

Research Paper

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On behalf of the Public Affairs Executive (PAE) of the EUROPEAN PRIVATE EQUITY AND VENTURE CAPITAL INDUSTRY

18 May 2012

Research Paper: “Calibration of Risk and Correlation in Private Equity”

A proposal for a new approach for the development of a private equity index

Executive Summary

- The European Private Equity and Venture Capital Association (EVCA) highly appreciates the opportunity to continue the discussions regarding the calibration of the standard risk weighting and benchmark for private equity under Solvency II.
- The calibration methodologies in this document are applied to two of the several, widely available, private equity benchmarks which are typically used by investors in private equity funds. EVCA also strongly believes that it is unfortunate that the many available industry benchmarks appear to have been overlooked by CEIOPS in the QIS 5 calibration paper.
- The study develops a new Private Equity Index based on changes of the net asset value (NAV) adjusted by cash flows. By making this cash flow adjustment, the calibration incorporates a very important risk characteristic of private equity which the original approach overlooked.

About the PAE

The Public Affairs Executive (PAE) consists of representatives from the venture capital, mid-market and large buyout parts of the private equity industry, as well as institutional investors and representatives of national private equity associations (NVCAs). The PAE represents the views of this industry in EU-level public affairs and aims to improve the understanding of its activities and its importance for the European economy.



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- The calibration methodology presented in this paper has been run on two databases, each containing almost two thousand private equity funds. This helps ensure the robustness of the results.
- The new approach more appropriately reflects the characteristics of private equity as an asset class, such as the illiquidity and the limited partnership closed-end fund structure. Hence, the proposed approach captures the risks of private equity for investors much more adequately as it takes into account the specifics of the asset class.
- In addition to the quarterly base index, an expanded monthly index is calculated in the paper. Even if the NAV is only available on a quarterly basis, this approach interpolates the values in-between and calculates the risk parameters based on this more volatile index.
- These results are supported by a second analysis, which is based mainly on cash flows. Applying the cash flow based method, it can be shown that the lower risk weighting is justified and appropriately reflects the risk. As the industry believes that the long-term risk of private equity is the most important one, the results of such an analysis are presented.
- Depending on the calibration method and the data base used, the shocks for the asset class, and hence the standard risk weighting for private equity, are between 20% and 35%.
- EVCA strongly recommends adjusting the current stand-alone calibration for private equity, derived from the use of the LPX 50 Total Return index, from 68.76% to a significantly lower number in order to adequately reflect the true risk of private equity and the long-term nature of the asset class. Consequently, we also recommend removing private equity from the asset category “Other Equities” as the overall risk calibration for this sub-group (49%) also does not accurately reflect the standard risk weighting for private equity.
- To summarize, EVCA believes the revised net asset value based index, presented in this paper, and supported by certain important cash flow analyses, is a better measure of the risk profile of private equity investments and provides a more appropriate basis for calculating the standard risk weighting for private equity under Solvency II.



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1 Introduction

1.1 Current situation

The European Venture Capital and Private Equity Association (EVCA) highly appreciates the opportunity to continue the discussion with the European Insurance and Occupational Pensions Authority (EIOPA) regarding the standard risk weighting for private equity. EVCA understands and recognises that EIOPA is not in a position to improve, review or refine the design or the calibration, unless a factual mistake is spotted or new relevant information that was not considered or overlooked at the time of the advice is evidenced. The new methodology EVCA proposes is based on a more accurate data set capturing the characteristics of private equity as an asset class, which we believe was not considered at the time of the advice.

The approach, which we present here, represents a new methodology for a private equity index which allows a more appropriate calculation of risk and applies this to a much more representative data set covering almost two thousand private equity funds each (covering many thousands of underlying portfolio companies). The dataset is much more representative of the type of funds institutional investors are likely to invest in and is diversified by country, industry, vintage year and stage of investment.

The newly proposed approach is based on the NAV movement of the underlying investments and adjusted by the consequent cash flows. We believe that this approach fully meets the requirements of Solvency II and reflects the market-risk based approach. However, EVCA and some of the industry's long-term institutional investors in private equity funds, who have contributed to this paper, strongly believe that the market-risk approach represents an oversimplification and fundamental misunderstanding of the risk faced by an institutional investor in private equity. The industry believes that an equally important risk measure of private equity is the long-term risk of losing any capital in private equity. Therefore, we have also run an analysis of a cash flow based index. The results of this analysis are consistent with the findings of the net asset value based index approach we have presented.

1.2 Typical investment characteristics

Pension funds, insurers and other investors typically gain exposure to private equity by investing in a portfolio of funds, which is diversified by vintage year, geography and stage of investment from early stage venture capital and growth equity, up to larger mega buyout funds.

Private equity is a long-term investment, which takes time to mature. Fund structures in private equity have been specifically designed to reflect this long-term characteristic. They are not designed to be traded like a liquid asset, or for investors to withdraw during the life of the fund. Funds are usually structured to have a minimum life-span of 10 years to ensure that the underlying companies have the time and potential to grow and develop further. Investors participate by making a legally binding commitment to invest a specified amount in the fund with the intention of remaining invested for the full life of the fund. Indeed, closed-end funds in the private equity industry usually specify from the outset that investors have no right of redemption before the end of the life of the fund. An investor's average net invested capital, or capital at risk as it is generally referred to, is measured by the paid-in amount minus distributed capital. This amount is invariably much lower, on average, than the investor's overall legal commitment to the fund. This is because funds often start making distributions back to investors before having drawn down and invested the entire commitment. In addition, proceeds from realizations can be used to fund that part of the investor's commitment still to be drawn down.

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Consequently, it is no surprise to investors that studies show that in a normal market environment the maximum proportion of capital at risk during the life of a fund is only around 60% of the commitment made by the investor. In extreme scenarios this number can be higher and reach up to 85%, but investors do not typically find their capital at risk to be as high as this¹. It is crucial to bear in mind these unique characteristics of private equity investing when determining the most appropriate method of calibrating risk for this asset class.

¹ Meyer and Mathonet - Beyond the J-Curve (2005)



2 Why is EVCA proposing a new methodology with a new data set?

The reasons for proposing a new approach are numerous and based primarily on the various shortcomings and substantially different characteristics of the LPX 50 which do not reflect the “real life” investment opportunities of institutional investors in private equity. In addition, there are already well-recognized methodologies for calculating private equity indices which have been developed over many years that are commonly used both by industry practitioners and academics for benchmarking. These processes continue to improve as the underlying data bases for private equity become more comprehensive with longer time series, which in turn allow even more meaningful calculations of the returns and risk for private equity.

2.1 The shortcomings of the LPX 50

The private equity industry has strong concerns about using the LPX 50 index as the starting point for the calibration of risk weightings in private equity. EVCA has previously stated the shortcomings of this index in its response to the Consultation on Call for Advice and Technical Specifications for the Quantitative Impact Study n° 5²².

The key criticisms of the LPX 50 as a proxy for measuring risk across a portfolio of private equity funds are:

- The listed funds included in the index are unlikely to be found in the private equity portfolio of an institutional investor as the funds typically found in an institutional investor’s private equity portfolio are not included in the LPX 50 index. If an institutional investor were to invest in listed private equity vehicles the investment would almost certainly be held in the investor’s public equity portfolio and not in the private equity portfolio.
- In an investor’s private equity portfolio, funds are structured as long-term, private vehicles. As such the performance of these vehicles is not impacted by short-term developments in the stock markets or “market sentiment”. Therefore, the funds in the LPX 50 neither reflect the universe of funds in which an institutional investor is likely to invest, nor do they share important investment characteristics of private equity investment vehicles with regard to risk and return.
- A large portion of the LPX 50 index comprises the listed management company vehicles of some of the very largest managers of private equity and other alternative asset funds. This has the consequence of introducing non-investment-driven returns, such as the management fee income of these managers into the performance data. This is a characteristic which is not reflected in the private equity portfolios of institutional investors.
- The LPX50 index only covers a very small and specialised segment of the investment universe and is by no means representative of private equity as an asset class. It has no

²² EVCA’s comments on the Consultation on Call for Advice and Technical Specifications for the Quantitative Impact Study n° 5



exposure to large areas of the private equity market and displays an unrepresentative geographic and strategic exposure.

- The LPX50 is also heavily concentrated - the top 10 constituents comprise 65% of the index by value. The index's market capitalisation is negligible relative to the private equity universe.
- The statistical characteristics (volatility, correlations to other assets, especially public equity) of LPX 50 returns are mainly driven by developments in the public markets, which can be observed as discounts or premia of the index's constituents to their underlying NAVs. The wide variances of these developments in the recent crisis show the significant influence of public market behaviour on the LPX 50 index.

2.2 Criteria for an alternative benchmark

The new benchmark EVCA proposes is in accordance with the criteria that EIOPA also used for other asset classes in the calibration process, in particular for property.

The benchmark used for property in QIS5 is a useful guide as to how an alternative benchmark for private equity risk calibrations can be developed. The property benchmark is based on the UK IPD total return indices, which in turn are based on appraised market values. Real estate is similar to private equity regarding its risk and return characteristics. In particular, it is equally illiquid in nature and requires similarly long investment and risk horizons.

The approach chosen and data used by EIOPA for calibrating the risk charge for property accommodate the long term and illiquid nature of real estate investments. While the publicly and liquidly traded segment for real estate is much broader and deeper than the corresponding one for private equity, we believe that the decision to divert from using a benchmark constructed from private assets was correct. EVCA proposes taking a similar conceptual approach for private equity in this paper. Unlike the choice of benchmark for calibrating property risk EVCA relies on a global database as opposed to one constituted from a specific market segment in one local market.

EVCA is therefore confident that the proposed index will meet the criteria which are important to EIOPA. It is important to note, that our proposed index covers the risk characteristics of private equity more accurately than the current approach based on the LPX 50 as it reflects both a more appropriate methodology as well as such methodology being applied to a more representative data base.

2.3 Description of the new approach

The approach we have taken is an index based on the quarterly (and if required monthly) changes in the net asset value of private equity funds, adjusted by the cash flows. After calculating the quarterly time-series returns, it is possible to derive their empirical distribution, including its density function, and fit theoretical distributions to the latter in order to infer risk parameters, as required by Solvency II, with a 99.5% confidence level over a one year time period. This approach would reflect the risk characteristics of the private equity asset class much better than the current index based on the LPX 50, as the NAV changes are reflected in the balance sheet of the investors and not the changes of a listed index. It is a good combination of



reflecting the risks of the private equity asset class and fulfilling the requirements of the market risk approach of Solvency II.

In addition to the NAV-based approach, we also present a cash flow method that calculates the risk of private equity. As the industry is driven by long-term behaviour of cash flows, we believe that this approach is even better suited to reflect the risk behaviour and is the approach which has traditionally been adopted by industry practitioners and academics. However, as Solvency II requires a market risk approach, we use the results of this index only as supporting material. It should however be noted, that this approach is consistent with the results, and proves the robustness, of the NAV-based approach.

2.4 What is new about the approach?

1. The proposed NAV approach much better reflects the characteristics of the private equity asset class much better compared to the current LPX 50 index, as it is based on long-term fund investments using with a limited partnership structure. As this is the common investment vehicle for institutional investors it does not only reflect the same investment type and illiquidity, it is also based on the correct underlying private equity investments.³ These are typically investments in privately held companies.
2. The new methodology also captures the valuation risk of private equity through NAV movements adjusted by cash flows. This is crucial for ensuring the characteristics of private equity are captured. While we believe that the quarterly NAV changes do not significantly influence the long-term risk of private equity, it has more influence on the balance sheet of investors and accordingly the solvency ratios considered by the regulatory framework. While pension funds have a long-term view and focus, insurance companies may be more affected as the net asset value of the private equity portfolio drives the value in the balance sheets.
3. The approach is based on the same statistical methods that have been used by EIOPA for calibrating the risk of similar asset classes such as property. Therefore, we use a statistical method to expand the data base from quarterly to monthly data. Based on the new index data, we calculate the empirical return distribution, fit it to a standardized distribution that has been used by EIOPA and that has the best fit and finally calculate the risk characteristics of private equity.

2.5 What is new about the data?

In recent years the quality and extent of data sets in private equity has increased dramatically. The reason is that the industry has become more aware of the need for transparency and information, driven primarily by discussions between the managers of private equity funds and their investors. In addition, the standardization of valuation techniques which have been developed by the industry has helped this to happen. Many of the larger investors in private equity apply stricter requirements in terms of transparency which results in better and more detailed information of underlying investments. While it was not common to report each underlying investment with detailed balance sheet and P&L information, most of the funds now

³ While the companies in the LPX 50 have a market capitalization of EUR 30bn, private equity funds raised over the last four years amounted to more than EUR 1,500bn. Hence, 96% of exposure is in unlisted funds with different characteristics.

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cover this information in their reporting to investors. The improved communication and reporting in the industry is one of the main reasons for the increased quality and quantity of information reported to investors.

In addition, the time series of the analyses are long enough to run meaningful analyses. The private equity market started in the 1970's in the US and in the 1980's in Europe. Therefore, historical time series data over the last three decades is now sufficient to run more meaningful analyses as it also covers different cycles of the market with boom markets like in 2000 and 2006, but also crises like in 2002 and 2008/09. Importantly, the number of funds which have completed their full 10 year life span, and so provide exact return data, have steadily increased which adds to the robustness of the data sets.

Finally, the data quality has also increased through the implementation of standardized valuation rules, like the International Private Equity Valuation guidelines (IPEV) supported and instigated by EVCA. These rules provide a global and common framework for different valuation techniques for the underlying companies of private equity funds. Together with the change of IRFS to the mark-to-market valuation, the volatility of the net asset value increased significantly.

All these developments and the increased total market size of private equity also highlight the importance of benchmarking for investors. Hence, many commercial firms are now offering their performance measurement services, building data sets and are competing against each other to develop the most comprehensive and highest quality benchmark.

However, "it can be always done better" and all participants in the private equity industry, from investors (LPs) and fund managers (GPs), to academics are keen to see the development of a truly comprehensive database of the highest integrity, with no gaps in data, or "cherry-picking" of funds to be included. Therefore, the EVCA is currently working on a project that combines the data bases of individual associations in order to build the most comprehensive data base with the highest objective quality requirements.

In the meantime, for the purpose of this paper, EVCA selected two different data bases from commercial providers for the calculation of the index. As the main data set, data from Prequin is used and as a check the calculation is also run on the Pevara database. Both data sets cover around two thousand private equity funds from across a broad range of stages of investment, vintages and geographies.

Prequin contains data on 1,882 private equity funds raised between 1979 and 2011, while Pevara covers 2,015 funds raised between 1991 and 2011. All observations have been filtered to come only from private equity core strategies (i.e. not real estate, timber or venture debt). A closer description of the Prequin and Pevara datasets can be found in Appendix 1.⁴

⁴ EVCA would like to thank Prequin and Pevara for providing the data for this report.

From www.prequin.com "Prequin is the alternative assets industry's leading source of data and intelligence. The products and services are utilized by more than 7,000 professionals located in over 70 countries for a range of activities including investor relations, fundraising and marketing, and market research. Prequin, founded in 2002, operates from offices in New York, London and Singapore."

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3 Proposal for the Base Index

Using the available data on private equity funds, a base index is created, which measures the return and risk of private equity. The intention is to measure the pure value change in private equity, taking out the effect of cash flows and un-invested capital entirely.

The first step is to construct the Base Index of quarterly valuation changes, adjusted for the cash flows each quarter. In order to calculate the quarterly return of a fund a chained Modified Dietz function is used. Under the Modified Dietz formula, the investor has a NAV at the start of every period. Over that period, investments draw down and distribute capital, then report another NAV at the end of the period. The return of this period is best described through the following formula:

$$R_{t1}^t = \frac{NAV_t - NAV_{t1} - \sum_{t1}^t Call + \sum_{t1}^t Distribution}{NAV_{t1} + \sum_{i>t1}^{i\leq t} \left(Call_i \times \left(1 - \frac{i-t1}{t-t1} \right) \right) - \sum_{i>t1}^{i\leq t} \left(Distribution_i \times \left(1 - \frac{i-t1}{t-t1} \right) \right)}$$

3.1 Value weighted versus equal weighted indices

With the creation of the index the question arises if the individual funds should be equal-weighted or value-weighted in an index. Equal-weighting would mean that the investor has committed the same amount to each fund. Equal-weighting all investments, however, is not entirely in-line with reality and does not account for the change in capital allocation by investors, depending on the size of fund to which the commitment is being made. By value-weighting all funds the situation of an investor who makes capital allocations relative to fund size is accurately reflected in the index. As such a value-weighted index for the calibration of private equity is chosen⁵.

3.2 Other elements considered during the creation of the index

During the creation process of the index, many other factors have been considered. The question of the index composition was discussed and it was decided to go with an index that covers the buyout as well as the venture capital market, as this reflects the range of fund types found in a typical investor's private equity portfolio. The results for the different individual calculations and their differences can be found in Appendix 2.

Additional analyses have been performed. For example, it was analysed how the results of the Base Index would be influenced if only funds with larger changes in the NAV were included and funds with smaller changes around zero excluded. While it was decided to keep all funds with an observable NAV in the analyses, funds have been removed that had no reported NAV in a quarter. It is much more sensible to assume that those funds, which do not report in the quarter, perform the same on average as those that do. Using the chained Modified Dietz this issue is eliminated. The results of the different analyses can be found in Appendix 2.

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4 Analysis of the Base Index

After discussing the advantages and disadvantages of various elements of the index creation, we decided to propose an index that includes buyout as well as venture capital funds. It can be seen that commitment sizes to large private equity funds are usually higher than the ones to small venture capital funds. Hence, all funds are value-weighted in the index to cover the historic development and size of the market. The following pages examine in more detail the features of the chosen Base Index and how they compare to the public markets.

4.1 Return and risk of the quarterly Base Index

The following table shows the values of the newly created private equity index starting with a value of 100 in June 1986. The index ending value reaches a value of 2,371 in 2011 which corresponds with an annual time-weighted return of 13.5% per year.

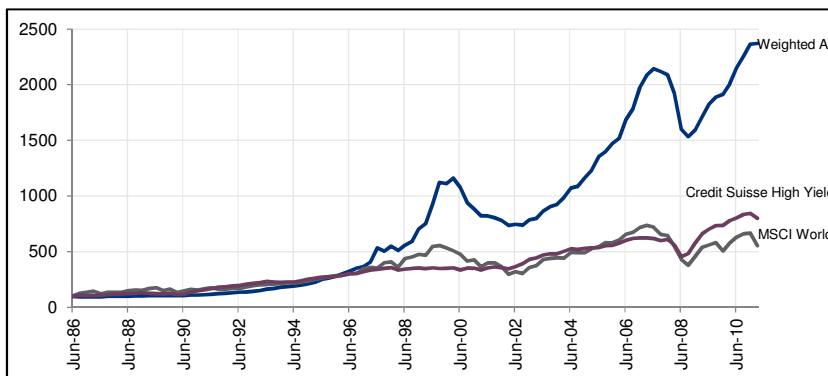


Figure 1: Comparison of the private equity index and public market indices from 1986 to 2011

The Index's gains during the dotcom boom are never entirely lost, which adds to a cumulative gain over public indices over time. From the height of the dotcom boom onwards, it shows good comparability to the public indices. Hence, the following figure only plots the time period from 2000 to 2011.

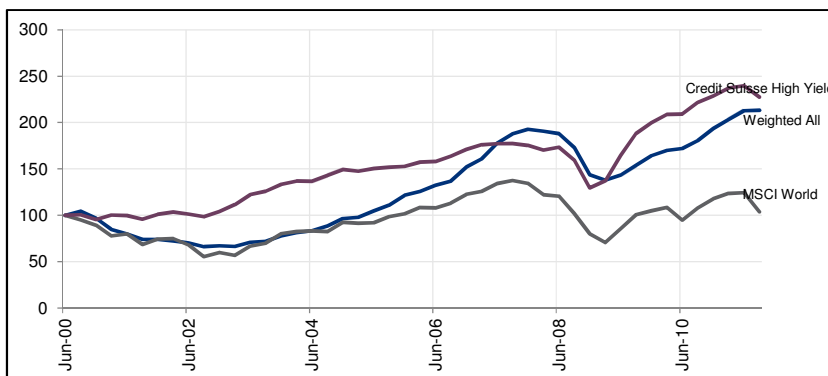


Figure 2: Comparison of the private equity index and public market indices from 2000 to 2011



4.2 Probability density

After showing the index values and plotting them in order to see the returns, the empirical probability density function of the quarterly returns of the index is calculated. This gives a picture of the behaviour of the distributions and its positive and negative tails.

The following figure shows two plots of the estimated probability density function of the private equity index returns (light blue line). The data is compared to a normal distribution (left chart; dotted dark blue) and to the MSCI World (right chart; dotted dark blue) and the Credit Suisse High Yield Index (right chart; dotted red). All three are estimated using a Gaussian kernel density estimator. The rightward skew of the private equity index return is clearly visible, as are the fat tails in all three of the index return series. The results on the shock of an NAV index have been calculated in different studies which support the same results. Studer / Ebibi conclude in a similar study based on Thomson Reuters data that the stress factor should not be higher than 30% based on their extensive study.

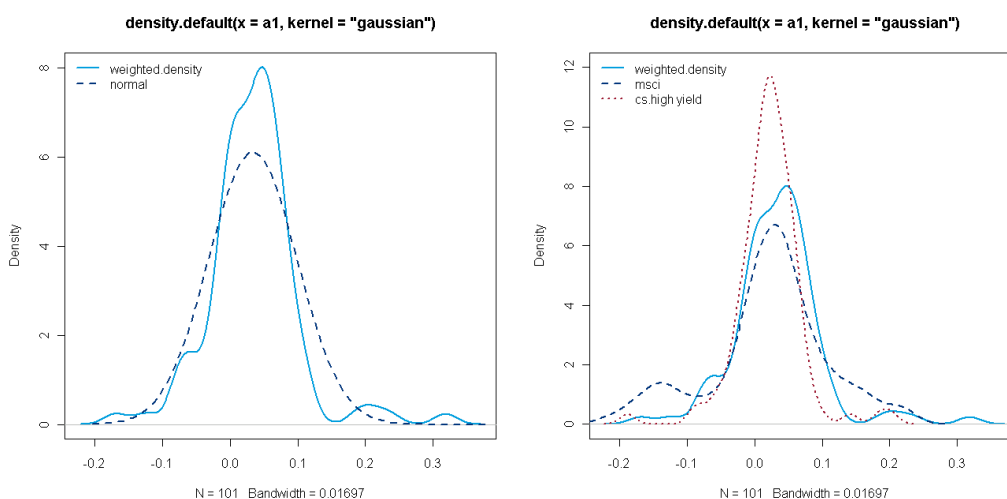


Figure 3: Kernel density function for the private equity index in comparison with normal distribution (left chart) and with other public indices (right chart)

Calculating the 99.5% Value at risk on this empirical density function shows a result of 29.1% which is very low for private equity based on data from Preqin. The calculation of the same measures over a one year period on the Pevara data base results in a value of 24.6%.

4.3 Autocorrelation of the private equity index

In addition, it is necessary to examine the Index for autocorrelation as excessive autocorrelation may cause spuriously low correlation to public markets and is a sign of staleness of information.

In order to calculate the auto-correlation, it is a standard approach to use so called autoregressive moving average, or short ARMA(p,q), processes for the analyses. ARMA processes are time-series models where the observation at time t is dependent on the past observation p and a noise term. The noise term itself depends on the past noise realizations q. ARMA models with q = 0 are autoregressive models AR(p). In order to adjust for the autocorrelation in the time



series, we used both models at the beginning, but decided to restrict our further analyses to the bivariate vector AR(1) model which gives a more stable fit to than the more general ARMA model.⁵

The autocorrelation of the Index is relatively low, with some effects visible three and six months after the date, but these effects are not very large. By removing 37.98% of the following quarter's results, autocorrelation is removed, though a small effect persists at the six months period. This effect is well known in the literature and reflects the time-lag of reporting of the private equity values. A graphical description of the autocorrelation can be found in Appendix 3 of the paper.

Removing the effects of autocorrelation actually reduces the standard deviation of the Index, from 6.45% to 6.05%, which indicates that the Index might be more accurate in its base version. In Sections 3.160 to 3.168 of the CEIOPS Calibration Paper it is made clear that it is possible to use base appraised values rather than smoothed figures, and it is shown here that this may also be more appropriate for private equity.

4.4 Correlation to other MSCI World index

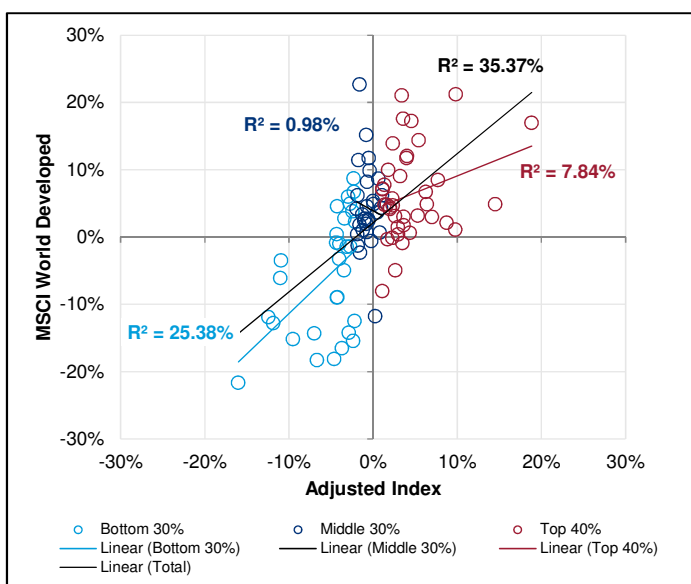


Figure 4: Comparison of correlation parameters of lowest and middle 30% groups and highest 40% return group

The correlation of the Index after removing autocorrelation (“Adjusted Index”) to public markets is 59.49%. However, looking at maximal values of correlation, and being aware that private equity valuation standards have varied considerably in the earlier part of the asset class’s history and developed further over the last years as described in section (2) of this paper, the Adjusted Index based on the time series correlation of, the correlation between private equity and the MSCI World is 73.55% for the period June 2000 to September 2011.

EIOPA has requested that we look into the tail correlation given the expectation that a fall in the MSCI will cause a fall in the Index. The results of this are shown in the figure below: The returns of the Index have been divided into the lowest 30% of returns, the middle 30% and the highest 40%. While the overall pattern is clear, it is the lowest 30% that individually represents the highest contribution to the correlation. The R² of the lowest 30% of returns is 25.38%, corresponding to a tail correlation of 50.38%.

⁵ See Studer / Ebibi (2011) for a detailed description and analyses of the two different models and results for private equity.

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Summarizing, the correlation of the Adjusted Index to the MSCI World is 59.49%, while the tail correlation is the largest contributor; reaching 50.38%. The time-series correlation reaches values up to 75%.

EVCA believes that the risk of the NAV index is best captured through the Base index and its real data. As shown before the numbers of the shock event are in the area of 25% to 29%. As EIOPA requests some checks with an expanded index on monthly data, we extend our index calculation in the next chapter of the paper.

5 Assessing the risk parameters for private equity based on an expanded index

5.1 Expansion of Data

A private equity index based on quarterly valuation changes reflects the real and observable risk of an investor in private equity. However private equity NAVs sometimes get criticized with the stale pricing and smoothing effect which is based on the time lag in reporting and the smaller movements of values.⁶ As this prevents the index from being more volatile, the question arises how we adjust for the smoothing effect of returns based on valuations of private equity funds. One solution to increase the volatility of the base index and to be consistent with other asset classes in Solvency II is to expand the quarterly index to a more frequent monthly index.

In order to expand the data from quarterly NAV observations to monthly values, it is necessary to make an assumption on the approach that derives the values in-between the quarterly valuations. Therefore the idea was to use an interpolation model that uses information from the return movements of the public market and from EVCA's statistical analysis to construct the Expanded index values.

Therefore, a model is created that interpolates the value between quarters and mainly depends on the change of the MSCI World index. A regression of private equity returns to public market returns was used as one factor to derive the monthly values. In addition it is assumed that the indexed value of the Expanded Index is equal to the same as the indexed value of the Base Index. We intend to correct for interim values, not to modify the Base Index.

A detailed description with formula can be found in Appendix 5 and a description of the goodness of the Fit is described in Appendix 6.

The results are as follows:

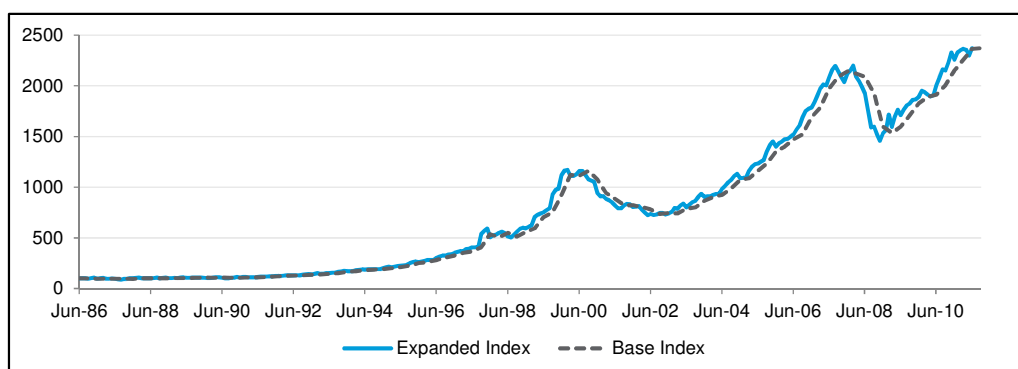


Figure 5: Comparison of Expanded index with Base Index

The Expanded Index appears capable of recognising the presence of autocorrelation by anchoring trends to the left of the Base Index. It also provides more detail to the more interesting parts of the Base Index, particularly the shape of the 2001 and 2008 rises and falls, and the speed and direction of the 2009-2011 recovery. With the expanded data there are now significantly more data points (304 compared to 101).

It would be expected that the correlation of the Expanded Index is higher given the incorporation of the MSCI in its own values. By using the same methodology as the Adjusted

⁶ See Emery (2003).



Index, the correlation of the entire Expanded Index is 55.80%. The time series correlation from June 2000 is 60.57%. The 30% lowest observations give a tail correlation of 41.52%.

5.2 Assessing the risk of private equity fitting standardized distributions to empirical data

For the calculation of the shock scenarios EIOPA uses a 99.5% case over a one year period. As we have created a well-diversified private equity index, this is the loss that could be ascribed to an investor with a diversified portfolio.

The base index results in a shock value of 15%, while the result based on the real data of the expanded Index concludes in a 1 in 200-year loss for private equity of 31.8%. The calculation of the same measures on the Pevara data base results in a value of 30.2%. Studer / Ebibi conclude in a similar study based on Thomson Reuters data that the stress factor should not be higher than 30%.

In order to fit the defined standardized distributions to empirical distributions, the normal distribution as well as the Generalized Extreme Value, which EIOPA recommends to use, is chosen. In addition in Appendix 7, a fit of the Johnson distribution is shown. The following two charts show the comparison of the kernel estimation of the density functions of the empirical expanded index returns with the normal and Generalised Extreme Value distribution.

Because the Index shows both skewness and kurtosis, fitting on a **normal distribution** only approximates the actual distribution. The chart shows the one-year changes in the Index returns (light blue) against its normal distribution (dark blue). The 0.5% probability for this normal distribution is 37.73%.

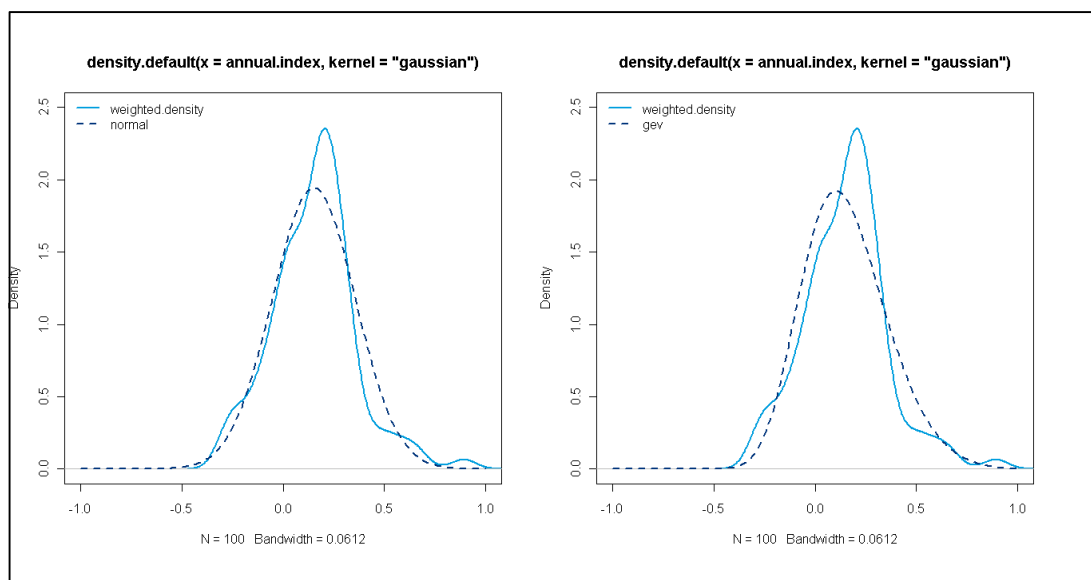


Figure 6: Comparison of Expanded index with normal distribution (left) and GEV (right)

The chart on the right shows the one-year changes in the Index (light blue) against a fitted GEV (location 0.0691, scale 0.1940, shape -0.1610). The convergence for the maximum-likelihood fitting was successful and leads to a 0.5% probability of 30.19%.



5.3 Summary of findings

EVCA has employed methods used for common statistical procedures and the calibrations of other modules within the QIS 5 calibration paper most notably Property.

In order to assess the appropriate risk and correlation parameters for private equity to be used in a regulatory framework, EVCA run various analyses; starting from a Base Index based on quarterly NAV data up to an Expanded Index which has higher correlation and volatility through the expansion to monthly data. All the empirical data has been used to fit it to standardized distributions in order to derive the shock and correlation parameters.

In regards to the **correlation** calibration, the following results were obtained:

Method	Correlation (Preqin)
Adjusted Index: Total correlation	59.5%
Adjusted Index: Tail correlation at lowest 30% of returns	50.4%
Adjusted Index: Time-series correlation from 2000 to 2011 (11yr)	74.6%
Expanded Index: Total correlation	55.8%
Expanded Index: Tail correlation at lowest 30% of returns	41.5%
Expanded Index: Time-series correlation from 2000 to 2011 (11yr)	60.6%

A correlation figure between private equity and the MSCI world index between 59% and 75% would be appropriate given these findings.

In regards to the **shock** calibration of private equity the following results were obtained:

Method	Shock (Preqin)	Shock (Pevera)
Real data from Base Index	29.1%	24.6%
Real data from Expanded Index	31.8%	30.2%
Normal distribution	37.8%	32.2%
Maximum likelihood GEV estimation	30.2%	28.8%
Johnson distribution matching of quants	29.2%	27.9%

Calculating the 99.5% Value at risk on the empirical density function of quarterly NAV changes shows results clearly below 30%, while the more stressed Expanded index shows figures below 38%. In summary, a shock figure of between 25% and 35% would be appropriate given these findings.



6 Supporting material using primarily long-term cash flow based information

In addition to the value based index previously presented, EVCA also shows evidence of a lower-risk weighting with a cash flow based approach.

Most investors in private equity focus on the long-term cash flow behaviour of the asset class and are not overly concerned with the quarterly changes of the valuations during the lifetime of the fund. This is because for investors the true economic value of the unquoted investments is only known upon realization of those investments. Investors in private equity are generally characterized by having a long-term investment horizon, so focus on the long-term return potential of a private equity fund commitment, while taking into consideration the loss risk of such an investment. Pension funds are a good example of the sort of typical investor that has a very long-term investment horizon. A pension fund is well-placed to bear the illiquid nature of private equity, as part of a balanced and diversified investment strategy. Moreover, exposure to private equity by such an investor will be gained through a diversified portfolio of private equity funds.

EVCA also presents an approach that fully captures the risk and return profile of investing in a portfolio of private equity funds. In private equity three main risks can be distinguished:

- **Liquidity and funding risk** is the risk that the investor cannot meet its obligations to pay draw downs on a commitment as they fall due. Funding risk can be expressed through the ratio of drawdowns to uncalled commitments over a defined time period and the ratio between distributions and draw downs over a defined time period.
- **Long-Term default risk** is the risk that the investor loses capital with its private equity investment over the entire lifetime of the product (“Hold to maturity”). Hence interim valuations do not really play a role, they only provide an indication of what the final and true value of the investment may be. Long term risk can be expressed through the ratio between capital returned and capital paid-in. Until the investor has received back its full capital drawn down it runs some risk of losing part of its capital.
- **Short-term valuation changes (risk)** is the risk that the value (NAV) changes over time. These values are mark-to-market, or often in the case of private equity, mark-to-model accounting values and not market values in the traditional sense used in public equity investing. By definition the underlying investments are not traded on any market, hence there is no real market value. Interim valuations and movements in the stated NAV can, however, play a role in the balance sheet of some institutional investors, such as banks.

While the short-term valuation changes have been addressed with the NAV-index, we analysed the liquidity and funding risk with an annual draw down rate (see Appendix 8) and the long-term default risk. In order to get a first impression for the long-term default rate, many studies have shown evidence that a diversified portfolio of private equity funds has a relatively low risk. One of the most important studies in this area from Weidig / Mathonet (2004) shows that a portfolio with more than 20 funds has extremely limited risks (i.e. zero risk) with a confidence level of 99% of losing any capital over the entire lifetime of the portfolio. A study from Diller / Herger shows that a well-diversified portfolio of 25 funds spread over 5 years will end up with a similar result. In order to derive their results, the invested capital at risk (iCaR) approach is used and the risk of an investor suffering any capital losses over the entire holding period until maturity is calculated. Meyer / Mathonet (2005) also show that a portfolio with more than 20 funds is considered as being well-diversified. The cash flow approach is mainly based on the cash flows of the underlying funds and takes the distributed to paid-in capital at the end of the lifetime (“DPI”) as main ratio and the total value to paid in capital (TVPI) during the lifetime.

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In a cash flow driven environment the main risk of an investor is to lose any capital at maturity of the fund lifetime. Therefore, the main risk is to end up with a DPI-ratio of smaller than one. The following chart demonstrates the risk of a well-diversified portfolio of private equity funds and shows how the risk of losing capital changes over time together with the market changes.

As the typical investor holds a well-diversified portfolio of private equity funds the following chart describes the typical exposure of capital at risk for such an investor.

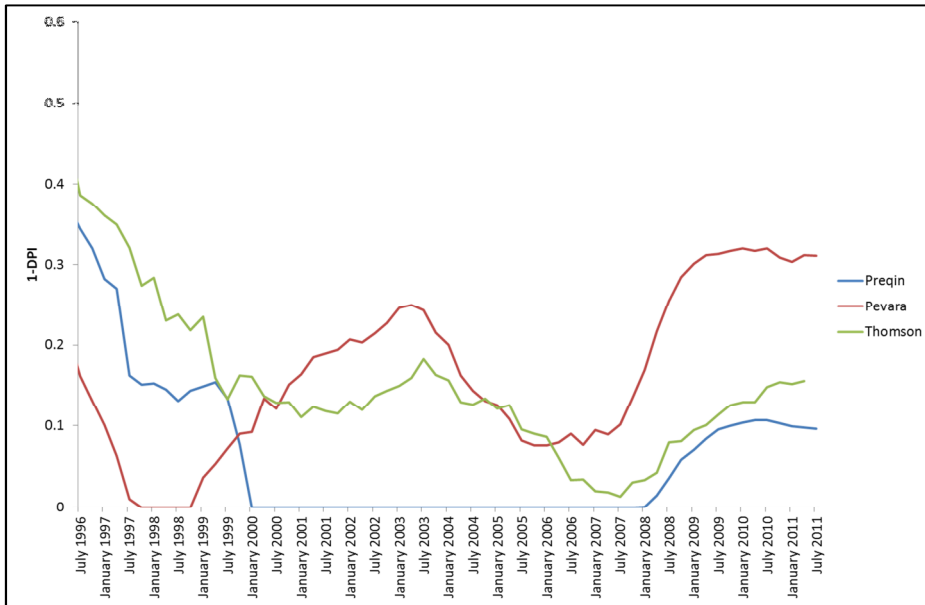


Figure 7: Capital at risk chart of entire private equity universe using a calculation of (1-DPI).

The above chart shows the cumulative distributed capital to cumulative paid in capital over the lifetime of an investor in a portfolio of private equity funds. The investor invests in each of the funds that are available on the market. The investor commences the private equity programme in 1986 and holds a well-diversified private equity portfolio. As described above, a portfolio can be seen as well-diversified as soon as the investor commits into more than 10 to 20 funds over a time horizon of 3 to 5 years. When the portfolio of private equity funds is well-balanced the capital at risk rate only fluctuates between 0% and 30%, with an average at 12%. It is important to highlight that this is an exposure measure reflecting how much can be lost in the worst case and not a loss rate of private equity. It can be seen that in years with good public market returns and high exit rates in the private equity market, like in 2006 and 2007, these risks can be reduced, while during crises the risk increases. Therefore, all these analyses show evidence that the long-term risk for private equity is very low.

Based on such observations, EVCA has created a cash flow based index. In order to combine the long-term view of the cash flow approach with the annual time horizon of the risk calculation in addition to cash flows the net asset value at the end of the observation period is included. Hence, the return is calculated from quarter to quarter with this formula:

$$R_k = \sum_{i=1}^M w_i \frac{\frac{\sum_{k=0}^T DI_k + NAV_k}{\sum_{k=0}^T TD_k}}{\frac{\sum_{k=0}^T DI_{k-1} + NAV_{k-1}}{\sum_{k=0}^T TD_{k-1}}}$$

The TVPI index reflects the changes of the cumulative distributions and draw downs from quarter to quarter per fund i from fund 1 to M and the net asset value at the end of this quarter, weighted with the invested amounts (w_i) similar to a market weighted index. During the lifetime only cash flows (draw downs and distributions) are taken into account, plus the net asset value at the end of the period. If a fund got liquidated it was taken out of the index. The returns of each funds for each quarter will be aggregated and weighted with each funds weighting w_i . Thereafter it is possible to aggregate all values per quarter and create an index based on these quarterly values. Thereafter the returns will be annualized and the 99.5% VaR can be calculated.

It is important to highlight that EVCA considered different approaches to calculate a cash flow based index and the statistical calibration of the risk parameters thereof. For example indices can be calculated on a TVPI or DPI basis and the returns can be annualized on different levels; e.g. on the level of each fund; on the portfolio level or even after deriving the VaR which will be adjusted by the time horizon. In order to keep the paper comprehensive, it was decided to not add each possibility. However if the results of these analyses are of interest to EIOPA, EVCA is happy to have a continued and deeper dialogue on the individual elements.

Based on the above mentioned definition, an index value has been assessed and the typical calculations of the empirical return distribution have been performed. The following graphs are plotted below in order to assess the risk of private equity fitting standardised distributions to empirical data. Here, the normal distribution and the Generalized Extreme Value (“GEV”) Distribution are used.

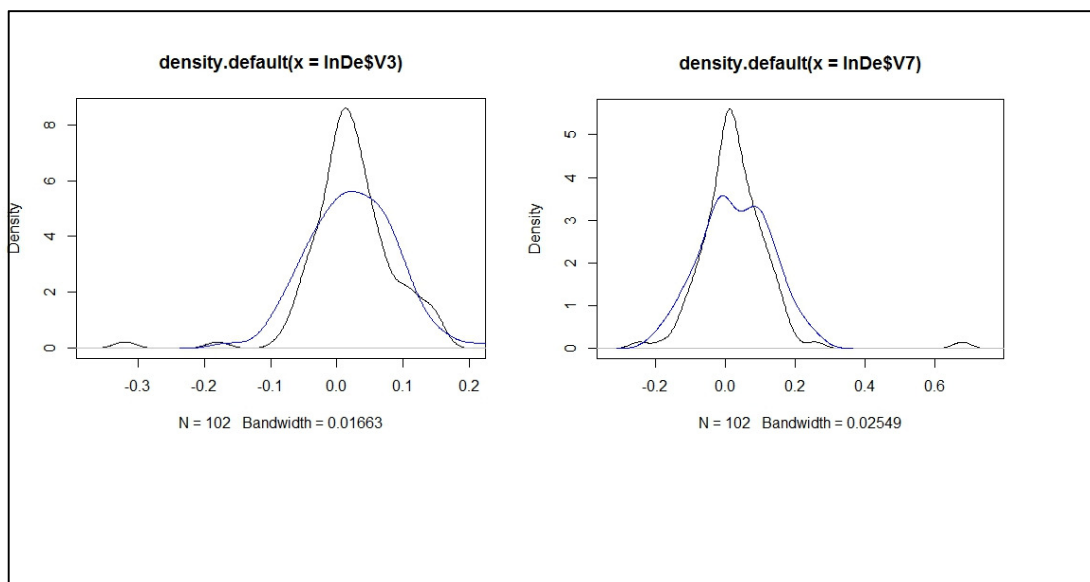


Figure 9: Comparison of the empirical distribution with normal distribution (left) and GEV (right)

Matching the distribution with the normal distribution and calculating the 99.5% confidence level, a risk weighting of 22.5% is derived, while the annual shock using the GEV is 25.0%. The calculation of the same measures on the Pevara data base results in a value of 15.6%. These results show that the annualized long-term risk of private equity is very low compared to the annual net asset value movement.



7 Conclusion & summary of results

The paper analyses the risk and correlation of private equity through the creation of a new index methodology. Based on the current regulatory environment, a NAV based private equity index has been developed that fulfils the requirements which EIOPA used to calculate the risk calibration for property risk.

The new NAV Base Index reflects the characteristics of private equity as an asset class more appropriately, in particular the illiquidity and the limited partnership closed-end fund structure in which investors hold the investment to maturity. Hence, the proposed approach captures the risks of private equity for investors more adequately as it takes into account the specifics of the asset class.

Adjusting the previously calculated Base Index by autocorrelation and expanding the data from quarterly to monthly data shows that the shock event increases from 25% to 29% at the Base Index to around 30% to 32% for the Expanded Index based on real data. Fitting these results with standardized distributions shows that the shock event for private equity is below 38%.

The following table summarises the results:

	Preqin data	Pevara data
NAV Base Index (Real data)	29.1%	24.6%
Expanded Index (Real data)	31.8%	30.2%
Normal Distribution fitted	37.8%	32.2%
GEV fitted	30.2%	28.8%
Cash flow index	22.5%	15.6%

The new approach and the new data sets employed in this paper are a more appropriate reflection of the characteristics of private equity. As a consequence the results show strong and compelling evidence that the risk of private equity is lower than currently reflected in the regulatory framework. As a result EVCA strongly recommends that the standard risk weighting for private equity should be based on the calibration from a new index that appropriately reflects the characteristics of private equity.

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8 Appendix:

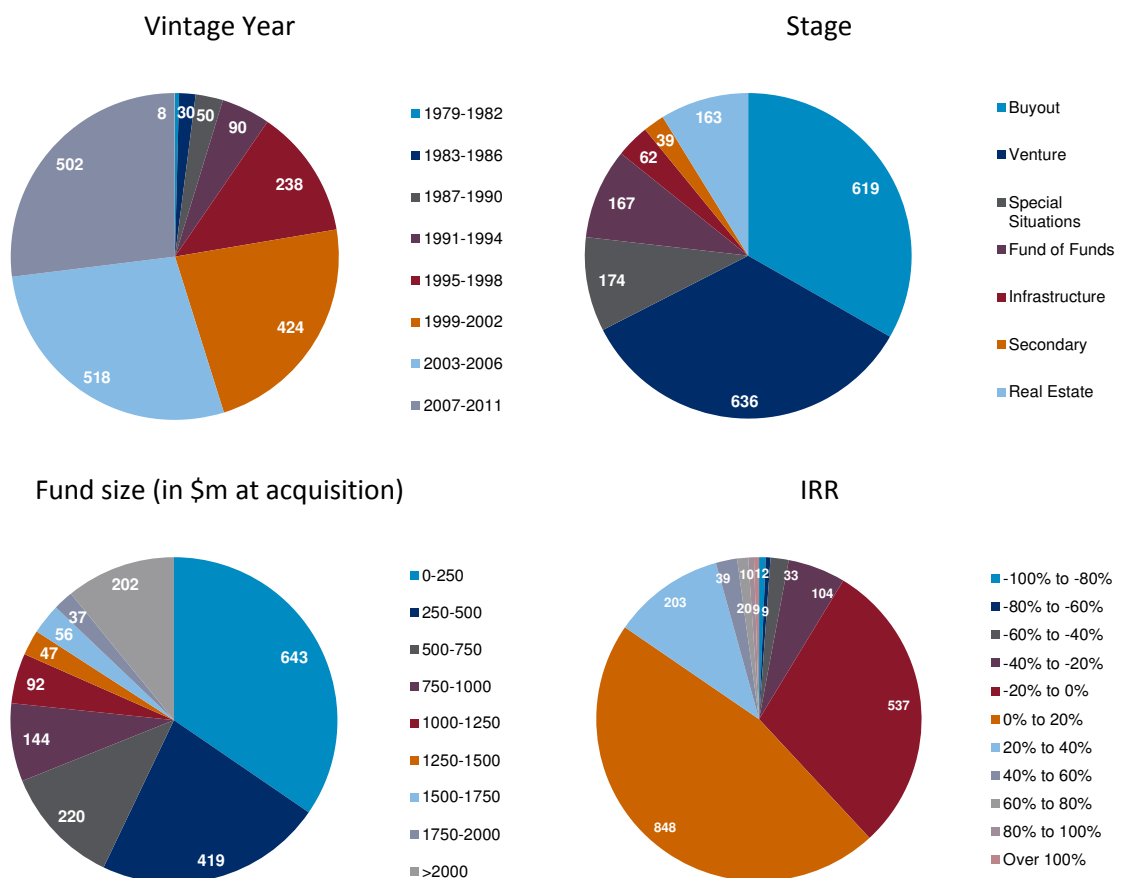
8.1 Appendix 1: Data description

In our study we used two different data sets; one from Preqin and another from Pevara - both cover approximately two thousand funds.

Preqin dataset

The Preqin dataset contains series of cash flows and NAVs for 1,882 funds from a diverse range of stages, regions and vintages. The information is for an investor with a \$10,000 commitment in each underlying fund with no currency effects after the initial investment.

A detailed description of the data is found below:



Source: Preqin

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Pevara dataset

The Pevara dataset contains series of cash flows and NAVs for 2.015 funds from a diverse range of stages, regions and vintages. The information is for an investor with a \$10,000 commitment in each underlying fund with no currency effects after the initial investment.

A detailed description of the data can be found below:

	Buyout				Venture Capital				All			
	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All
<1991	#NV	45	#NV	47	#NV	80	#NV	84	6	125	#NV	131
1991	#NV	8	#NV	8	#NV	#NV	#NV	8	#NV	13	#NV	16
1992	#NV	10	#NV	11	#NV	12	#NV	14	#NV	22	#NV	25
1993	#NV	16	#NV	16	#NV	18	#NV	19	#NV	34	#NV	35
1994	6	27	#NV	34	#NV	18	#NV	21	7	45	#NV	55
1995	#NV	20	#NV	24	#NV	15	#NV	16	#NV	35	#NV	40
1996	#NV	19	#NV	24	#NV	11	#NV	16	#NV	30	#NV	40
1997	9	35	#NV	46	#NV	24	#NV	30	10	59	7	76
1998	14	35	#NV	50	#NV	37	#NV	43	19	72	#NV	93
1999	12	32	#NV	47	6	67	#NV	74	18	99	#NV	121
2000	16	38	#NV	58	12	84	6	102	28	122	10	160
2001	17	39	#NV	58	9	49	#NV	60	26	88	#NV	118
2002	12	24	#NV	36	7	22	#NV	30	19	46	#NV	66
2003	16	27	#NV	44	10	19	#NV	29	26	46	#NV	73
2004	18	44	#NV	63	10	33	#NV	45	28	77	#NV	108
2005	29	67	6	102	9	55	7	71	38	122	13	173
2006	53	73	7	133	19	60	6	85	72	133	13	218
2007	58	69	13	140	15	58	15	88	73	127	28	228
2008	34	66	15	115	11	44	17	72	45	110	32	167
2009	10	15	#NV	26	#NV	18	#NV	26	13	33	6	52
All	313	709	60	1082	127	729	77	933	440	1438	137	2015

The fund size classifications are defined as follows:

Buyout Size Classifications				
Vintages	Small	Medium	Large	Mega
1993 - 94	<= \$100m	>\$100 <= \$500m	>\$500m	N/A
1995 - 96	<= \$200m	>\$200 <= \$500m	>\$500 <= \$1,000m	> \$1,000m
1997 - 99	<= \$250m	>\$250 <= \$750m	> \$750 <= \$2,000m	> \$2,000m
2000 - 05	<= \$300m	>\$300 <= \$1,000m	> \$1000 <= \$2,500m	> \$2,500m
2006 - 12	<= \$300m	>\$300 <= \$1,000m	> \$1000 <= \$3,500m	> \$3,500m
Venture Capital Size Classifications				
Vintages	Small	Medium	Large	
1990-91	<\$50m	>\$50m >\$100m	>\$100m	
1992-12	<= \$50m	>\$50 <=\$150m	>\$150m	

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Benchmark Sample Size Pivot Table - Mega Funds

	Buyout			
	Europe	North America	R.o.W	All
1995	#NV	7	#NV	7
1996	#NV	#NV	#NV	#NV
1997	#NV	6	#NV	8
1998	#NV	#NV	#NV	6
1999	#NV	#NV	#NV	#NV
2000	#NV	#NV	#NV	7
2001	#NV	#NV	#NV	8
2002	#NV	#NV	#NV	#NV
2003	#NV	#NV	#NV	#NV
2004	#NV	#NV	#NV	#NV
2005	7	7	#NV	14
2006	10	10	#NV	20
2007	6	11	#NV	19
2008	12	10	#NV	24
2009	#NV	#NV	#NV	#NV
All	47	80	#NV	131

Benchmark Sample Size Pivot Table - Large

	Buyout				Venture Capital				All			
	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All
<1991	#NV	8	#NV	10	#NV	25	#NV	27	#NV	33	#NV	37
1991	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV
1992	#NV	#NV	#NV	#NV	#NV	6	#NV	6	#NV	9	#NV	9
1993	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	8	#NV	8
1994	#NV	8	#NV	13	#NV	#NV	#NV	#NV	#NV	11	#NV	17
1995	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV
1996	#NV	#NV	#NV	#NV	#NV	#NV	#NV	8	#NV	8	#NV	13
1997	#NV	#NV	#NV	6	#NV	13	#NV	14	#NV	16	#NV	20
1998	#NV	8	#NV	11	#NV	21	#NV	25	6	29	#NV	36
1999	#NV	13	#NV	14	#NV	55	#NV	58	#NV	68	#NV	72
2000	#NV	11	#NV	13	8	63	#NV	76	10	74	#NV	89
2001	#NV	#NV	#NV	6	#NV	42	#NV	48	6	46	#NV	54
2002	#NV	#NV	#NV	6	6	15	#NV	22	8	19	#NV	28
2003	#NV	#NV	#NV	#NV	7	13	#NV	20	9	16	#NV	25
2004	#NV	#NV	#NV	6	#NV	24	#NV	30	6	29	#NV	36
2005	#NV	12	#NV	17	7	50	#NV	62	9	62	8	79
2006	9	27	#NV	38	14	46	#NV	64	23	73	6	102
2007	10	22	#NV	34	10	45	11	66	20	67	13	100
2008	7	20	6	33	#NV	36	12	53	12	56	18	86
2009	#NV	#NV	#NV	#NV	#NV	17	#NV	24	#NV	19	#NV	28
All	55	163	14	232	78	485	51	614	133	648	65	846

Benchmark Sample Size Pivot Table - Medium

	Buyout				Venture Capital				All			
	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All
<1991	#NV	21	#NV	21	#NV	28	#NV	29	#NV	49	#NV	50
1991	#NV	7	#NV	7	#NV	#NV	#NV	#NV	#NV	10	#NV	11
1992	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	6	#NV	8
1993	#NV	8	#NV	8	#NV	7	#NV	8	#NV	15	#NV	16
1994	#NV	13	#NV	14	#NV	8	#NV	8	#NV	21	#NV	22
1995	#NV	7	#NV	8	#NV	7	#NV	8	#NV	14	#NV	16
1996	#NV	7	#NV	7	#NV	6	#NV	8	#NV	13	#NV	15
1997	#NV	12	#NV	14	#NV	9	#NV	12	#NV	21	#NV	26
1998	#NV	15	#NV	19	#NV	14	#NV	16	#NV	29	#NV	35
1999	6	8	#NV	5	#NV	11	#NV	14	8	19	#NV	29
2000	#NV	8	#NV	5	#NV	16	#NV	19	7	24	#NV	34
2001	#NV	19	#NV	24	#NV	6	#NV	11	9	25	#NV	35
2002	#NV	11	#NV	14	#NV	#NV	#NV	6	#NV	16	#NV	20
2003	8	15	#NV	24	#NV	6	#NV	8	10	21	#NV	32
2004	8	21	#NV	30	#NV	8	#NV	13	12	29	#NV	43
2005	14	23	#NV	38	#NV	#NV	#NV	14	26	43	#NV	43
2006	23	26	#NV	53	#NV	12	#NV	19	28	38	6	72
2007	31	20	6	57	#NV	10	#NV	19	36	30	10	76
2008	12	22	#NV	36	#NV	7	#NV	15	16	29	6	51
2009	#NV	8	#NV	12	#NV	#NV	#NV	#NV	#NV	9	#NV	14
All	23	276	22	421	38	168	21	227	161	444	43	648

Benchmark Sample Size Pivot Table - Small

	Buyout				Venture Capital				All			
	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All	Europe	North America	R.o.W	All
<1991	#NV	16	#NV	16	#NV	27	#NV	28	#NV	43	#NV	44
1991	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV
1992	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	7	#NV	8
1993	#NV	#NV	#NV	#NV	#NV	8	#NV	8	#NV	11	#NV	11
1994	#NV	6	#NV	7	#NV	7	#NV	9	#NV	13	#NV	16
1995	#NV	#NV	#NV	7	#NV	6	#NV	6	#NV	11	#NV	13
1996	#NV	6	#NV	9	#NV	#NV	#NV	#NV	#NV	6	#NV	9
1997	#NV	14	#NV	18	#NV	#NV	#NV	#NV	#NV	16	#NV	24
1998	7	7	#NV	14	#NV	#NV	#NV	#NV	7	9	#NV	16
1999	#NV	7	#NV	14	#NV	#NV	#NV	#NV	6	8	#NV	16
2000	7	14	#NV	23	#NV	#NV	#NV	7	9	19	#NV	30

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8.2 Appendix 2: Twelve sub-indices and their results

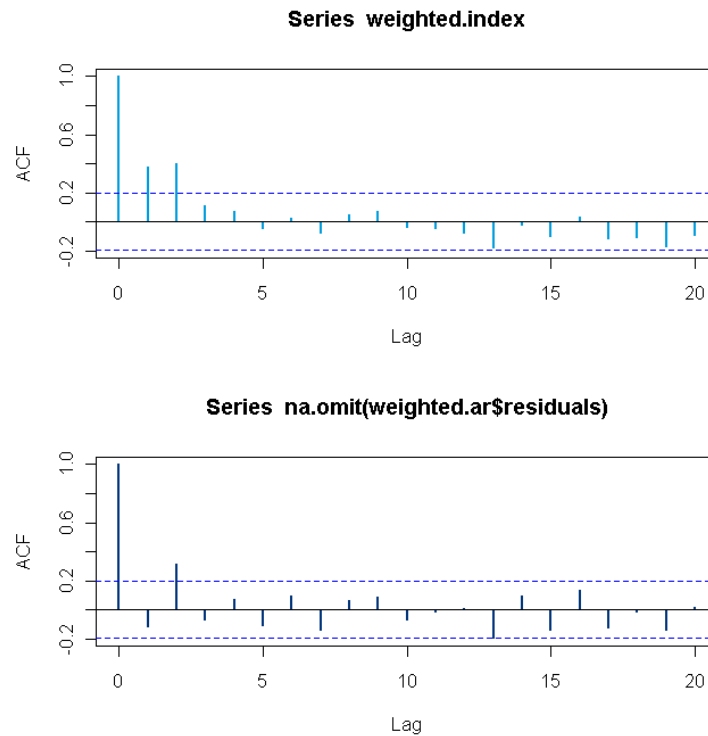
	Equal / All /		Weight / All /		Equal /		Weight /		Equal / VC /		Weight / VC /	
	Must Move	Weight / Must Move	Buyout / Must Move	Buyout / Must Move	Must Move	Buyout / Must Move	Must Move	Buyout / Must Move	Must Move	Buyout / Must Move	Must Move	Buyout / Must Move
2001 max. drawdown	-39.56%	-41.87%	-29.14%	-31.14%	-16.68%	-18.22%	-19.55%	-20.02%	-53.23%	-54.47%	-52.58%	-53.45%
2008 max drawdown	-19.44%	-21.27%	-27.65%	-29.10%	-21.57%	-30.60%	-23.62%	-31.91%	-17.01%	-18.57%	-16.77%	-18.12%
Ending Value	2,077	4,057	2,371	4,277	2,337	2,248	5,294	3,448	1,431	2,074	1,804	2,664
Mean	3.20%	3.91%	3.29%	3.93%	3.21%	3.22%	4.07%	3.68%	3.11%	3.52%	3.38%	3.83%
Median	2.81%	3.94%	3.41%	4.30%	3.51%	3.13%	4.24%	3.46%	1.26%	1.87%	1.19%	1.51%
Variance	0.55%	0.65%	0.42%	0.54%	0.28%	0.39%	0.41%	0.45%	1.25%	1.35%	1.33%	1.47%
Stdev	7.38%	8.05%	6.45%	7.33%	5.25%	6.23%	6.39%	6.71%	11.16%	11.63%	11.52%	12.11%
Skew	162.54%	130.68%	84.61%	82.02%	53.10%	94.93%	62.10%	66.55%	252.48%	226.32%	242.06%	213.44%
Kurtosis	7.56	5.84	4.75	3.52	3.14	7.62	3.02	5.55	11.81	10.01	10.88	8.71
Average annual growth	12.63%	15.63%	13.22%	15.87%	13.15%	12.98%	16.79%	14.89%	11.00%	12.63%	12.01%	13.74%



8.3 Appendix 3: Plot of auto correlation

In order to calculate the auto-correlation, it is a standard approach to use so called autoregressive moving average, or short ARMA(p,q), processes for the analyses. ARMA processes are time-series models where the observation at time t is dependent on the past observation p and a noise term. The noise term itself depends on the past noise realizations q. ARMA models with q = 0 are autoregressive models AR(p). In order to adjust for the autocorrelation in the time series, we used both models at the beginning, but decided to restrict our further analyses to the AR(1) model which gives a more stable fit to than the more general ARMA model.

The intercept is 2.1253% indicating that there is a significant backstop to private equity returns. Given the cash-generative effect of private equity investments, it is not especially surprising that there would be this level of backstop over the lifespan of the asset class.



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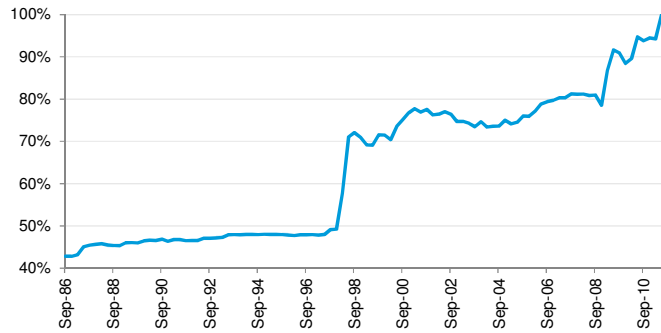
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8.4 Appendix 4: Correlation

Please note that this is a cumulative time series correlation, with the leftmost value corresponding to the correlation of the entire dataset, and the rightmost value corresponding to the correlation for the two data points June 2011 to September 2011.





8.5 Appendix 5: Interpolation

In order to expand the data from quarterly NAV observations to monthly values, it is necessary to make an assumption on the approach that derives the values in-between the quarterly valuations.

Many models exist, e.g. Interpolation, hedonic model, autoregression and generalised method of moments (GMM). Similar to the asset class “property”, we decided to use the interpolation approach.

Real estate indices such as the Case-Shiller index rely upon repeat-sales methods to carry values forward through periods of missing data. The interim data is filled in through the medium of taking the missing period root of the geometric growth and applying that to the data. Knowing the final value of the increase in NAV in a period means it might also be possible to guess at when those periods of growth occur.

If it is assumed that all calls to a fund directly increase NAV by the same amount, whatever remains is down to unrealised NAV growth and distributions, the division of which can be made in some regard or left entirely transactional. This follows the methodology of IPD, which is used as the index for real estate.

Therefore the idea for the asset class private equity was to use an interpolation model that uses information from the return movements of the public market and from EVCA’s statistical analysis to construct the Expanded index values.

As the intercept and autocorrelation of private equity is known through our statistical analysis, additionally a regression between the private equity returns and the public market returns over the last three observations can be calculated. This enables us to interpolate the data between quarters, so we can expand our model to monthly data. Technically this is an auto regression, noise and correlation model, designed to achieve the highest goodness of fit.

For any interim period the following is observed:

$$R_{t+n} = \frac{I_{ac}}{n} + \frac{(R_t) \cdot W_{ac}}{n} + \frac{I_c}{n} + \left(\left(\frac{MSCI_{t+n}}{MSCI_{t+n-3}} \right) - 1 \right) \cdot W_c$$

Where R is the return, n is the period after the last real date t, I is the intercept, W is the coefficient of correlation, with ac being the autocorrelation function and c being the linear model of the after-autocorrelation model.

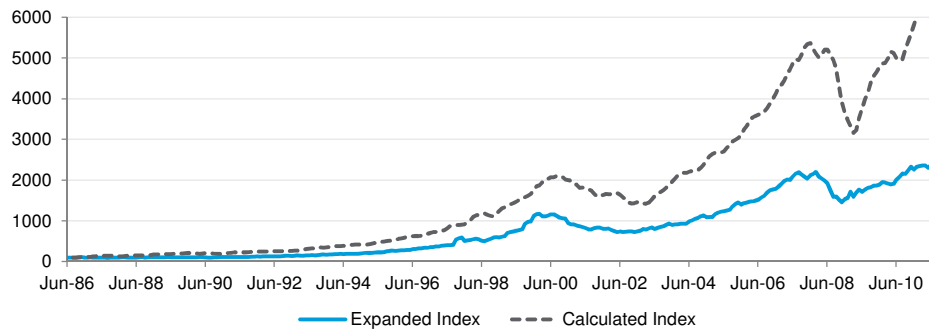
Where the period is a quarter end (n=0) R is set to equal an amount such that the indexed value of the Expanded Index is the same as the indexed value of the Base Index. We intend to correct for interim values, not to modify the Base Index.



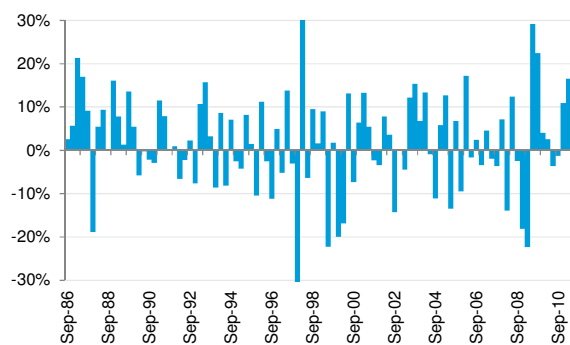
8.6 Appendix 6: Goodness of fit

The goodness of fit of a model is usually expressed through the fit of the regression to the observed data expressed through the classic R^2 . As one time series (“real data”) and the time series of the Expanded Index have only an overlapping value every third period in time, the overall goodness-of-fit is hard to calculate and another approach to measure the goodness of fit is necessary.

One way is to calculate an additional Index using the calculation for the interim period only which shows the goodness of fit of the whole model (“Calculated Index”). The newly Calculated Index has as its inputs only its own prior values and the MSCI World and compares to the Expanded Index as follows:



It is also possible to look at the differences between the Expanded Index and the Calculated Index where both data points exist:⁷



Excluding some unexpected behaviour in 1998 where private equity declines in value before it is predicted by the model (this data point was also excluded from the correlation calculations) the average difference between the model and the real data is 8.16%, implying a rough R^2 of the model of 84.3%.

⁷ Simply, (Calculated Index / Expanded Index) - 1, less the sum of all the differences already recorded.

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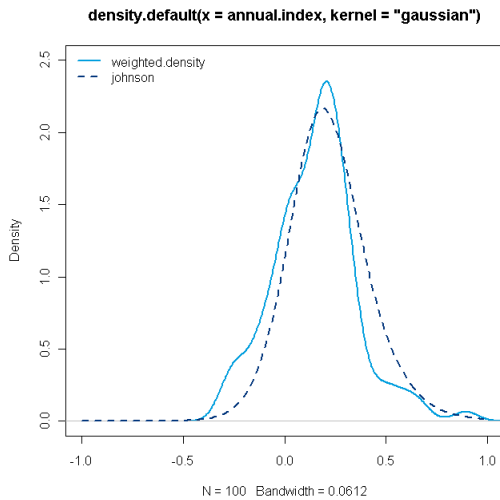
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8.7 Appendix 7: Johnson Distribution

A Johnson-distribution matching can be attempted compared to the underlying empirical return data. The chart shows the one-year changes in the Index (light blue) against the Johnson distribution (dark blue). The 0.5% probability for the distribution is 29.16%.



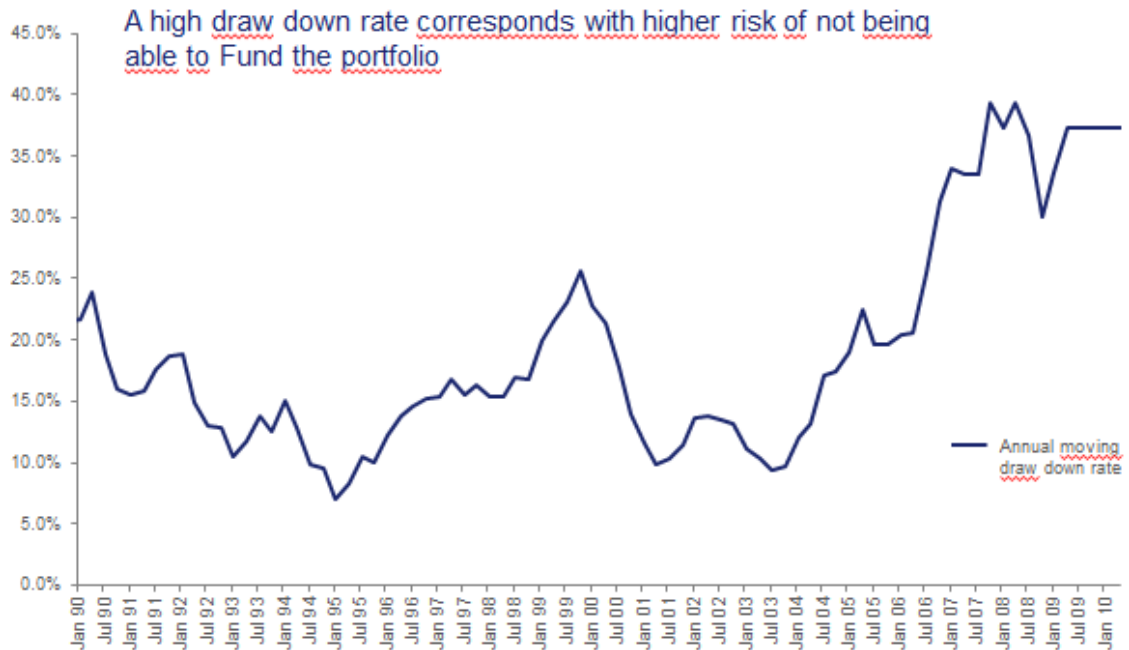
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8.8 Appendix 8: Liquidity and Funding Risk - Annual moving draw down rate

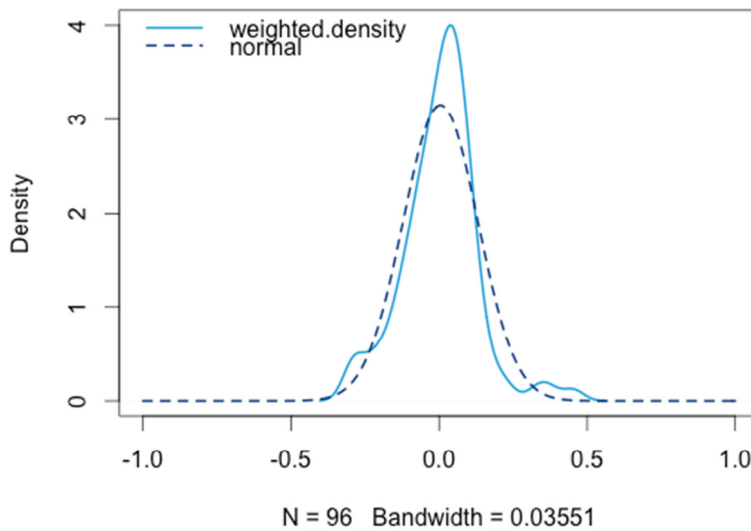




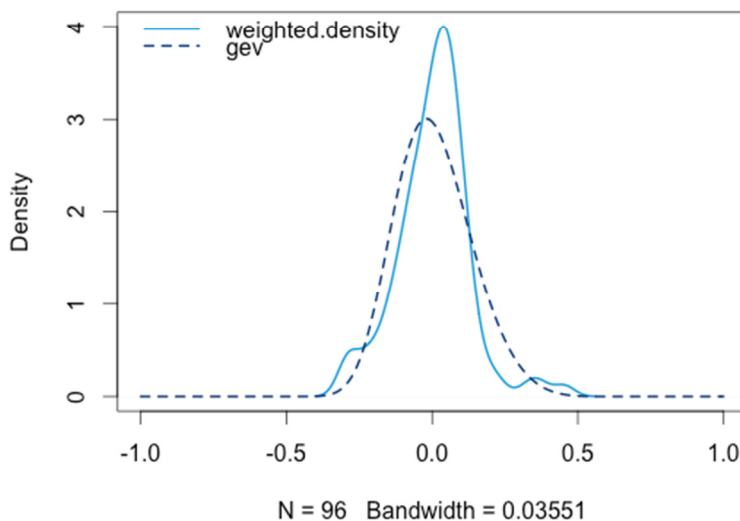
8.9 Appendix 9: Results from Pevera:

In addition to the calculation on the Preqin data set, we also fitted the distributions of the Pevera index to the normal distribution and to the GEV. Therefore we used 99.5% percentile and annual returns. The results for the index are 32.2% and 28.8%.

`density.default(x = annual.index[, 1], kernel = "gaussian"`



`density.default(x = annual.index[, 1], kernel = "gaussian"`





8.10 Appendix 10: Code in SQL and “R” for calculating the different indices

All the calculations have been performed of the index have been performed from two different companies on the same data set in order to show the robustness of the results. One used a mix of SQL and R code, while the other firm only used R codes. Both codes can be found below.

SQL-Code for calculating the various indices

This is based upon the Preqin data, but can be easily converted to use other data sources. Firm_id is not required, and the conversion of types can be altered to suit other providers' definitions. Note here that some Preqin stages such as real estate, timber and venture debt have been excluded altogether as not being suitably close to a definition of private equity. The code has been tested on Microsoft SQL Server 2008.

```
If object_id('tempdb..#provider_static') is not null DROP TABLE #provider_static
If object_id('tempdb..#provider_cf') is not null DROP TABLE #provider_cf
If object_id('tempdb..#provider_nav') is not null DROP TABLE #provider_nav
If object_id('tempdb..#temp_cf') is not null DROP TABLE #temp_cf
If object_id('tempdb..#fund_level') is not null DROP TABLE #fund_level
If object_id('tempdb..#evca_index') is not null DROP TABLE #evca_index
```

```
SET DATEFORMAT ymd
```

```
create table #provider_static(
fund_id int null,
firm_id int null,
vintage int null,
type varchar(255) null,
status varchar(255) null,
currency varchar(255) null,
fs_local money null,
fs_usd money null,
region varchar(255) null)
```

```
create table #provider_cf(
fund_id int null,
trans_category varchar(255) null,
trans_date date null,
trans_amount money null)
```

```
create table #provider_nav(
fund_id int null,
trans_date date null,
trans_amount money null)
```

```
create table #fund_level(
fund_id int null,
fund_size money null,
type varchar(255) null,
trans_date date null,
prior_date date null,
this_nav money null,
this_nav_w money null,
prior_nav money null,
prior_nav_w money null,
datedifference int null,
sumcf money null,
sumcf_w money null,
weightsumcf money null,
weightsumcf_w money null,
m_dietz float null)
```

```
create table #temp_cf(
trans_date date null,
date_diff int null,
```

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```
trans_amount money null,
indexed_amount money null)

create table #evca_index(
trans_date date null,
this_nav money null,
prior_nav money null,
cf_sum money null,
weighted_cf money null,
m_dietz float null,
observations int null,
index_value float null)

BULK INSERT #provider_static
FROM '\\pan-lon-fs01\data\UK\Operations Team\Performance\Projects\Benchmarking\Preqin
Benchmarking\preqin_static.csv'
WITH (FIELDTERMINATOR = ',' , ROWTERMINATOR = '\n', FIRSTROW = 2)

BULK INSERT #provider_nav
FROM '\\pan-lon-fs01\data\UK\Operations Team\Performance\Projects\Benchmarking\Preqin
Benchmarking\preqin_nav.csv'
WITH (FIELDTERMINATOR = ',' , ROWTERMINATOR = '\n', FIRSTROW = 2)

BULK INSERT #provider_cf
FROM '\\pan-lon-fs01\data\UK\Operations Team\Performance\Projects\Benchmarking\Preqin
Benchmarking\preqin_cf.csv'
WITH (FIELDTERMINATOR = ',' , ROWTERMINATOR = '\n', FIRSTROW = 2)

update #provider_static set
type = (CASE WHEN type in('Buyout','Balanced','Co-investment') then 'Buyout' else
(case when type in('Early Stage','Early Stage: Seed','Early Stage: Start-up','Venture
(General)','Expansion / Late Stage','Growth') then 'Venture' else
(case when type in('Special Situation','Mezzanine','Fund of Funds', 'Co-Investment Multi-
Manager','Turnaround','Distressed Debt') then 'Other' else
'Exclude' end) end) end)

delete from #provider_cf where trans_category = 'Value'

insert into #fund_level (fund_id, trans_date, prior_date, this_nav, prior_nav, fund_size,
type)
select n1.fund_id, n1.trans_date, dateadd(day,-1,(DATEADD(month,-
3,dateadd(day,1,n1.trans_date))), n1.trans_amount, n2.trans_amount, s.fs_usd, s.type from
#provider_nav n1, #provider_nav n2, #provider_static s where n2.trans_date = dateadd(day,-
1,(DATEADD(month,-3,dateadd(day,1,n1.trans_date)))) and n2.fund_id = n1.fund_id and
DATEPART(month,n1.trans_date) in(3,6,9,12) and s.fund_id = n1.fund_id and
n2.trans_amount<>0 and n1.trans_amount<>0

update #fund_level set
datedifference = datediff(day,f.prior_date,f.trans_date)
from #fund_level f

update #fund_level set
sumcf = (select isnull(sum(cf.trans_amount),0) from #provider_cf cf where cf.fund_id =
f.fund_id and cf.trans_date > f.prior_date and cf.trans_date <= f.trans_date)
from #fund_level f

update #fund_level set
weightsumcf = (isnull((select
SUM(cf.trans_amount*datediff(day,f.prior_date,cf.trans_date)/f.datedifference) from
#provider_cf cf, #provider_nav nav, #fund_level f where cf.trans_date > f.prior_date and
cf.trans_date <= f.trans_date and cf.fund_id = f.fund_id and nav.fund_id = f.fund_id and
f.fund_id = f2.fund_id and f.trans_date=f2.trans_date and nav.trans_date
=f2.trans_date),0))
from #fund_level f2

update #fund_level set
this_nav_w = (CASE WHEN fund_size = 0 then 0 else this_nav * fund_size /10 end),
prior_nav_w = (CASE WHEN fund_size = 0 then 0 else prior_nav * fund_size /10 end),
sumcf_w = (CASE WHEN fund_size = 0 then 0 else sumcf * fund_size /10 end),
weightsumcf_w = (CASE WHEN fund_size = 0 then 0 else weightsumcf * fund_size /10 end)

update #fund_level set
```

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```
m_dietz = (CASE WHEN ((prior_nav - weightsumcf) <=0 OR (this_nav = 0 AND prior_nav = 0))
then 0 else (this_nav - prior_nav + sumcf)/(prior_nav - weightsumcf) end)

--ENDS FUND LEVEL

DELETE from #evca_index

DECLARE @opt_mustmove varchar(3)
DECLARE @opt_move_amt float
DECLARE @opt_type varchar(20)
DECLARE @opt_weight varchar(6)

SET @opt_mustmove = 'No'
SET @opt_move_amt = 0.005
SET @opt_type = 'Buyout'
SET @opt_weight = 'Weighted'

INSERT INTO #evca_index(trans_date)
SELECT DISTINCT trans_date FROM #fund_level ORDER BY trans_date

UPDATE #evca_index SET
m_dietz = CASE WHEN @opt_weight = 'Equal' then

(SELECT (case when (ISNULL(sum(prior_nav),0)-isnull(sum(weightsumcf),0))<=0 then 0 else
(isnull(SUM(this_nav),0)-
ISNULL(sum(prior_nav),0)+ISNULL(sum(sumcf),0))/(ISNULL(sum(prior_nav),0)-
isnull(sum(weightsumcf),0)) end) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type<>'Exclude' and type =
(case when @opt_type = 'All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end))
else
(SELECT (case when (ISNULL(sum(prior_nav_w),0)-isnull(sum(weightsumcf_w),0))<=0 then 0 else
(isnull(SUM(this_nav_w),0)-
ISNULL(sum(prior_nav_w),0)+ISNULL(sum(sumcf_w),0))/(ISNULL(sum(prior_nav_w),0)-
isnull(sum(weightsumcf_w),0)) end) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type<>'Exclude' and type =
(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end))
end

from #evca_index i

If @opt_weight='Equal' begin

UPDATE #evca_index SET
observations =
(select count(this_nav) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)
and this_nav <>0 and prior_nav <>0)
from #evca_index i

update #evca_index set
this_nav=(select SUM(fl.this_nav) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)),

prior_nav = (select SUM(fl.prior_nav) from #fund_level fl where fl.trans_date =
i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)),

cf_sum = (select sum(fl.sumcf) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
```

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```
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)),

weighted_cf = (select sum(fl.weightsumcf) from #fund_level fl where fl.trans_date =
i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end))
from #evca_index i

end
else
begin

UPDATE #evca_index SET
observations =
(select count(this_nav) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)
and this_nav_w <>0 and prior_nav_w <>0)
from #evca_index i

update #evca_index set
this_nav=(select SUM(fl.this_nav_w) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)),

prior_nav = (select SUM(fl.prior_nav_w) from #fund_level fl where fl.trans_date =
i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)),

cf_sum = (select sum(fl.sumcf_w) from #fund_level fl where fl.trans_date = i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end)),

weighted_cf = (select sum(fl.weightsumcf_w) from #fund_level fl where fl.trans_date =
i.trans_date
and fl.type in (select distinct type from #fund_level where type <>'Exclude' and type
=(CASE WHEN @opt_type='All' then type else @opt_type end))
and abs(fl.m_dietz)>=(CASE WHEN @opt_mustmove = 'Yes' then @opt_move_amt else
ABS(fl.m_dietz) end))
from #evca_index i

end

declare @this_index float
declare @prior_index float
declare @this_m_dietz float
declare @this_date datetime
declare @flag int

set @prior_index = 100
set @this_index = 100
set @flag = 0

declare c cursor for
select trans_date, m_dietz from #evca_index i
open c

fetch next from c
into @this_date, @this_m_dietz

while @@FETCH_STATUS=0
```

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```
begin

set @this_index = (CASE WHEN @flag = 0 then 100 else @prior_index * (1+@this_m_dietz) end)
set @prior_index = @this_index
set @flag = 1

update #evca_index set
index_value = @this_index
from #evca_index where trans_date = @this_date

fetch next from c
into @this_date, @this_m_dietz

end

close c
deallocate c

select * from #evca_index
```

Determination of the Risk and Correlation calibrations in R

Use all of these sections of code in one session of R so that the variables persist.

Part 1: Distribution

```
require(Design)
weighted.index <- read.csv("weighted.index.csv") #load the quarterly modified Dietz
plot(density(weighted.index, kernel = "gaussian"), col = rgb(0,157,219,max=255), lwd=2)
lines(seq(from = min(weighted.index)*1.2, to = max(weighted.index)*1.2, by = 0.01),
dnorm(seq(from = min(weighted.index)*1.2, to = max(weighted.index)*1.2, by = 0.01), mean =
mean(weighted.index), sd = sd(weighted.index)), col = rgb(0,52,121,max=255), lwd=2, type =
"l")
legend(x="topleft", legend = c("weighted.density", "normal"), lwd = 2, col =
c(rgb(0,157,219,max = 255), rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))
```

Part 2: Autocorrelation

```
require(tseries)
weighted.ar <- arma(weighted.index, c(1,0))

summary(weighted.ar) #obtain the coefficients

plot(acf(weighted.index), type = "h", col=rgb(0,157,219,max=255),lwd=2)

plot(acf(na.omit(weighted.ar$residuals)), type = "h", col=rgb(0,52,121,max=255),lwd=2)
```

Part 3: Risk (Normal)

```
require(SuppDists)

require(evd)

annual.index <- read.csv("weighted.annual.csv") #load the annual changes to the Index

plot(density(annual.index, kernel = "gaussian"), col = rgb(0,157,219,max=255),
lwd=2,xlim=c(-1,1),ylim=c(0,2.5))

lines(seq(-1,1,0.01),dnorm(seq(-1,1,0.01),mean(annual.index),sd(annual.index)),col =
rgb(0,52,121,max=255), lwd=2, type = "l",lty=2)

legend(x="topleft", legend = c("weighted.density", "normal"), lwd = 2, col =
c(rgb(0,157,219,max = 255), rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))

qnorm(0.005,mean=mean(annual.index), sd=sd(annual.index))
```

Part 4: Risk (GEV)



```
fgev(annual.index) #return the coefficients of the GEV fitting

gev.fit <- fgev(annual.index)

plot(density(annual.index, kernel = "gaussian"), col = rgb(0,157,219,max=255),
     lwd=2,xlim=c(-1,1),ylim=c(0,2.5))

lines(seq(-1,1,0.01),dgev(seq(-1,1,0.01), gev.fit$estimate["loc"],
gev.fit$estimate["scale"], gev.fit$estimate["shape"]), col = rgb(0,52,121,max = 255),
     lwd=2, lty=2)

legend(x="topleft",legend = c("weighted.density","gev"), lwd = 2, col = c(rgb(0,157,219,max
= 255),rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))

qgev(0.005, gev.fit$estimate["loc"], gev.fit$estimate["scale"], gev.fit$estimate["shape"])
```

Part 5: Risk (Johnson)

```
parms <- JohnsonFit (annual.index, moment = "find")

plot(density(annual.index, kernel = "gaussian"), col = rgb(0,157,219,max=255),
     lwd=2,xlim=c(-1,1),ylim=c(0,2.5))

plot(function(x)dJohnson(x,parms),-1,1,add=TRUE, col = rgb(0,52,121,max=255),lwd=2, lty=2)

legend(x="topleft",legend = c("weighted.density","johnson"), lwd = 2, col =
c(rgb(0,157,219,max = 255),rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))

qJohnson(0.005,parms)
```

“R”-code

```
library(reshape)
library("lubridate")
#rm(list=ls())
cashflowtb <- read.csv("../PooledCF.csv",stringsAsFactors=TRUE)
navtb <- read.csv("../ValueCF.csv",stringsAsFactors=TRUE)

#Use previously uploaded data
cf.tb <- cashflowtb
nav.tb <- navtb
cf.dt.fmt <- "%m/%d/%Y"
nav.dt.fmt <- "%d/%m/%Y"

grp.type <- nav.tb$cattype
grp.type <- as.character(grp.type)

#The various fund categories are recategorized into core and non-core
#business. The purpurpose is to exclude the non-core operations
grp.type[grp.type %in% c('Buyout',
                        'Balanced',
                        'Co-investment')] <- 'Buyout'
grp.type[grp.type %in% c('Early Stage',
                        'Early Stage: Seed',
                        'Early Stage: Start-up',
                        'Venture (General)',
                        'Expansion / Late Stage',
                        'Growth')] <- 'Venture'

grp.type[grp.type %in% c('Special Situation',
                        'Mezzanine',
                        'Fund of Funds',
                        'Co-Investment Multi-Manager',
                        'Turnaround',
                        'Distressed Debt')] <- 'Other'
grp.type[!(grp.type %in% c('Other',
                          'Buyout',
```

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```
'Venture'))] <- 'Exclude'

nav.tb<- cbind(nav.tb,grp.type )
nav.tb<- subset(nav.tb, grp.type!='Exclude')

nav.tb$date <- mdy(as.character(nav.tb$date))
nav.tb$quarter <- mdy(as.character(nav.tb$quarter))
cf.tb$date <- mdy(as.character(cf.tb$date))

#Excludinding data points prior to 1985
nav.tb <- subset(nav.tb,nav.tb$date>dmy("31-12-1985"))
cf.tb <- subset(cf.tb,cf.tb$date>dmy("31-12-1985"))

cf.tb <- subset(cf.tb,cf.tb$type!='Value')

#This implies that only data points reported on the last day
#of each quarter will be taken into account
dtlist <- unique(subset(nav.tb$quarter,nav.tb$quarter>dmy("30-6-1986")))
dtlist <- subset(dtlist, month(dtlist) %in% c(3,6,9,12))

#index is a container for storing the returns
index <- c()
windex <- c()
uindex <- c()
aindex <- c()
laindex <- c()
ix <- 0
outtb<-cbind()
dtlist<-dtlist[order(dtlist)]

for(i in 1:length(dtlist)){
  ix <- ix +1

  #Setting up the relevant computation dates and differences
  cur.qrtr <- dtlist[i]
  prev.qrtr <- (cur.qrtr + days(1)) - months(3) - days(1)
  qrt.diff <- cur.qrtr - prev.qrtr

  #Select all NAVs reported in the current and previous quarters
  cur.nav <-
subset(nav.tb,nav.tb$date==cur.qrtr)[c("fundid","date","size","grp.type", "amount")]
  prev.nav <-
subset(nav.tb,nav.tb$date==prev.qrtr)[c("fundid","date","size","grp.type","amount")]

  #Selecting funds that have reported NAVs for the current and previous quarters
  prev.cur.nav <- merge (cur.nav,prev.nav, by.x="fundid", by.y="fundid",suffixes =
c(".cur",".prev"))

  #This the mechnism for picking off cash-flows occuring between the current and
previous quarter
  cur.cf<-subset(cf.tb,(cf.tb$date<=cur.qrtr & cf.tb$date>prev.qrtr))

  #This are the necessary modificications required for modelling the Dietz return
#i.e reducing cashflows by elapsed time dt.weight is the weight of elapsed time
  dt.weight <- as.numeric(difftime(cur.qrtr,
cur.cf$date,units='days'))/as.numeric(qrt.diff)
  cur.cf <- cbind(cur.cf,dt.weight)
  w.amt <- cur.cf$amount * cur.cf$dt.weight
  cur.cf <- cbind(cur.cf,w.amt)

  #Aggregation of cashflows and NAVs by fundid. This takes
#care of the situation where one fund may have more than one
#transaction within the quarter --weighted by time
  sumw.cf <- cur.cf[,c("fundid","date","w.amt")]
  sumw.cf <- aggregate(sumw.cf$w.amt, by=list(sumw.cf$fundid),sum)
  colnames(sumw.cf) <- c("fundid","wcf.amount")

  #Aggregation of cashflows and NAVs
  sum.cf <- cur.cf[,c("fundid","date","amount")]
  sum.cf <- aggregate(sum.cf$amount, by=list(sum.cf$fundid),sum)
  colnames(sum.cf) <- c("fundid","cf.amount")

  #All cashflows by fundid are bound into a single data.frame
```

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```
cf <- cbind(sum.cf, sumw.cf$wcf.amount)
colnames(cf) <- c("fundid","cf.amount","wcf.amount" )

#This then puts everything into one data.fram where it could be viewed and analyzed
cf.nav <- merge (prev.cur.nav,cf,
                by.x="fundid", by.y="fundid",
                suffixes = c(".nav",".cf"),all.x=TRUE,all.y=FALSE)

#The next couple of lines replace #NAs with zeros
cf.nav$cf.amount[is.na(cf.nav$cf.amount)]<-0
cf.nav$wcf.amount[is.na(cf.nav$wcf.amount)]<-0

#Apparently, these cashflow amounts are not numbers!
cf.nav$amount.cur <- as.numeric(as.character(cf.nav$amount.cur))
cf.nav$amount.prev <- as.numeric(as.character(cf.nav$amount.prev))
cf.nav$cf.amount <- as.numeric(as.character(cf.nav$cf.amount))
cf.nav$wcf.amount <- as.numeric(as.character(cf.nav$wcf.amount))
cf.nav$size.cur <- as.numeric(as.character(cf.nav$size.cur))

#Adjustment
cf.nav$size.cur[is.na(cf.nav$size.cur)]<-0

#Weighting cashflows and NAVs
cur.navw <- cf.nav$amount.cur * cf.nav$size.cur/10
prev.navw <- cf.nav$amount.prev * cf.nav$size.cur/10
cf.amountw <- cf.nav$cf.amount* cf.nav$size.cur/10
wcf.amountw <- cf.nav$wcf.amount* cf.nav$size.cur/10

#Putting it all together
cf.nav<-cbind(cf.nav,cur.navw,prev.navw, cf.amountw, wcf.amountw)

#Fund-level modified Dietz returns
dietz <- (cf.nav$amount.cur - cf.nav$amount.prev +
cf.nav$cf.amount)/(cf.nav$amount.prev -cf.nav$wcf.amount )
#Bind fund-level Dietz returns with cashflow and NAV values
cf.nav <- cbind(cf.nav, dietz)

#Fund-level weighted modified Dietz returns
wdietz <- (cur.navw - prev.navw + cf.amountw)/(prev.navw -wcf.amountw)
#Bind fund-level weighted modified Dietz returns with cashflow and NAV values
cf.nav <- cbind(cf.nav, wdietz)

#An alternative index
call<- subset(cf.amountw,cf.amountw<0)
dist<- subset(cf.amountw,cf.amountw>0)
laindex[ix] <-log(sum(dist)/sum(abs(call)))
aindex[ix] <- (sum(dist)/sum(abs(call)))

#Aggregate for entire quarter -----Equal-weight
curnav <- sum(cf.nav$amount.cur)
prevnav <- sum(cf.nav$amount.prev)
curcf <- sum (cf.nav$cf.amount)
modcurcf <- sum(cf.nav$wcf.amount)
index[ix] <- (curnav - prevnav + curcf)/(prevnav - modcurcf)

#Aggregate for entire quarter -----Capital-weighted
curnavw <- sum(cf.nav$cur.navw)
prevnavw <- sum(cf.nav$prev.navw)
curcfw <- sum (cf.nav$cf.amountw)
modcurcfw <- sum(cf.nav$wcf.amountw)
windex[ix] <- (curnavw - prevnavw + curcfw)/(prevnavw - modcurcfw)
obs<-length(cur.navw[cur.navw>0])
#-----Vanilla
uindex[ix] <- (curnav - prevnav)/(prevnav)
out<- data.frame(cur.qrtr,curnavw, prevnavw, curcfw,modcurcfw,obs,
                uindex[ix],
                index[ix],
                windex[ix],
                aindex[ix],
                laindex[ix])
outtb <- rbind(outtb,out)
}
```

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```
index_value<-100*cumprod(windex+1)
outtb<-cbind(outtb,index_value)
write.csv(outtb[order(outtb$cur.qrtr),], file="indices.csv")

#Distribution
returns <- windex
returns <-returns[!is.infinite(returns)]
returns <-returns[!is.na(returns)]
weighted.index <- returns
plot(density(weighted.index, kernel = "gaussian"),
     col = rgb(0,157,219,max=255),
     lwd=2,
     main="Alternative Index")
lines(seq(from = min(weighted.index)*1.2,
          to = max(weighted.index)*1.2, by = 0.01),
      dnorm(seq(from = min(weighted.index)*1.2,
                to = max(weighted.index)*1.2, by = 0.01),
            mean = mean(weighted.index), sd = sd(weighted.index)),
      col = rgb(0,52,121,max=255), lwd=2, type = "l")
legend(x="topleft",legend = c("weighted.density","normal"),
      lwd = 2, col = c(rgb(0,157,219,max = 255),
                      rgb(0,52,121,max=255)),
      bty= "n", lty = c(1,2))

#Autocorrelation ARMA model - AR(1)
require(tseries)
weighted.ar <- arma(weighted.index, c(1,0))
summary(weighted.ar) #obtain the coefficients
plot(acf(weighted.index), type = "h", col=rgb(0,157,219,max=255),lwd=2)
plot(acf(na.omit(weighted.ar$residuals)), type = "h", col=rgb(0,52,121,max=255),lwd=2)

vars<-c()
require(SuppDists)
require(evd)

annual.index <- read.csv('annual.csv') #load the annual changes to the Index
plot(density(annual.index[,1], kernel = "gaussian"), col = rgb(0,157,219,max=255),
     lwd=2,xlim=c(- 1,1))
lines(seq(-1,1,0.01),dnorm(seq(-1,1,0.01),mean(annual.index[,1]),sd(annual.index[,1])),col
= rgb(0,52,121,max=255), lwd=2, type = "l",lty=2)
legend(x="topleft",legend = c("weighted.density","normal"), lwd = 2, col =
c(rgb(0,157,219,max = 255),rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))
qnorm(0.005,mean=mean(annual.index[,1]), sd=sd(annual.index[,1]))

fgev(annual.index[,1]) #return the coefficients of the GEV fitting
gev.fit <- fgev(annual.index[,1])
plot(density(annual.index[,1], kernel = "gaussian"), col = rgb(0,157,219,max=255),
     lwd=2,xlim=c(- 1,1))
lines(seq(-1,1,0.01),dgev(seq(-1,1,0.01), gev.fit$estimate["loc"],
gev.fit$estimate["scale"], gev.fit$estimate["shape"]), col = rgb(0,52,121,max = 255),
lwd=2, lty=2)
legend(x="topleft",legend = c("weighted.density","gev"), lwd = 2, col = c(rgb(0,157,219,max
= 255),rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))
qgev(0.005, gev.fit$estimate["loc"], gev.fit$estimate["scale"], gev.fit$estimate["shape"])

parms <- JohnsonFit (annual.index[,1], moment = 'find')
plot(density(annual.index[,1], kernel = "gaussian"), col = rgb(0,157,219,max=255),
     lwd=2,xlim=c(- 1,1))
plot(function(x)dJohnson(x,parms),-1,1,add=TRUE, col = rgb(0,52,121,max=255),lwd=2, lty=2)
legend(x="topleft",legend = c("weighted.density","johnson"), lwd = 2, col =
c(rgb(0,157,219,max = 255),rgb(0,52,121,max=255)), bty= "n", lty = c(1,2))
qJohnson(0.005,parms)
```



9 Glossary

Autocorrelation	<p>The likelihood that a future value is based upon a previous value. In private equity in particular, prices are “sticky” due to illiquidity and appraisal, and thus any change in value may happen over a long period. It is thus possible to predict part of future values knowing historical relationships.</p> <p>While this is very useful for modelling, it causes difficulties when estimating correlation given that a change in the market (which naturally cannot display autocorrelation for any meaningful period without it being traded away) in one period may have an effect on multiple periods in private equity.</p>
Correlation	<p>Universally in this document refers to the Pearson product-moment correlation coefficient. For any two sets of data x and y with a standard deviation σ, the correlation is given as</p> $\rho_{(x,y)} = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sigma_x \sigma_y}$ <p>-1 indicates a perfect negative correlation, 1 a perfect positive correlation and 0 no correlation.</p>
Kurtosis	<p>The “peakedness” or variation from a curve of a distribution. High kurtosis often indicates fat tails where extreme gains or losses are more likely than a normal distribution.</p>
MSCI World or MSCI	<p>The Gross Dividend Total Return MSCI World Developed Index. Bloomberg code: GDDUWI Index.</p>
Moment	<p>Moments describe the shape of a distribution. Each successive moment is the integral of the previous moment. In order, the moments are mean, variance (or sometimes standard deviation), skewness and kurtosis. While these four do not exactly describe any possible curve they enable good approximation with a fitting algorithm.</p>
Noise	<p>In the sense used in this paper, “noise” is taken to mean the residuals from an autocorrelation model; essentially the part of any series of data that cannot be predicted.</p>
Normal distribution	<p>This is a distribution of values which follows a fixed natural pattern whereby observations near the mean are very likely, and successively less likely the further away from the mean the observation is. Normal</p>

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distributions do not exhibit skewness or kurtosis.

R ²	The absolute accuracy of a model. Given as the square of correlation for two-factor models. 0 indicates no model accuracy and 1 indicates perfect model accuracy.
Skew or Skewness	For a given probability curve, the direction and magnitude of any lean in the curve away from the mean. For example, a right (or positive)-skewed type of investment means that returns tend to lie towards the higher end of the mean. A lottery-type investment would be deeply left (or negative)-skewed.
Stdev or Standard Deviation	The average amount by which each observation in a dataset deviates from the mean.
Variance	The mean of the squared deviations from the mean (and thus equal to the square of the standard deviation). This variable is the second moment of a distribution and often used to describe scale parameters.

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The European Private Equity and Venture Capital Association is the voice of European private equity and venture capital, representing more than 1,300 members. In addition to promoting the industry among key stakeholders, such as institutional investors, entrepreneurs and employee representatives, EVCA develops professional standards, research reports and holds professional training and networking events.