indices on data coming from the properties under their management), fund level indices that are produced directly for specific clients (funds), and most importantly independent indices, that are dominated by IPD indices provided by the UK based company Investment Property Databank (IPD).[48]

As an independent company IPD and its international partners publish sets of indices that monitor market movements in various European countries by compiling records of actual properties owned by investors. To avoid any conflict of interest IPD does explicitly not participate in any investment market as principal or intermediary. Nevertheless, in over 20 years of experience IPD established a unique international standard of independent property market benchmarking that finds highest industry acceptance.

3.1. IPD's Pan-European Index[49]

To address the need of a European benchmark, used for investment strategies involving whole Europe, IPD plans (next to providing performance histories of all European countries) to establish a Pan-European property index.[50] This Pan-European Index (PEI) measures the combined performance of investible real estate in eleven countries across Europe, and is based on IPD's indices for Denmark, Finland, France, Germany, Ireland, Netherlands, Norway, Portugal, Spain, Sweden, and the UK.[51] More properties are planned to be added in the near future, esp. Austria, Belgium, Italy, and Switzerland.

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[48] It is clear that not all European countries provide reliable data on the private real estate market. The most refined reporting is generally found in the Anglo-Saxon and assimilated countries. However, one can assume that in the near future data will be available for most of Europe, especially for all countries that are part of the EU.

[49] Chapter 3.1 is mainly extracted from technical notes and data IPD provides to their customers.

[50] IPD's further goals: Fully published Pan-European Index in June 2005, consultation release of the global index in 2005/2006 (Cullen, Vienna, 2004).

[51] The Pan-European Index is the second international IPD index. There already exists a Nordic Index covering Denmark, Finland, Norway, and Sweden.

It is obvious that European investment strategies are difficult to create without a set of performance histories for the targeted countries and sectors. To produce this kind of sufficiently robust set of histories, a reasonably lengthy series of data for various market indicators (countries and sectors) is required.[52] Also, the sources of the data sets should be consistent, meaning the appraisal or measurement methods used to value the private real estate market in the different countries and sectors should be similar or ideally be alike.

Accordingly, IPD faces several challenging issues coming along with the planned Pan-European Index. First, not all the countries provide long enough data streams to be used for an index; second, some countries do not provide data reliable enough to be taken into consideration; and third, the size of the real estate market that will be defining the weight of the performance of a specific country in the Pan-European Index is not directly observable. Therefore, IPD defines very clear guidelines regarding these issues that have to be met by the countries that are part of the Pan-European Index. For example, a minimum of 3 years of data history as of 2004 is required; also, the valuation method has to be based on the generally used market value theory. Countries which do not meet these standards will not be included in the index.

3.1.1. Index Construction

In its current stadium, the Pan-European Index (PEI) is conceived as an open index (as opposite to a frozen index like the annual UK office index) and enables to add indices of additional countries (e.g. Austria, Belgium, Italy, and Switzerland) as soon as they fulfill the necessary requirements. In this “open structure” obviously the performance of the index changes each time a new data set is added. If the new data set also involves historical performance, the data set added will in addition have an historical impact on the index, meaning the reported performance will change ex post.[53]

Since IPD changed in 2001 the used money weighted returns to monthly time weighted returns for most of their country property indices, the monthly time weighted returns will also be the base of the Pan-European Index. The stated reason for this higher frequency is, *”to ensure comparability with other assets where time-weighted return calculations are the norm”* and, *”to meet client demand for more frequent reporting based on quarterly or half-yearly valuations”* (Understanding the new formula for annual total return, IPD, 2001). The trend towards more frequent valuations requires that IPD is able to provide measurements over almost any period on a consistent basis, what can only be achieved by using a consistent building block of monthly cash flows.

[52] As a rule of thumb, to significantly reflect on the performance of specific markets and their correlation behavior among each other and among other asset classes, one needs approx. the time length of one economic cycle.

[53] The main problem of open indices that change retrospectively through data added with history is the fact that they can not really be used for “long time” benchmarking and derivatives that refer to specific constant historical prices.

Method[54]

According to the technical report regarding the construction of IPD's Pan-European Index (2004), there are four fundamental stages in calculating the aggregate property index returns:

- Deriving monthly components of total return.
- Reweighting local currency index data according to the sizes of the investible markets in each country.
- Converting reweighted local currency data to a common currency.
- Calculating monthly and annual returns.

First, apart from the UK and Ireland, the databank structures for the countries are based on annual valuations, so the individual annual databanks of these countries are being converted into monthly structures by apportioning the capital and income flows evenly across twelve months, and linear interpolation of capital values between year-ends. This provides the four components necessary to calculate a time weighted total return. Start-month capital values, end-month capital values, monthly net income, and monthly net capital expenditure.

Second, the components of returns are then adjusted to reflect the total value of professionally invested funds in each country (cp. chapter 3.2.1); this ensures that the weight of each country within the index is consistent with the relative value of these funds. The definition of professionally invested funds includes life & pension funds, unitized vehicles, pooled and collective investment funds, traditional estates & charities, quoted property companies and REITS, unquoted property companies and all overseas investors. But the definition excludes small private landlords, owner-occupied property, private equity, or PFI funds where investors own the operating business as well as the property (e.g. pubs, hotels, hospitals), mortgages and property assets of leasing companies and municipal housing.

Third, the start- and end-month capital values, monthly net income and monthly net capital expenditure which now represent 100% of each market is converted into common currencies at the month end. Currency conversion has an impact on the local market returns as changes in values from one month to the next are partly the result of fluctuations in the currency rates in addition to local property market factors.[55]

Forth, the reweighted and currency converted components can then be used to generate single currency monthly returns using the standard total return formula to calculate time weighted returns. This monthly or annual total return is calculated in two stages: The total returns are first calculated for each individual month and then compounded over the relevant period of 12 months.

[54] The information of the method is directly extracted from IPD's technical report of the Pan-European Index, June 2004.

[55] The aggregate Pan-European Index return in local currencies is calculated using a constant conversion rate for each month in a given year to exclude year-to-year currency impacts. The constant rate used is the respective year's end-December rate.

Step one represents the basic building block for the monthly return from which all other periods are computed[56] and is represented mathematically as follows:

$$TR_t = \frac{(CV_t - CV_{(t-1)} - C_t + NI_t)}{(CV_{(t-1)} + \frac{1}{2} C_t - \frac{1}{2} NI_t)} \qquad (3)^{57}$$

TRt...... Total return in month t.
CV_t...... Capital value at the of month t.
C_t........ Is the net value of all other capital expenditure less receipts during the month.
NI_t....... Day-dated rent receivable during the month, net of asset management costs, ground rent and other irrecoverable expenditure.

Step two compounds the monthly total returns. Starting from the base value of 100, each successive index value is calculated by multiplying the preceding index value by (1+growth rate[58]). Accordingly, the annual growth rate is calculated as percentage change in the index (X_t) over the relevant twelve months:

$$TR_t = [(\frac{X_{(t+12)}}{X_{(t)}}) - 1] * 100 \qquad (4)$$

Interpolation of Capital Values

The annual time-weighted return calculation requires monthly cash flows and month-end-valuations. Where monthly valuations are not available, IPD has to estimate the missing values using the following two methods (Technical Note, IPD, 2001, p.3):[59]

- "*When there is an actual valuation at both start and end of the period, intervening valuations are interpolated between the current and previous values using the best available index of capital movements for that property type at a monthly level, allowing for any intervening capital expenditure or*

[56] Whatever the interval is, equal weights are given to each month's return in any period (quarter or annual).

[57] This formula is based on the formula for the annual UK property market index:

$$TR_t = \frac{(CV_t - CV_{(t.1)} - P_t - S_t - C_t + NI_t)}{(CV_{(t-1)} + P_t + \frac{1}{2} C_t - \frac{1}{2} NI_t)}$$

Where the capital expenditure is further refined by adding P_t as the gross purchase cost of the whole property purchases and any other capital expenditure greater than 20% of the start month value of the asset, and S_t as the net sale receipts from whole property sales during the month and any other capital receipts greater than 20% of the start month value of the asset. (Technical Note, IPD, 2001).

[58] The percentage growth rate is obviously expressed as a decimal.

[59] IPD (Technical Note, 2001) further explains that, *"On properties without expenditure the annual capital return calculated by the time-weighted method will be the same regardless of whether the highest capital growth was concentrated at the start or end of the year, but extreme index movements will result in small differences in the monthly income returns (due to different capital values in the denominator of the return equation). These will feed through to differences in total return at an annual level."*

receipts. The index provides only the 'shape' of the growth between the actual valuations, not the magnitude." This obviously works only for countries like the UK, where monthly index data is available for some properties. For most of the European countries, monthly values can only be computed as linear interpolations between the two valuation points.

- "*If the property has been purchased or sold during the period, intervening values are estimated by interpolating between the actual valuation at either start or end of the period and the net purchase price or gross sale price, using the shape of the relevant capital growth index and pattern of expenditure as above. This means that any profits or losses between agreed transaction prices and average market movements will be spread over the period from the previous valuation. Transaction costs are concentrated entirely in the month of the transaction*."

Naturally, interpolations are only approximations of the true value movements between two valuations, which will rarely look like a linear interpolation. In chapter 4 we will investigate this issue further and compare the linear interpolation with other index construction methods to estimate their accuracy in creating monthly or annual indices.

3.1.2. Market Coverage

The Pan-European Index is currently covering the named eleven European countries i.e. these eleven countries provide reliable data (i.e. market size estimates, total capital value, and number of properties as of June 2004) of their property market performance for a long enough period of time. As expected, the countries do not all provide the same amount of data, nor do these data represent the same share of the true investible or invested real estate market. IPD generally needs a certain amount of market coverage, i.e. the properties under surveillance must represent a certain part of the observed market to be accepted as a representative sample of the population, cp. chapter 2.4.1.

Table 1 shows the significant difference in available data, market coverage as well as duration of data series of the countries, currently being part of in the PEI. Since IPD is based in the UK, which has a long tradition in the surveillance profession, it is clear that the number of properties as well as the length of the series substantially exceeds the other countries. On the other hand, the 18% market coverage of Germany may be a concern, especially since compared to other European countries, Germany has a very heterogeneous real estate market due to comparatively many different business centers.

The question about the sample size necessary to reliably represent the investible real estate market of a country may be one of the key issues for the Pan-European Index. Since IPD's data base is constantly growing, this issue may though be solved within time, i.e. regarding market coverage the PEI will constantly gain reliability. The question of whether Germany is currently represented enough needs to be solved before the PEI is published.

Table 1: Overview Pan-European Index Coverage

Country	Start Date	Available Data	Market Coverage	Total Capital Value in EURO	No of Prop.
Denmark	2000	ERV growth Yield Income, Capital & Total Return	39%	88.8	1,414
Finland	1998	Total Return	58%	12.5	1,768
France	1998[60]	ERV growth (2002 on) Yield Income, Capital & Total Return	62%	56.8	4,743
Germany	1996	Yield Income, Capital & Total Return	18%[61]	34.8	2,380
Ireland	1984	ERV growth Yield Income, Capital & Total Return	79%	3.7	329
Netherlands	1995 and tracked back to 1977[62]	ERV growth (1995 on) Yield (1995 on) Income, Capital & Total Return	59%	38.5	6,243
Norway	2000	Income, Capital & Total Return	35%	7.0	452
Portugal	2000	ERV growth (2001 on) Yield Income, Capital & Total Return	39%	4.9	291
Spain	2001	Yield Income, Capital & Total Return	28%	7.8	350
Sweden	1997 and backtracked to1984	ERV growth (1998 on) Yield (1997 on) Income, Capital & Total Return	38%	22.0	1,692
UK	1981	ERV growth Yield Income, Capital & Total Return	45%	160.0	10,811

Source: Columns 2-3: Chaplin, R. 2004 May 12-14. Synthesizing and forecasting IPD type indices in Europe. Paper presented at the IPD / INREV European Property Investment Conference, Vienna / Austria.
Columns 4-6: Cullen, I. 2004 May 12-14. Towards a Pan-European Index: Measuring the Size, Structure and Performance of the Markets. Presentation at the IPD / INREV European Property Investment Conference, Vienna / Austria.

[60] Office tracked back to 1986 (Chaplin, Vienna, 2004, p.3).

[61] This number was updated according to the latest release of, "Constructing the IPD Pan-European property index" (IPD, June, 2004).

[62] Retail and Office only (Chaplin, Vienna, 2004, p.3).

3.2. The European Real Estate Markets

3.2.1. The Potential of One European Real Estate Market

Given the diversity of the countries in Europe regarding the cultural, legal, as well as economical environment it is difficult to talk of "one" European real estate market; it would probably be more appropriate to talk about a combined European real estate market. This combination of real estate markets is clearly characterized by its heterogeneity, its lack of transparency as well its missing standardized measurement procedures.[63]

In terms of investment ground the European real estate market is perceived especially by US investors as rather unfamiliar, partially illiquid and just simply risky. This current perception of this market is for sure the main reason why the planned implementation of a Pan-European Index makes sense and is a necessity to further develop the European real estate market in terms of transparency, liquidity, and refined investment products. The estimated global disposition of real estate (cp. Table 2) exhibits that the market in Europe contributes to approx. one third to the global real estate market and therefore can not be left undeveloped.

Table 2: Global Key Statistics in Percentage

Country	Population	Land Area	GDP	Real Estate
Asia Pacific	58	29	26	24
Europe	16	7	30	34
Latin America	15	32	6	4
US/Canada	11	32	37	38

Source: McIntosh, W. 2004 May 12-14. A U.S. Perspective on One European Market. Presentation at the IPD / INREV European Property Investment Conference, Vienna / Austria.

It may be also obvious that the European market has potential for especially globally diversified investors.[64] Europe represents additional investment opportunities and with additional diversification possibilities. The perceived lack of transparency also implies quantifiable inefficiencies which can be exploited by experienced investors to generate extraordinary returns on real estate investments. Accordingly, there is a clear potential for a single, unified, and standardized European real estate investment market.

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[63] The differences further include, political risk, legal structures, liquidity, tax structures, currency risk, data availability and quality, lack of investment products, etc. (McIntosh, Vienna, 2004).

[64] One can note that there is not yet a direct real estate investor that is globally diversified. Nevertheless, through the securitization of the markets as well as through hedge funds (in the type of funds of funds) it is and will even more be the case that a global diversification is applicable.

3.2.2. Size of the Pan-European Markets

Next to the market coverage, the market size is of a key interest and its correct estimation is necessary to combine the different markets (cp. chapter 2.4.2). Currently IPD uses the invested market of specific companies (cp. chapter 3.1.1). They choose this approach because the measurement of the total real estate market (that would be ideal for IPD to use)[65] is as reflected difficult and not yet applicable for a Pan-European Index.

Nevertheless, the European market size is discussed and studied and some data was recently presented by Hordijk at the IPD conference in Vienna (2004). Based on the market data from the Netherlands (that can be described as a well surveyed country), Hordijk first established a quantifiable relationship between the invested real estate market, the investible real estate market, the GDP, and the PCG. Second, he applied this relationship to measure the markets in other European countries using the model of Liang and McIntosh (cp. Chapter 2.4.2) that can be represented mathematically as follows:

$$REx = REy * \frac{GDPx}{GDPy} * \frac{PCGx}{PCGy} * \frac{1}{3} F \qquad (5)$$

RE....... investment-grade real estate
GDP.... gross domestic product
PCG.... gross domestic product per capita
y.......... subscript for well observed country
X .... subscript not observed country
F .... adjustment factor

To obtain the total value of the national real estate markets, the study further uses reports from real estate institutes, national statistical databanks or simply taxation values. For countries where there is no such information available (Finland, Ireland, Norway, Portugal and Spain) a ratio based upon the GDP to the national real estate is applied for total market size estimates (cp. Table 3).[66]

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[65] The entire market size would be ideal for a research index - for a benchmark index it may be more feasible to only look at the market where peers are invested in (chapter 3.1.1).

[66] 3.19 was used as the ratio of the total real estate asset market to GDP, based on observations in the Netherlands (Hordijk, Vienna, 2004). Especially in countries where the invested market is not yet observable, meaning the companies under observation of IPD and their peers have not yet (or not to a full extend) entered this market, the method applied by Hordijk may be applicable.

Table 3: Market Size of the Countries Included in the PEI in Billion EURO[67]

Country	Invested Market	Investible Market	Total Market	GDP in Million	Population in Million
Denmark	23	76	612	183	5.4
Finland	20	55	464	140	5.2
France	125	604	4868	1521	59.3
Germany	292	819	7109	2110	82.5
Ireland	5	55	432	129	3.9
Netherlands	65	180	1467	445	16.1
Norway	20	83	632		
Portugal	9	45	430	129	10.3
Spain	24	273	2401	696	40.5
Sweden	58	104	552	256	8.9
UK	358	625	5054	1574	59.4

Source: Hordijk, A. and C. Ahlqvist. 2004 May 12-14. European Market Dimensions: An Inventory of the Investible Market in 11 European Countries. Paper presented at the IPD / INREV European Property Investment Conference, Vienna / Austria.

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3.2.3. Performance of the Pan-European Countries

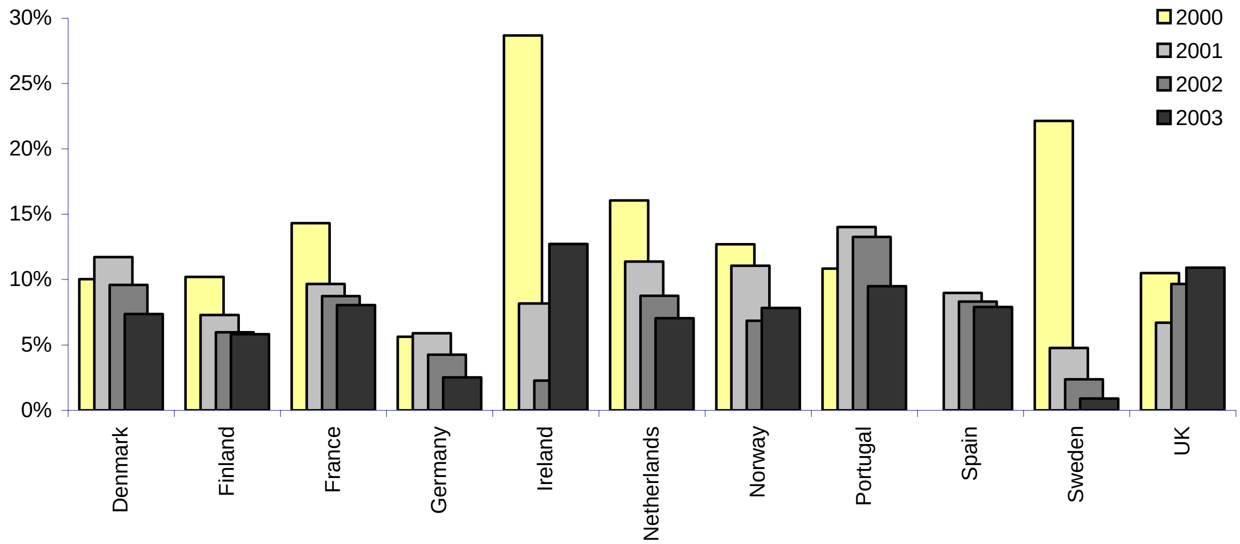
Total Return

As prior discussed, the most important measurement of the performance of the real estate market is clearly the reported total return (income yield and capital appreciation cp. chapter 2.3.1). Since the different countries provide a wide range of data history, it may be reasonable to look at the performance of the last 4 years (Figure 2)[68], which is observed in all the countries included in the Pan-European Index except Spain, which starts in 2001.

[67] The numbers presented in this table may not be identical with the latest update of IPD.

[68] In this table as well as in all following ones, there is no average provided since the countries would need to be weighted, which is as described in chapter 2.4.2 an issue of its own.

Figure 2: Total Returns of the Countries Included in the Pan-European Index



Source: IPD Multi Country Index Spreadsheet, Update 4, June 2004.

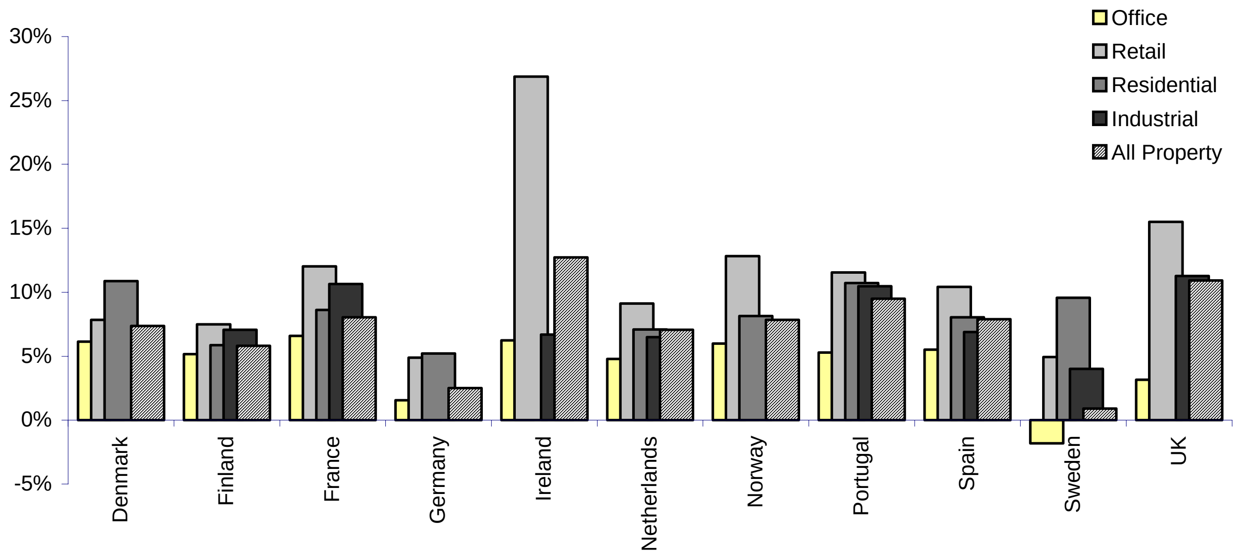
Figure 2 shows the explicit heterogeneity of the various country performances in terms of mean and volatility of the total returns. If one compares, for example, the returns of Ireland or Sweden with the ones of Germany, there is significant difference in the volatility of the returns; whereas the ones of Ireland and Sweden move in double digits, Germany exhibits a movement of just 3 percent over 3 years.

Also notable is the differing reaction time of the various real estate markets on changes of the underlying economy. Even though one can assume that generally whole Europe was hit by a recession directly after 2000, Figure 2 exhibits that the real estate markets reacted differently. For example the returns of the UK, Ireland, Sweden etc. dropped significantly in 2001, whereas the ones of Denmark, Germany, Portugal did not react at all. It is clear that the economic sectors, the fiscal and monetary policies etc. differ in the observed countries.

However, it is very different to draw conclusions from that short return history regarding the quality of one index in relation to the others. The differences in return volatility may be caused by different market behavior, indicating that the country markets in fact work differently and are heterogeneous;[69] or by different appraisal behavior, indicating that the country markets are in fact similar and that the heterogeneity in the returns is introduced by different appraisal behavior. This will be further discussed in chapter 3.3.

[69] The existence of market inertia or sluggishness (market participants only adjust gradually to the arrival of new information) is a violation of the "weak form of market efficiency". As discussed in chapter 2.1.1, real estate markets can be expected to have some sluggishness (also shown by Fu and Ng 2001 for the Hong Kong real estate market). Similar to the effect of appraisal smoothing, the consequence of market sluggishness is a less volatile and lagged index.

Figure 3: Sector Return of the Countries Included in the PEI in 2003



Source: IPD Multi Country Index Spreadsheet, Update 4, June 2004.

The fundamental differences in the index characteristic of the countries are further reflected in the sector performance. A snapshot of 2003, presenting the sectors retail, office, industrial, and residential shows (as expected) a differing pattern of returns (Figure 3). Big differences are especially observable in the sectors retail and office.

In order to be combined into a Pan-European Index, the total return components have to be transformed into the EURO. As an example, the exchange rates as of the end of 2003 are depicted in Table 4.

Table 4: Currency Exchange as of 31 December 2003

31 December 2000		**DKK**	**EUR**	**NOK**	**SEK**	**GBP**	**USD**
Denmark	*DKK*	1	0.134	1.132	1.222	0.095	0.169
Eurozone	*EUR*	7.449	1	8.427	9.094	0.706	1.256
Norway	*NOK*	0.884	0.119	1	1.080	0.084	0.149
Sweden	*SEK*	0.820	0.110	0.927	1	0.078	0.138
UK	*GBP*	10.550	1.417	11.936	12.885	1	1.779

Source: IPD, 2004, Constructing the IPD Pan-European property index, unpublished technical note.

3.3. Valuation Issues in European Countries

In the last chapter we looked at the reported numbers of the European real estate market, and observed strong differences among the countries. As we discussed in chapter 2.2, one has to be aware of the fact that the reported numbers do not precisely reflect the underlying market; especially that the property appreciation strongly depends on the valuation method used by appraisers.

3.3.1. Valuation Issues on a Disaggregate Level

For simplification one can identify three groups of European countries with a "uniform" valuation approach. First, the Anglo-Saxon countries or related ones (e.g. Scandinavian countries), which use a clearly defined valuation method based on RICS guidelines.[70] Second, the non Anglo-Saxon countries which use another clearly defined method to value real estate (for example Germany), and third the non Anglo-Saxon countries which use no clearly defined or regulated appraisal methods or do not provide any reliable data at all. The Anglo-Saxon valuation approach is widely described and was discussed in chapter 2.1.2. To illustrate differing valuation methods and the diverse understanding of real estate, occurring from different historical and cultural backgrounds of the European countries, the further reflection will be on the latter two groups of countries.

The Non Anglo-Saxon Countries with Differing Methods

A widely discussed valuation approach of a non Anglo-Saxon country is the one of Germany. The way real estate valuation is preceded in Germany is defined by the German Federal Building Code (BauGB) and does not directly follow the method proposed by RICS. (Thomas, Vienna, 2004)

Section 194 of the German Federal Building Code defines what we called market value as: "*The standardized value is defined as the price which would be achieved in an ordinary transaction at the time when the assessment is made, taking into account the existing legal circumstances and the actual characteristics, general condition and location of the property or other subject of assessment, without consideration being given to any extraordinary or personal circumstances*"[71] If one recalls the definition given by the IVS (cp. chapter 2.1.1) one sees that this definition of market value is conceptually the same as the one of IVS and should therefore not lead to any different result in the appraised market value.[72]

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[70] RICS stands for the Royal Institution of Chartered Surveyors, one of the most respected and high profile global 'standards and membership' organization for professionals involved in land, valuation, real estate, construction and environmental issues.

[71] Translation of the original text by M. Thomas (Vienna, 2004).

[72] There is also no fundamental difference in the definition of the EC directive 91/674/EEC which describes in Article 49 market value as, "*Market value shall mean the price at which land and buildings could be sold under private contract between a willing seller and an arm's length buyer on the date of valuation, it being assumed that the property is publicly exposed to the market, that market conditions permit orderly disposal and that a normal period, having regard to the nature of the property, is available for the negotiation of the sale*" (Thomas, Vienna, 2004).

However, to find the market value a potential buyer or seller normally hires an appraiser who uses a defined method to come up with estimation of such. Accordingly, the method used to do so may be more relevant than the pure definition of the market value; and exactly in the method applied in Germany vs. the US (or the Anglo-Saxon Europe) one finds some basic difference. In Germany a property is often not only viewed as an income generating asset and accordingly the method used is only partly based on cash flow valuation theory.

The IVS cite three basic methods to evaluate a property: the cost approach, the comparison approach, and the income approach (IVS, 2003, see chapter 2.1.2). As the recommendation is to use the most appropriate method applicable for the property, investment properties in the Anglo-Saxon countries are practically all valuated by the income approach. In Germany, however, the appraised value is often calculated as a weighted average of the three different approaches.[73] Therefore the income approach only accounts partly for the property value.

The other parts are often based on the so called "comparison value" as well as on the "replacement costs" including the construction costs and the land acquisition costs. To find the "comparison value" there are guidelines (quantifiable property and land characteristics) after that an appraiser can conduct the comparison of the property of interest with other properties. Similar guidance is provided to evaluate the replacement costs that are adjusted (depreciated or also appreciated)[74] to the time of the valuation.

Any specific valuation method follows basically the understanding of the asset or asset class it is meant to appraise. Accordingly, one can argue that the understanding of the asset class, i.e. the private real estate market, may in Germany slightly differ from the one in the US or the UK. Where the latter one understands real estate generally as income generating assets, the former one often also accounts for what could be called "user independent inherent value".

As example, given a brand new piece of core office real estate, with high end construction at prime location, which can not be leased up for an appropriate rent, could have a substantially differing valuation in the UK and Germany. The German valuation could account more for the construction and the land value and therefore estimate the value higher than the one in the UK. Also, the capital market or changes in interest rates will have a different effect on the values appraised by these differing methods. Since the rate, the cash flows are discounted with partly depends on the interest rates, the UK approach could be more sensitive to changes in such exogenous economic variables. Generally, the German appreciation returns may appear more smooth due to their partial reliance on the cost approach.

However, European countries have a varying understanding of the real estate asset class, and consequently use a different method to estimate the value of a property. The use of unequal valuation methods

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[73] German regulation recognizes the same basic approaches to valuation, although the detailed appraisal procedure deviates for each approach.

[74] This happens when the appreciation of the land value exceeds the depreciation of the built structure or if value was directly added to the build structure during the holding period.

partly explains why the observed private real estate market returns may differ in terms of mean and standard deviation among certain countries.[75] The question, why the perception of real estate differs and which method should be considered the “correct” one is though difficult to answer.

The Non Anglo-Saxon Countries with No Standardization

As another example of valuation methods used in Europe, one can also mention countries where the understanding of the private real estate market and the method used for its valuation are only barely standardized. This means, depending on who reports, the value of a property may differ significantly. Consequently, the attempt to create an appraisal based property investment index fails in such environments due to inconsistency of the provided data.

In such countries one is best served by starting out of the rent level figures that are reported by local agents that follow international standards (like DTZ, CBRE, JLL, SPD, Colliers, Cushman & Wakefield etc.). Normally these firms are represented in any city of international exposure and provide information about the office prime rent in the CBD; depending on the local involvement i.e. the portfolios under management, they sometimes also provide refined information like sector specific returns.

This data does not yet give a reliable index, so the method of synthesized indices needs to be applied. We talked in chapter 2.3.4 about the possibilities of deducting a private real estate market index from available economic data like the public real estate markets, the GDP etc. Since some European countries will not establish a continuously applied standardization for the valuation industry in the near future, one still may have to rely on this kind of index construction. The specific method to use may though be less important then the application consistency.

3.3.2. Reporting Issues on an Aggregate Level

As discussed in Chapter 2, the characteristics of the private real estate market, the appraisal practice, and the index construction method influence the amount of temporal lag in the index. It is clear that the countries in Europe differ substantially in these named characteristics. The established categories of Anglo-Saxon (and related countries) and non Anglo-Saxon may be a good starting point to reflect about possible lagging characteristics in the European countries.

[75] One has to note that the understanding of the asset class is only one factor which causes the private real estate market in Germany to differ regarding the return characteristics. In Germany also the capital inflow into the real estate market stems from differing sources, e.g. open ended funds.

The Anglo-Saxon European Countries

The real estate markets in the Anglo-Saxon countries are clearly the best observed and studied ones. For example, Geltner and Ling (2001) studied the lagging parameter of the UK, based on a comparison to the US, and came up with following specification and lagging characteristics for the UK:

First, the UK property asset market is generally observed as less sluggish (i.e. more informational efficient) than the one in the US, which allows the property market to better incorporate the effect of the latest news and information in a property valuation. Geltner and Ling identify three major sources causing this situation:

- The property leasehold difference: In the UK the institutional commercial property market incorporates more long term leases than the one in the US. In a traditional arrangement, typically 25 year leases are signed (with a 5 year upward only rent review). This long-term commitment of the tenants make the investment in the direct real estate market more homogeneous and give it a more “bond like” characteristic (Geltner & Ling, 2000).

- The geographical difference: In the UK (as well as in Atlantic Europe, for example France, Ireland, Portugal and Spain) the economic geography is dominated by a single metropolitan area, which also tends to make the real estate market more homogenous.

- The role of publicly traded property companies: A greater share of institutional commercial property is owned by publicly traded companies. The price discovery process (cp. chapter 2.1.1) is heavier influenced by the more efficient public stock exchange.

Second, the appraisal industry may be more standardized than in the US, as it is dominated by the RICS, which is accepted by the whole industry. The appraisal profession may also be based on a sounder education of the chartered surveyors. Also the index quality may differ in terms of the frequency of the reporting. (The NCREIF index reports quarterly whereas the UK index reports annually, which reduces the lag, cp. chapter 2.3.1).

The Non Anglo-Saxon European Countries

The non Anglo-Saxon European countries like Germany, France, and Spain are less well observed and studied than the Anglo-Saxon ones and are generally less transparent. Less transparent markets can also be described as less efficient and accordingly the price finding may take longer and may also end far away from the efficient market equilibrium (cp. chapter 2.1.1).

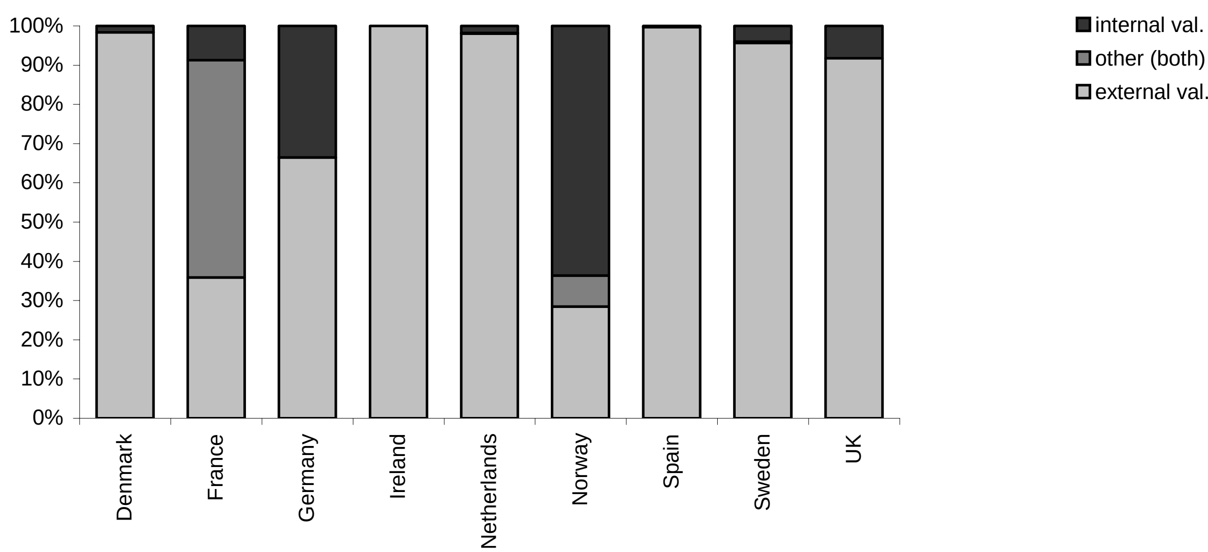
In such markets the single appraisers may have a bigger influence on the price level of the private property market than in a more efficient market environment. Every transaction price is finally based on the reservation price of a buyer and a seller. If now the market is not transparent, meaning there is no clear price indication, the appraisers are the single source informing about the value of the property of interest.

One may argue, that in inefficient markets the appraiser does not report on the values of the property markets but even more so define these. Accordingly, in such context, there is a close connection between the valuation method used and the observable market performance.

On a reporting level, as far it exists at all, one can assume that due to illiquidity in the market the appraisers have less comparables to use for their valuation than in an efficient market. One could imply that therefore any reappraising process is stronger based on the last estimated property value than on current market information (since they may not exist at all). Consequently we would find a stronger lagging in indices coming from countries with a less transparent and less liquid real estate market.

Further, as mentioned in chapter 2.3.1, an important source or the temporal aggregation problem are infrequent appraisals. All properties in the IPD indices are reappraised at least annually. However, the seriousness of reappraisal can not be tested, i.e. it is unknown if each property is fully reviewed or just adjusted to the inflation and capital expenditures. In the latter case, the appraised value would strongly rely on the previous valuation i.e. come close to no appraisal at all ("stale appraisal").

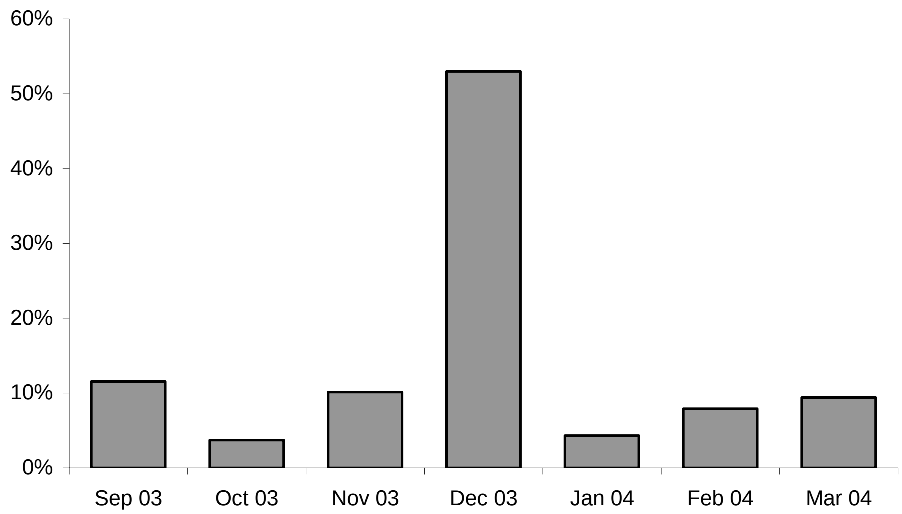
Figure 4: Internal vs. External Appraisals in Percentage of Capital Values



Source: IPD, 2004.

One indication for stale appraisals could be the share of properties that are appraised internally. Although the fact that an appraisal is done internally does not mean it has automatically a lower quality, but the in-house appraiser may be more biased to the previous valuation than the independent valuation company (see chapter 2.2.3). As shown in Figure 4, most of the PEI countries have a very high share of external reappraisals, only Norway and Germany have a significant portion of internal appraisals. In France a big portion of appraisals is done by a mix of internal and external appraisal.

Figure 5: Date of Reappraisal in Germany for Year-End Values 2003 in Percentage of Total Capital Value



Source: IPD, 2004.

Appraisals could also appear in the index as stale because of their earlier valuation than the index reporting date (cp. chapter 2.3.1). As many funds in Germany end their financial year in September or March, some part of the properties are not appraised as of December, the index reporting date, but up to 3 months earlier or later (cp. Figure 5). The reported capital value in December is therefore more an average of 7 months than a value as of a single point in time. Although the lagging effect may not be very big due to the inclusion of later as well as earlier values, this certainly may lead to an additional smoothing effect in the index.

Although Germany seems to be a special case with regard to smoothing, a reported valuation date as of December does not guarantee that the value is actually the best estimate for that date. Valuation firms are regularly overloaded with work at the end of every year, and may start to collect information and comparables about a property much earlier. The information that the appraisal is based on may actually be a couple of months old, so the appraisal itself will be slightly outdated.

3.3.3. Specific Pan-European Index Considerations

The nature of real estate investment - heterogeneity, lack of a centralized market, illiquidity - always imply challenges for the investors and managers. Nevertheless, the observable heterogeneity in the returns and volatility of the European real estate market raises the question of whether the direct combination of these private real estate markets in a single time series is finally feasible for an index. The combination of indices which are based on different valuation methods (e.g. combining the Anglo-Saxon with the non Anglo-Saxon) will create an index that may be of little use especially for benchmarking purpose.

Therefore one can ask whether there are any statistical procedures that allow to adjust or say transform the German approach to the one of RICS or IVS. We discussed in chapter 2.3.3 how to reengineer time series to get rid of the appraisal smoothing. Such an approach could be used to address a heavier reliance on past information caused for example by the lack of comparables. However, the systematic bias introduced for example by the partial use of the cost approach in Germany can merely be met by reverse engineering. One possible solution though may be to extract the value of the property after the income approach from the appraisal report and to only report this value to IPD.

Further we showed that the market sizes of the countries that are part of the Pan-European Index are difficult to measure. Up to now IPD is using estimates of the size of the investible market. This situation probably stems from IPD's main activity of benchmarking, where the market of interest is the one where participants with the same asset allocation agenda are currently investing. One can raise the question whether this approach stands in contradiction to the research use of the index, which should maybe rather represent the total real estate stock instead of the investible market.[76]

However, one may argue that the weight of the countries in the Pan-European Index is not solved yet. In chapter 2.4.1, we briefly outlined that an index which is viewed as statistical sample should be equally weighted, unless the sample is stratified and would represent disproportionate shares of the underlying population. In the case of Germany though, where IPD covers a sample of mere 18% of a very heterogeneous population, an equally weighted approach may not be feasible. The stratification of the German real estate market by the main cities (like Berlin, Frankfurt, Munich, Hamburg, etc.) may be more appropriate.

Generally, the named issues are hardly quantifiable but have to be considered and further discussed, what reflects not the key issues of this thesis. What can though be developed and quantified is what method to use for aggregating data. We briefly exhibited some differences between Anglo-Saxon and non Anglo-Saxon countries and identified on an aggregate level the impact of the reappraising distribution and external vs. internal method. To further refine the understanding of the characteristics of the methods that are used to construct an index an in depth analysis of their dynamic statistics is necessary.

[76] From a research perspective it would be more interesting to see the performance of the asset class real estate than of its investible market. Especially since the investible market strongly depends on IPD's strict company selection.

4. SIMULATION ANALYSIS OF TEMPORAL AGGREGATION

This chapter addresses one of the key issues of the Pan-European Index identified in the previous chapter, namely the problem of infrequent reappraisal and the consequent temporal aggregation in an index. Depending on the method used for adding together data in an index, the level of temporal aggregation differs significantly. Accordingly, we examined several methods normally used to address this situation of the missing observation problem, and further identified the ideal approach to deal most efficiently with the appraiser's data depleting best the stale appraisal in an index.

Basically, as IPD aims for the planned Pan-European Index to report monthly total returns and further to base the annual index on these monthly returns, they face the inherent challenge of high frequency reporting.[77] In chapter 2.3.1 we explained, that normally the best way to increase frequency without increasing either noise or lag is to improve the underlying property level valuation.[78] As IPD has just limited influence on this frequency, and as an increased appraisal frequency leads to significant cost increase for the member firms, the improvement clearly has to stem from the method used to aggregate the data.

As we discussed in previous chapters, there are three of these methods which are used in practice for index construction. First, what we called "Stale Appraisals", where the monthly capital gain simply refers to the last observed or appraised value and is not further adjusted to monthly changes (traditional method used for IPD indices); second, the "Linear Interpolation", where the monthly appreciation is simulated by a linear interpolation between the reappraisals (the plan for the PEI); and third the "Repeated Measures Regression" (RMR), where more frequently available data of smaller samples is used to compute representative monthly changes.

At the aggregate level the properties often are neither reappraised at the same point in time nor with the same frequency. Following, we tested the named methods in four different scenarios using different distributions of reappraisals over the year. In the first, all properties are reappraised as of the end of December, in the second, 80% of properties are reappraised as of the end of December (with the other properties evenly spread over the other months), in the third 50% of the reappraisals occur by the end of the year (with again the others evenly spread over the other months), and in the fourth, all reappraisals are spread evenly over the 12 months.

In our tests we clearly did not solely try to solve the question, which method gives generally the most accurate results. This question is widely documented and discussed and it is clear that the RMR generally proves to do a better job than the other two. We rather addressed the question which method shall be ap-

[77] As prior discussed, the challenge of the high frequency mainly concerns the appreciation of the properties normally reappraised yearly rather then monthly, cp. chapter 2.3.1. Accordingly, to close this gap of the missing capital values observations, is the concern of the index construction method.

[78] We also noted that the underlying sluggishness in private real estate asset markets reduces the incremental benefits from greater frequency since the appraised values also depend on the adjacent period; an influence that will be greater the shorter the observation period.

plied for each reporting frequency to make the most efficient use of the underlying appraisal data. For example, in case the monthly returns are aggregated back to annual returns, a method like Linear Interpolation may provide enough accuracy and even the traditional method of using Stale Appraisals will not have as much negative effect as generally assumed.

4.1. Testing Methodology

4.1.1. The Simulation Approach

To quantify the impact of different plausible assumptions or concerns on the characteristics of the Pan-European Index, a minimum return history of one market cycle is recommended, cp. chapter 3.1.1. Since most of the European country indices just started some years ago and can not build on such a long history their time series don't provide enough evidence to perform a statistically significant analysis or draw reliable conclusions. For this reason we decided to perform an analysis with simulated instead of real data.

Using randomly generated numbers and general assumptions about the statistical properties of the real estate market, we generated three series of "true" real estate market returns, representing three European countries. Next, the described assumptions about appraisal frequency and temporal aggregation are applied to result in three individual country property indices, which further are aggregated into a "European" index using equal market weights.

The advantage of such simulation analysis derives, next to generating a long enough time series, from providing what we called true market returns. As described in chapter 2.1.1, these true market returns are not directly observable in reality; so any analysis based on real data would only partly generate conclusions about index characteristics. Analyzing the behavior of appraised indices based on simulated true market returns (or indices) allows though to directly compare the specific statistical properties stemming from the different index construction methods with the "true" characteristics.

There are, however, following caveats to this method: First, observed characteristics of the simulated indices may just be accidental outcomes of the randomly selected samples. Although, this issue can be mitigated by simply working with very large samples or by repeating the analysis with different numbers, the problem still remains (especially as computer generated random numbers are not really random, but in fact calculated). Second, the simulation of the true market indices and the appraised index includes specific assumptions that can not be directly deducted from existing (European) historic data. Consequently, the made assumptions have to be considered best estimates of the market and the appraisal behavior, and could, if far off the facts, flaw the simulation.

4.1.2. The Simulation Steps

- **Simulating True Value Indices:** To simulate true return series we generate property appreciation series of random numbers that most closely resemble the ones in the real world in terms of mean, standard deviation, serial autocorrelation, and correlation among each other.[79] Next we aggregate the appreciation series of 1200 individual properties, whose capital gains were simulated over the period of 240 months (20 years), into a “country” index. Finally, three of such country indices are combined into a “European” index, representing the true underlying value index that the appraised indices are compared to.

- **Assuming Reappraisal Timing:** As the appreciation of properties is not reappraised monthly, there is in reality less information available than in our simulated true index. Based on the prior discussed assumptions of appraisal frequency and timing, values of specific dates of observations are extracted out of the true property value database to simulate the limited information. As we are not concerned with appraisal issues on a disaggregate level, but with different index construction methods, we assume a correct appraisal that exactly matches the true value without any “appraisal error” at this stage.[80]

- **Applying Different Index Construction Methods:** Using this extracted database of property appraisal information, we construct three resulting indices using the prior defined methods. Index one through simple aggregation (Stale Appraisals), index two through linear interpolation of the missing values and subsequent aggregation, and index three through a Repeated Measures Regression.

- **Comparing the Appraised Index to the True Index:** The behavior of these three indices is now compared with the one of the true capital returns regarding mean, standard deviation, serial autocorrelation, correlation among each other and with the true returns.[81]

- **Repeating the Simulation:** In order to eliminate purely random effects on the statistics, due to the random nature of the ingoing true returns, the simulation is repeated 100 times. The generated distribution of statistical results is further studied for potential evidence of informing about index characteristics.

The main part of the simulation was programmed in the matrix manipulation program GAUSS 3.2.32, tables and diagrams were generated in MS Excel. The program code and the results tables are attached in the appendix for further reference.

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[79] Or, as these are unobservable, to what is estimated to be the true underlying series.

[80] Alternatively, the simulated true index could also be seen as already including some “appraisal error”. Accordingly, the analysis would still only test deviations based on the index construction level.

[81] As the capital return is the part of the return that captures most volatility, it is the one most examined. However, the currency conversion effect should be most apparent in the income return part, so the effect on the income return is covered in a separate part.

4.2. Simulating True Returns

4.2.1. Generating Appreciation Returns

The simulation of the true market index starts with generating arrays with random numbers for every property and every time period that is covered. For this analysis, the extent of 3 countries, 1200 properties in each country, and 240 months is chosen to produce a statistically significant sample. The numbers generated are normally distributed, have a mean of 0 and a standard deviation of 1.

In order to make these random numbers comparable to real appreciation returns, their characteristics were adjusted to the ones generally observed in private real estate markets. These targeted characteristics include the mean, the standard deviation, the serial autocorrelation, the correlation among the country returns, and the heterogeneity of the individual property returns.

- **Mean:** As the generated returns represent only capital returns, it is convenient to take a mean of 0 as realistic assumption. If the property stock is not changed, building depreciation would cause negative real returns, which would be offset by inflation. The in average positive capital returns in real estate indices can be attributed to a constant update of the properties in the portfolio.

- **Standard Deviation:** According to Geltner and Miller (2001, p. 569) the estimated standard deviation of total returns for private real estates markets is on the index level approx. 10%. As income returns are very stable, one can assume that this volatility is mainly derived from movements in capital returns. As real estate markets are not perfectly informational efficient, one also can assume that market sluggishness would additionally smooth values and thus would lower the effective volatility. Accordingly, we used a target (annual) standard deviation between 8% and 9% to represent the appreciation volatility.

- **The Serial Autocorrelation:** To account for the assumed market sluggishness, some serial autocorrelation is introduced into the monthly value series by applying the simple exponential smoothing model using the factor $K = 0.8$ (cp. chapter 2.1.2), meaning that current real estate values reflect only 80% of the new market information, and still contain 20% of the value of the previous month.

- **Correlation Among the Countries:** To account for the correlation among the country indices, random numbers with the same characteristics as explained above that represent European and country components were generated. Based on the correlation of the real GDP growth of selected European countries (Table 5), a target correlation of 0.3 to 0.4 among the country returns was applied.

Table 5: Cross-Correlation of Real-GDP Growth in Selected European Countries, 1994 – 2003

	UK	FRA	GER	SPA	CH
UK	1.00				
FRA	0.18	1.00			
GER	0.09	0.52	1.00		
SPA	0.18	0.47	-0.06	1.00	
CH	0.06	0.80	0.26	0.29	1.00

Source: Globalfindata.com, 7 July 2004, own calculations 2004.

- **Heterogeneity:** Generally, the heterogeneity of an index is defined by the average of the individual property variances divided by the variance of the aggregate index and is accordingly influenced by the relative volatility of the idiosyncratic component as well as by its given weight. For this simulation, a target variance of 3 was assumed.

The individual property return is finally calculated as a weighted average of the European, the country and the idiosyncratic return component, where the weights of each component control for the correlation. We found that the targeted characteristics are best met with the idiosyncratic component having a weight of 30% and a monthly standard deviation of 0.0125, and the country as well as the European component having a weight of 40% and a standard deviation of 0.005.

A sample calculation of the weighted average return for one period with all assumed parameters is shown in Table 6. These property returns of every period are then further compounded from a starting value of 1 at time 0 to generate a value index of every property.

Table 6: Example of True Return Calculation

	Europe	Country	Property	Comment
1) Random number	-0.300232	-1.277683	0.244257	Normally distributed, mean = 0, stdev = 1
2) Target stdev	0.005	0.005	0.0125	To match heterogeneity and total stdev.
3) Return component	-0.001501	-0.006388	0.003053	Multiplied with target stdev.
4) Weight	30%	40%	30%	To match heterogeneity and cross-correl.
5) Total return			-0.002090	r_1, weighted average of components
6) True index value t = 0			1.000000	V_0, in this case equal to V^*_0
7) Index value t =1			0.997910	$V_1 = V_0 (1 + r_1)$, incl. all new information
8) Market sluggishness			0.8	α (i.e. K)
9) True index value t = 1			0.998328	$V^*_1 = 0.8 V_1 + 0.2 V^*_0$
10) True return in t = 1			-0.001672	$r^*_1 = (V^*_1 - V^*_0) / V^*_0$

4.2.2. Generating Income Returns

As previously noted, most index volatility is generally found in the capital return, whereas the income return remains relatively stable. Cash flows from a property are basically not very volatile due to long-term leases, so even the small changes in the income return are more due to changes in the denominator, which in turn is the property value. Therefore, most of the research being done only looks at appreciation returns, and for the most part of this simulation, this is also the case. However, as the currency conversion mainly affects the income return, cp. chapter 2.4.3, some conclusions are also drawn from the effect of the different index construction methods on the income return, i.e. on changes in the denominator.

For all properties and all time periods, a uniform annual income return of 7% was assumed, that would also be evenly spread across the months (0.57% per month, continuously compounded). This return was applied to the true index in order to get “cash” value for every period. These cash values were then used to calculate the monthly returns for the appraised indices, which were compounded to annual income returns and compared to the true annual returns of 7%.

4.2.3. Aggregating the Country and European Index

To generate the monthly country index series, the 1200 property indices are simply added and then again standardized to a value of 1 at time 0 (simply through dividing by the number of properties, as every property also starts with a value of 1).[82] The European index is calculated accordingly, by using the weighted average of the three country indices. For simplification we do not include the potential change of the country specific market size and keep the weights of these the same throughout the time span. Out of the three countries, we examined “Country A” in more detail. The other two countries and the European index are computed in order to observe the correlation between these indices and Country A under different scenarios.[83]

Similar to the method applied by IPD (cp. Equation (4) in chapter 3.1.1), the annual index is computed out of the monthly index by simply taking every twelfth value out of the monthly index. As the annual index was computed by compounding the monthly returns, the annual returns calculated out of the annual index will exactly equal the compounded (time-weighted) monthly returns.

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[82] Although this procedure amounts to a value-weighting of the country index, whereas equally weighting would more represent the sample character of the properties, the difference between the two methods is not considered substantial, as it is assumed that all property values are about the same size.

[83] The setup of the program would allow to further define different assumptions for each country index. One can explore additional issues regarding the behavior of different indices together, which is though not the scope of this analysis.

Figure 6: Example of a Monthly True Index Series: Repetition 6

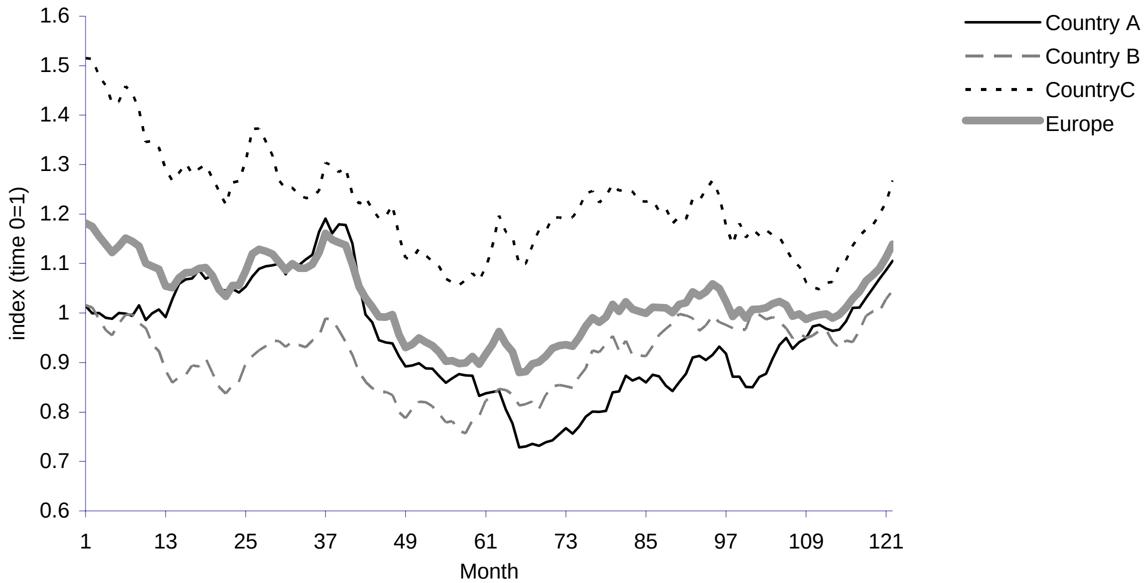

Figure 7: Example of an Annual True Index Series: Repetition 6

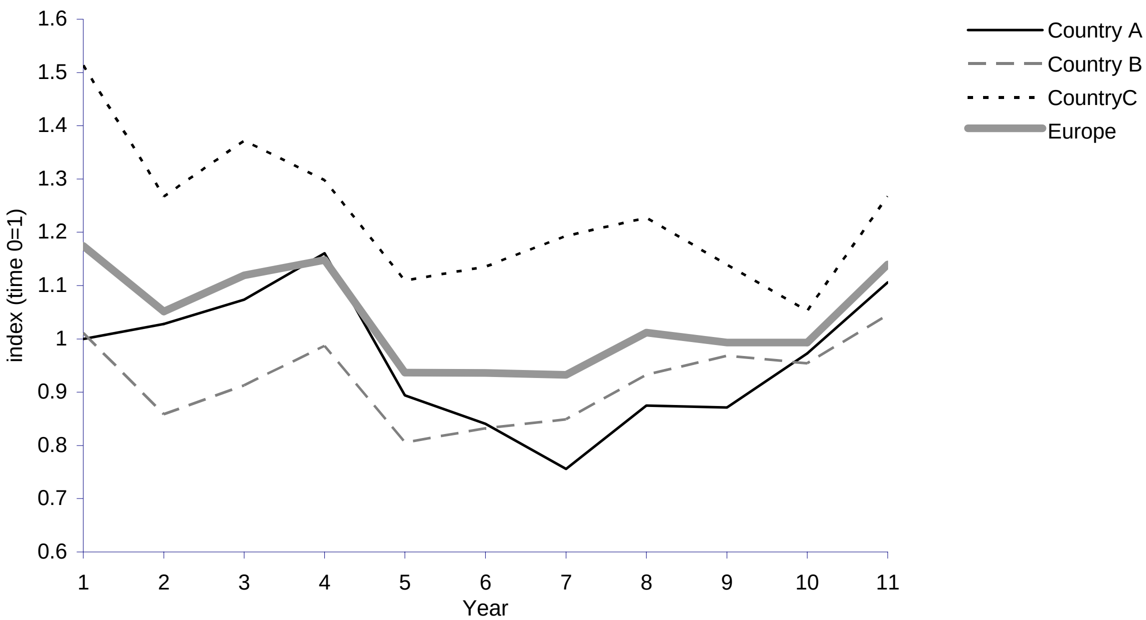

Figure 6 shows an example of one repetition of a monthly index series, Figure 7 shows the same index series at an annual level. As the mean appreciation return is 0, the index fluctuates around the starting value of 1. The three country indices are clearly correlated, but also show some individual cycles. The comparison between the monthly and the annual index reveals that the annual index does not capture the detailed vertical movement of the monthly index, but exhibits the general direction.

4.2.4. Index Statistics

Table 7: Statistics of 100 Repetitions of Monthly True Returns for Country A

	Mean	Stdev	Acorr 1	Acorr 12	Ccorr B	Ccorr C	Ccorr EU	Id. Var.	Hetero-geneity
Mean	0.0000	0.0204	0.1850	-0.0063	0.3658	0.3636	0.7599	0.0014	3.2708
Stdev.	0.0013	0.0010	0.0591	0.0684	0.0556	0.0548	0.0504	0.0000	0.2361
95% Confid.	-0.0003	0.0202	0.1734	-0.0197	0.3549	0.3528	0.7500	0.0013	3.2245
Interval	0.0002	0.0206	0.1966	0.0071	0.3767	0.3743	0.7697	0.0014	3.3171
Min	-0.0033	0.0177	0.0659	-0.1876	0.1927	0.2317	0.5317	0.0013	2.7456
Max	0.0044	0.0232	0.3318	0.1331	0.4901	0.4917	0.8790	0.0015	4.0117

Mean ....Arithmetic mean, average
Stdev ....Standard deviation
Acorr1, Acorr12 ....1st, 12th order serial autocorrelation
CcorrB, CcorrC, CcorrEU ......Cross correlation with Country B, C, and Europe
Id.Var ....Average of idiosyncratic property variances
Heterog ....Heterogeneity, = Id.Var / Variance of Index = Id.Var. / $Stdev^2$
See appendix for further explanations and formulas.

Table 7 and Table 8 show the statistics of 100 repetitions of random returns generated as described. These returns are the basis for the different index construction methods and appraisal scenarios that are calculated. The monthly statistics show very homogeneous numbers for the mean and standard deviation over the 100 repetitions. The positive first order serial autocorrelation reflects the exponential smoothing. The average heterogeneity is slightly above 3, and the country cross correlations lie mostly between .3 and .4, as targeted.

Table 8: Statistics of 100 Repetitions of Annual True Returns for Country A

	Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU
Mean	0.0010	0.0852	-0.0662	0.3708	0.3713	0.7512
Stdev.	0.0164	0.0153	0.2039	0.1884	0.2021	0.1027
95% Confid.	-0.0022	0.0822	-0.1062	0.3339	0.3317	0.7310
Interval	0.0042	0.0882	-0.0262	0.4078	0.4109	0.7713
Min	-0.0368	0.0518	-0.5752	-0.1598	-0.1879	0.4648
Max	0.0552	0.1282	0.3955	0.7711	0.7776	0.9189

See Table 7 for abbreviations and appendix for formulas and further explanations.

But, the comparison across repetitions also shows the effects of randomness. Especially the autocorrelation and cross correlation statistics exhibit a broad range of possible values. The annual returns show even more dispersion across the 100 repetitions than the monthly returns, explainable by the much smaller sample size of only 20 annual returns instead of 240 monthly returns. The average statistics show, however, the expected numbers, so over the 100 repetitions one can expect consistent results. The high range in the first order autocorrelation of annual returns may be an example of correlation introduced by averaging "*successive items of a random chain*" (Working, 1960).[84]

4.3. Modeling Index Construction Methods

4.3.1. Reappraisal Assumptions

Table 9: Scenario Assumptions about Reappraisal Timing

	Scenario 100%		Scenario 80%		Scenario 50%		Scenario Equal	
	# Prop.	% Prop.	# Prop.	% Prop.	# Prop.	% Prop.	# Prop.	% Prop.
Jan	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Feb	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Mar	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Apr	0	0.0%	24	2.0%	55	4.6%	100	8.3%
May	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Jun	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Jul	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Aug	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Sep	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Oct	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Nov	0	0.0%	24	2.0%	55	4.6%	100	8.3%
Dec	1200	100.0%	936	78.0%	595	49.6%	100	8.3%
Total	1200	100.0%	1200	100.0%	1200	100.0%	1200	100.0%

For all the simulations we assumed a yearly reappraisal frequency for all properties, as this is the case for most of the IPD countries. As discussed in chapter 3.3.2, not all properties are normally reappraised as of

[84] Working noted that even with a stochastic series that is completely uncorrelated, the averaging of successive segments can lead to a serial autocorrelation of up to 0.25. As the monthly series in this case already included some autocorrelation, a serial autocorrelation of even more than 0.25 in the aggregated series was occasionally the consequence.

the end of the year, as it would ideally be required by IPD. Accordingly, three scenarios about the reappraisal timing are assumed: The “Scenario 100%” where all properties are reappraised as of the end of December; the “Scenario 80%” where 80% of the properties are reappraised in December, and all other reappraisals are spread evenly over the other 11 months; the “Scenario 50%” where similarly 50% of reappraisals take place in December; and finally the “Scenario Equal” with an equal amount of reappraisals every month (Table 9).

Properties from the true value databases are assigned to appraisal months in consecutive order. Since all values are random and of the same size, this should not introduce any selection bias. As the properties are reappraised every year, only a single value every twelve months is extracted from the true value database for each property. For the 240 months, there are therefore 20 reappraisals for every property that are actually observable. In addition, as prior explained, the properties starting value is 1.[85]

4.3.2. Stale Appraisals

In this method, the appraised value simply stays in the database at its last reported value until a new value is entered. This is the traditional method of index construction and involves no additional calculation. The index that is constructed every month therefore contains only partially updated property values. For Scenario 100%, where all reappraisal occur in December, this would mean that the index is flat from January to November and jumps to the new value only in December (cp. Figure 8).

4.3.3. Linear Interpolation

This method assumes that the property values change continuously and linearly between two points of appraisal (cp. Figure 8). This linear interpolation can of course only be performed when the later reappraisal is known, which means that monthly returns are not instantly available, what poses a problem for properties that are reappraised early in the year. In this case one has to either wait until updated information is available or estimate some changing rate, often based on historical data. Otherwise the same stale appraisal effect will take place as in the prior method.[86]

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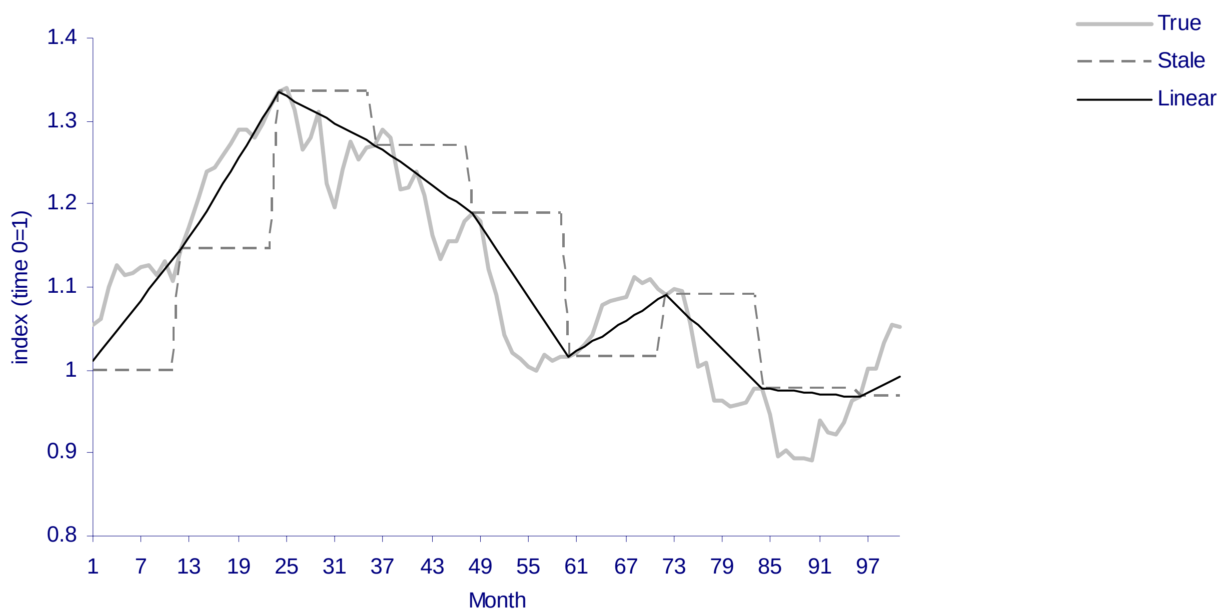
[85] This information is the only input for the following index construction, using different methods.

[86] Although seldom possible in practice, for the sake of demonstrating the characteristics of this method, in the following figures all second reappraisal values are assumed to be known before the index is updated.

Figure 8: Examples of Stale Appraisal and Linear Interpolation of Annual Reappraisals



4.3.4. Repeated Measures Regression

The Repeated Measures Regression is a statistical method especially developed to deal with the problem of missing observations, as in the case of infrequent reappraisals (cp. chapter 2.3.3). The method applied here computes the value weighted average.[87] In this method, the regression is based on columns for each time period. Every row, representing a single property, contains only one observation pair, consisting of two appraisals in the period they occur (all other values are 0). The first period (time 0) is considered the dependent Y variable. For the current simulation, the regression database therefore has 240 columns and 25,200 rows (1200 properties x 21 observations). The regression results are beta coefficients for every time period whose inverses equal an aggregate value index (see also Geltner & Miller, 2001).

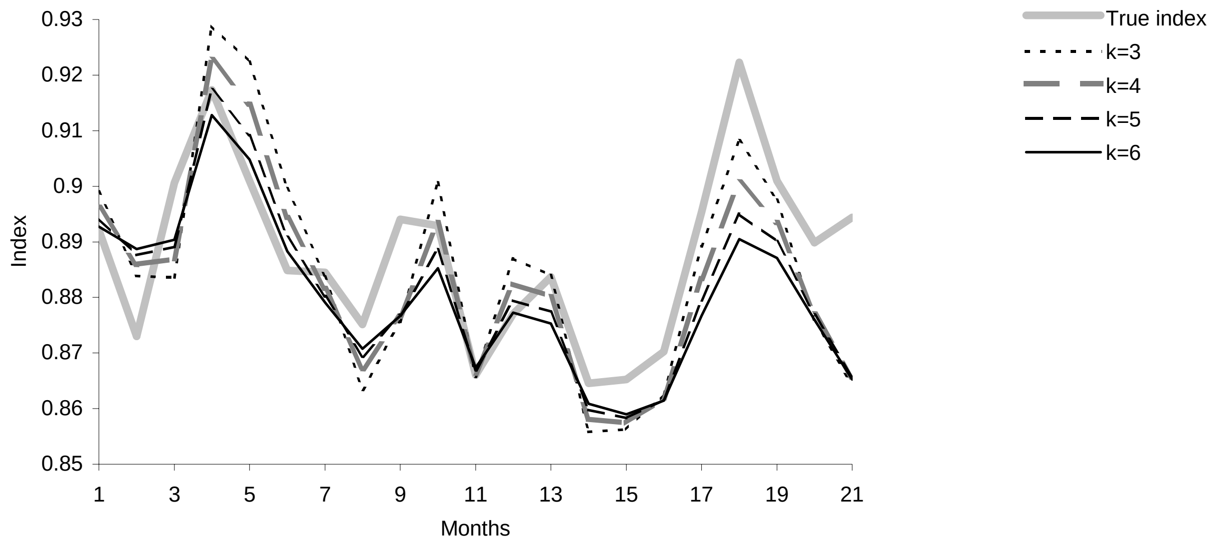
As this RMR method is based on the calculation of OLS (ordinary least squares), the results are very sensitive to outliers and idiosyncratic noise in the periodic values, which generally applies to property values (Geltner & Goetzmann, 2000). Accordingly, a ridge estimator is introduced to control this noise. This estimator, k, affects the resulting standard deviation and autocorrelation of the index. Its value is normally an input in order to match the outcome with a desired result.[88] As seen in the example results in Figure 9, k does not change the general direction or position of the index, but rather its amplitude, i.e. its standard

[87] The value-weighted arithmetic average price index was first developed by Shiller for price indices, and further refined by Geltner and Goetzmann for total return indices (Geltner & Miller, 2001, p. 692).

[88] The more heterogeneous the property returns are, the higher k should be assumed.

deviation. For this simulation the regression results could be compared to the true index series. In practice, however, the characteristics of the true returns are not available and have to be estimated. A k of 4 was chosen for this analysis for all scenarios, as the resulting index matched the true standard deviation and the autocorrelation statistics the best.

Figure 9: Comparison Between True Index and RMR Using Different Ridge Estimators k



Generally, in order for the regression to work properly, at least one observation has to be available in each period (= independent variable). The ridge estimator, however, provides a solution in this case because it adds some fake but perfectly correlated values to the database that affect the volatility of the returns. Where no reappraisals are available for a period, the RMR performs a linear interpolation of values.

4.4. Simulation Results

The following chapters describe the simulation results. First we show a graphical example of the simulation outcome, using a section of the sixth of 100 repetitions generated. Then we compare the computed statistics of the simulated index returns with the statistics of the true returns. Finally we describe the impact of the different value indices on the income return component.

4.4.1. Examples of the Generated Value Indices

To keep the index diagrams readable and to show the small differences between the indices, only a section of the results is depicted in the following diagrams. We chose a section of the last 90 months of Repetition 6, as this part exhibits a good example of vertical value movements. All indices in the following diagrams are depicted for this specified section. The diagrams are therefore comparable to each other, but one has to keep in mind that they only represent one small example of all the generated indices.

Figure 10: Monthly Index for Scenario Equal: Repetition 6, Months 151-240

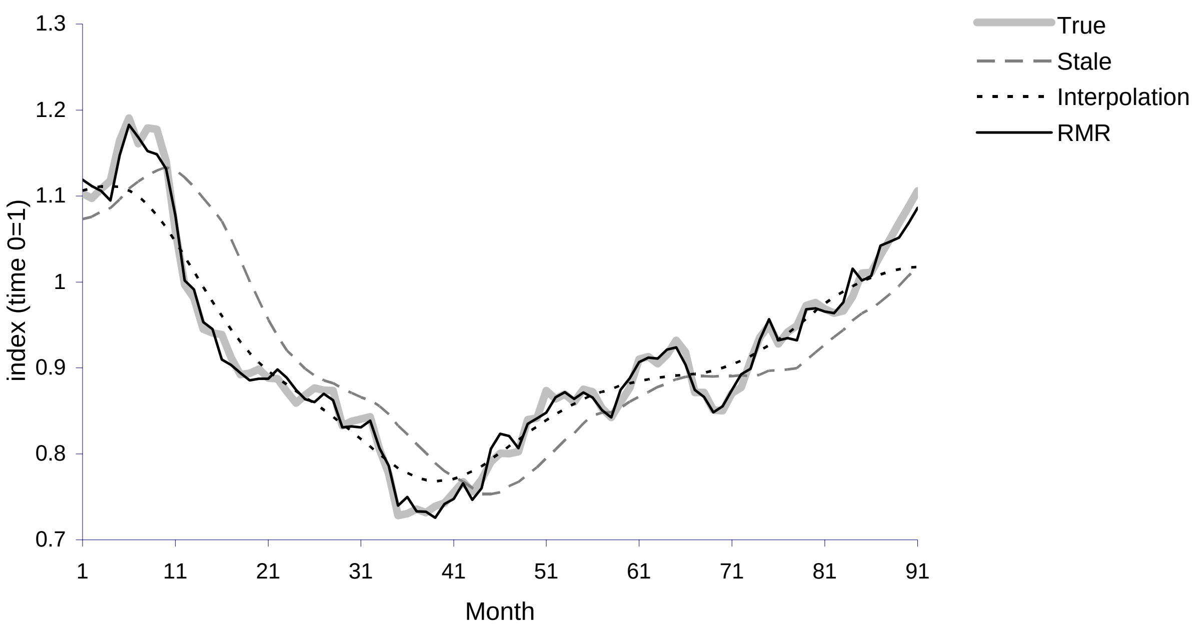
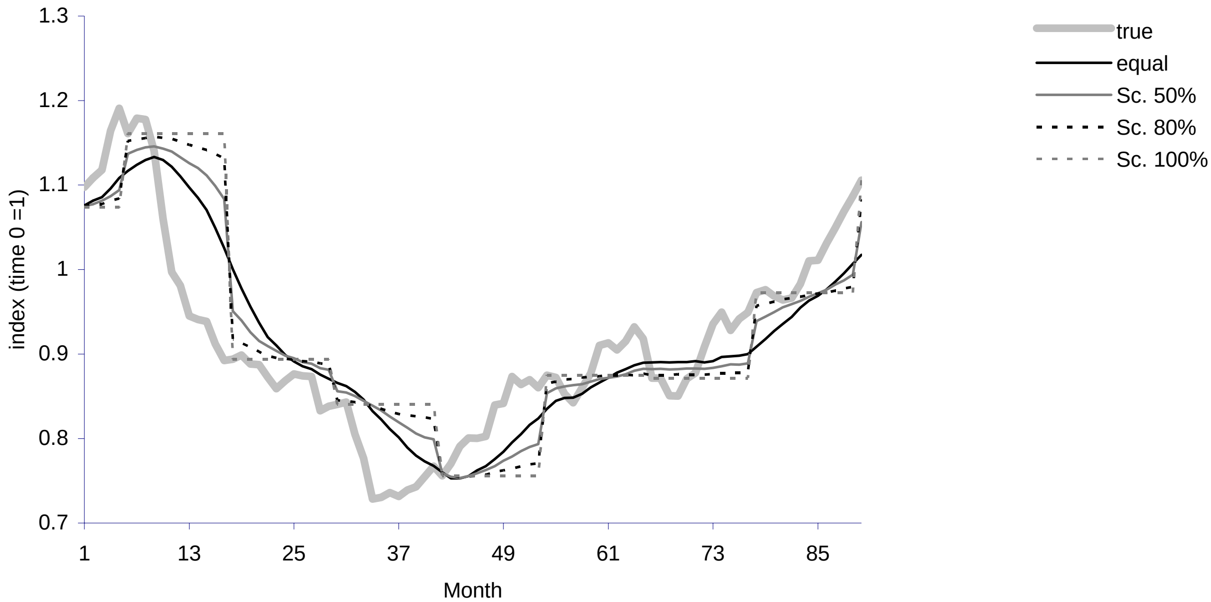


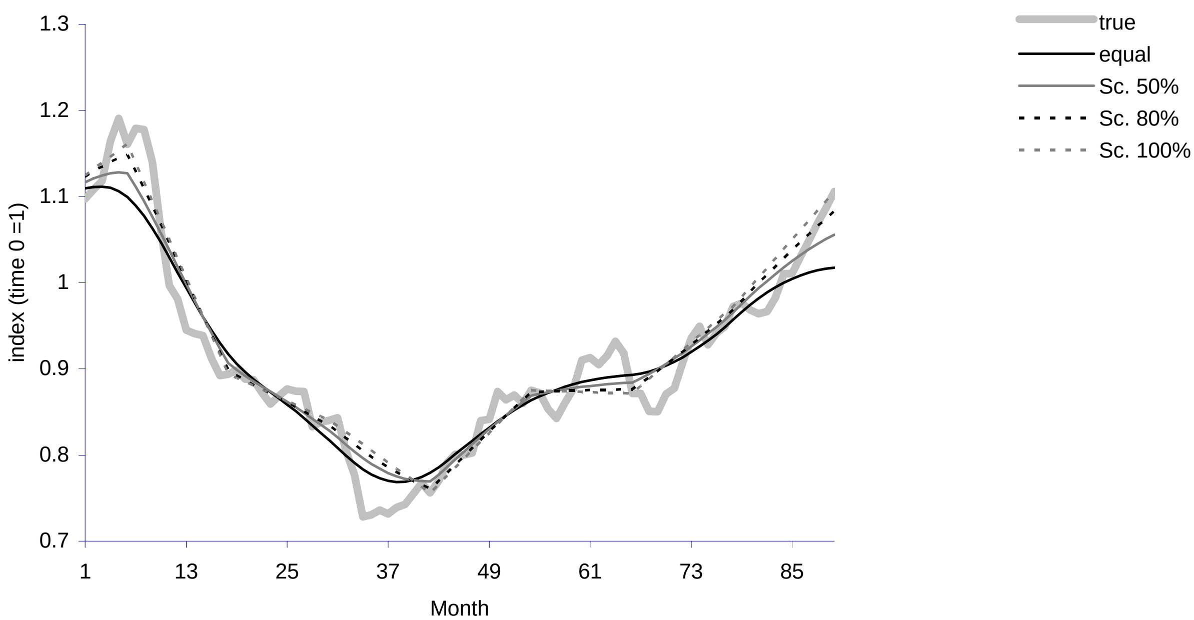
Figure 10 shows all monthly indices of Scenario Equal and reveals the fundamental differences of the three index construction methods on a monthly level: The RMR index follows the true index quite well, whereas both other methods exhibit large deviations from the true index. They follow the general direction, but are considerably smoother. The lagging effect of the Stale Appraisals is very obvious, as this index lags the true index for up to 12 months. The Linear Interpolation index does not exhibit any lagging, but is otherwise very similar to the Stale Appraisal index.

Figure 11: Stale Appraisals of Monthly Index for all Scenarios: Repetition 6, Months 151-240



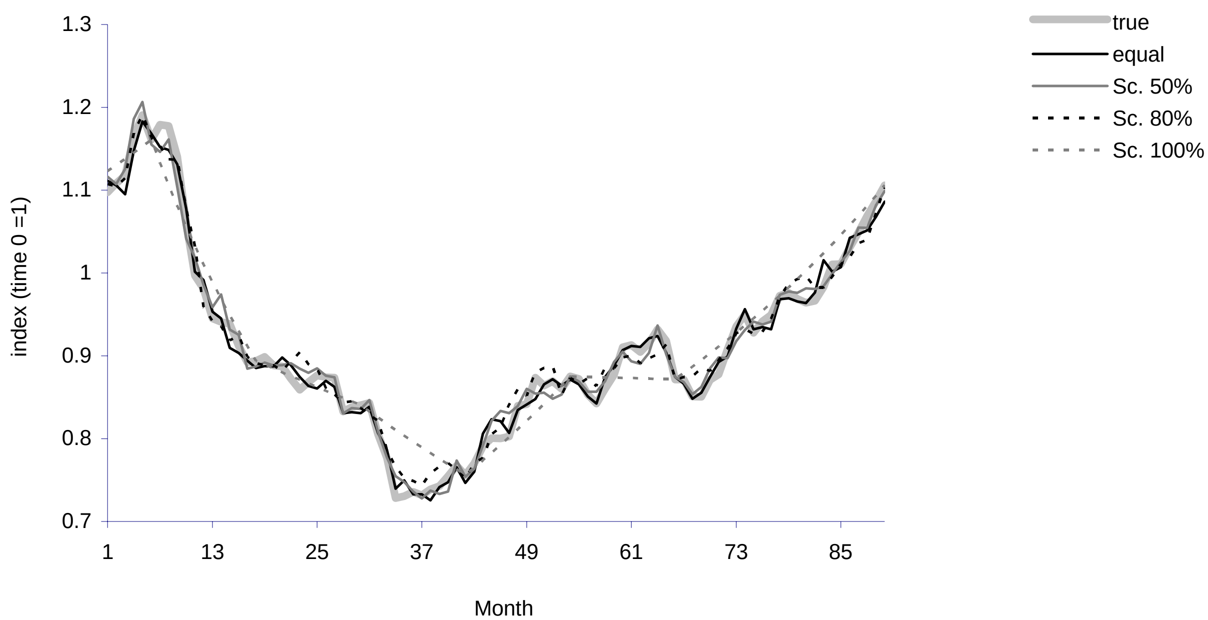
As seen in Figure 11, the monthly Stale Appraisal index always lags the true index considerably. The more properties are reappraised in December, the more seasonality is introduced in the index. In the extreme case of Scenario 100%, the Stale Appraisal index is constant for 11 Months and jumps up to the new value in December.

Figure 12: Linear Interpolation of Monthly Index for all Scenarios: Repetition 6, Months 151-240



The Linear Interpolation index does not exhibit big time lags (cp. Figure 12). Through the averaging effect of the linear interpolation, the indices are also not very different between the scenarios. All monthly Linear Interpolation indices are, however, very smooth and can be expected to show a very high serial autocorrelation.

Figure 13: RMR of Monthly Index for all Scenarios: Repetition 6, Months 151-240



The RMR is the only construction method that correctly catches all peaks and troughs of the monthly true index. Surprisingly, the RMR index works very well not only for Scenario Equal, but also when a big share of the properties are reappraised in December. Figure 13 shows that the monthly indices for the Scenarios Equal, 50%, and 80% follow the true index very well. Only for Scenario 100%, where no appraisal information is available throughout the year, the RMR can as expected not reveal the true value movements. But as long as some appraisal information is available, the RMR can produce a good monthly index out of annual reappraisals.

If the monthly indices are aggregated to annual indices, the picture changes considerably. As now the appraisal frequency equals the reporting frequency, the problem of temporal aggregation only exists in appraisal timing. So if all properties are reappraised at the end of December, as in Scenario 100%, the situation for the annual index is ideal and the appraised index can completely match the true index. As shown in Figure 14, this is the case for all index construction methods. No matter what shape the monthly capital returns have, the compounded annual returns will equal exactly the true returns. However, this is only true for the capital returns, whereas the income returns can still exhibit differences, as they are based on the monthly capital values (cp. chapter 4.4.4).

Figure 14: Annual Index for Scenario 100%: Repetition 6, Year 11-20

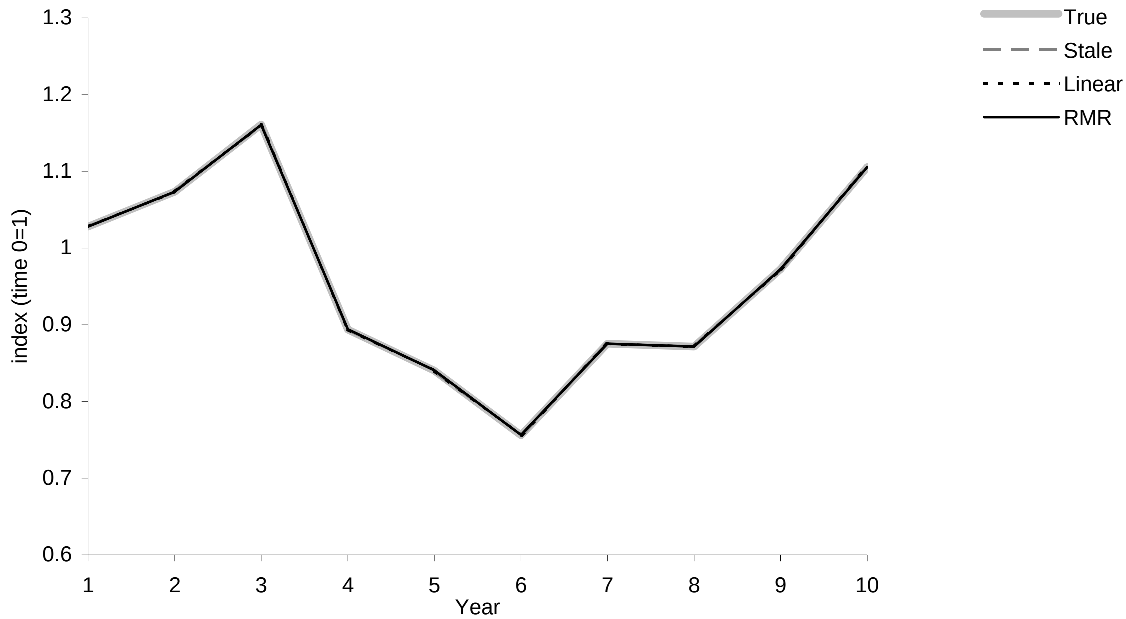


Figure 15: Annual Index for Scenario Equal: Repetition 6, Year 11-20

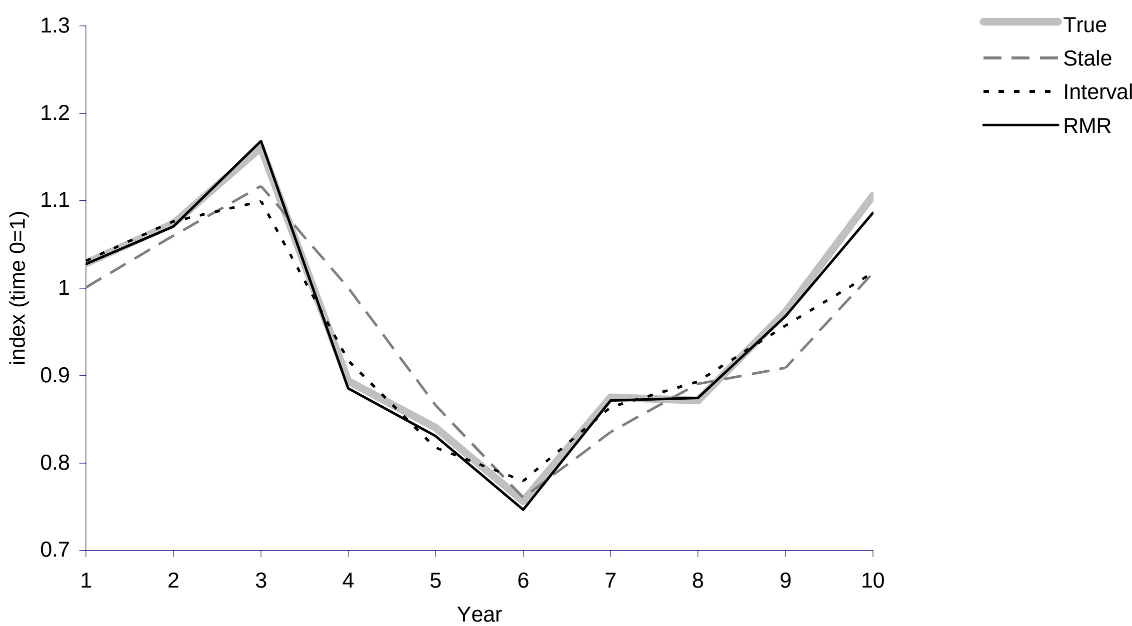
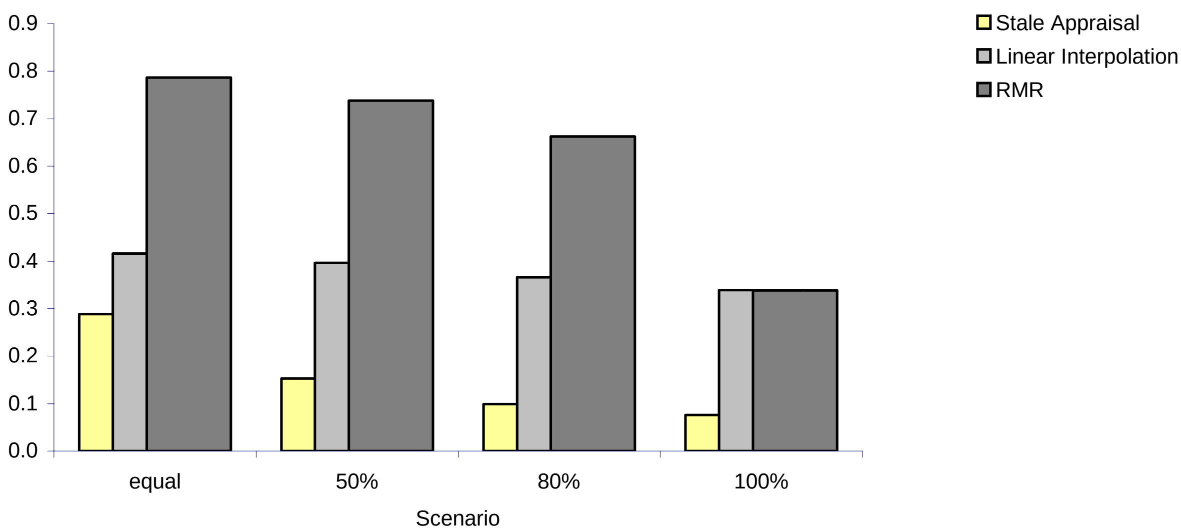


Figure 15 shows all annual indices for Scenario Equal and reveals the effect of appraisal timing, as not all properties are reappraised in December and are therefore “stale”. The RMR can again almost make up that effect and results in an index very similar to the true index; the other two methods exhibit deviations that are, however, not as big as the ones for the monthly index.

4.4.2. Monthly Capital Return Statistics

To compare the characteristics of the different index returns, we computed statistics similar to the ones described for the true index for every scenario. As not all the resulting numbers can be shown in this chapter, all statistic tables are listed in the appendix for further reference. The appendix also contains the explanation and formulas of all the statistics used (see page 89). The following diagrams exhibit the most important facts derived from these statistics. Regarding the interpretation one always has to keep in mind that these diagrams only show the mean of a certain statistics over 100 repetitions, and that some of these statistics actually showed a very broad range across the repetitions (see appendix).

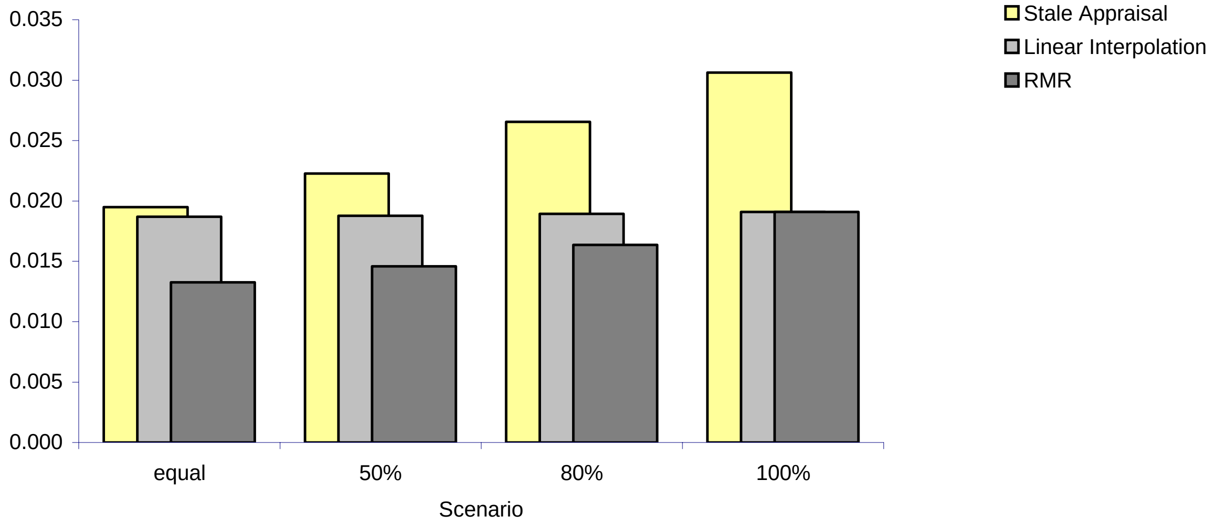
Figure 16: Cross Correlation of Monthly Index Returns with True Returns (Mean over 100 Rep.)



As a first indicator of the accuracy of the different methods, we look at the cross correlation of the appraised returns with the true returns. As already expected from the diagram in Figure 10, RMR exhibits the highest correlation with the true index returns, reaching up to 0.8, whereas the other two methods are getting only a maximum correlation of about 0.3 and 0.4 (cp. Figure 16). Only for Scenario 100%, the RMR is not better than the Linear Interpolation.[89] For the other three scenarios, however, the RMR seems to work very well. Even when only 2% of all properties are appraised per month from Jan. to Nov. (Scenario 80%), the cross correlation with the true returns is still high.

[89] As seen in Figure 13, with no reappraisals available from January until November in Scenario 100%, the RMR can only interpolate linearly between these appraisals and therefore equals the Linear Interpolation method for this scenario.

Figure 17: Root Mean Squared Error of Monthly Returns (Mean over 100 Rep.)



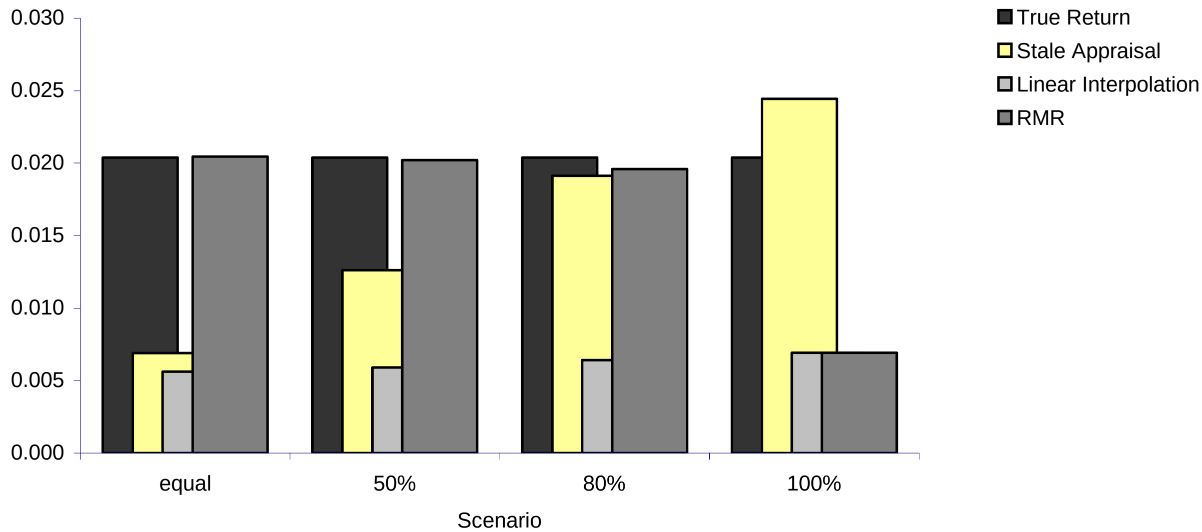
As the returns statistics show, all methods exhibit a mean of capital returns that is always very similar to the true mean. However, the difference between the individual returns is often quite high. To show this, we compute the Root Mean Squared Error (RMSE), a measure that shows the average deviation of the index returns from the true returns. Figure 17 shows that the average RMSE over 100 repetitions seems relatively high (reaching up to 3% per month for the Stale Appraisal method). The RMR exhibits the lowest RMSE in every scenario, with a minimum of 1.33% in Scenario Equal. As the share of the properties appraised in December and the seasonality of the appraised indices increases, the RMSE increases for the Stale Appraisal and RMR method (with the RMR finally approaching the Linear Interpolation).

Looking at Figure 10, one would expect the RMSE to be even lower for the RMR than actually measured; especially for Scenario Equal, as it clearly follows the true index better than any other method. The reason for this not being the case could lie in extreme outliers that influence the overall RMSE unproportionately or in the noise of the property returns, which would call for a further increase of the ridge estimator k.[90] However, comparing the RMSE to the standard deviation (stdev) of the true returns of 2% (Figure 18) reveals that the RMSE statistics for the RMR are actually not very high, as the true stdev is lower than the RMSE and a stdev-to-RMSE ratio of 1.5 for Scenario Equal can be achieved.

Following the direct comparison of the true with the appraised returns, we compared statistics of the appraised returns with the true statistics. The goal for these characteristics, which are depicted in the following diagrams, is not to minimize the deviation but rather to match the true statistic.

[90] The ridge estimator was chosen to fit the standard deviation and autocorrelation characteristics of the true returns, a further increase of k would therefore lead to deviations in these statistics, but lower the RMSE.

Figure 18: Standard Deviation of Monthly Index Returns (Mean over 100 Rep.)



One important characteristic to compare is the standard deviation (cp. Figure 18). With the exception of Scenario 100%, the RMR returns exhibit the same stdev as the true returns, whereas the other two methods show big deviations. The Linear Interpolation returns have as expected a constantly low stdev of almost a third of the true stdev. The Stale Appraisals, however, show increased stdev the more seasonality the scenarios exhibit. For Scenario Equal its stdev is as low as the one of Linear Interpolation, for Scenario 100% its stdev even exceeds the true stdev, due to the return of 0 for 11 months and the sudden jump to the updated value in December.

Figure 19: 1st Order Autocorrelation of Monthly Index Returns (Mean over 100 Rep.)

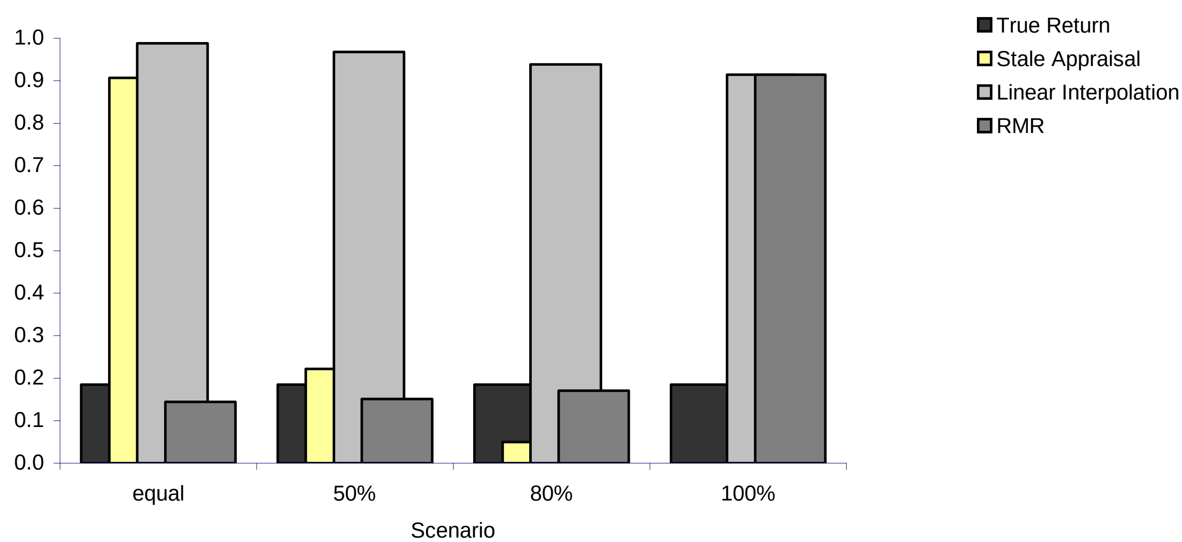


Figure 19 shows another important statistic, the first order serial autocorrelation. As the Linear Interpolation methods results in very smooth indices for all scenarios, its first order serial autocorrelation is as expected very high (above 0.9) for all scenarios. The RMR results in similar autocorrelation as the true index (again with the exception of Scenario 100%), whereas the Stale Appraisals have high first order autocorrelation for Scenario Equal, but very low for all other scenarios.

Figure 20: Cross Correlation of Monthly Index Returns with Country B (Mean over 100 Rep.)

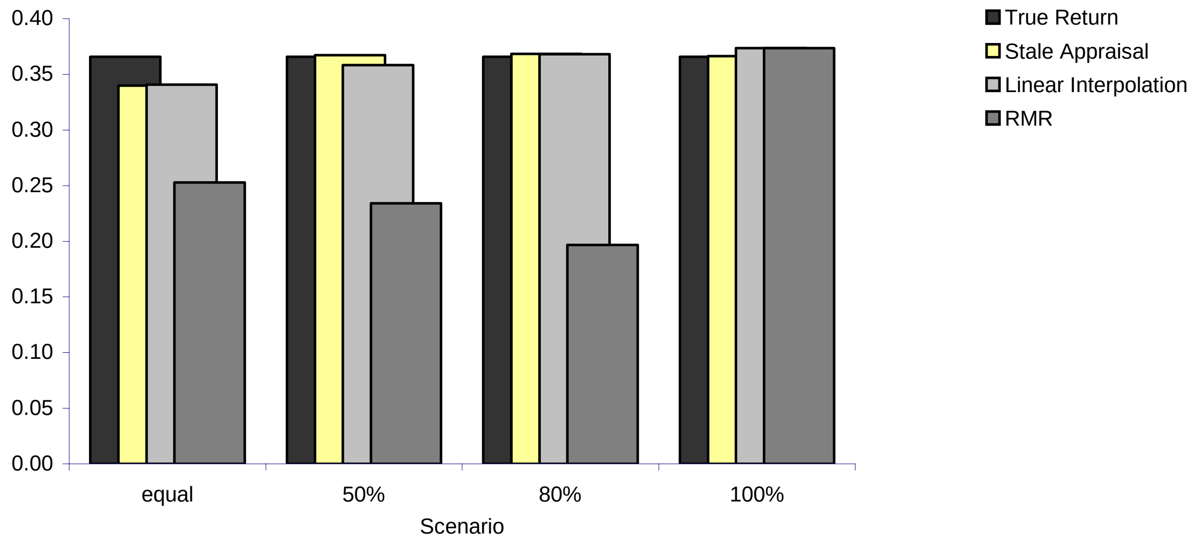
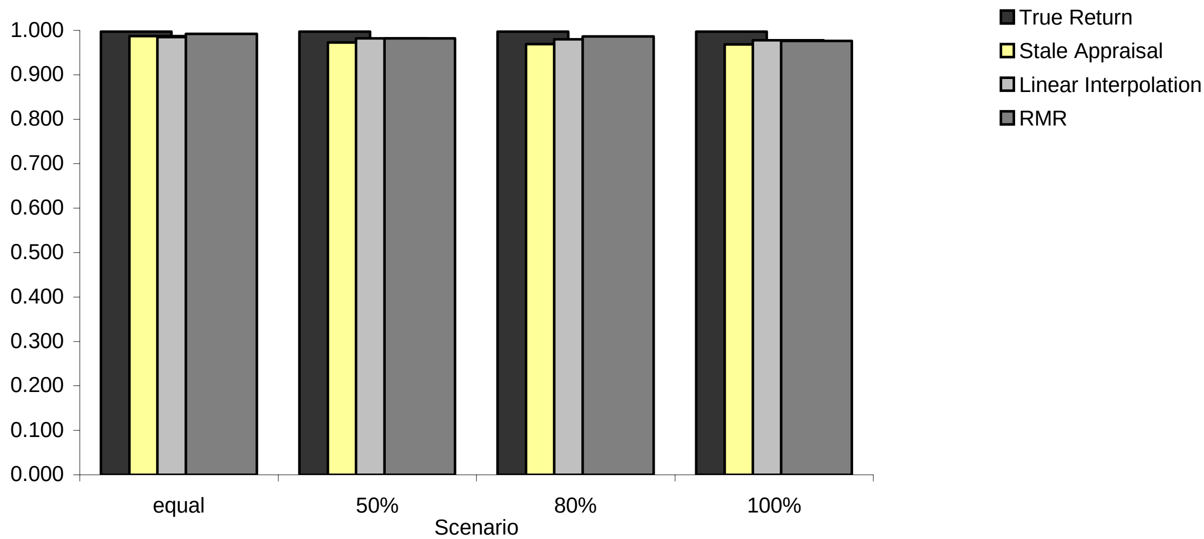


Figure 20 pictures the cross correlation between the returns of the countries A and B, with both country indices being produced using the same method and scenario. Both the Stale Appraisal and the Linear Interpolation method result in very similar correlation statistics to the true returns. However, the RMR procedure lowers the average cross correlation significantly from about 0.35 to 0.20. Whereas the index construction errors seem to cancel out for the first two methods, the statistical procedure of the RMR obviously introduces some idiosyncrasy in both countries that lowers their correlation.[91]

[91] One has to keep in mind, however, that these numbers only represent averages over 100 repetitions, and the distribution of correlations (see appendix) was very large in this simulation.

Figure 21: Beta with Respect to Europe of Monthly Index Returns (Mean over 100 Rep.)



This characteristic of the RMR to lower the correlation could be a reason for concerns, as the correlation is an important input for portfolio allocation research. However, the most important measure for portfolio allocation is beta, which is not only influenced by the cross correlation but also by the standard deviations of the country and the European market returns. As an example Figure 21 displays the beta of Country A with respect to the European index. This figure shows that all methods are very near the true beta, and that the RMR is actually the closest to the true beta.[92]

In general, it can be noted that the RMR does work very well in reconstructing a monthly index from annual appraisals, as long as some appraisal information is available for every month in the year. The return characteristics of the other two methods are not satisfactory, especially regarding the standard deviation and autocorrelation statistics. They can just signal a general trend but not indicate the true monthly index.

4.4.3. Annual Capital Return Statistics

For the annual capital returns, the same statistics were calculated as for the monthly returns. As already noted in chapter 4.4.1, the differences of the construction methods are smaller, so the differences of the statistics are also expected to be smaller for the annual returns than for the monthly returns. The following diagrams show, however, important differences from the monthly return level.

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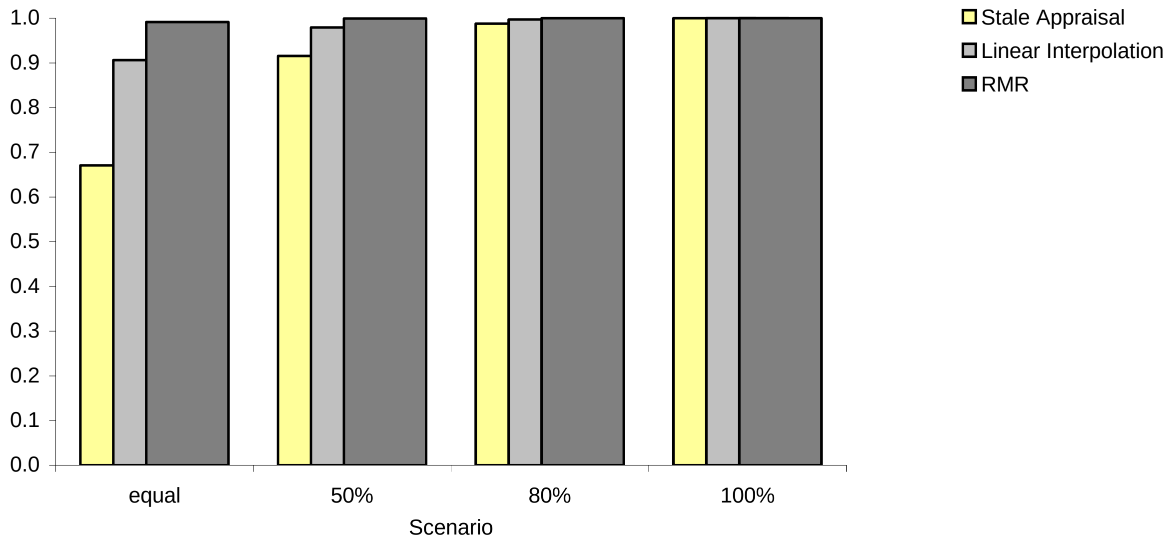
[92] Figure 21 mainly shows that the RMR does not lower the beta with respect to the real estate returns. The European return for each index construction method is aggregated out of three indices of the same index construction methods and therefore similarly flawed than the index of Country A. The high betas for the Stale Appraisal and Linear Interpolation method are therefore no surprise. The picture can be expected to change when instead of only real estate returns, the whole market portfolio containing stocks and bonds is taken into consideration.

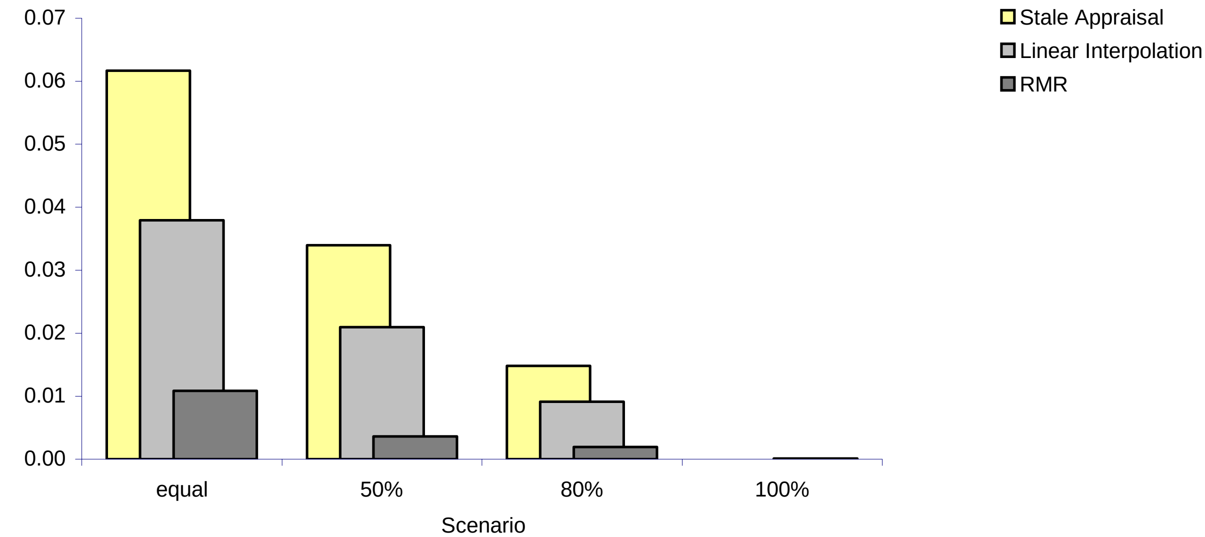
Figure 22: Correlation of Annual Index Returns with True Returns (Mean over 100 Rep.)



The higher accuracy of the annual returns is easily observable looking at the cross correlations with the true returns in Figure 22. All methods except for the Stale Appraisals in Scenario Equal have a higher correlation than 0.9, with the RMR always showing the best results and quasi perfect correlation with the true returns. For the Stale Appraisal method in Scenario Equal, the impact of the appraisal timing is significant and lowers the correlation of the annual returns to below 0.7.

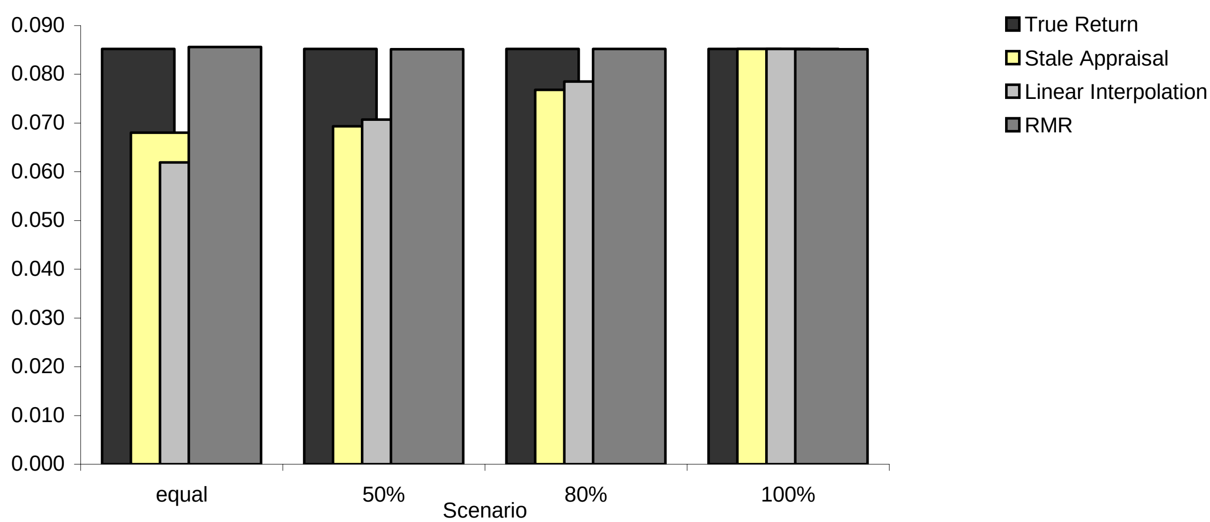
Figure 22 also reveals a significant difference between the annual and the monthly level: Whereas the monthly indices generally show better results the more equally spread the appraisals are, the opposite is the case for the annual index. The more properties are reappraised in December, the more accurate the annual index becomes. If all data is reappraised in December, the resulting aggregate annual index is equal to the true index, independent of the construction method. Obviously the intended reporting frequency of the index has significant implication for the desired appraisal timing.

Figure 23: Root Mean Squared Error of Annual Index Returns (Mean over 100 Rep.)



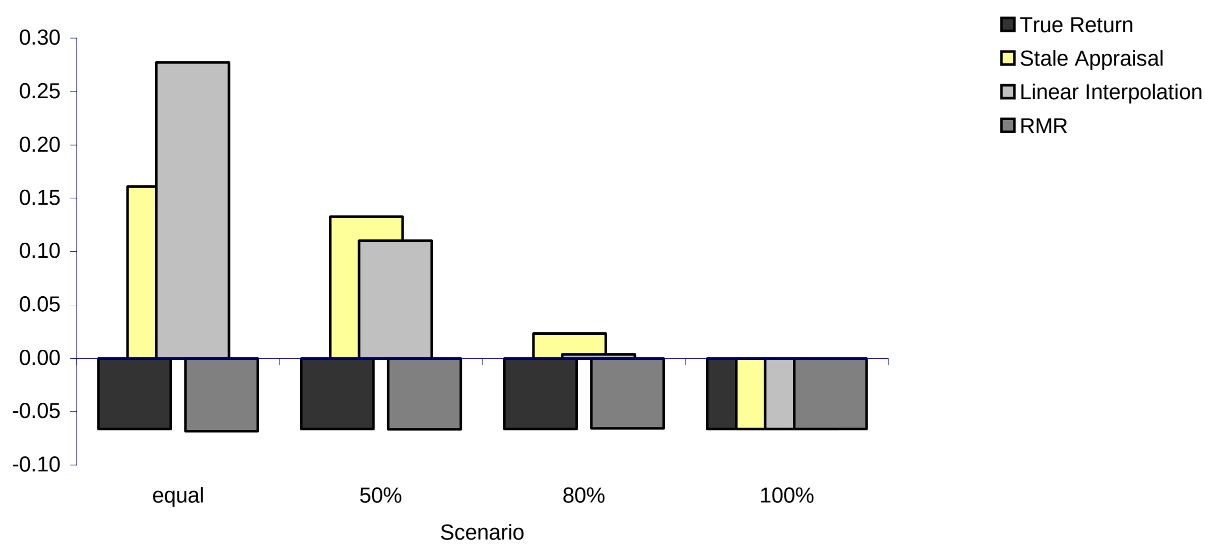
This link between appraisal timing and accuracy can also be observed in the RMSE statistic (Figure 23), where the highest RMSE for every method is in Scenario Equal. All RMSE statistics are relatively low comparing to the true stdev of about 8.5%, however, the differences between the methods are significant. Stale Appraisals have the highest RMSE of up to 6% per year, but the RMR method only exhibits about one sixth of that. As expected, the RMSE is 0 for all methods in Scenario 100%.

Figure 24: Standard Deviation of Annual Index Returns (Mean over 100 Rep.)



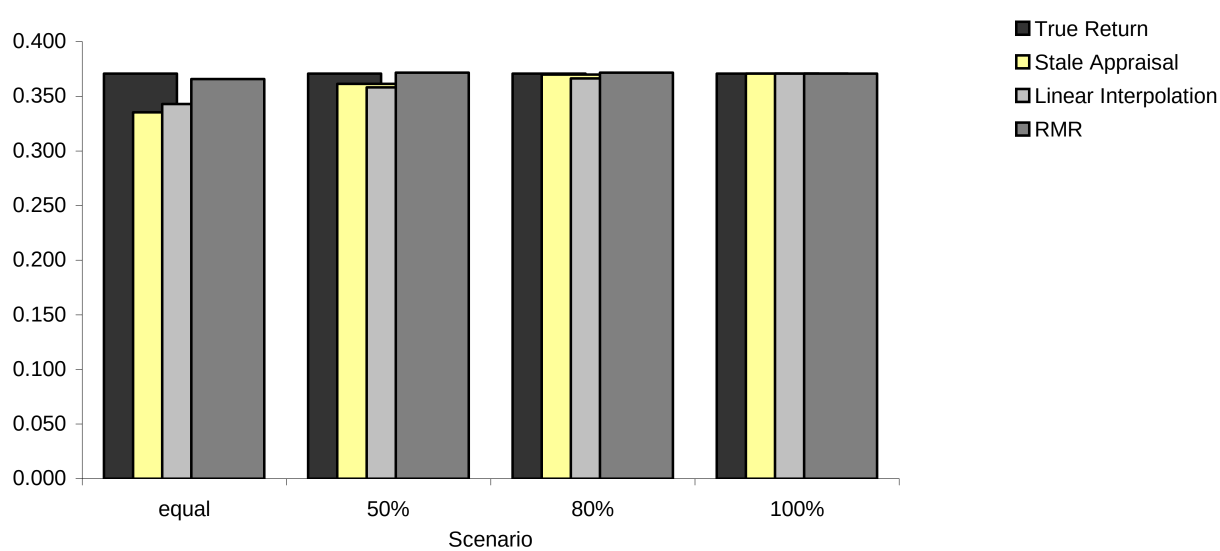
Comparing the annual stdev of the true and appraised returns in Figure 24 shows a similar picture. The stdev is remarkably lower for the Stale Appraisal and Linear Interpolation methods, especially for Scenario Equal, whereas the RMR constantly matches the true stdev.

Figure 25: First Order Autocorrelation of Annual Index Returns (Mean over 100 Rep.)



The fact that the annual true returns show a slightly negative average first order autocorrelation is somehow puzzling, as already mentioned in chapter 4.2.4. Figure 25, however, shows that the RMR is able to match the true autocorrelation for all scenarios, whereas the other two methods introduce positive autocorrelation even in the annual returns.

Figure 26: Correlation of Annual Index Returns with Country B (Mean over 100 Rep.)



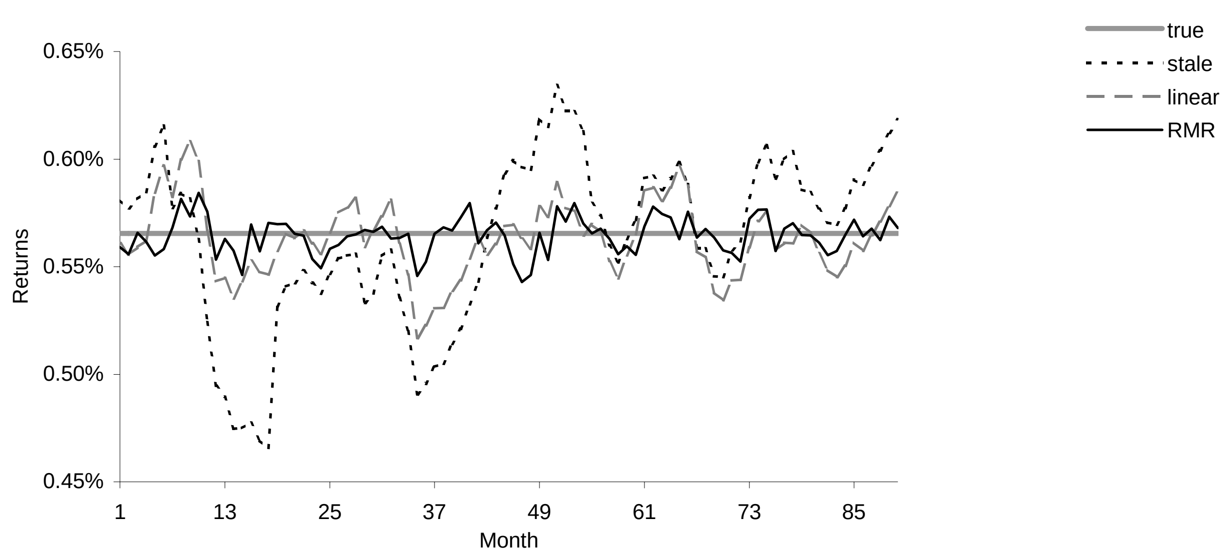
Contrary to the monthly returns, the RMR gets the best results also regarding the correlation with the annual returns of Country B (Figure 26), as the noise introduced in the monthly index disappears through the annual aggregation. Although a bit lower, the cross correlation of the returns of the other two methods are all very close to the true return statistics.

Overall, looking at the annual capital return data, the difference between the index construction methods is not as big as for the monthly returns. The more properties are appraised in December, the more accurate is the annual index independent of the index construction method used. The Linear Interpolation method doesn't exhibit substantially better results than the Stale Appraisals. Accordingly one can conclude that if there is only an annual index to be constructed, the Stale Appraisal method works sufficiently.

4.4.4. Income Returns

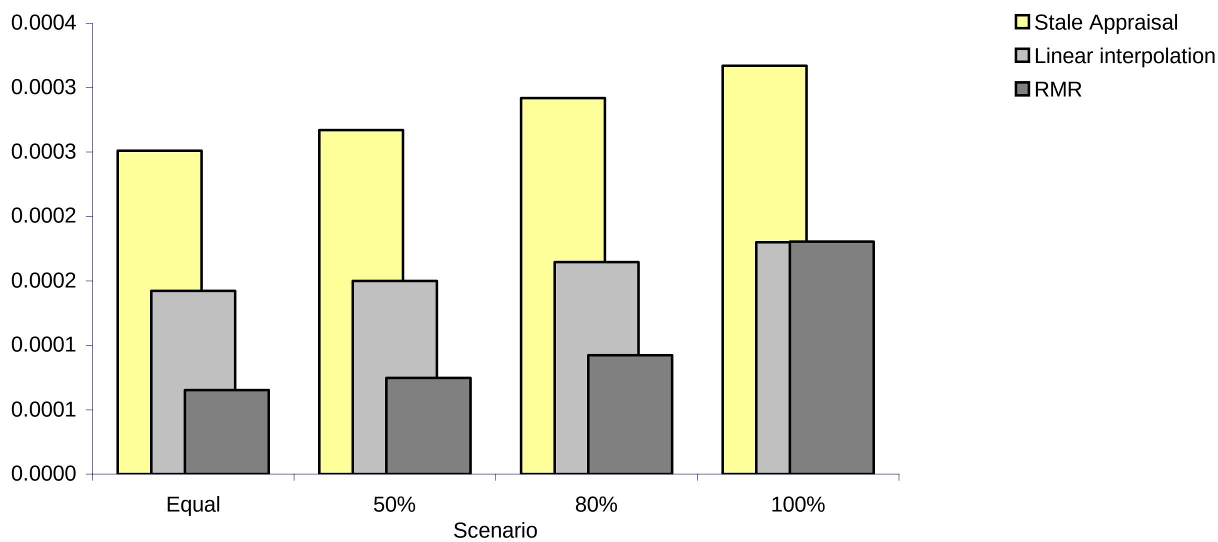
For analyzing the impact of the index construction method on the income returns, we assumed constant annual income returns of 7% (0.57% per month). The straight line in Figure 27 therefore represents the true income return, whereas the amplitude of the appraised income return lines indicate deviation from that true return.

Figure 27: Monthly Income Returns for Scenario 50%: Repetition 6, Months 151-240



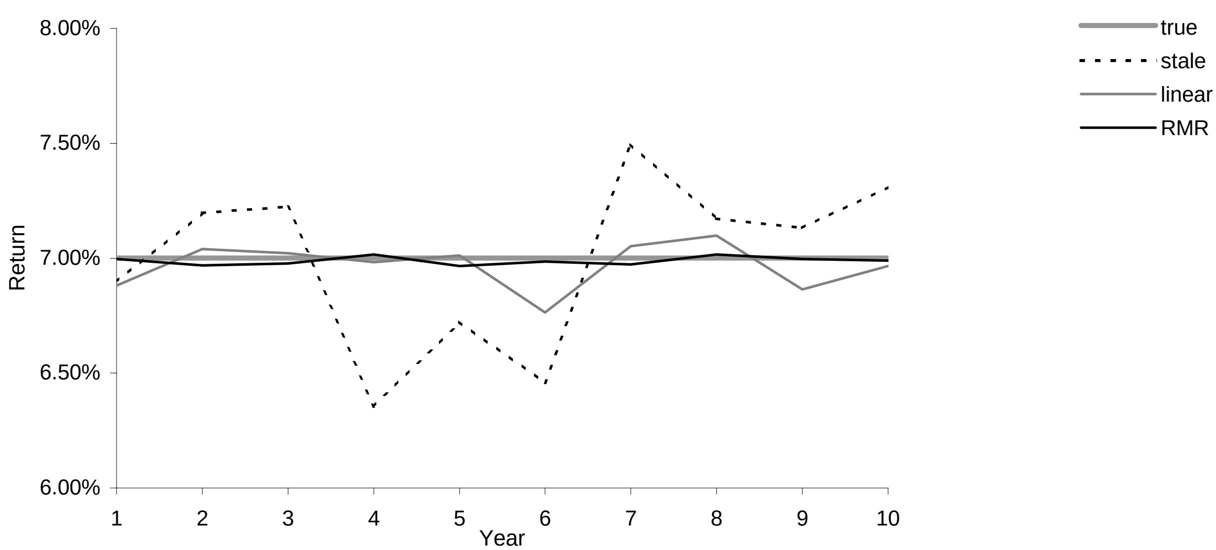
Deviations from the assumed income returns result from changes in the denominator of the formula, which is the monthly capital value. As therefore expected from the previous results, the RMR based income returns exhibit the smallest deviations from the straight line, whereas the Stale Appraisal income returns actually cover a broad range in Figure 27.

Figure 28: Root Mean Squared Error of Monthly Income Returns (Mean over 100 Rep.)



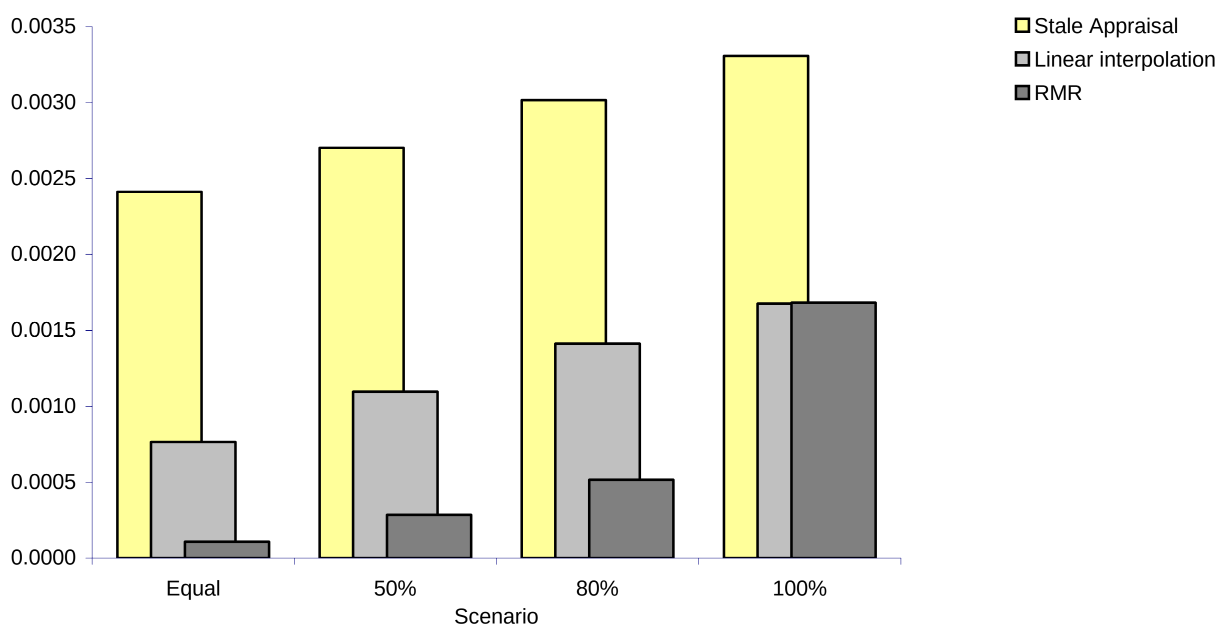
This observation, however, has to be put into the right scale. The average RMSE over 100 repetitions (Figure 28) is tiny and not comparable to the RMSE of the capital returns: the RMSE of the capital returns is about 100 times that of the income returns. So although there are some differences in the accuracy among the methods, the overall impact of the methods on the monthly income return is negligible.

Figure 29: Annual Income Returns for Scenario 50%: Repetition 6, Year 11-20



The same general conclusion can be drawn for the annual income returns. Although the aggregation doesn't make the deviations disappear and the Stale Appraisal returns show quite a range around the true return of 7% (6.5% to 7.5% for Repetition 6, Figure 29), the RMSE statistics reveal that these deviations are again tiny compared to those resulting from differences in the capital returns (Figure 30). The income returns add therefore only minimal to the return differences of index construction methods. Accordingly, conclusions drawn for the capital returns will generally also hold for the total return characteristics.

Figure 30: Root Mean Squared Error of Annual Income Returns (Mean over 100 Rep.)



However, even the minimal deviations of the income returns can play a significant role when currency conversions come into play. Different conversion rates for different months will amplify the return differences and therefore increase the measurement error of the income return. Especially for Scenario 100%, where the capital returns don't exhibit any error, the income return is the only source of deviation in the total return. Under these circumstances, impacts on the income returns will be more important than the RMSE statistics currently indicate.

5. CONCLUSIONS

Three key questions regarding the planned Pan-European property index were considered in this thesis:

- How to generally deal with the heterogeneity of the European markets, addressing the fundamentally differing nature of these markets and their appraisal methods.

- How to weigh the current country indices on an aggregate level, as each country index represents a different share of its total real estate market, and how to define the term total real estate market at all.

- What index construction method to use for a most accurate and efficient interpolation of infrequent appraisal data, in order to adapt to changing currency rates and to eventually publish quarterly or monthly indices.

We addressed the first two issues qualitatively in chapter 3 and performed a quantitative analysis of the last question in chapter 4. Our conclusions and recommendations from these analyses are summarized in the following sections.

5.1. The Heterogeneity of the European Real Estate Market

The heterogeneity of the European real estate market is on the one hand considered as an attractive characteristic, as it provides diversification benefits, on the other hand viewed as a major obstacle, as it leads to a lack in transparency and constrains large-scale intercontinental investments. The observed country differences seem to be deeply rooted and even result in different market functioning and perception of real estate as an asset class.

As discussed on a theoretical level, different market conditions and information availability will have an effect on the rational appraisal behavior. Specific country regulations and costumes may further add to systematic differences in the appraisal process and consequently lead to differences in appraised values, which will in turn be apparent in a country index. One would therefore naturally expect index differences between European countries.

The European IPD property indices clearly exhibit many differences. It is, however, very hard to decide whether the observed differences are a result of different appraisal behavior or a result of the fundamental differences in the real estate markets. The short return history for most European countries does not provide enough evidence to address this issue.

Even if it would be clear that different appraisal procedures actually introduce a systematic bias into the index and make some country indices less comparable, the question of a possible solution would represent a further issue. Remedial methods like reverse engineering only work for specific cases (reliance on past values) and with very subjective assumptions about the appraisal behavior.

To correctly represent the European real estate market, the Pan-European Index should include as many country indices as possible. The heterogeneity of the European real estate market itself does not impact the credibility of the Pan-European Index. On the contrary, introducing a false homogeneity that does not represent whole Europe would presumably harm the credibility of the Pan-European Index much more and also undermine its acceptance in the Pan-European real estate industry.

5.2. Market Weights and Index Use

Current research does not provide a final and satisfying answer to this question. Finding the total size of the real estate market of a country or region will always require a definition of the term "real estate market" and further involve estimates rather than exact calculations. However, this very broad and almost philosophical approach to the question of market weights can be narrowed down to specific requirements when considering the intended application of the index. In this regard, one can distinguish between benchmark and research purposes.

As the benchmark index intends to compare specific company performance to the overall investment performance, this use requires a very narrow definition of the real estate market, namely the market currently used for professional investment purposes, or "invested" market. The index database should also possibly include the whole investment universe to allow for an appropriate value weighting of the property returns.

In contrast, real estate research does not confine itself to the professional invested environment but rather sees real estate as the whole built environment. Consequently, a property index for research purposes involves a much broader definition of the real estate market. As research questions usually aim at uncovering specific statistical characteristics, a sample of equally weighted property returns is the most suitable for this purpose. If the sample is stratified, i.e. is representative of the whole real estate market in its composition and diversity, the sample size can be very small to still serve the intended purpose.

The planned Pan-European Index currently serves neither purpose perfectly. As IPD provides a separate benchmarking service to its clients, the main intended use of the Pan-European Index is research. From this perspective, the market weights should be estimated from the largest market definition possible. Limited market coverage, like in Germany, would not pose as much of a problem as the lack of stratification, i.e. representation of the whole real estate market.

5.3. Methodological Opportunities

Three index construction methods, namely Stale Appraisal, Linear Interpolation, and RMR, have been tested for their dynamic statistical qualities and their application potential depending on the reporting frequency and the temporal distribution of the underlying appraisals. The following conclusions can be drawn from the results of this simulation analysis:

Monthly Capital Returns

- The RMR is clearly the most accurate method for producing a monthly index out of annual appraisals. The simulation statistics indicate that the RMR generated index returns demonstrate a superior cross correlation with the true returns and match the true return characteristics, namely the mean, the standard deviation, and the autocorrelation. This strong level of accuracy was maintained even with as few as 24 appraisals (2% of the total sample) in each of the months.

- The more equally distributed the reappraisals are across the year, the more accurate are the resulting monthly indices. This is apparent in all return statistics and for all index construction methods, although at different levels of accuracy.[93]

- The Stale Appraisals and Linear Interpolation methods lead to very smooth monthly indices with unsatisfactory dynamic statistical characteristics. Although the Linear Interpolation index performs better than the Stale Appraisal index in that it doesn't exhibit any lagging, it also results in a very high autocorrelation and decreases the standard deviation significantly. This decrease in standard deviation is especially problematic if the index is used for research purposes (cp. chapter 2.4.1.).

- The correlation between two property indices that use the same index construction method is on average sufficient for the Stale Appraisal and Linear Interpolation method, but is considerably lower for the RMR method. The "errors" in index construction seem to cancel out for the first two methods, whereas the RMR introduces more noise in the index, which results in lower cross correlations. The calculation of the beta of country A with respect to Europe, however, showed betas very close to the true betas for all the methods, including the RMR.

Annual Capital Returns

- The RMR is again the method that results in the most accurate annual index. With almost no difference between the appraisal distributions, the resulting index is nearly identical to the true index. Contrary to the monthly index, the annual index becomes the more accurate, the more appraisals are per-

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[93] A more equal distribution does not mean that the properties are reappraised more frequently, and will not impact the quality of the appraisals nor their costs, cp. chapter 2.3.1.

formed in December of every year. When 100% of the properties are reappraised as of December, the resulting annual index is identical to the true index, no matter what construction method is used.

- On an annual level, the differences between the different methods are not as big as on a monthly level. All methods reach very high levels of accuracy. However, as soon as some properties are reappraised during the year, the mean squared error of the returns is significantly higher for the Stale Appraisal method and the Linear interpolation, and the standard deviation and autocorrelation statistics exhibit similar flaws than the monthly return statistics, though not of the same degree.

Monthly and Annual Income Returns

- The impact of index construction methods on the income return is minimal in comparison to the impact on the capital returns. In general, income return deviations are therefore negligible when looking at index construction methods. However, differences between the construction methods are apparent for both the monthly and the annual income returns, with the RMR method resulting in very low deviations and the Stale Appraisal method in relatively high deviations of up to 50 basis points for the annual returns.

- Currency conversions have the potential to amplify the small deviations in the income returns. Especially when the capital return deviations are minimal or 0, as for the annual index in Scenario 100%, the currency conversion impact on the income return could be much more important than what the results currently indicate.

Recommendations Regarding the Efficient Use of Appraisal Data

If IPD continues to publish an annual index with all of the properties appraised at the end of December, we showed that the index construction method is not affecting the capital returns and has only minor impacts on the income returns.[94] Accordingly, the intended use of the Linear Interpolation as the index construction method for the PEI (cp. chapter 3.1.1), is regarded more than sufficient for keeping the income return deviations small and making efficient use of the available data.

However, we think that advanced index construction methods provide a big potential for IPD to make more use of the available appraisal data. The simulations in chapter 4 showed that the RMR technique can create a credible monthly index from only annual reappraisals. It's implementation is not only technically desirable but also practically possible for the following reasons:

- The Repeated Measures Regression is an objective mathematical procedure that is widely accepted in the statistics profession (Geltner & Ling, 2001). The method allows almost no room for subjective

[94] Except for the indirect currency impact discussed in chapter 2.4.3.

manipulation and is therefore highly suited for the construction of an independent and well-respected property index.

- The higher reporting frequency would not result in higher appraisal costs for the member companies, as the new monthly index would be based, like the existing index, on annual appraisals. This eliminates one major obstacle for a higher index reporting frequency.

- The only change in the current reporting policy would be a loosening of the requirement that all appraisals have to be performed as of December. In contrast, the new policy would require all appraisals to be spread across the year, the more equally, the better. This requirement may, however, be well aligned with other interests and even present a facilitation to some industry participants. In some countries, e.g. Germany, appraisals are currently already spread across several months. Also appraisal firms could appreciate the new requirements as it would ease their workload seasonality.

- IPD is already interpolating annual reappraisals to get monthly total returns. The RMR clearly is a better way to interpolate between missing values. Applying the RMR would require a small additional effort, but result in a more accurate index, even for the current use, and eventually in a whole new product, namely a monthly index for Europe.

It should be noted that a negative side-effect of all interpolation methods that rely on continuous reappraisals is the backwards adjustment effect. As new appraisals become available, all past returns up to the last recorded value of that property are affected.[95] This would, however, be the case for the Linear Interpolation as well as the RMR, if some properties are reappraised during the year. Other issues, like the necessary sample size to also compute sector or regional returns, have also to be addressed. These issues though are very similar to those of the index construction methods currently applied and therefore not insurmountable.

The RMR technique is a very cost effective and powerful tool to construct a monthly index from annual observations. We think it enables IPD to use the available appraisal data more efficiently, and would recommend its implementation.

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[95] For annual reappraisals, the index would remain provisional for one year and only become constant after that period. This would actually mean that IPD had to loose its policy of “freezing” some of their indices immediately after they are published and allow for a certain time to update the numbers. However, other indices like the GDP are also published on a preliminary basis, updated, and then “frozen” at a later point in time.

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APPENDIX I – STATISTICS OF SIMULATION ANALYSIS

Statistics of Appraised Index Returns (Table Columns)

Label	Description	Formula
Mean	Mean of returns x over all time periods T	$\bar{x} = \sum_{t=1}^{T} \frac{x_t}{T}$
Stdev	Standard deviation of returns x over all time periods T	$\sigma(x) = \sqrt{\sum_{t=1}^{T} \frac{(x_t - \bar{x})^2}{T}}$
Acorr1	First order serial autocorrelation of returns x. Degree to which the return of one period predicts the return of the next period.	$\alpha_1(x) = \sum_{t=2}^{T} \frac{(x_t - \bar{x}_{2,T})*(x_{t-1} - \bar{x}_{1,T-1})}{T*\sigma(x_{1,T-1})*\sigma(x_{2,T})}$
Acorr12	Twelfth order serial autocorrelation of returns. Degree to which the return of one period predicts the return of the 12th period.	$\alpha_{12}(x) = \sum_{t=13}^{T} \frac{(x_t - \bar{x}_{13,T})*(x_{t-12} - \bar{x}_{1,T-12})}{T*\sigma(x_{1,T-12})*\sigma(x_{13,T})}$
CcorrB, CcorrC, CcorrEU	Cross correlation of returns x of country A with returns y of country B (or C, or Europe)	$\rho(x,y) = \sum_{t=1}^{T} \frac{(x_t - \bar{x})*(y_t - \bar{y})}{T*\sigma(x)*\sigma(y)}$
CorrT	Cross correlation of appraised returns x* with true returns x	$\rho(x^*,x) = \sum_{t=1}^{T} \frac{(x_t^* - \bar{x}^*)*(x_t - \bar{x})}{T*\sigma(x^*)*\sigma(x)}$
RMSE	Root Mean Squared Error, square root of the sum of squared differences between appraised return x* and true return x, divided by the number of periods T	$RMSE = \sqrt{\sum_{t=1}^{T} \frac{(x_t^* - x_t)^2}{T}}$
Mean - MeanT	Mean of appraised returns minus mean of true returns	$\bar{x}^* - \bar{x}$
Stdev / StdevT	Standard deviation of appraised returns divided by standard deviation of true returns	$\frac{\sigma(x^*)}{\sigma(x)}$
Acorr1 – Acorr1T	Difference of first order serial autocorrelations of appraised and true returns	$\alpha_1(x^*) - \alpha_1(x)$
Acorr12 – Acorr12T	Difference of twelfth order serial autocorrelations of appraised and true returns	$\alpha_{12}(x^*) - \alpha_{12}(x)$
CcorrB / CcorrBT	Cross correlation of appraised returns of countries A and B (or C, Europe) divided by cross correlation of true returns of the two countries.	$\frac{\rho(x^*, y^*)}{\rho(x,y)}$

Additional Statistics for Monthly True Returns

Label	Description	Formula
Id.Var.	Average of idiosyncratic property variances over all properties N in an Index	$\overline{V}_I = \frac{1}{N}\sum_{t=1}^{T}\left[\sum_{i=1}^{N}\frac{(x_{ti}-\overline{x}_i)^2}{T}\right]$
Heterog.	Heterogeneity of an index, average property variance divided by index variance	$H = \frac{\overline{V}_I}{V} = \frac{\overline{V}_I}{\sigma(x)^2}$

Statistics for Distribution of Index Statistics over 100 Repetitions (Table Rows)

Label	Description	Formula
Mean	Mean of statistic s over all repetitions	$\overline{x} = \sum_{t=1}^{T}\frac{x_t}{T}$
Stdev	Standard deviation of statistic s over all repetitions	$\sigma(x) = \sqrt{\sum_{t=1}^{T}\frac{(x_t-\overline{x})^2}{T}}$
95% CI UB	95% confidence interval for 100 repetitions of return statistics, upper bound	$CI_{95,L} = \overline{x} + t_{.025,N-1} * \frac{\sigma}{\sqrt{N}}$
95% CI LB	95% confidence interval for 100 repetitions of return statistics, lower bound	$CI_{95,U} = \overline{x} - t_{.025,N-1} * \frac{\sigma}{\sqrt{N}}$
Min	Minimum statistic of 100 repetitions calculated.	
Max	Maximum statistic of 100 repetitions calculated.	

True Returns

Monthly Returns		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	Id.Var.	Heterog.
Repetition stat.	Mean	0.0000	0.0204	0.1850	-0.0063	0.3658	0.3636	0.7599	0.0014	3.2708
	Stdev.	0.0013	0.0010	0.0591	0.0684	0.0556	0.0548	0.0504	0.0000	0.2361
	95% CI LB	-0.0003	0.0202	0.1734	-0.0197	0.3549	0.3528	0.7500	0.0013	3.2245
	95% CI UB	0.0002	0.0206	0.1966	0.0071	0.3767	0.3743	0.7697	0.0014	3.3171
	Min	-0.0033	0.0177	0.0659	-0.1876	0.1927	0.2317	0.5317	0.0013	2.7456
	Max	0.0044	0.0232	0.3318	0.1331	0.4901	0.4917	0.8790	0.0015	4.0117

Annual Returns		Return statistics					
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU
Repetition stat.	Mean	0.0010	0.0852	-0.0662	0.3708	0.3713	0.7512
	Stdev.	0.0164	0.0153	0.2039	0.1884	0.2021	0.1027
	95% CI LB	-0.0022	0.0822	-0.1062	0.3339	0.3317	0.7310
	95% CI UB	0.0042	0.0882	-0.0262	0.4078	0.4109	0.7713
	Min	-0.0368	0.0518	-0.5752	-0.1598	-0.1879	0.4648
	Max	0.0552	0.1282	0.3955	0.7711	0.7776	0.9189

Scenario Equal – Stale Appraisals

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0069	0.9065	-0.0631	0.3400	0.3394	0.7426	0.2884	0.0195
	Stdev.	0.0013	0.0009	0.0233	0.1685	0.1502	0.1661	0.0872	0.0440	0.0010
	95% CI LB	-0.0004	0.0067	0.9019	-0.0961	0.3105	0.3068	0.7255	0.2798	0.0193
	95% CI UB	0.0001	0.0071	0.9111	-0.0300	0.3694	0.3719	0.7597	0.2971	0.0197
	Min	-0.0032	0.0051	0.8269	-0.4444	-0.0401	-0.1236	0.4894	0.1773	0.0167
	Max	0.0039	0.0095	0.9500	0.3850	0.7915	0.6712	0.9047	0.4032	0.0218

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0001	0.3390	0.7215	-0.0568	0.9240	0.9271	0.9778
	Stdev.	0.0002	0.0409	0.0508	0.1624	0.3768	0.4442	0.1016
	95% CI LB	-0.0002	0.3310	0.7116	-0.0886	0.8502	0.8400	0.9578
	95% CI UB	-0.0001	0.3471	0.7315	-0.0250	0.9979	1.0141	0.9977
	Min	-0.0006	0.2435	0.5722	-0.4387	-0.1295	-0.3176	0.6977
	Max	0.0003	0.4453	0.8097	0.2893	1.8927	1.8647	1.3540

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0002	0.0680	0.1608	0.3352	0.3373	0.7358	0.6706	0.0617
	Stdev.	0.0159	0.0125	0.1849	0.2080	0.2160	0.1150	0.1196	0.0135
	95% CI LB	-0.0029	0.0656	0.1246	0.2944	0.2949	0.7133	0.6472	0.0590
	95% CI UB	0.0033	0.0705	0.1971	0.3760	0.3796	0.7584	0.6941	0.0643
	Min	-0.0364	0.0447	-0.2654	-0.2255	-0.3374	0.3692	0.2582	0.0295
	Max	0.0499	0.1032	0.6140	0.8515	0.7058	0.9265	0.9012	0.0975

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0008	0.8034	0.2270	1.8387	0.7931	0.9840
	Stdev.	0.0022	0.0964	0.1702	11.9547	1.7126	0.1201
	95% CI LB	-0.0012	0.7845	0.1937	-0.5044	0.4574	0.9605
	95% CI UB	-0.0003	0.8223	0.2604	4.1817	1.1287	1.0076
	Min	-0.0060	0.5597	-0.1957	-27.2115	-11.8837	0.5256
	Max	0.0041	1.0278	0.6223	116.3854	4.8979	1.2347

Scenario Equal – Linear Interpolation

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0056	0.9879	0.1459	0.3407	0.3403	0.7405	0.4158	0.0187
	Stdev.	0.0013	0.0010	0.0029	0.1836	0.1943	0.2036	0.1065	0.0386	0.0010
	95% CI LB	-0.0004	0.0054	0.9873	0.1099	0.3026	0.3004	0.7196	0.4083	0.0185
	95% CI UB	0.0001	0.0058	0.9884	0.1819	0.3787	0.3802	0.7614	0.4234	0.0189
	Min	-0.0032	0.0038	0.9816	-0.3374	-0.1284	-0.2630	0.4281	0.3134	0.0163
	Max	0.0039	0.0083	0.9940	0.5569	0.8489	0.6977	0.9232	0.5147	0.0212

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0001	0.2754	0.8029	0.1522	0.9247	0.9308	0.9752
	Stdev.	0.0002	0.0440	0.0584	0.1801	0.5075	0.5605	0.1326
	95% CI LB	-0.0002	0.2667	0.7915	0.1169	0.8253	0.8209	0.9492
	95% CI UB	-0.0001	0.2840	0.8144	0.1875	1.0242	1.0406	1.0012
	Min	-0.0006	0.1810	0.6544	-0.2932	-0.4143	-0.6757	0.6102
	Max	0.0003	0.3956	0.9192	0.5243	2.0301	2.1166	1.4190

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0619	0.2771	0.3429	0.3410	0.7409	0.9063	0.0379
	Stdev.	0.0158	0.0119	0.1804	0.2167	0.2197	0.1137	0.0378	0.0087
	95% CI LB	-0.0033	0.0596	0.2417	0.3004	0.2980	0.7186	0.8988	0.0362
	95% CI UB	0.0029	0.0642	0.3125	0.3854	0.3841	0.7632	0.9137	0.0396
	Min	-0.0364	0.0409	-0.2581	-0.1230	-0.3166	0.4331	0.6894	0.0166
	Max	0.0490	0.0947	0.6378	0.8573	0.7544	0.9383	0.9685	0.0705

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0012	0.7288	0.3433	1.6421	0.8282	0.9885
	Stdev.	0.0022	0.0727	0.1200	8.5646	1.8383	0.0956
	95% CI LB	-0.0016	0.7146	0.3198	-0.0366	0.4679	0.9698
	95% CI UB	-0.0007	0.7431	0.3668	3.3207	1.1885	1.0072
	Min	-0.0065	0.5432	0.0974	-13.1781	-16.5253	0.6890
	Max	0.0037	0.8899	0.6761	84.9508	3.5974	1.2469

Scenario Equal – RMR

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0000	0.0205	0.1443	-0.0967	0.2527	0.2493	0.7083	0.7867	0.0133
	Stdev.	0.0014	0.0010	0.0608	0.0607	0.0691	0.0636	0.0613	0.0323	0.0008
	95% CI LB	-0.0003	0.0203	0.1324	-0.1086	0.2392	0.2368	0.6963	0.7804	0.0131
	95% CI UB	0.0003	0.0207	0.1562	-0.0848	0.2663	0.2618	0.7203	0.7930	0.0134
	Min	-0.0032	0.0183	-0.0116	-0.2279	0.0118	0.0886	0.4693	0.7009	0.0115
	Max	0.0044	0.0225	0.3018	0.1234	0.4129	0.4254	0.8619	0.8471	0.0154

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	1.0042	-0.0407	-0.0904	0.6840	0.6844	0.9313
	Stdev.	0.0001	0.0353	0.0510	0.0613	0.1399	0.1397	0.0359
	95% CI LB	0.0000	0.9973	-0.0507	-0.1024	0.6566	0.6571	0.9243
	95% CI UB	0.0000	1.0111	-0.0307	-0.0784	0.7114	0.7118	0.9384
	Min	-0.0002	0.9186	-0.1951	-0.2761	0.0525	0.3640	0.8259
	Max	0.0002	1.1241	0.0727	0.0667	0.9144	1.0253	1.0044

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0010	0.0856	-0.0681	0.3658	0.3649	0.7503	0.9912	0.0108
	Stdev.	0.0164	0.0154	0.2101	0.1920	0.1974	0.1036	0.0040	0.0019
	95% CI LB	-0.0022	0.0826	-0.1093	0.3282	0.3262	0.7300	0.9904	0.0105
	95% CI UB	0.0043	0.0886	-0.0270	0.4034	0.4036	0.7706	0.9919	0.0112
	Min	-0.0357	0.0503	-0.5494	-0.1628	-0.1899	0.4577	0.9734	0.0045
	Max	0.0549	0.1277	0.4307	0.7657	0.8018	0.9256	0.9986	0.0162

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0001	1.0048	-0.0019	1.4827	0.9638	0.9991
	Stdev.	0.0009	0.0296	0.0370	4.0418	0.6712	0.0325
	95% CI LB	-0.0001	0.9990	-0.0092	0.6905	0.8322	0.9927
	95% CI UB	0.0002	1.0106	0.0053	2.2749	1.0953	1.0055
	Min	-0.0019	0.9106	-0.0943	0.3783	-4.8833	0.9017
	Max	0.0026	1.0732	0.1063	40.0554	2.8151	1.0911

Scenario 50% – Stale Appraisals

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0001	0.0126	0.2223	-0.0400	0.3672	0.3636	0.7490	0.1529	0.0223
	Stdev.	0.0013	0.0022	0.0212	0.1953	0.1818	0.1888	0.0966	0.0528	0.0014
	95% CI LB	-0.0004	0.0122	0.2181	-0.0783	0.3316	0.3266	0.7300	0.1426	0.0220
	95% CI UB	0.0001	0.0131	0.2264	-0.0017	0.4029	0.4006	0.7679	0.1633	0.0226
	Min	-0.0032	0.0081	0.1658	-0.5455	-0.1243	-0.1328	0.4909	0.0007	0.0189
	Max	0.0041	0.0189	0.2597	0.4066	0.7679	0.7437	0.9112	0.3138	0.0265

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0001	0.6192	0.0373	-0.0337	1.0115	1.0024	0.9869
	Stdev.	0.0001	0.0991	0.0630	0.1892	0.4977	0.5192	0.1208
	95% CI LB	-0.0001	0.5998	0.0249	-0.0708	0.9140	0.9007	0.9632
	95% CI UB	-0.0001	0.6386	0.0496	0.0033	1.1091	1.1042	1.0105
	Min	-0.0003	0.3846	-0.0980	-0.4696	-0.3572	-0.4442	0.6872
	Max	0.0001	0.8969	0.1486	0.3726	2.0865	2.0449	1.3317

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0001	0.0693	0.1327	0.3612	0.3598	0.7489	0.9158	0.0340
	Stdev.	0.0160	0.0128	0.1951	0.1992	0.2076	0.1072	0.0344	0.0074
	95% CI LB	-0.0031	0.0668	0.0945	0.3222	0.3191	0.7279	0.9090	0.0325
	95% CI UB	0.0032	0.0718	0.1710	0.4003	0.4004	0.7699	0.9225	0.0354
	Min	-0.0370	0.0446	-0.3707	-0.0971	-0.2945	0.4533	0.7321	0.0162
	Max	0.0517	0.1032	0.5897	0.8231	0.7615	0.9343	0.9720	0.0538

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0009	0.8150	0.1989	1.5215	0.9506	0.9992
	Stdev.	0.0013	0.0619	0.1047	8.5847	0.8285	0.0779
	95% CI LB	-0.0012	0.8029	0.1784	-0.1610	0.7882	0.9840
	95% CI UB	-0.0007	0.8272	0.2194	3.2041	1.1130	1.0145
	Min	-0.0040	0.6601	-0.0327	-28.4280	-6.0598	0.7443
	Max	0.0018	0.9741	0.4870	80.8387	2.5790	1.1760

Scenario 50% – Linear Interpolation

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0059	0.9674	0.0837	0.3583	0.3551	0.7472	0.3966	0.0188
	Stdev.	0.0013	0.0010	0.0086	0.1955	0.1870	0.2019	0.1019	0.0448	0.0010
	95% CI LB	-0.0004	0.0057	0.9657	0.0454	0.3217	0.3156	0.7272	0.3878	0.0186
	95% CI UB	0.0001	0.0061	0.9691	0.1220	0.3950	0.3947	0.7672	0.4054	0.0190
	Min	-0.0033	0.0039	0.9475	-0.4514	-0.0656	-0.2552	0.4780	0.2945	0.0160
	Max	0.0040	0.0084	0.9846	0.5149	0.8205	0.7356	0.9216	0.5289	0.0210

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0002	0.2898	0.7824	0.0900	0.9793	0.9759	0.9845
	Stdev.	0.0001	0.0474	0.0590	0.1887	0.4952	0.5596	0.1286
	95% CI LB	-0.0002	0.2805	0.7709	0.0530	0.8822	0.8662	0.9593
	95% CI UB	-0.0001	0.2991	0.7940	0.1270	1.0764	1.0856	1.0097
	Min	-0.0004	0.1796	0.6374	-0.3791	-0.1885	-0.6557	0.6601
	Max	0.0001	0.4076	0.8941	0.4481	1.9620	2.1203	1.4238

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0002	0.0707	0.1101	0.3580	0.3563	0.7467	0.9790	0.0210
	Stdev.	0.0160	0.0129	0.1981	0.1948	0.2089	0.1050	0.0086	0.0048
	95% CI LB	-0.0030	0.0682	0.0713	0.3199	0.3153	0.7261	0.9773	0.0200
	95% CI UB	0.0033	0.0732	0.1489	0.3962	0.3972	0.7672	0.9807	0.0219
	Min	-0.0364	0.0448	-0.4411	-0.0908	-0.2702	0.4777	0.9194	0.0090
	Max	0.0518	0.1013	0.5374	0.8225	0.7335	0.9215	0.9920	0.0385

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0008	0.8302	0.1763	1.3546	0.8870	0.9948
	Stdev.	0.0012	0.0433	0.0577	5.0222	0.9418	0.0493
	95% CI LB	-0.0011	0.8217	0.1650	0.3703	0.7024	0.9851
	95% CI UB	-0.0006	0.8387	0.1876	2.3390	1.0716	1.0044
	Min	-0.0039	0.7211	0.0565	-9.2280	-7.5850	0.8409
	Max	0.0018	0.9242	0.3351	49.8966	2.1912	1.1351

Scenario 50% – RMR

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0000	0.0202	0.1514	-0.1218	0.2341	0.2328	0.6968	0.7383	0.0146
	Stdev.	0.0013	0.0010	0.0731	0.0629	0.0579	0.0581	0.0624	0.0404	0.0009
	95% CI LB	-0.0003	0.0200	0.1370	-0.1341	0.2228	0.2214	0.6846	0.7304	0.0144
	95% CI UB	0.0002	0.0204	0.1657	-0.1095	0.2455	0.2442	0.7090	0.7462	0.0148
	Min	-0.0032	0.0175	-0.0463	-0.2638	0.0412	0.0706	0.4153	0.6194	0.0125
	Max	0.0044	0.0230	0.3189	0.0475	0.3918	0.3551	0.8628	0.8128	0.0169

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	0.9924	-0.0336	-0.1155	0.6400	0.6416	0.9160
	Stdev.	0.0000	0.0386	0.0538	0.0676	0.1359	0.1394	0.0403
	95% CI LB	0.0000	0.9849	-0.0442	-0.1288	0.6133	0.6143	0.9082
	95% CI UB	0.0000	1.0000	-0.0231	-0.1023	0.6666	0.6689	0.9239
	Min	-0.0001	0.9112	-0.1605	-0.3547	0.1826	0.2446	0.7810
	Max	0.0001	1.0789	0.1148	0.0644	0.9392	0.9724	0.9867

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0010	0.0852	-0.0664	0.3715	0.3703	0.7513	0.9990	0.0036
	Stdev.	0.0164	0.0154	0.2053	0.1865	0.2005	0.1011	0.0005	0.0006
	95% CI LB	-0.0022	0.0821	-0.1066	0.3349	0.3310	0.7315	0.9989	0.0035
	95% CI UB	0.0042	0.0882	-0.0261	0.4080	0.4096	0.7712	0.9991	0.0037
	Min	-0.0362	0.0518	-0.5768	-0.1569	-0.1799	0.5011	0.9969	0.0022
	Max	0.0555	0.1279	0.4016	0.7656	0.7680	0.9185	0.9997	0.0051

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	0.9991	-0.0002	1.3526	0.9866	1.0007
	Stdev.	0.0004	0.0116	0.0124	3.2613	0.2189	0.0135
	95% CI LB	0.0000	0.9968	-0.0026	0.7134	0.9437	0.9980
	95% CI UB	0.0001	1.0013	0.0023	1.9918	1.0295	1.0033
	Min	-0.0008	0.9666	-0.0287	0.6875	-0.9824	0.9674
	Max	0.0009	1.0258	0.0380	33.5968	1.4970	1.0891

Scenario 80% – Stale Appraisals

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0000	0.0191	0.0495	-0.0328	0.3683	0.3666	0.7482	0.0990	0.0265
	Stdev.	0.0013	0.0034	0.0079	0.2015	0.1911	0.1957	0.1012	0.0540	0.0024
	95% CI LB	-0.0003	0.0185	0.0480	-0.0723	0.3308	0.3282	0.7283	0.0884	0.0261
	95% CI UB	0.0002	0.0198	0.0511	0.0067	0.4057	0.4050	0.7680	0.1096	0.0270
	Min	-0.0032	0.0119	0.0204	-0.5595	-0.1427	-0.1332	0.4640	-0.0607	0.0214
	Max	0.0044	0.0289	0.0612	0.4053	0.7724	0.7559	0.9110	0.2775	0.0336

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	0.9374	-0.1354	-0.0265	1.0159	1.0125	0.9858
	Stdev.	0.0001	0.1548	0.0592	0.1958	0.5283	0.5400	0.1267
	95% CI LB	0.0000	0.9071	-0.1470	-0.0649	0.9123	0.9067	0.9609
	95% CI UB	0.0000	0.9678	-0.1238	0.0119	1.1194	1.1183	1.0106
	Min	-0.0002	0.5556	-0.2800	-0.4499	-0.4102	-0.4079	0.6513
	Max	0.0002	1.3723	-0.0205	0.3960	2.2477	2.0667	1.2803

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0005	0.0768	0.0232	0.3700	0.3680	0.7521	0.9875	0.0148
	Stdev.	0.0162	0.0138	0.2032	0.1893	0.2030	0.1022	0.0048	0.0033
	95% CI LB	-0.0027	0.0741	-0.0166	0.3329	0.3282	0.7321	0.9865	0.0142
	95% CI UB	0.0036	0.0795	0.0630	0.4071	0.4078	0.7722	0.9884	0.0155
	Min	-0.0372	0.0470	-0.5055	-0.1192	-0.2427	0.4917	0.9609	0.0071
	Max	0.0534	0.1123	0.4733	0.7969	0.7377	0.9214	0.9951	0.0233

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0005	0.9016	0.0894	1.2477	0.9853	1.0021
	Stdev.	0.0006	0.0297	0.0419	4.0516	0.3961	0.0330
	95% CI LB	-0.0007	0.8958	0.0812	0.4536	0.9076	0.9956
	95% CI UB	-0.0004	0.9075	0.0976	2.0418	1.0629	1.0085
	Min	-0.0020	0.8341	-0.0049	-13.0663	-2.4996	0.9085
	Max	0.0006	0.9865	0.2077	38.6367	1.6161	1.0795

Scenario 80% – Linear Interpolation

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0064	0.9383	0.0024	0.3682	0.3644	0.7508	0.3659	0.0189
	Stdev.	0.0013	0.0011	0.0141	0.2043	0.1853	0.2007	0.1007	0.0506	0.0010
	95% CI LB	-0.0005	0.0062	0.9355	-0.0377	0.3318	0.3251	0.7310	0.3560	0.0187
	95% CI UB	0.0001	0.0066	0.9411	0.0424	0.4045	0.4038	0.7705	0.3759	0.0191
	Min	-0.0034	0.0040	0.9045	-0.5362	-0.1248	-0.2353	0.4628	0.2553	0.0160
	Max	0.0041	0.0094	0.9678	0.4666	0.7929	0.7677	0.9243	0.5188	0.0212

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0002	0.3143	0.7533	0.0087	1.0103	1.0032	0.9893
	Stdev.	0.0000	0.0517	0.0598	0.1965	0.4985	0.5545	0.1282
	95% CI LB	-0.0002	0.3042	0.7416	-0.0299	0.9126	0.8945	0.9642
	95% CI UB	-0.0002	0.3245	0.7650	0.0472	1.1080	1.1119	1.0144
	Min	-0.0003	0.1859	0.6028	-0.4860	-0.3586	-0.6856	0.6619
	Max	-0.0001	0.4621	0.8629	0.3775	2.0310	2.0389	1.4241

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0006	0.0785	0.0037	0.3662	0.3652	0.7496	0.9968	0.0091
	Stdev.	0.0162	0.0141	0.2038	0.1884	0.2045	0.1025	0.0014	0.0021
	95% CI LB	-0.0026	0.0758	-0.0363	0.3293	0.3251	0.7295	0.9965	0.0087
	95% CI UB	0.0038	0.0813	0.0436	0.4032	0.4053	0.7697	0.9970	0.0096
	Min	-0.0367	0.0487	-0.5306	-0.1347	-0.2354	0.4648	0.9874	0.0043
	Max	0.0536	0.1139	0.4558	0.7941	0.7660	0.9199	0.9987	0.0174

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0004	0.9215	0.0699	1.1789	0.9489	0.9982
	Stdev.	0.0006	0.0194	0.0227	2.3890	0.4110	0.0187
	95% CI LB	-0.0005	0.9178	0.0654	0.7107	0.8683	0.9945
	95% CI UB	-0.0003	0.9253	0.0743	1.6472	1.0295	1.0018
	Min	-0.0018	0.8749	0.0235	-3.1148	-2.6718	0.9430
	Max	0.0007	0.9641	0.1357	24.4366	1.4889	1.0575

Scenario 80% – RMR

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0000	0.0196	0.1705	-0.1754	0.1967	0.1885	0.6791	0.6628	0.0164
	Stdev.	0.0013	0.0009	0.0652	0.0568	0.0725	0.0662	0.0691	0.0421	0.0008
	95% CI LB	-0.0003	0.0194	0.1577	-0.1865	0.1825	0.1755	0.6656	0.6546	0.0162
	95% CI UB	0.0002	0.0198	0.1833	-0.1642	0.2109	0.2014	0.6927	0.6711	0.0165
	Min	-0.0033	0.0172	0.0238	-0.3095	0.0076	0.0095	0.4612	0.5499	0.0145
	Max	0.0044	0.0221	0.3258	-0.0337	0.3886	0.3180	0.8526	0.7410	0.0191

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	0.9619	-0.0145	-0.1691	0.5322	0.5156	0.8924
	Stdev.	0.0000	0.0378	0.0604	0.0676	0.1710	0.1672	0.0505
	95% CI LB	0.0000	0.9545	-0.0263	-0.1823	0.4987	0.4828	0.8825
	95% CI UB	0.0000	0.9693	-0.0027	-0.1559	0.5657	0.5484	0.9023
	Min	-0.0001	0.8841	-0.1888	-0.3274	0.0396	0.0345	0.7339
	Max	0.0000	1.0784	0.0962	-0.0353	0.8970	0.8989	0.9823

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0010	0.0852	-0.0656	0.3715	0.3709	0.7514	0.9997	0.0019
	Stdev.	0.0164	0.0153	0.2049	0.1872	0.2016	0.1021	0.0002	0.0003
	95% CI LB	-0.0022	0.0822	-0.1057	0.3348	0.3314	0.7314	0.9997	0.0018
	95% CI UB	0.0042	0.0882	-0.0254	0.4082	0.4104	0.7714	0.9997	0.0020
	Min	-0.0365	0.0513	-0.5788	-0.1513	-0.1952	0.4784	0.9990	0.0012
	Max	0.0553	0.1273	0.3977	0.7701	0.7718	0.9189	0.9999	0.0028

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	0.9996	0.0006	1.0180	0.9785	1.0004
	Stdev.	0.0002	0.0053	0.0068	0.0931	0.2030	0.0064
	95% CI LB	0.0000	0.9985	-0.0007	0.9998	0.9387	0.9992
	95% CI UB	0.0001	1.0006	0.0020	1.0363	1.0183	1.0017
	Min	-0.0003	0.9906	-0.0170	0.7827	-0.8979	0.9765
	Max	0.0004	1.0176	0.0227	1.6709	1.1492	1.0292

Scenario 100% – Stale Appraisals

Monthly Returns 1	Return statistics: Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat. Mean	0.0001	0.0244	-0.0028	-0.0322	0.3665	0.3670	0.7470	0.0762	0.0306
Stdev.	0.0014	0.0044	0.0041	0.2017	0.1940	0.1977	0.1028	0.0550	0.0034
95% CI LB	-0.0002	0.0236	-0.0037	-0.0718	0.3284	0.3282	0.7268	0.0655	0.0300
95% CI UB	0.0003	0.0253	-0.0020	0.0073	0.4045	0.4057	0.7671	0.0870	0.0313
Min	-0.0031	0.0153	-0.0208	-0.5565	-0.1603	-0.1343	0.4730	-0.0780	0.0239
Max	0.0046	0.0376	0.0001	0.3980	0.7772	0.7662	0.9106	0.2618	0.0408

Monthly Returns 2	Return statistics: Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat. Mean	0.0001	1.1987	-0.1878	-0.0260	1.0105	1.0141	0.9841
Stdev.	0.0001	0.2010	0.0587	0.1966	0.5370	0.5461	0.1286
95% CI LB	0.0001	1.1593	-0.1993	-0.0645	0.9053	0.9070	0.9589
95% CI UB	0.0001	1.2381	-0.1763	0.0126	1.1158	1.1211	1.0093
Min	-0.0001	0.7042	-0.3336	-0.4295	-0.4607	-0.4389	0.6708
Max	0.0004	1.7459	-0.0664	0.3851	2.2802	2.0783	1.2602

Annual Returns 1	Return statistics: Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat. Mean	0.0010	0.0852	-0.0662	0.3708	0.3713	0.7512	1.0000	0.0000
Stdev.	0.0164	0.0153	0.2039	0.1884	0.2021	0.1027	0.0000	0.0000
95% CI LB	-0.0022	0.0822	-0.1062	0.3339	0.3317	0.7310	n/a	n/a
95% CI UB	0.0042	0.0882	-0.0262	0.4078	0.4109	0.7713	n/a	n/a
Min	-0.0368	0.0518	-0.5752	-0.1598	-0.1879	0.4648	1.0000	0.0000
Max	0.0552	0.1282	0.3955	0.7711	0.7776	0.9189	1.0000	0.0000

Annual Returns 2	Return statistics: Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat. Mean	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000
Stdev.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
95% CI LB	n/a	n/a	n/a	n/a	n/a	n/a
95% CI UB	n/a	n/a	n/a	n/a	n/a	n/a
Min	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000
Max	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000

Scenario 100% – Linear Interpolation

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0069	0.9144	-0.0633	0.3734	0.3707	0.7526	0.3390	0.0191
	Stdev.	0.0013	0.0012	0.0167	0.2053	0.1859	0.1989	0.1007	0.0554	0.0010
	95% CI LB	-0.0005	0.0067	0.9112	-0.1036	0.3370	0.3317	0.7329	0.3281	0.0189
	95% CI UB	0.0001	0.0072	0.9177	-0.0231	0.4099	0.4097	0.7723	0.3498	0.0193
	Min	-0.0034	0.0042	0.8722	-0.5819	-0.1492	-0.1903	0.4634	0.2047	0.0161
	Max	0.0042	0.0105	0.9510	0.4176	0.7693	0.7805	0.9237	0.5073	0.0214

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0002	0.3395	0.7294	-0.0571	1.0265	1.0210	0.9918
	Stdev.	0.0000	0.0563	0.0601	0.1975	0.5044	0.5473	0.1287
	95% CI LB	-0.0002	0.3285	0.7177	-0.0958	0.9276	0.9138	0.9666
	95% CI UB	-0.0002	0.3506	0.7412	-0.0184	1.1253	1.1283	1.0171
	Min	-0.0002	0.2032	0.5766	-0.5469	-0.4289	-0.6594	0.6626
	Max	-0.0001	0.5131	0.8408	0.3284	2.1087	2.0615	1.4246

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0010	0.0852	-0.0662	0.3708	0.3713	0.7512	1.0000	0.0000
	Stdev.	0.0164	0.0153	0.2039	0.1884	0.2021	0.1027	0.0000	0.0000
	95% CI LB	-0.0022	0.0822	-0.1062	0.3339	0.3317	0.7310	n/a	n/a
	95% CI UB	0.0042	0.0882	-0.0262	0.4078	0.4109	0.7713	n/a	n/a
	Min	-0.0368	0.0518	-0.5752	-0.1598	-0.1879	0.4648	1.0000	0.0000
	Max	0.0552	0.1282	0.3955	0.7711	0.7776	0.9189	1.0000	0.0000

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000
	Stdev.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	95% CI LB	n/a	n/a	n/a	n/a	n/a	n/a
	95% CI UB	n/a	n/a	n/a	n/a	n/a	n/a
	Min	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000
	Max	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000

Scenario 100% – RMR

Monthly Returns 1		Return statistics								
		Mean	Stdev	Acorr1	Acorr12	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	-0.0002	0.0069	0.9145	-0.0633	0.3734	0.3707	0.7526	0.3385	0.0191
	Stdev.	0.0013	0.0012	0.0172	0.2053	0.1859	0.1989	0.1007	0.0565	0.0010
	95% CI LB	-0.0005	0.0067	0.9111	-0.1036	0.3370	0.3317	0.7328	0.3274	0.0189
	95% CI UB	0.0001	0.0072	0.9179	-0.0231	0.4099	0.4097	0.7723	0.3496	0.0193
	Min	-0.0034	0.0042	0.8743	-0.5820	-0.1492	-0.1902	0.4635	0.2036	0.0160
	Max	0.0042	0.0105	0.9513	0.4176	0.7692	0.7805	0.9240	0.5148	0.0214

Monthly Returns 2		Return statistics						
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	Acorr12 - Acorr12T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	-0.0002	0.3392	0.7295	-0.0571	1.0264	1.0210	0.9918
	Stdev.	0.0000	0.0562	0.0602	0.1975	0.5044	0.5473	0.1288
	95% CI LB	-0.0002	0.3281	0.7177	-0.0958	0.9276	0.9138	0.9666
	95% CI UB	-0.0002	0.3502	0.7413	-0.0184	1.1253	1.1283	1.0171
	Min	-0.0002	0.2029	0.5806	-0.5469	-0.4288	-0.6592	0.6628
	Max	-0.0001	0.5125	0.8432	0.3284	2.1087	2.0615	1.4272

Annual Returns 1		Return statistics							
		Mean	Stdev	Acorr1	CcorrB	CcorrC	CcorrEU	CcorrT	RMSE
Repetition stat.	Mean	0.0010	0.0851	-0.0662	0.3708	0.3713	0.7512	1.0000	0.0001
	Stdev.	0.0164	0.0153	0.2039	0.1884	0.2020	0.1027	0.0000	0.0000
	95% CI LB	-0.0022	0.0821	-0.1062	0.3339	0.3317	0.7311	1.0000	0.0001
	95% CI UB	0.0042	0.0881	-0.0262	0.4078	0.4109	0.7713	1.0000	0.0001
	Min	-0.0368	0.0517	-0.5753	-0.1598	-0.1878	0.4649	1.0000	0.0001
	Max	0.0551	0.1281	0.3955	0.7710	0.7776	0.9188	1.0000	0.0001

Annual Returns 2		Return statistics					
		Mean - MeanT	Stdev / StdevT	Acorr1 - Acorr1T	CcorrB / CcorrBT	CcorrC / CcorrCT	CcorrEU / CcorrEUT
Repetition stat.	Mean	0.0000	0.9989	0.0000	1.0001	1.0000	1.0000
	Stdev.	0.0000	0.0001	0.0001	0.0009	0.0018	0.0001
	95% CI LB	0.0000	0.9989	0.0000	0.9999	0.9997	1.0000
	95% CI UB	0.0000	0.9989	0.0000	1.0003	1.0004	1.0000
	Min	-0.0001	0.9986	-0.0003	0.9987	0.9906	0.9999
	Max	0.0000	0.9991	0.0002	1.0086	1.0150	1.0004

Calculation of Beta

StdevEU, σ(EU): Standard Deviation of Aggregated European Returns (Mean over 100 Rep.)

Monthly Returns					Annual Returns				
Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR	Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR
equal	0.0155	0.0052	0.0043	0.0146	equal	0.0661	0.0516	0.0470	0.0660
50%	0.0155	0.0098	0.0045	0.0144	50%	0.0661	0.0532	0.0543	0.0661
80%	0.0155	0.0149	0.0050	0.0135	80%	0.0661	0.0593	0.0607	0.0661
100%	0.0155	0.0190	0.0054	0.0054	100%	0.0661	0.0661	0.0661	0.0660

StdevA, σ(A): Standard Deviation of Country A Returns (Mean over 100 Rep.)

Monthly Returns					Annual Returns				
Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR	Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR
equal	0.0204	0.0069	0.0056	0.0205	equal	0.0852	0.0680	0.0619	0.0856
50%	0.0204	0.0126	0.0059	0.0202	50%	0.0852	0.0693	0.0707	0.0852
80%	0.0204	0.0191	0.0064	0.0196	80%	0.0852	0.0768	0.0785	0.0852
100%	0.0204	0.0244	0.0069	0.0069	100%	0.0852	0.0852	0.0852	0.0851

CcorrEU, ρ(A,EU): Cross Correlation between Country A and Europe (Mean over 100 Rep.)

Monthly Returns					Annual Returns				
Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR	Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR
equal	0.7599	0.7426	0.7405	0.7083	equal	0.7512	0.7358	0.7409	0.7503
50%	0.7599	0.7490	0.7472	0.6968	50%	0.7512	0.7489	0.7467	0.7513
80%	0.7599	0.7482	0.7508	0.6791	80%	0.7512	0.7521	0.7496	0.7514
100%	0.7599	0.7470	0.7526	0.7526	100%	0.7512	0.7512	0.7512	0.7512

Beta of Country A with Respect to Europe $\beta = \frac{\rho(A,EU) * \sigma(A)}{\sigma(EU)}$

Monthly Returns					Annual Returns				
Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR	Scena-rio	True Return	Stale Appr.	Linear Interpol.	RMR
equal	0.9964	0.9820	0.9768	0.9908	equal	0.9682	0.9698	0.9758	0.9739
50%	0.9964	0.9654	0.9735	0.9808	50%	0.9682	0.9753	0.9723	0.9686
80%	0.9964	0.9611	0.9713	0.9839	80%	0.9682	0.9734	0.9701	0.9684
100%	0.9964	0.9595	0.9696	0.9683	100%	0.9682	0.9682	0.9682	0.9682

APPENDIX II – SIMULATION PROGRAM

The following program for GAUSS 3.2 was used to perform the simulation analysis in chapter 4. This program creates true returns for every run and every repetition. For the different appraisal scenarios using the same true return history a slightly modified program (not listed here) was used after the first run using only components of the first program below.

```
/***********************************************************************
*******  Program to simulate Index construction methods ****************
************************************************************************
*
* Created by Friederike Helfer and Markus Mitta
* for their Master's Thesis at MIT, Center for Real Estate
* July 2004
*
************************************************************************
*
* Program simulates true returns, appraisal behavior, and three index
* construction methods for multiple repetitions
* written for GAUSS 3.2
*
* variables to define in the beginning:
*       savepath...path where all data is saved
*       nrep...number of repetitions
*       p...number of properties in each country
*       t....number of periods (months)
*       n...number of countries (extracted from matrices below)
*       tstd...target standard deviation of monthly returns (see thesis for explanation)
*       icomp...nx2 matrix, weights on the property and country idiosyncratic components
*       (columns), for each country (rows), weight on European market = 1-idiosyncratic components
*       slug...nx1 matrix, sluggishness of the country markets 1 = no sluggishness
*       weight...nx1 matrix, weight of each country in the European index.
*       interval...nx12 matrix, number of months between each appraisal for 12 possible cohorts
*       amonth...nx12 matrix, month of first appraisal in each cohort
*       sfactor...nx12 matrix, smoothing factor alpha, weight that the appraiser puts on
*               current value, 1 = no smoothing
*       g...parameter for the ridge regression, long-term return growth,
*       k...parameter for the ridge regression, factor to correct for return heterogeneity
*
***********************************************************************/

new;

/**********************************
****       Simulation inputs    ***
***********************************/

savepath = "c:\\gauss\\sdata01\\";
nrep = 100;                                         /* number of repetitions */

p = 1200;
t = 240;
tstd = 0.05;
tmean = 0;
icomp = { 0.3 0.4,
          0.3 0.4,
          0.3 0.4 };
slug = { 0.8,
         0.8,
         0.8 };
```

```
weight = { 1,
           1,
           1 };

/* define appraiser behavior in cohorts, one row for each country */

interval =   { 12 12 12 12 12 12 12 12 12 12 12 12,
               12 12 12 12 12 12 12 12 12 12 12 12,
               12 12 12 12 12 12 12 12 12 12 12 12 };

amonth =     { 1 2 3 4 5 6 7 8 9 10 11 12,
               1 2 3 4 5 6 7 8 9 10 11 12,
               1 2 3 4 5 6 7 8 9 10 11 12 };

sfactor =    { 1 1 1 1 1 1 1 1 1 1 1 1,
               1 1 1 1 1 1 1 1 1 1 1 1,
               1 1 1 1 1 1 1 1 1 1 1 1 };

vweight =    { 1 1 1 1 1 1 1 1 1 1 1 1,
               1 1 1 1 1 1 1 1 1 1 1 1,
               1 1 1 1 1 1 1 1 1 1 1 1 };

g = 0;                                              /* ridge regression parameters */
k = 4;


/****************************************
*****     setting up variables   ********
****************************************/

tt = hsec;
c = cols(interval);
vweight = vweight ./ sumc(vweight');
weight = weight / sumc(weight);

n = rows(icomp);
yr = t / 12;
yrv = seqa(12,12,yr);

inames = { true stale int rmr };
tnames = { mean, stdev, acorr1, acorr12, ccorrB, ccorrC, ccorEU, Idiovar, Heterog };
tnamesa = { mean, stdev, acorr1, ccorrB, ccorrC, ccorEU };
snames = { mean, stdev, acorr1, acorr12, ccorrB, ccorrC, ccorrEU, corrT, RMSE, meanT, stdevT,
acorr1T, acorr12T, ccorrBT, ccorrCT, ccorrEUT };
snamesa = { mean, stdev, acorr1, ccorrB, ccorrC, ccorrEU, corrT, RMSE, meanT, stdevT, acorr1T,
ccorrBT, ccorrCT, ccorrEUT };

tstats = zeros(nrep,9);
astats = zeros(nrep,16);
istats = zeros(nrep,16);
rstats = zeros(nrep,16);

tstatsa = zeros(nrep,6);
astatsa = zeros(nrep,14);
istatsa = zeros(nrep,14);
rstatsa = zeros(nrep,14);

tindex = { };
aindex = { };
iindex = { };
rindex = { };


/****************************************
*******     repetitions     ***********
****************************************/
```

```
rep = 1;

do while rep <= nrep;
	et = hsec;
	mcomp = rndn(t,1) * tstd + tmean;	/* create market and country return components */
	ccomp = rndn(t,n) * tstd + tmean;

	cnames = { };
	ctindex = { };
	caindex = { };
	ciindex = { };
	crindex = { };
	repindex = { };

	i = 1;
	do while i <= n;
	/* for each country */
		cnames = cnames | (chrs(i+64) $+ ftos(rep,"%*.*lf",1,0));
		{ ctindex, pindex, pvar } = trueindx(ctindex);
		if i == 1;
			tstats[rep,8] = pvar;
		endif;
		{ caindex, ciindex }  = appindx(caindex, ciindex, pindex);
		crindex = rmr(crindex);
		i = i+1;
	endo;

	cnames = cnames | ("EU" $+ ftos(rep,"%*.*lf",1,0));

	ctindex = euroindx(ctindex);
	caindex = euroindx(caindex);
	ciindex = euroindx(ciindex);
	crindex = euroindx(crindex);
	ctret = creturn(ctindex);
	caret = creturn(caindex);
	ciret = creturn(ciindex);
	crret = creturn(crindex);

	ctindexa = ctindex[yrv,.];				/* annual index */
	caindexa = caindex[yrv,.];
	ciindexa = ciindex[yrv,.];
	crindexa = crindex[yrv,.];
	ctreta = creturn(ctindexa);
	careta = creturn(caindexa);
	cireta = creturn(ciindexa);
	crreta = creturn(crindexa);

	repnames = reshape (inames,(n+1)*4,1) $+ vec(reshape(cnames,4,n+1));
	i = 1;
	do while i <= n+1;
		repindex = repindex ~ ctindex[.,i] ~ caindex[.,i] ~ ciindex[.,i] ~ crindex[.,i];
		i = i+1;
	endo;
	repret = creturn(repindex);
	call eurosave("reprm", repret, repnames);
	call eurosave("repim", repindex, repnames);
	repindexa = repindex[yrv,.];
	repreta = creturn(repindexa);
	call eurosave("repra", repreta, repnames);
	call eurosave("repia", repindexa, repnames);

	s1 = corrx(ctret);			@ monthly cross correlation statistics @
	s2 = corrx(caret);
	s3 = corrx(ciret);
	s4 = corrx(crret);
```

```
tstats[rep,5:7] = s1[1,2:4];
astats[rep,5:7] = s2[1,2:4];
istats[rep,5:7] = s3[1,2:4];
rstats[rep,5:7] = s4[1,2:4];

s1 = corrx(ctret[1:t-1,1]~ctret[2:t,1]);     @ monthly autocorrelation statistics @
s2 = corrx(caret[1:t-1,1]~caret[2:t,1]);
s3 = corrx(ciret[1:t-1,1]~ciret[2:t,1]);
s4 = corrx(crret[1:t-1,1]~crret[2:t,1]);
tstats[rep,3] = s1[1,2];
astats[rep,3] = s2[1,2];
istats[rep,3] = s3[1,2];
rstats[rep,3] = s4[1,2];

s1 = corrx(ctret[1:t-12,1]~ctret[13:t,1]);
s2 = corrx(caret[1:t-12,1]~caret[13:t,1]);
s3 = corrx(ciret[1:t-12,1]~ciret[13:t,1]);
s4 = corrx(crret[1:t-12,1]~crret[13:t,1]);
tstats[rep,4] = s1[1,2];
astats[rep,4] = s2[1,2];
istats[rep,4] = s3[1,2];
rstats[rep,4] = s4[1,2];

s1 = corrx(caret[.,1]~ctret[.,1]);           @ monthly correlation with true returns @
s2 = corrx(ciret[.,1]~ctret[.,1]);
s3 = corrx(crret[.,1]~ctret[.,1]);
astats[rep,8] = s1[1,2];
istats[rep,8] = s2[1,2];
rstats[rep,8] = s3[1,2];

s1 = meanc((caret[.,1] - ctret[.,1]) .* (caret[.,1] - ctret[.,1]));       @ RMSE @
s2 = meanc((ciret[.,1] - ctret[.,1]) .* (ciret[.,1] - ctret[.,1]));
s3 = meanc((crret[.,1] - ctret[.,1]) .* (crret[.,1] - ctret[.,1]));
astats[rep,9] = sqrt(s1);
istats[rep,9] = sqrt(s2);
rstats[rep,9] = sqrt(s3);

s1 = corrx(ctreta);                          @ annual cross correlation statistics @
s2 = corrx(careta);
s3 = corrx(cireta);
s4 = corrx(crreta);
tstatsa[rep,4:6] = s1[1,2:4];
astatsa[rep,4:6] = s2[1,2:4];
istatsa[rep,4:6] = s3[1,2:4];
rstatsa[rep,4:6] = s4[1,2:4];

s1 = corrx(ctreta[1:yr-1,1]~ctreta[2:yr,1]);        @ annual autocorrelation statistics @
s2 = corrx(careta[1:yr-1,1]~careta[2:yr,1]);
s3 = corrx(cireta[1:yr-1,1]~cireta[2:yr,1]);
s4 = corrx(crreta[1:yr-1,1]~crreta[2:yr,1]);
tstatsa[rep,3] = s1[1,2];
astatsa[rep,3] = s2[1,2];
istatsa[rep,3] = s3[1,2];
rstatsa[rep,3] = s4[1,2];

s1 = corrx(careta[.,1]~ctreta[.,1]);         @ annual correlation with true returns @
s2 = corrx(cireta[.,1]~ctreta[.,1]);
s3 = corrx(crreta[.,1]~ctreta[.,1]);
astatsa[rep,7] = s1[1,2];
istatsa[rep,7] = s2[1,2];
rstatsa[rep,7] = s3[1,2];

s1 = meanc((careta[.,1] - ctreta[.,1]) .* (careta[.,1] - ctreta[.,1]));    @ RMSE @
s2 = meanc((cireta[.,1] - ctreta[.,1]) .* (cireta[.,1] - ctreta[.,1]));
s3 = meanc((crreta[.,1] - ctreta[.,1]) .* (crreta[.,1] - ctreta[.,1]));
astatsa[rep,8] = sqrt(s1);
```

```
        istatsa[rep,8] = sqrt(s2);
        rstatsa[rep,8] = sqrt(s3);


        tindex = tindex ~ ctindex[.,1];                               @ total index update @
        aindex = aindex ~ caindex[.,1];
        iindex = iindex ~ ciindex[.,1];
        rindex = rindex ~ crindex[.,1];

        et = (hsec - et)/100;
        print et " seconds for Repetition: " rep;
        rep = rep + 1;

endo;

/***********************************************
******  final output and statistics     *******
***********************************************/

rep = 0;

tret = creturn(tindex);                             @ monthly returns and statistics @
aret = creturn(aindex);
iret = creturn(iindex);
rret = creturn(rindex);

repnames = 0 $+ "rep" $+ ftocv(seqa(1,1,nrep),3,0);

call eurosave("mtindex", tindex, repnames);
call eurosave("maindex", aindex, repnames);
call eurosave("miindex", iindex, repnames);
call eurosave("mrindex", rindex,repnames);
call eurosave("mtret", tret, repnames);
call eurosave("maret", aret, repnames);
call eurosave("miret", iret, repnames);
call eurosave("mrret", rret, repnames);

tstats[.,1] = meanc(tret);
astats[.,1] = meanc(aret);
istats[.,1] = meanc(iret);
rstats[.,1] = meanc(rret);

tstats[.,2] = stdc(tret);
astats[.,2] = stdc(aret);
istats[.,2] = stdc(iret);
rstats[.,2] = stdc(rret);

tstats[.,9] = tstats[.,8] ./ (tstats[.,2] .* tstats[.,2]);         @ Heterogeneity @

i = 2;
do until i > 7;
        astats[.,i+9] = astats[.,i] ./ tstats[.,i];  @ relation for stdev and crosscorrelation @
        istats[.,i+9] = istats[.,i] ./ tstats[.,i];
        rstats[.,i+9] = rstats[.,i] ./ tstats[.,i];
        i = i+1;
endo;

astats[.,10] = astats[.,1] - tstats[.,1];                  @ difference in means @
istats[.,10] = istats[.,1] - tstats[.,1];
rstats[.,10] = rstats[.,1] - tstats[.,1];

astats[.,12] = astats[.,3] - tstats[.,3];           @ difference in 1st order autocorrelation @
istats[.,12] = istats[.,3] - tstats[.,3];
rstats[.,12] = rstats[.,3] - tstats[.,3];

astats[.,13] = astats[.,4] - tstats[.,4];           @ difference in 12th order autocorrelation @
```

```
istats[.,13] = istats[.,4] - tstats[.,4];
rstats[.,13] = rstats[.,4] - tstats[.,4];

call eurosave("mtstats", tstats, tnames);
call eurosave("mastats", astats, snames);
call eurosave("mistats", istats, snames);
call eurosave("mrstats", rstats, snames);


tindexa = tindex[yrv,.];                             @ annual returns and statistics @
aindexa = aindex[yrv,.];
iindexa = iindex[yrv,.];
rindexa = rindex[yrv,.];

treta = creturn(tindexa);
areta = creturn(aindexa);
ireta = creturn(iindexa);
rreta = creturn(rindexa);

call eurosave("atindex", tindexa, repnames);
call eurosave("aaindex", aindexa, repnames);
call eurosave("aiindex", iindexa, repnames);
call eurosave("arindex", rindexa,repnames);
call eurosave("atret", treta, repnames);
call eurosave("aaret", areta, repnames);
call eurosave("airet", ireta, repnames);
call eurosave("arret", rreta, repnames);

tstatsa[.,1] = meanc(treta);
astatsa[.,1] = meanc(areta);
istatsa[.,1] = meanc(ireta);
rstatsa[.,1] = meanc(rreta);

tstatsa[.,2] = stdc(treta);
astatsa[.,2] = stdc(areta);
istatsa[.,2] = stdc(ireta);
rstatsa[.,2] = stdc(rreta);

i = 2;
do until i > 6;
       astatsa[.,i+8] = astatsa[.,i] ./ tstatsa[.,i];
       istatsa[.,i+8] = istatsa[.,i] ./ tstatsa[.,i];
       rstatsa[.,i+8] = rstatsa[.,i] ./ tstatsa[.,i];
       i = i+1;
endo;

astatsa[.,9] = astatsa[.,1] - tstatsa[.,1];
istatsa[.,9] = istatsa[.,1] - tstatsa[.,1];
rstatsa[.,9] = rstatsa[.,1] - tstatsa[.,1];

astatsa[.,11] = astatsa[.,3] - tstatsa[.,3];
istatsa[.,11] = istatsa[.,3] - tstatsa[.,3];
rstatsa[.,11] = rstatsa[.,3] - tstatsa[.,3];

call eurosave("atstats", tstatsa, tnamesa);
call eurosave("aastats", astatsa, snamesa);
call eurosave("aistats", istatsa, snamesa);
call eurosave("arstats", rstatsa, snamesa);

tt = (hsec - tt)/100;
print tt " seconds total";


/***********************
*******  END  **********
***********************/
```

```
/********************************
*********  PROCEDURES  **********
********************************/

proc(0) = eurosave(fname, file, vname);
        LOCAL name, f;
        screen off;
        if rep == 0;
                name = savepath $+ fname;
        else;
                name = savepath $+ fname  $+ ftos(rep,"%*.*lf",1,0);
        endif;
        create f = ^name with ^vname,cols(file),8;
        call writer(f, file);
        call export(file, name $+ ".xls", vname);
        f = close(f);
        screen on;
endp;

/*********************************************/

proc(0) = propsave(fname, file);
        LOCAL name, f;
        name = savepath $+ fname $+ chrs(i+64) $+ ftos(rep,"%*.*lf",1,0);
        create f = ^name with prop,p,8;
        call writer(f, file);
        f = close (f);
endp;

/************************************************/

proc(1) = creturn(index);            /* calculates returns out of a value matrix */
        LOCAL indexs, r, c, ret;
        r = rows(index);
        c = cols(index);
        indexs = ones(1,c) | index;
        indexs = indexs[1:r,.];
        ret = (index - indexs) ./ indexs;
        retp (ret);
endp;

/************************************************/

proc(1) = euroindx(index);       /* weight country indices and add them up in the first column */
        LOCAL r, c, w, windex;
        r = rows(index);
        c = cols(index);
        w = reshape(weight, r, c);
        windex = index .* w;
        windex = sumc(windex');
        index = index ~ windex;
        retp(index);
endp;


/************************************************/

proc(3) = trueindx(cindex);
        LOCAL pcomp, pw, cw, mw, pret, pindex, slugf, slugv, psret, psvar, het;
        pcomp = rndn(t,p) * tstd * 2.5 + tmean;             /* create property component */
        pw = icomp[i,1];
        cw = icomp[i,2];
        mw = 1 - pw - cw;
        pret = (mcomp * mw) + (ccomp[.,i] * cw ) + (pcomp * pw);    /* aggregate components */
        pindex = pret + 1;                            /* create values out of property returns */
        pindex = cumprodc(pindex);
```

```
        slugf = slug[i,1];
        slugv = reshape(1-slugf,1,p);                /* adjust values for market sluggishness */
        pindex = recserar(pindex * slugf,pindex[1,.],slugv);        /* autoregressive function */
        psret = creturn(pindex);
        psvar = stdc(psret);
        psvar = meanc(psvar .* psvar);
        cindex = cindex ~ (sumc(pindex')/p);  /* compute country index and add to container pi*/
        call propsave("ptr", psret);
        call propsave("pti", pindex);
        retp(cindex, pindex, psvar);
endp;

/**************************************************/

proc(2) = appindx(caindex, ciindex, vmatrix);
        LOCAL pweight, avalues, aaindex, ivalue, yvariable, xvariable, yname, fy, xname, fx, wc,
        j, w, x, m, a, cmatrix, cvalues, cindex, av, iv, r, rr, ro, smoothv, smoothvo, xvaradd,
        yy, xx;
        pweight = round(vweight[i,.]*p);
        pweight[c] = p - sumc(pweight[1:c-1]');

        avalues = { };
        aaindex = { };
        yvariable = zeros(1,1);                              /* setting up matrices for the RMR */
        xvariable = zeros(1,t);
        yname = savepath $+ "yvar" $+ chrs(i+64) $+ ftos(rep,"%*.*lf",1,0);
        create fy = ^yname with month0,1,4;
        xname = savepath $+ "xvar" $+ chrs(i+64) $+ ftos(rep,"%*.*lf",1,0);
        create fx = ^xname with month,t,4;

        wc = 1;
        j = 1;
        do until j > c;               /* calculate smoothed index for every cohort */
                w = pweight[j];
                x = interval[i,j];
                m = amonth[i,j];
                a = sfactor[i,j];
                j =j+1;
                if w == 0;
                        continue;
                endif;
                cmatrix = vmatrix[.,wc:wc+w-1];      /* cohort submatrix with true values */
                wc = wc+w;
                av = seqa(m,x,ceil(t/x));
                av = delif(av,av .> t);       /* vector with months where reappraisal occurs */
                cvalues = ones (t,w);  /* smoothing the values of the cohort, first observation */
                cindex = ones(t,w);

                rr = av[1];
                ro = 1;
                smoothv = (cmatrix[rr,.] * a) + (cindex[ro,.] * (1-a));
                if rr >1;
                        ivalue = reshape(smoothv - 1,rr-ro,w);       /* linear interpolation */
                        iv = reshape(seqa(1/rr,1/rr,rr-ro),w,rr-ro)';
                        ivalue = ones(rr-ro,w) + ivalue .* iv;
                        cvalues[ro:rr-1,.] = ivalue;
                endif;
                yvariable = ones(w,1);
                xvariable = zeros(w,t);              /* setting up matrices for the RMR */
                xvariable[.,rr] = smoothv';
                iv = reshape(seqa(0,1/x,x),w,x)';
                r = 2;

                do while r<= rows(av);        /* smoothing values for other observations */
                        smoothvo = smoothv;
                        ro = rr;
```

```
                rr = av[r];
                smoothv = (cmatrix[rr,.] * a) + (cindex[ro,.] * (1-a));
                cindex[ro:rr-1,.] = reshape(smoothvo,x,w);
                ivalue = reshape(smoothvo,x,w) + reshape(smoothv - smoothvo,x,w) .* iv;
                cvalues[ro:rr-1,.] = ivalue;
                yvariable = yvariable | zeros(w,1);
                xvaradd = zeros(w,t);
                xvaradd[.,ro] = -smoothvo';
                xvaradd[.,rr] = smoothv';
                xvariable = xvariable | xvaradd;
                r = r+1;
            endo;

            cvalues[rr:t,.] = reshape(smoothv,t-rr+1,w);
            cindex[rr:t,.] = reshape(smoothv,t-rr+1,w);
            avalues = avalues ~ cvalues;
            aaindex = aaindex ~ cindex;
            yy = writer(fy,yvariable);
            xx = writer(fx,xvariable);
        endo;

        fy = close (fy);
        fx = close (fx);
        call propsave("pii", avalues);
        call propsave("pai", aaindex);
        caindex = caindex ~ (sumc(aaindex')/p);
        ciindex = ciindex ~ (sumc(avalues')/p);
        retp(caindex, ciindex);
endp;

/***************************************************/

proc(1) = rmr(crindex);
        LOCAL yname, xname, r, x, y, z, f1, f2, zridge, lagzr, absx, v, xridge, yridge,
        xk, zk, yk, zxk, zyk, beta1;
        yname = savepath $+ "yvar" $+ chrs(i+64) $+ ftos(rep,"%*.*lf",1,0);   /* loading data */
        open f2 = ^yname for read;
        r = rowsf(f2);
        y = readr(f2,r);
        f2 = close(f2);
        xname = savepath $+ "xvar" $+ chrs(i+64) $+ ftos(rep,"%*.*lf",1,0);
        open f1 = ^xname for read;
        x = readr(f1,r);
        f1 = close(f1);
        z = (x .> 0) - (x .< 0);

        zridge=(1+g)*eye(cols(x));                         /* making and appending rigde */
        lagzr=eye(cols(x)-1);
        lagzr=zeros(1,cols(x)-1)|lagzr;
        lagzr=lagzr~zeros(cols(x),1);
        zridge=zridge-lagzr;
        absx=abs(x);
        v=sumc(sumc(absx))/(2*r);
        xridge=v*zridge;
        yridge=v|zeros(cols(x)-1,1);
        xk=x|k*xridge;
        zk=z|k*zridge;
        yk=y|k*yridge;

        zxk = zk' * xk;
        zyk = zk' * yk;
        beta1 = zyk / zxk;
        crindex = crindex ~ (1 ./ beta1);
        retp(crindex);
endp;
```