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Pricing of Listed Private Equity

—

Risk and Return, Net Asset Values, and Loss Aversion

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Abstract

Studies of private equity often face difficulties caused by the lack of readily available market data. This thesis aims to answer research questions related to the pricing of private equity vehicles by examining an international sample of 509 listed private equity (LPE) vehicles.

The first part of this thesis investigates the stock performance of listed private equity in a sample of 274 liquid vehicles. Listed private equity shows an aggregate Dimson beta of 1.7 without any significant excess return. Market risk is high in internally managed vehicles but low in externally managed ones, which I attribute to different sources of cash flow such as management fees and carried interest. Aggregate market risk varies strongly over time, which should be incorporated into valuation and portfolio allocation processes by long-term private equity investors.

The second part examines determinants and consequences of net asset value discounts in listed private equity funds. LPE funds start at an initial premium of –2.5 % and adapt to the long-term average of –21 % after two years. Fund returns display a U-shaped seasonality, which can be partly explained by abnormal returns after the publication of annual reports. Premia predict future returns and are explained by investor sentiment and liquidity. I find little evidence in support of the managerial ability hypothesis. Premia also seem to depend on credit markets and systematic risk, which suggests that some information about the fund's portfolio is not reflected in net asset values.

The third part measures the quality of net asset values in listed private equity vehicles. I develop a procedure to detect earnings management that is characterized by discontinuities in distributions of standardized earnings and changes of net asset values. Results indicate that findings of loss aversion in reported earnings are rather sensitive to the denominator chosen to standardize earnings. Net asset value returns do not show any significant discontinuity. This is surprising, since private equity funds have substantial leeway when determining net asset values due to the nontransparent nature of their portfolio.

Keywords: Listed private equity, net asset value discount, earnings management

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List of Abbreviations

Abbreviation	Definition
AIM	Alternative investment market
BAS	Bid-ask spread
BD	Burgstahler and Dichev
BDC	Business development company
Bimbo	Buy-in and management buyout
CAPM	Capital Asset Pricing Model
CDF	Cumulative distribution function
DPI	Distribution to paid-in ratio
ECDF	Empirical cumulative distribution function
EPS	Earnings per share
EUR	Euro
EVCA	European Private Equity and Venture Capital Association
GBP	British Pound
GLS	Generalized least squares
GMM	Generalized method of moments
GP	General partner
IBO	Institutional buyout
ICB	Industry classification benchmark
IKDE	Integrated Kernel Density Estimate

Continued on next page

List of abbreviations – continued from previous page

Abbreviation	Definition
IPO	Initial public offering
IRR	Internal rate of return
JPY	Japanese Yen
KDE	Kernel density estimate
KS	Kolmogorov-Smirnov
LP	Limited partner
LPA	Limited partnership agreement
LPE	Listed private equity
MBI	Management buy-in
MBO	Management buyout
MTM	Markov transition matrix
NAV	Net asset value
PDF	Probability density function
PE	Private equity
PIPE	Private investment in public companies
PME	Public market equivalent
PTPE	Publicly traded private equity
SBIC	Small business investment company
SIC	Standard industry classification
SPAC	Special purpose acquisition company
SR	Sharpe ratio
STAC	Structured trust acquisition company
TVPI	Total value to paid-in ratio
USD	United States Dollar
VC	Venture capital
VCT	Venture capital trust

Chapter 1

Introduction

Along with the rapid growth of private equity (PE) as an asset class, there has been an increasing demand for accurate information on prices of fund shares and corresponding risk and return measures. Portfolio allocation considerations played a major role in the rise of private equity. Investors were flocking to private equity mostly in an attempt to collect excess returns that were believed to be generated by the superior governance structure of private equity investments. In addition, investors often hold private equity to benefit from an assumed low correlation with public equity markets. Private equity firms have raised more than USD 3.9 trillion worldwide for over 14 000 funds since the first boom in the 1980s.[1] This supply of capital led to ever-increasing fund and deal sizes, which peaked in 2006 and 2007 with the acquisition of the Equity Office Properties Trust by the Blackstone Group (transaction value was USD 38.8 billion) and the Hospital Corp. of America by a consortium of Kohlberg Kravis Roberts, Bain Capital, and Merrill Lynch (for USD 32.6 billion). These transactions even surpassed KKR's RJR Nabisco deal (USD 31.1 billion) in 1989.[2]

These claims of excess returns and low correlations with established asset classes call for a thorough empirical investigation. Consequently, several authors tried to

[1] See chapter 2 for more information on the private equity market.
[2] Fundraising and deal information is from Thomson VentureXpert.

estimate risk and return characteristics from private equity data.[3] These objectives have proven difficult to attain, since market prices for traditional PE funds — and therefore market returns from which to estimate model parameters — are usually unavailable. Most studies have resorted to obtaining return data from fund cash flows and changes in net asset values. This introduces additional uncertainties, in particular with regard to the quality and timeliness of book values. Internal rates of return (IRRs) that are reported by fund managers can hardly serve as an economically sound performance measure and are useless when trying to solve asset allocation problems. Due to these empirical challenges, findings range from considerable excess returns in the early literature to even negative excess returns net of fees in more recent studies.[4] Moreover, an economic understanding of what is driving cross-sectional and time-series risk and return properties of private equity funds is needed.

Establishing a market price is necessary not only for performance measurement and portfolio allocation, but also when shares in PE funds are to be sold. Investors may not want or might not be able to hold private equity assets until maturity. The volume of transactions involving the transfer of fund shares between investors (secondaries) has surged since 2004 and selling pressure has intensified during the recent financial crisis. As a result, funds specializing in the secondary market that were raised during the financial crisis reached considerable sizes. Goldman Sachs closed its GS Vintage Fund V at USD 5.5 billion in April 2009[5] and Lexington Capital Partners raised USD 3.1 billion for their seventh fund in March 2010.[6]

To arrive at a market value for fund shares, the unlisted assets on the fund's balance sheet can be used as a source of information. If pairs of market price and book value can be observed for some funds, their characteristics could be used to infer market prices of other funds. This approach, however, is only feasible if book values are not biased in unpredictable ways. Since privately held assets are rather

3 See chapter 2.1.6 for an overview.
4 See, for example, Phalippou and Gottschalg (2009).
5 See Private Equity International, May 2009.
6 See Global Investor, March 2010.

opaque to fund investors, the fund management could use its degrees of freedom to inflate or otherwise manage net asset values. The pricing of fund shares by using net asset values therefore necessitates an examination of the quality of fund NAVs and earnings.

These problems in traditional PE funds caused by missing market prices can be resolved by studying traditional funds' listed counterparts. Exchange listed private equity (LPE) vehicles provide the opportunity to estimate model parameters in a straightforward way using readily available market prices. Since business models and organizational forms of LPE vehicles bear a strong resemblance to traditional PE funds and firms, results obtained from examining LPE vehicles are likely transferable. Moreover, traditional PE returns seem to be correlated with listed private equity to a higher degree than with public equity markets. Pooled periodic IRRs from Thomson VentureXpert for the period 1994–2009 show a correlation of 0.72 with quarterly MSCI World returns and 0.77 using yearly returns. Correlations with FTSE 100 returns are 0.61 and 0.78, respectively, whereas correlations with listed private equity, measured by LPX50 returns, are 0.76 and 0.87, respectively.[7]

LPE is a fairly new asset class, although first listings of publicly traded funds with a focus on private equity investments date back to the 1940s, while the first limited partnerships appeared in 1958.[8] Publicity has increased strongly over the last decade with the implementation and promotion of several large listed private equity indices, the foundation of public relations initiatives[9] and an increasing appetite for listed private equity by institutional investors[10]. Despite these developments and the opportunity to analyze characteristics of private equity that are not yet fully understood, the topic has been virtually neglected by academic research so far.[11]

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7 I use the MSCI World index in USD as a proxy for world equity markets and the FTSE 100 in USD as proxy for the U.K. equity market, since most LPE vehicles are traded at the London Stock Exchange. Periodic private equity IRRs by Thomson VentureXpert are based on U.S. portfolios in USD. See chapter 2.2.5 for a description of the LPE market and LPE indices.

8 See Phalippou (2007).

9 See chapter 2.2.5 for an overview of market participants.

10 See Cumming et al. (2010).

11 In the first and — up to this date — sole major account of listed private equity, Bilo (2002) analyzes performance, liquidity, and sample selection problems in listed private equity.

1.1 Objectives

This thesis aims to answer research questions related to the pricing of private equity vehicles by examining an international sample of listed private equity vehicles. In particular, it contributes to the literature in three main areas:

Systematic risk and return: The first part of this thesis investigates the stock performance and systematic risk of listed private equity vehicles in a sample of 274 liquid listed private equity vehicles. In order to account for the greater diversity of LPE vehicles compared to traditional private equity funds, I introduce a new classification of LPE vehicles according to their organizational structure. An international capital asset pricing model then provides systematic risk estimates for different organizational forms and time periods.

Market value and book value: The causes and consequences of net asset value discounts in listed private equity funds are the subject of the second part. The importance of listed private equity funds is that they bridge the gap between closed-end mutual funds, unlisted private equity funds and listed holding companies. Examining the applicability of related theories is thus important for explaining NAV discounts and premia.

Quality of book values: Do private equity funds manage earnings to avoid posting losses? The quality of net asset values has to be measured if market values are to be inferred from book values. I develop a method to detect discontinuities in distributions of earnings and NAV returns, which can also be applied to a wide range of research questions including and beyond earnings quality.

The basic sample used throughout this thesis contains 509 LPE vehicles as of March 2010. It consists of all vehicles found in the last complete screening as described in chapter 2.2.5.2. This sample represents the largest collection of LPE vehicles to date. Although it seems to be free of any selection bias, it is geared towards smaller British companies, which could limit the generalizability of my results. But then again, many characteristics of LPE outlined throughout this thesis indicate a strong similarity to traditional private equity funds and firms.

1.2 Structure of this thesis

Following this introduction, chapter 2 gives an overview of the private equity industry and reviews the literature that is relevant to the pricing of traditional private equity funds. If literature pertains to specific chapters only, a discussion of this literature can be found at the beginning of each chapter. In this chapter on private equity in general, I define key terms and describe the private equity business model, which plays an important role in economic considerations regarding risk factors of private equity and informational content of share prices. Listed private equity as an asset class makes up the better part of this chapter. I argue that LPE vehicles cannot be treated as a homogeneous industry but must be grouped according to their organizational forms before analyzing pricing characteristics. This chapter also gives an overview of the LPE market, which includes descriptions of predominant legal forms and of my sample of LPE vehicles, from which the subsamples used in this thesis are taken.

Chapter 3 analyzes risk and return characteristics of LPE vehicles depending on their organizational structure. Private equity returns are sometimes believed to exhibit only marginal correlation to public equity markets. I test this claim by estimating coefficients in an international capital asset pricing model for listed private equity. Because of the greater diversity of this asset class compared to traditional private equity funds, vehicles must be grouped into firms, funds, investment companies, and funds of funds before estimating their risk and return parameters. Results indicate that internally managed entities exhibit higher systematic risk than externally managed ones. Contrary to previous research, LPE vehicles do not show risk-adjusted excess returns on a value-weighted basis.

Chapter 4 investigates the stability of aggregate and individual market risk in listed private equity over time. I first measure market risk in an international capital asset pricing model using Dimson (1979) betas over a rolling window to generate a continuous set of beta observations, which describes the aggregate asset class risk over time. Second, I examine the stability of individual betas by calculating correlations of beta cross-sections and Markov transition matrices for consecutive years. I find that market risk of listed private equity is highly unstable, especially over time periods longer than two years.

Chapter 5 asks whether the ratio of LPE market prices to respective net asset values (NAVs) bears any relation to fund-specific variables or external determinants. Since market prices cannot be observed in traditional PE funds, being able to explain NAV discounts and premia could help to price unlisted fund shares. In this chapter, I review the literature on the puzzle of closed-end fund discounts and provide several private equity-related explanations for NAV discounts. After various descriptive statistics, I use NAV premia as a dependent variable in capital asset pricing model estimations. Results indicate a seasonal return pattern that can partly be explained by severe informational deficiencies in private equity funds. Premia, when used as a dependent variable in several panel regressions, are explained by investor sentiment and discount rate proxies, but much less by the managerial ability hypothesis.

Chapter 6 explores the amount of earnings management by loss aversion in listed private equity vehicles. Since fund managers have substantial degrees of freedom in determining the value of unlisted assets, the quality of net asset values is crucial when using this information for pricing purposes. I develop a procedure to test distributions of NAV returns and standardized earnings for discontinuities, which improves other methods proposed in the literature. Accounting data for German firms provides a test of this procedure, which I then apply to listed private equity. I find that LPE vehicles do not seem to avoid posting losses. Results are sensitive to the variable chosen to deflate earnings, which highlights the importance of using the right deflator.

Chapter 7 concludes the thesis. It summarizes the results of the previous chapters and provides implications for financial theory, investors in private equity and future research.

Chapter 2

Background and Data Sample

This chapter provides an overview of the markets for private equity and listed private equity. I discuss the structure and business models of private equity funds and firms and other organizational forms. Descriptions of the sample of LPE vehicles used in this study and the sample generation process make up the last part of this chapter. To make this study easily accessible, I limit the literature review in this chapter to works that provide a recurring theme throughout this thesis. Literature pertaining to specific chapters only is reviewed in these chapters.

2.1 Private equity

2.1.1 Definition

Historically, the definition of *private equity* and *venture capital* differed substantially between Europe and the United States due to the different historical development of this asset class.[1] Private equity can stand for the underlying assets, a strategy which aims at investing in those assets, or the asset class covering all different kinds

[1] See Kaserer et al. (2007, p. 13); Berg (2005, p. 11). Sometimes the term *venture capital* is used instead of *private equity* to refer to the asset class, as in Coyle (2000, p. 2): "In broad terms, venture capital is an investment, usually in small private companies to finance their start-up, expansion, survival or change of ownership. However, venture capital is occasionally invested in large companies to support a management buyout or buy-in."

of this strategy.[2]

Today, most academic researchers and industry experts use a common terminology with some disagreement regarding the classification of special business models and organizational arrangements. Lerner et al. (2009, p. 1) define private equity funds as “partnerships specializing in venture capital, leveraged buyouts, mezzanine investments, build-ups, distressed debt, and related investments”. According to the European Private Equity and Venture Capital Association (EVCA), “private equity provides equity capital to enterprises not quoted on a stock market. Private equity can be used to develop new products and technologies (also called venture capital), to expand working capital, to make acquisitions, or to strengthen a company’s balance sheet. It can also resolve ownership and management issues. A succession in family-owned companies, or the buyout and buy-in of a business by experienced managers may be achieved by using private equity funding.”[3] The Private Equity Council — an organization established by leading private equity firms[4] — defines the term *private equity* as referring to “a range of investments that are not freely tradable on public stock markets. Private equity firms raise money for two types of funds: venture capital funds and buyout/growth funds, although in recent years, the distinction between venture capital and buyout/growth funds has blurred...”[5]

Private equity in the context of this thesis is defined as professionally managed equity investments[6] in securities of non-public companies.[7] In the relationship between investors and portfolio companies (arranged by the fund and its management),

2 See Ibbotson Associates (2007, p. 4).

3 See http://www.evca.eu/toolbox/glossary.aspx?id=982 (accessed 2010-03-17).

4 Apax Partners; Apollo Global Management LLC; Bain Capital Partners; The Blackstone Group; The Carlyle Group; Hellman & Friedman LLC; Kohlberg Kravis Roberts & Co.; Madison Dearborn Partners; Permira; Providence Equity Partners; Silver Lake; and TPG Capital (formerly Texas Pacific Group).

5 See http://www.privateequitycouncil.org/just-the-facts/private-equity-frequently-asked-questions/ (accessed 2010-03-17).

6 See Fenn et al. (1995, p. 2); Sahlman (1990, p. 1); Bilo (2002, p. 8); Bance (2004, p. 2); Private equity investors can be regarded as financial investors, who invest for financial motives only (contrary to strategic investors, who might be interested in products, markets, etc. See Achleitner (2002).

7 Equity investments may be understood as any form of security that has an equity participation feature, e. g. common stock, convertible preferred stock and subordinated debt with conversion privileges or warrants.

the attribute *private* can refer to the origin of funds or their destination. Following the extant literature, I require the underlying assets to be non-public. However, in some cases public companies are taken private when receiving private equity financing in so-called *going privates* or *take-private transactions*.[8] These investments would be regarded as private equity investments from the date they are no longer publicly traded. Private investments in public companies (PIPEs), which sometimes are made by private equity funds, are characterized by private investors, but public assets.[9] The definition of private equity from an asset perspective in the sense of this thesis excludes these transactions, for otherwise private investors owning stock in public corporations would be regarded as private equity investors. In order to be distinguished from ordinary holding companies, I require private equity vehicles to follow the private equity business model, which includes the objective of exiting portfolio investments after some holding period.

2.1.2 Stages of investment

Private equity comprises several sub-categories defined by the portfolio investments' life-cycle stages shown in figure 2.1. As Temple (1999, p. 1) notes, "management buy-outs and buy-ins, venture capital and other forms of 'private equity' investment often hit the headlines. Private equity, a generic term for all these variants, is equivalent to buying a stake in a private company, with all the risk (and potential rewards) that this implies."

The two main strategies that can be distinguished are venture capital and buyouts with a third category being investments in special situations.[10]

Venture capital can be defined as "professional equity co-invested with the entrepreneur to fund an early-stage (seed and start-up) or expansion venture."[11] Gom-

8 See Bilo (2002, p. 9); Sahlman (1990, p. 473); Diller (2006, p. 24).

9 Hedge funds, which also invest in public companies but are privately held themselves, are excluded as well. For a discussion of private equity and hedge funds, see Achleitner and Kaserer (2005).

10 See, for example, Kaserer et al. (2007, p. 14); Coyle (2000, p. 5); Fenn et al. (1997, p. 28); Fenn et al. (1995, p. 3–5); Wright and Robbie (1998, p. 522).

11 See http://www.evca.eu/toolbox/glossary.aspx?id=982 (accessed 2010-03-17)

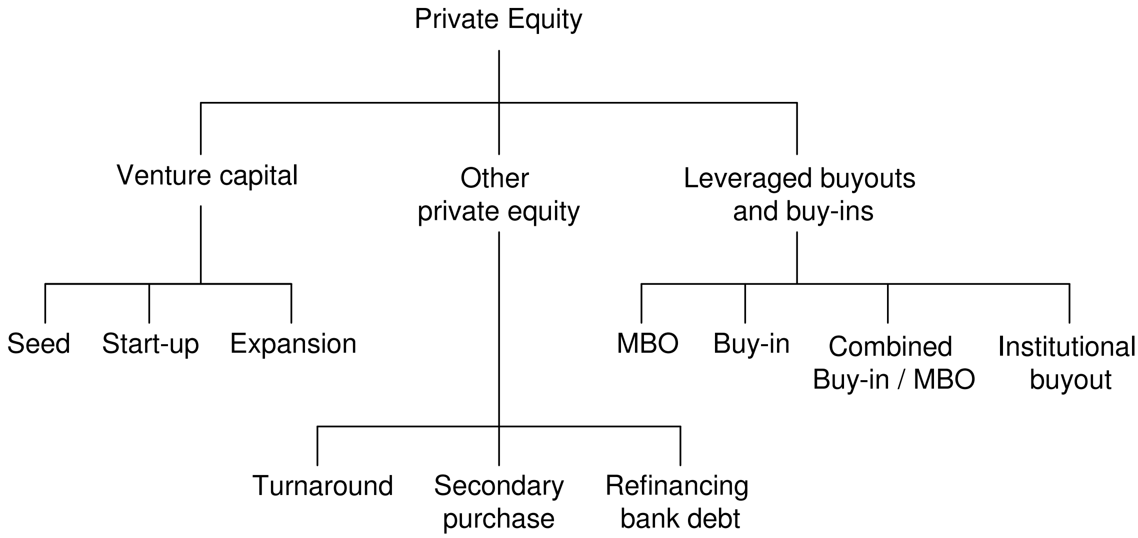

Figure 2.1: Stages of private equity investments
Source: Adapted from Coyle (2000, p. 5), Kaserer et al. (2007, p. 14), and Fenn et al. (1997, p. 28).

pers and Lerner (2001, p. 145) define the core part of venture capital as "dedicated pools of capital which are managed by independent PE firms and focus on equity or equity-linked investments in privately held, high growth companies."[12] According to Schell (2006, §1.03[1]), "venture capital investing involves the provision of capital to business enterprises in the early stages of the development of new products or services."

According to the stage of development that a company has reached at the time it needs financing, venture capital is further divided into subcategories:[13]

- Seed stage: Seed capital refers to the provision of mostly mezzanine capital (e. g. convertible preferred stock) to a company which has not been established yet. For example, seed capital is often provided before a product-based business can be set up to fund a lengthy period of research and development (R&D), converting the business concept into a product.

- Start-up stage: This type of financing could be provided to a company in the

[12] See also Gompers and Lerner (2004, p. 17).
[13] See Coyle (2000, pp. 5–8).

process of setting up or at some point in its life-cycle where its product or service has not yet been sold commercially. The product or service exists, and no additional R&D expenditure is needed before the company becomes operational. Seed and start-up stages are often referred to as early stages, which can also include funding of initial marketing, manufacturing and sales activities. Companies in this stage will not yet be making a profit, and cannot finance their development out of operational cash flows.

- Expansion stage: Capital is provided for the first expansion of a company, which is already producing and selling is product. Growth in inventory and accounts receivable, increasing manufacturing capacity or development of marketing channels require additional funding. The distinction between expansion stage venture capital and late stage private equity is not always easy to draw. If management changes during the expansion period or the capital structure is reorganized, venture capital financing and late-stage private equity / special situations can overlap considerably.

Buyouts can be defined as "the purchase of a controlling interest in a company from its owners."[14] The term buyout refers to the acquisition of a business by a management team or group of employees with private equity or bank support. Buyouts include management buyouts (MBOs), management buy-ins (MBIs), MBOs and buy-ins combined (Bimbos), and institutional buyouts (IBOs). A management buy-in is the purchase of an existing company or a business unit by an external management team, with financing provided by private equity funds. Institutional buyouts refer to the process when a vendor decides to sell a business in a controlled auction, seeking competitive bids for the company by a limited number of equally informed bidders. Because a substantial part of the purchase price in buyouts is financed by debt in the form of bank loans, corporate bonds, or loans from private equity funds, these transactions may be called leveraged buyouts.[15]

[14] See Coyle (2000, p. 34).

[15] For these and related definitions, see also Temple (1999, pp. 12–14).

Private equity can be the preferred way to finance a company in several situations that may occur during the company's life. If a company has been in decline, additional turnaround capital might be required to develop plans for halting the decline and staging a recovery. An established company that is excessively financed by bank debt, which might reach maturity, can choose to take on private equity to repay the banks. A secondary purchase comes about if existing shares in a company are purchased by one private equity funds from another, or from another shareholder or shareholders in the company. This type of financing does not provide additional capital to the company concerned.[16]

2.1.3 Structure and key terms

Venture capital and buyout funds invest the investor's money for the long term, usually ten years and longer. To govern these investments, complex contracts have been developed.[17] Private equity entities act as intermediaries between investors and portfolio companies — the issuers of equity — that seek to raise capital (see figure 2.2).[18]

A typical private equity fund is organized as a limited partnership with a limited life of about ten years, and most U.S. private equity limited partnerships are established under the laws of the State of Delaware.[19] The most comprehensive and concise description of the legal and economic relations within such a fund structure is given by Schell (2006, §1.01):

The fund is initiated by one or more key individuals (the "Principals") and has, in some cases, the support and resources of an existing financial institution (the "Sponsor"). The principals would ordinarily organize and own an entity, often a limited liability company, to serve as general partner of the fund (the "General Partner"). The principals would in many cases also organize a second entity, often a

16 See Coyle (2000, p. 7).
17 See Lerner et al. (2009, 72–74).
18 See Fenn et al. (1997, p. 6); Burgel (2000, p. 14)
19 See Lerner et al. (2009, p. 72–74); Schell (2006, §1.01); Gompers and Lerner (2004); Fenn et al. (1995).

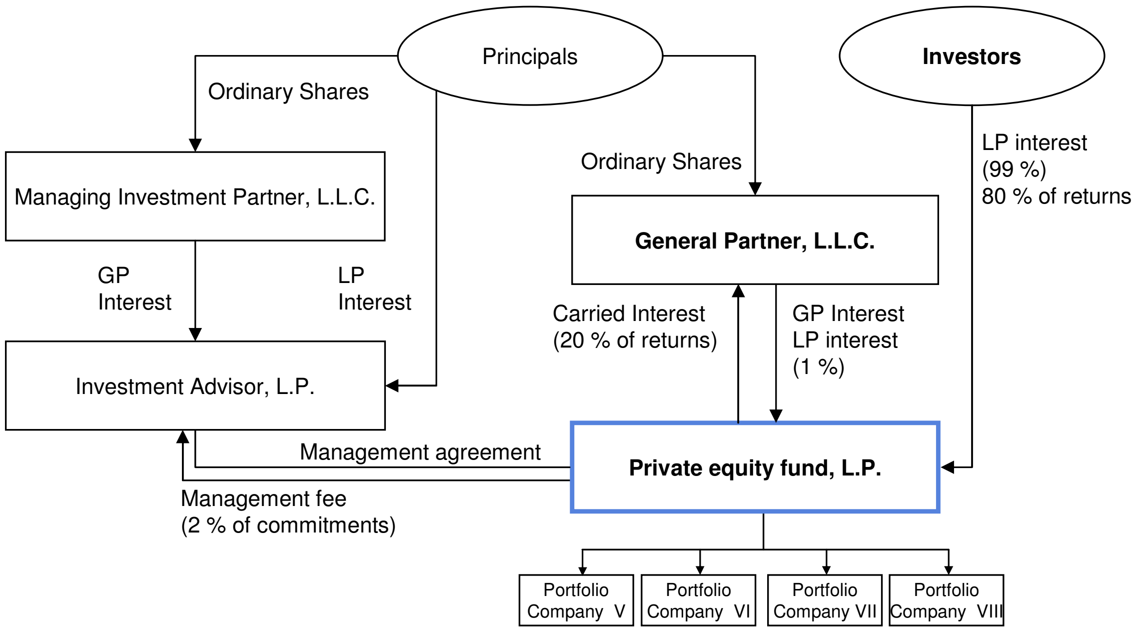

Figure 2.2: Structure of a typical private equity fund
Source: Based on Schell (2006, §1.01).

limited liability company, to serve as the manager or investment adviser to the fund (the "Manager" or the "Investment Advisor").

Investors would subscribe for interests in and become limited partners ("Limited Partners") of the fund. Under the terms of the fund's partnership agreement, the general partner and the investors would each have commitments ("Capital Commitments") to make capital contributions ("Capital Contributions") in specified maximum amounts to the fund.[20] Capital contributions would be used by the fund, under the exclusive control of the general partner, to pay specified expenses of the fund and to make investments ("Portfolio Investments") in a manner consistent with the investment strategy or guidelines established for the fund (the "Investment Guidelines").

The manager would be responsible under the terms of an investment advisory or management agreement (the "Management Agreement") for identifying and evaluat-

[20] The general partners usually contribute a very small proportion of the fund's capital, usually 1 %, which was a legal requirement until the 1986 U.S. Tax Reform Act. See Lerner et al. (2009, p. 73).

ing prospective portfolio investments, monitoring portfolio investments on behalf of the fund and devising and recommending sales or other exit strategies.[21] PE managers typically become members of the board of directors in the companies they are funding and retain important economic rights in addition to their ownership rights.[22] Ultimate authority as to the purchase or sale of portfolio investments would, however, remain with the general partner. In return for its services, the manager would be paid by the fund or the limited partners an annual fee (the “Management Fee”), typically 2 %. The management fee would be expected to cover salaries for the principals and other ordinary and recurring operating costs (“Management Expenses”).[23] The fund’s objective is to generate returns for its investors through capital gains that are realized when exiting a portfolio investment, which is typically already planned for at the time of the initial investment.[24] Holding periods usually range between five and seven years.

Profits generated by the fund would ordinarily be divided according to a formula which provides the general partner with a share (typically 20 %) of the profits (the “Carried Interest”) attributable to the investors’ capital contributions. In many cases, the investors would be entitled to receive a specified return on all or a portion of their capital contributions before the general partner receives distributions of carried interest. In many cases where investors are provided a preferential return, the general partner is thereafter entitled to receive a share of incremental profits which exceeds the carried interest percentage until, on a cumulative basis, the general partner has received the carried interest percentage of total profits. An arrangement of this kind is sometimes referred to as a “General Partner Make-up.” A preferential return to investors coupled with a general partner make-up is referred to as a “Preferred Return” or a “Hurdle Rate.” In cases where early portfolio investments are profitably sold but later ones are not, an obligation by the general

[21] See Wright and Robbie (1998, p. 525); Fenn et al. (1995, p. 2); Bilo (2002, p. 9).

[22] See Sahlman (1990, p. 473); Ibbotson Associates (2007, p. 4).

[23] In many cases, PE funds acquire majority ownership stakes in portfolio companies, which grant them control rights and provide considerable influence on key management decision within those companies. See Fenn et al. (1997, p. 2); Bader (1996, p. 11).

[24] See Müller (2007, p. 11); Bance (2004, p. 12); Bilo (2002, p. 8); Levin (2002, p. 102).

partner (the “Clawback”) is used to restore to the fund all or a portion of the carried interest distributions previously received by the general partner so that cumulative distributions are consistent with the profit sharing formula.

2.1.4 Investment process

The process of PE financing from the fund’s (principal’s) point of view can be divided into four stages (Gompers and Lerner, 2004, p. 3):

(1) The venture capital cycle[25] starts with the principals structuring a new fund, marketing to investors, raising capital and setting up the fund. In this stage, the fund’s legal structure, investment guidelines and profit sharing formula are fixed in a partnership agreement. Investors make capital commitments to the fund until a predetermined fund size is reached. (2) The investment stage includes deal screening, valuation and due diligence, deal approval and structuring as well as post-investment monitoring and value creation. At the beginning of the investment process it is crucial to obtain access to viable projects which can be funded at entry prices that will allow value generation to generate target rates of return. Many academic studies relate to agency problems and value drivers in deal generation and post-transaction monitoring in this phase.[26] (3) During the exit stage, the fund exits successful portfolio investments and returns capital to its investors. Successful exits are critical to ensuring attractive returns for investors and to marketing follow-up funds. The venture cycle renews itself with the principals raising additional funds.

The PE business model with its essential parties involved in the investment cycle is shown in figure 2.3. The PE fund’s objective is to realize capital gains from successful portfolio investments. Dividends paid to the fund through portfolio company recapitalizations are quite common in buyout funds. Portfolio companies are held

[25] Gompers and Lerner (2004) call it the *venture capital* cycle. It applies equally well to private equity in general; see chapter 2.1.1 for a definition of private equity and venture capital. Life-cycle stages are defined similarly by Wright and Robbie (1998, p. 535) and Coyle (2000, p. 46).

[26] For an overview, see Berg and Gottschalg (2005) and Achleitner et al. (2009).

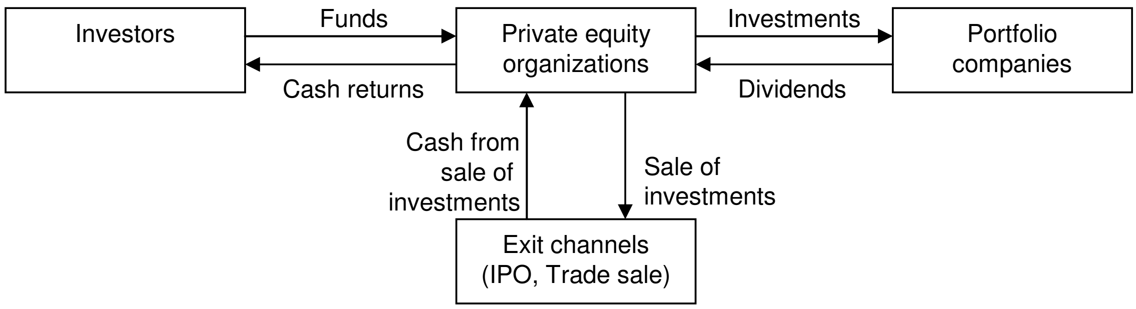

Figure 2.3: Private equity business model
Source: Adapted from Coyle (2000, p. 15)

for 5-10 years in venture funds and 3-7 years in buyout funds[27], although holding periods vary considerably depending on the type of investment. Exits typically occur through initial public offerings, sales to strategic buyers (trade sale) or sales to private equity funds managed by the same or another PE group (secondary sale).

2.1.5 The market for private equity

According to Thomson Financial, 5 640 private equity firms exist with capital under management larger USD 10 million as of 2009. They manage USD 600 million on average, while the median is at USD 98 m. The largest private equity houses are The Carlyle Group with USD 92 billion and The Blackstone Group with USD 60 billion under management. There are, however, only about 50 firms having more than USD 10 billion of capital under management.

Firms raised an impressive USD 3.9 trillion worldwide until 2009 in 14 695 funds, if funds with committed capital larger than USD 10 million are considered. The average fund has a size of USD 265 million (median at USD 87.5 million). The largest funds raised to date are GS Capital Partners VI and GS Mezzanine Partners V with USD 20 billion committed capital each. Buyout funds are usually much larger than venture capital or mezzanine funds and dominate aggregate fundraising in most years.

The venture capital cycles consists of three main phases: fundraising, investment

[27] See Coyle (2000, p. 10).

in portfolio companies, and exit of investments. According to this distinction, market data is available from a number of national and international industry organizations and specialized data providers.[28] I focus on aggregate international data, since my listed private equity sample has a global scope.

2.1.5.1 Fundraising

At USD 29 billion in the last quarter of 2009, fundraising by private equity firms was at the lowest level since early 2004. The largest funds were the Clayton, Dubilier & Rice Fund VIII (USD 5 billion) and Onex Partners III (USD 4.3 billion). Buyout and distressed debt funds collected most of the total committed capital. Distressed debt funds raised a total of USD 23 billion in 2008, which surpasses the previous peak of USD 9.3 billion in 2003.

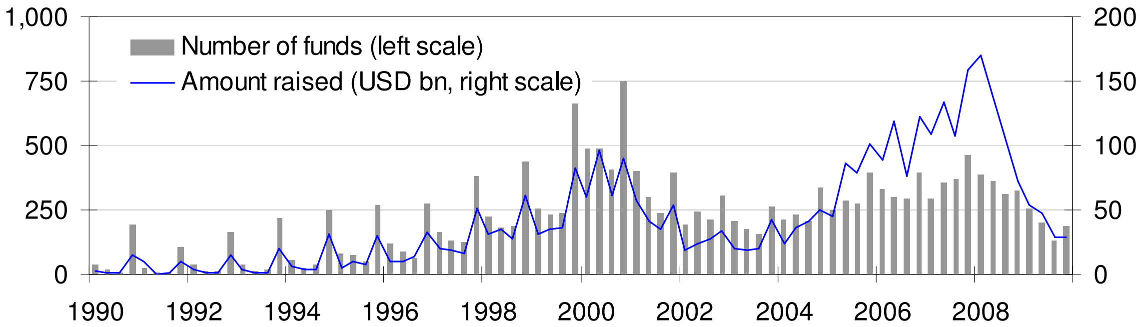

Figure 2.4: Fundraising of private equity funds worldwide
Numbers and volume are on a quarterly basis. Source: Thomson Financial.

Private equity fundraising activity is similar to the number of listed private equity vehicles going public (see chapter 2.2.5). Figure 2.4 reveals two peaks in fundraising activity. The number of funds raised and total fund size both exhibit a cyclicality similar to listed vehicle IPOs and the overall economic climate. It is therefore

[28] For example, market data can be obtained from the National Venture Capital Association (NVCA), the European Private Equity & Venture Capital Association (EVCA), the British Private Equity & Venture Capital Association (BVCA), the German Private Equity & Venture Capital Association (BVK), or the French Private Equity Association (AFIC). Independent data providers include Thomson VentureXpert, Dow Jones VentureSource, Cepres, Preqin, PriceWaterhouseCoopers, Standard & Poor's, and Ernst & Young.

tempting to use fundraising volume as an indicator for investor sentiment[29] and for the demand for private equity investments, which could drive up prices[30]. I examine the relation between fund commitments and pricing of listed funds in chapter 5.

2.1.5.2 Investments

Investments in portfolio companies shown in figure 2.5 exhibit a pattern over time similar to the fundraising volume. In times of large market movements, however, both the number and volume of deals show less volatility than fundraising variables. The number of portfolio investments, for instance, had been almost flat since 2001 before it dropped to the lowest level since 1998 due to the financial crisis in 2009. Contrary to fundraising, investment trends point upward again, possibly because of portfolio restructuring by private equity funds.

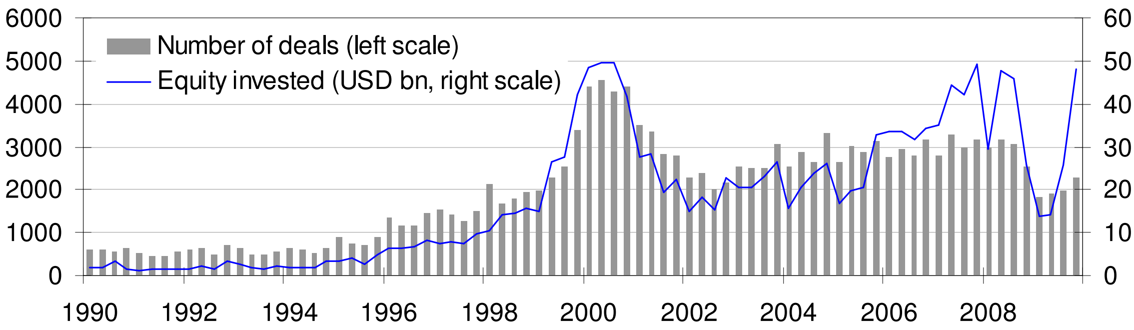

Figure 2.5: Investments by private equity funds worldwide
Numbers and volume are on a quarterly basis. Source: Thomson Financial.

Portfolio net asset values of private equity funds, which result from investments and disinvestments, peaked in 2008 for the U.S. at USD 391 billion and in 2007 for Europe at EUR 120 billion. Since then, the drop in net asset values has not been nearly as dramatic in private equity funds as it has been in equity markets. PE funds reported net asset values of USD 382 billion in the U.S. and EUR 104 billion in Europe as of September 2009. Listed PE funds experienced a decrease in net asset values similar to traditional PE funds, but a strong decline in market values

29 See, for example, Baker and Wurgler (2006).
30 See Kaserer and Diller (2009) and Gompers and Lerner (2000).

similar to stock indices. Chapter 5 takes a closer look at patterns of co-movements between market prices and net asset values.

Net asset value growth rates since the 1990s have been impressive 13 % per year in the U.S. and 15 % in Europe. Some caution must be exercised, however, when dealing with private equity data from different sources, which usually disagree to some extent.[31]. VentureXpert data is sometimes believed to be slightly biased in favor of larger funds, which could be part of the reason for the large difference between portfolio volume documented by VentureXpert (e. g. EUR 120 billion in Europe 2007) and by PEREP_Analytics (EUR 258 billion)[32], which gathers data on behalf of European private equity associations.

2.1.5.3 Exits

The private equity business model largely depends on the availability of opportunities to sell portfolio companies in order to realize capital gains from investments.[33] Trends in exits through initial public offerings and direct sales follow the same pattern as fundraising and investment activity, respectively. Private equity funds sold most portfolio companies to the public during the dot-com bubble and less during recent years. The IPO channel has been neglected in favor of trade sales and sales to other PE funds (i. e. secondary transactions), which can be seen from figures 2.6 and 2.7.

Mergers and acquisitions with private equity sell-side involvement remained strong even through the financial crisis. This indicates a selling pressure, which has been prevalent throughout most of the private equity industry. Distributions to investors by U.S. funds in 2009 were at the lowest level since 1994, which again confirms the hypothesis that funds were severely liquidity constrained. Since late 2009, however, IPO numbers and volume seem to pick up again after almost no activity during 2008 and 2009.

31 See Kaplan et al. (2002).
32 See EVCA Yearbook 2008, http://www.evca.eu.
33 See, for example, Wright et al. (2006) and Black and Gilson (1998).

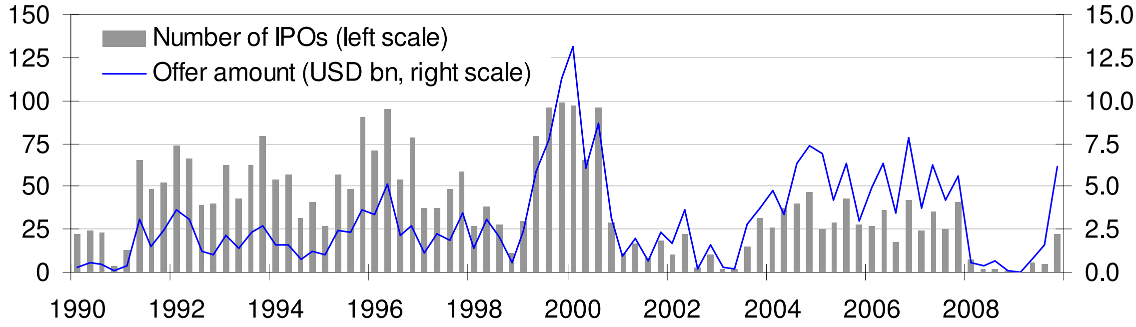

Figure 2.6: Private equity-backed IPOs worldwide
Numbers and volume are on a quarterly basis. Source: Thomson Financial.

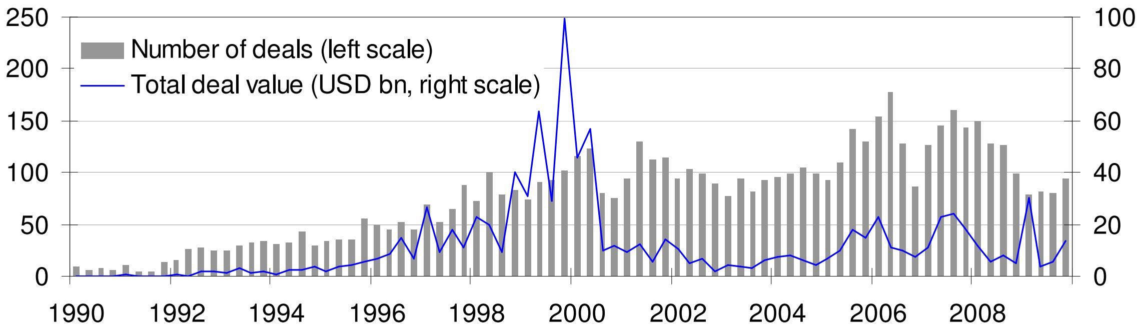

Figure 2.7: Private equity-backed M&A deals worldwide
Total deal values are based on disclosed deal values, which do not necessarily correspond to the total number of deals. Numbers and volume are on a quarterly basis. Source: Thomson Financial.

2.1.6 Returns of private equity investments

Returns and risk of private equity investments can be measured at the level of a fund's single portfolio investments, at the fund level (net or gross of fees), or for funds investing in PE funds. I discuss risk and return of listed private equity vehicles in chapter 3.

2.1.6.1 Portfolio investments

In one of the first studies of private equity portfolio investments, Gompers and Lerner (1997) find average arithmetic returns of 30.5 % with a standard deviation of 32 % for the period 1972–1997.

Cochrane (2005) assumes that changes in the values of portfolio companies follow a logarithmic capital asset pricing model (CAPM). Measuring returns of 7 765 investments over the period 1987–2000, he calculates an average adjusted arithmetic return of 59 % and logarithmic returns of 15 % per year. This high return is due to large standard deviations of 107 % for arithmetic and 89 % for log-returns. Systematic risk (CAPM beta) is 1.9 using the Standard & Poor's 500 (S&P 500) index as the market factor. Firms that go bankrupt cause a selection bias, for their low returns might not be reported to data providers and might therefore be missing from the sample of investments. Cochrane corrects for this selection bias by modelling probabilities for reporting low returns and exiting through bankruptcy.

Woodward and Hall (2004), Quigley and Woodward (2003), and Peng (2001) calculate venture capital indices from different sources (VentureOne, Thomson SDC, Sand Hill Econometrics). They use data from valuation events, such as financing rounds, IPOs[34], or liquidations. Woodward and Hall (2004) calculate average quarterly returns of 4.62 %, which correspond to geometric returns of 19.8 % per year. Return volatility in their study is 8.86 % per quarter, equivalent to 17.7 % per year if returns are not autocorrelated. Quigley and Woodward (2003) measure inflation-adjusted index returns of less than 5 % per year for the period 1987–2000, which is less than the return achieved from investing in the Standard & Poor's 500 index or the NASDAQ index for the same period. Return volatility is 15 %. Peng (2001) develops a venture capital index based on the data set used by Cochrane and finds a geometric return of 55 %, which is considerably higher than Cochrane's 15 %, even in logs. Return volatility in his study is 59 %.

Lossen (2006) uses cash flows from portfolio investments for funds issued in the period 1979 to 1998. He calculates an average IRR of 50.2 % before management fees, which has a standard deviation of 31.7 %. If cashflows are replicated using returns MSCI World returns as a benchmark, this public market equivalent (PME)

[34] Returns of companies that had been taken private but were exited through initial public offerings (reverse LBOs) are studied by Cao and Lerner (2009) for the period 1980–2002. They find buy-and-hold returns of 18.3 % over the first year after an IPO, 43.8 % after two years, and 72.3 % three years after the IPO.

is 3.08, which indicates a superior performance of PE investments compared to public markets.

Cumming and Walz (2010) study returns of realized and partially realized investments between the years 1971 and 2003. Their sample of 2 419 realized investments shows an average performance of 68.7 %; returns for the sample of 2 619 partially realized investments are 63.2 % on average. Their data is provided by the Center of Private Equity Research (CEPRES). Using a similar data set with 2 380 investments, Ick (2005) documents an average internal rate of return (IRR) of 50.5 % with a huge standard deviation of 354.2 %.

2.1.6.2 Funds

In one of the first studies on PE fund performance, Bygrave and Timmons (1992) calculate a mean IRR of 13.5 % for venture funds over the period 1974–1989, but do not report risk measures. Ljungqvist and Richardson (2003) examine a sample of 73 international PE funds and calculate returns using cash flow data. They document mean IRRs net of fees and carried interest of 19.8 % for equally weighted fund returns and 18.1 % if returns are weighted by committed capital. The IRRs' standard deviation is 22.3 %. This corresponds to an excess return of 5.7 % to 8.1 % compared to the S&P 500 index, depending on the investment strategy chosen. Ljungqvist and Richardson also try to assess the funds' systematic risk by assigning each of the funds' portfolio companies to one of the 48 industry betas provided by Fama and French (1997) and calculating value-weighted betas for each fund. They find a mean systematic risk of 1.08 in buyout funds and 1.12 in venture capital funds.

Chen et al. (2002) examine all 148 venture capital funds from the Venture Economics database that have been liquidated until 1999. They calculate mean arithmetic returns of 45 % and a standard deviation of 115.6 %. Corresponding geometric returns are 13.4 %.

Jones and Rhodes-Kropf (2003) use a sample of 1 245 funds and report value-weighted IRRs net of fees and carried interest of 9.2 % with a standard deviation of

39 %. Buyout funds return 4.57 % on a value-weighted basis, while venture capital funds have a mean IRR of 19.31 %. Jones and Rhodes-Kropf estimate a systematic risk in single-factor CAPM regressions for all funds of 1.05 if contemporary and lagged market returns are used. Betas for venture capital funds and buyout funds are 1.79 and 0.66, respectively.

Kaplan and Schoar (2005) calculate IRR, PME, and the total value to paid-in ratio (TVPI) for 746 funds over the period 1980–2001. Based on cash flow data provided by Thomson Venture Economics, they find sub-par returns compared to the S&P 500 (PMEs of 0.74 to 0.96, depending on the method used for calculation) except for committed capital-weighted PMEs, where the public market equivalent is 1.05. IRRs weighted by committed capital average 18 % for all private equity funds, 17 % for venture funds, and 18 % for buyout funds. The standard deviation of IRRs is 26 % (31 % for venture capital and 26 % for buyout funds). After correcting for management fees, Kaplan and Schoar conclude that private equity funds probably outperform public markets slightly. They also document a strong performance persistence: Follow-up funds outperform on average, if the last fund initiated by the general partner outperformed relative to other PE funds.

Kaserer and Diller (2004) measure IRR, excess IRR, and PME for three samples covering a total of 794 funds, which are composed of liquidated funds and funds whose net asset value relative to distributed capital does not exceed certain thresholds. Kaserer and Diller find IRRs on an equally weighted basis of 10 % for liquidated funds (17.8 % standard deviation), 12 % for funds with net asset values less than 10 % of total value (16.5 % standard deviation), and 14 % for funds with net asset values less than 20 % of total value (22.8 % standard deviation). Private equity yields a performance similar to public markets with subsample PMEs of 0.94, 1.04, and 1.16. Excess IRRs compared to MSCI World returns are 0.58 %, 4.45 %, and 6.68 %, respectively. Buyout funds perform better than venture capital funds in all three subsamples.

Driessen et al. (2008) apply a GMM-style methodology to a sample of 958 mature private equity funds between 1980 and 2003. They find that venture capital funds have a market beta of 3.21, while buyout funds have a market beta of 0.33. For venture capital funds, CAPM alpha is significant at –15 % per year. Buyout funds, however, have slightly positive but insignificant alpha.

Phalippou and Gottschalg (2009) argue that a large part of the outperformance of private equity funds found in prior studies is driven by inflated accounting valuation of ongoing investments. They document a bias toward better performing funds in their data, which is provided by Thomson Venture Economics, and find an average fund performance net of fees of 3 % per year (CAPM alpha) below that of the S&P 500 if a market risk of unity is assumed. Adjusting for risk leads to an underperformance of 6 %. To each of the transactions studied, they assign a public company to measure systematic risk (beta), which is 1.01 at exit and 1.4 at deal closing.

2.1.6.3 Funds of funds

Research on returns and risk characteristics of funds of funds is limited to date. Studies exploring possible returns to fund of funds strategies examine return distributions of hypothetical funds of funds.

Weidig and Mathonet (2005) use Monte Carlo simulations to generate DPI (distribution to paid-in) multiples for funds of funds that are drawn from a sample of 282 European and 745 U.S. funds for the years 1983 to 1998. They exclude all funds younger than five years to mitigate the difficulty of estimating residual net asset values. Venture capital funds of funds simulated from 20 randomly drawn funds can generate DPI multiples of 2.3 (U.S.) and 1.8 (Europe) at standard deviations of 0.8 and 0.5, respectively. Multiples for U.S. and European buyout funds are 2.0 (0.7 standard deviation) and 1.8 (0.2). Management fees reduce DPI multiples by only 0.05 to 0.1. Funds of funds greatly reduce the risk associated with single investments or funds while yielding similar average multiples.

Schmidt (2003) measures cash flow-based returns for portfolios constructed from 3 620 private equity investments in 642 U.S. companies by 123 funds. In a simulation of funds of funds, diversifiable risk can be reduced by 80 % in portfolios consisting of 15 investments. A simulated minimum variance portfolio yields 14 % per year at a standard deviation of 6.2 % if the fund of funds includes 200 funds and 90.1 % if only 1 fund is chosen for each portfolio. Venture capital fund returns are strongly skewed to the right as in most studies of private equity returns.[35]

These studies show that extraordinary returns from private equity investments can be observed in many instances, but risk is usually high as well. Performance studies often suffer from methodological difficulties, which include selection biases and difficulties in inferring returns from cash flows and net asset values. Risk-adjusted return measures in particular are hard to construct. I therefore use a sample of listed private equity funds to measure PE returns on the level of funds and funds of funds in chapter 3.

2.2 Listed private equity and data sample

2.2.1 Definition

Private equity vehicles that are quoted on international stock markets are the subject of this thesis. Several synonyms for this asset class can be found in the literature: *listed private equity* (LPE), *publicly traded private equity* (PTPE) and more seldom *quoted private equity* and *liquid private equity*.[36] While older academic studies used the term PTPE, today listed private equity (LPE) is the most common name for this asset class. Bilo (2002) classifies instruments as LPE, if the underlying business is PE investing, but the funds themselves are quoted on an exchange.

For the analyses conducted in this thesis, I follow a definition of LPE from an investor's perspective: LPE entities are listed vehicles that offer an investor the opportunity to participate directly or indirectly in private equity investments. These vehicles pursue a PE strategy (e. g. venture, buyout, mezzanine) and are committed

35 See, for example, Cochrane (2005).
36 See LPX GmbH (2008); RedRocks LPE (2008); Bilo et al. (2005); Partners Group (2008).

to the PE investment process — that is, selecting portfolio companies, structuring transactions, monitoring and divesting portfolio companies. LPE vehicles must describe themselves as private equity investment vehicles or show evidence of activities related to the investment process. Underlying investments must be predominantly non-public companies.

Bilo et al. (2005) distinguish three different types of LPE vehicles: *Listed companies* whose core business is private equity (e. g. 3i Group), *quoted investment funds*, which invest a predetermined proportional equity share in specific private firms together with the company's private funds (e. g. SVG Capital Trust) and *specially structured investment vehicles* which invest in private equity directly (e. g. investing into private companies), and/or indirectly through various private funds (e. g. Castle Private Equity).[37] As far as *listed companies* are concerned, this category does not correspond to her definition of LPE, since not the fund but the management company is listed on the stock exchange. The term "PE investing" is not further defined. However, in a later version of the paper, Bilo et al. (2005) state that the underlying investments of these companies include all kinds of financing stages and styles. Companies investing only partially in private equity, e. g. investment banks, holding companies, venture capital pools and the likes were excluded (Bilo, 2002).

I follow Bilo's definition of listed private equity but propose a different classification of LPE vehicles to capture economically relevant differences in organizational forms. As opposed to traditional PE where the vast majority of entities is structured as limited partnerships, the LPE universe is quite heterogeneous with respect to their legal and economic structure. In order to allow for comparisons with traditional private equity, I identify similar structures in LPE and point out additional organizational forms that exist mainly in listed vehicles. From an investor's perspective, a distinction of organizational forms is essential to understand the underlying value generation processes, which might have an impact on risk and return characteristics.

[37] See also Bergmann et al. (2009) for a classification that distinguishes direct from indirect investments.

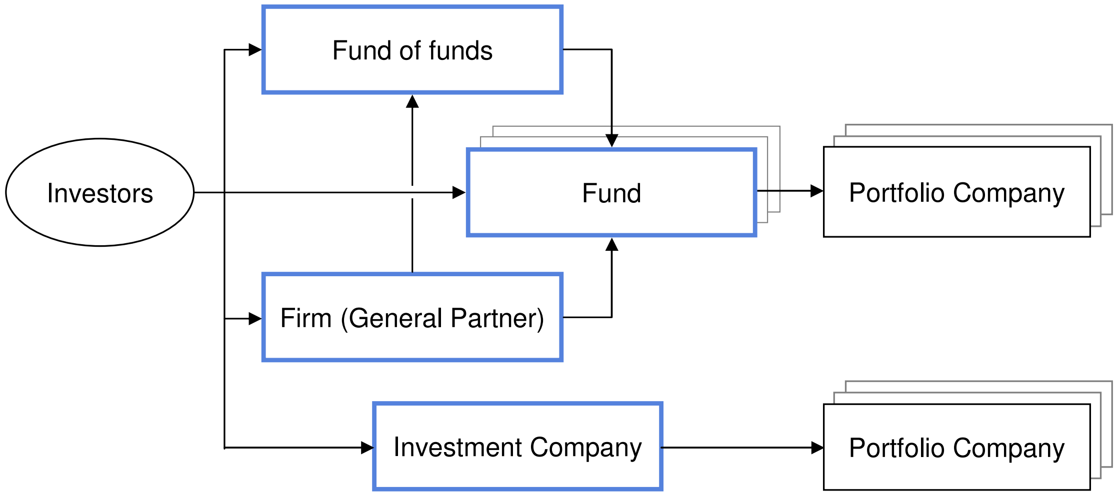

Figure 2.8: Relations between organizational forms of listed private equity vehicles

According to the traditional private equity business model, I distinguish funds that invest in unlisted companies directly and management companies (henceforth "firms") that provide investment management for funds (see figure 2.8). Indirect exposure but higher degrees of diversification can be achieved by listed funds of funds, which invest in traditional private equity funds. A fourth category are investment companies, which invest directly in private company.

2.2.2 Organizational forms

Vehicles can be classified along two dimensions into internally or externally managed companies and into structures consisting of single or multiple funds as shown in figure 2.9. Investment mandates often do not prescribe exclusive investment in private companies only, but allow funds to be invested in other assets as well, such as AIM-quoted companies or third-party funds. The organizational forms described below have considerable overlap, which necessitates close inspection of portfolios and legal structures when assigning vehicles to categories.

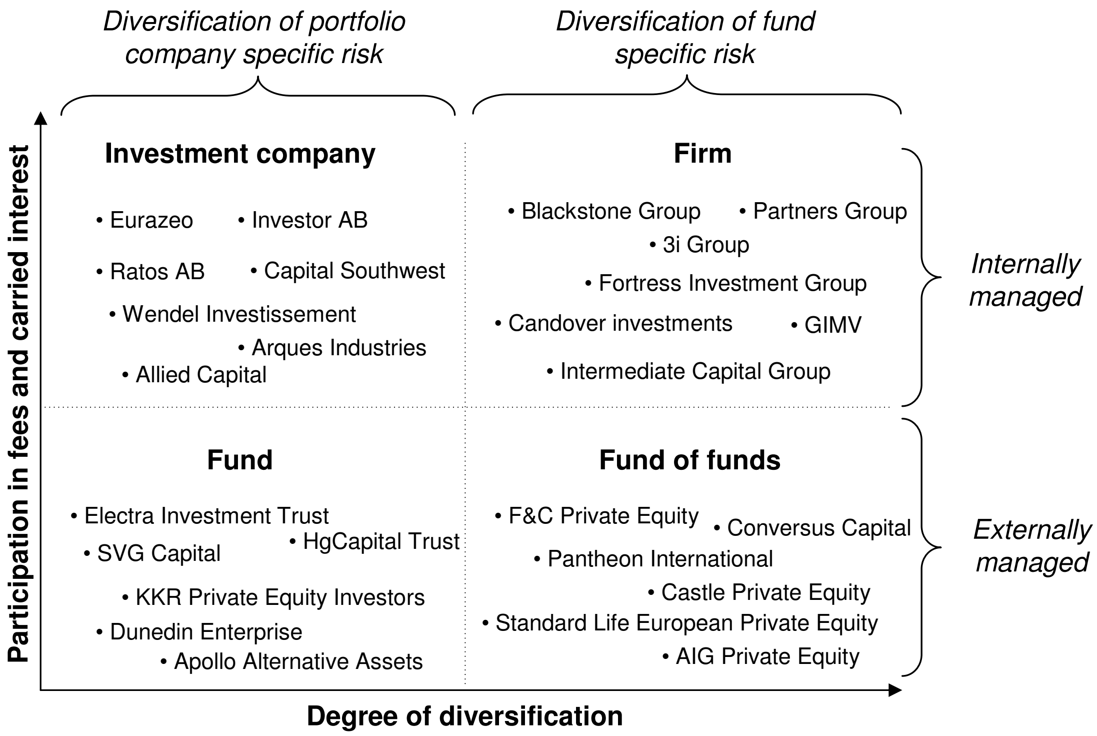

Figure 2.9: Generalized organizational forms of listed private equity vehicles
Source: Lahr and Herschke (2009).

2.2.2.1 Funds

LPE funds are externally managed vehicles that invest directly in private companies similar to traditional PE funds (see figure 2.10). Examples include Electra Private Equity, KKR Private Equity Investors, and HgCapital Trust. Funds usually have legal forms of public limited partnerships and other standard legal forms (PLC, Ltd.). These vehicles invest their balance sheet, which consists of funds provided by unit- or shareholders (balance sheet-investing) with the purpose of earning capital gains from balance sheet investments in private companies.

Similar to private limited partnerships, investment management for LPE funds is provided by third parties (management companies), which are often affiliated with traditional PE groups. Managers are paid management fees as well as performance based fees, which are mostly based on net asset value returns, but sometimes depend on the fund's market value. Funds typically invest directly or hold co-investments

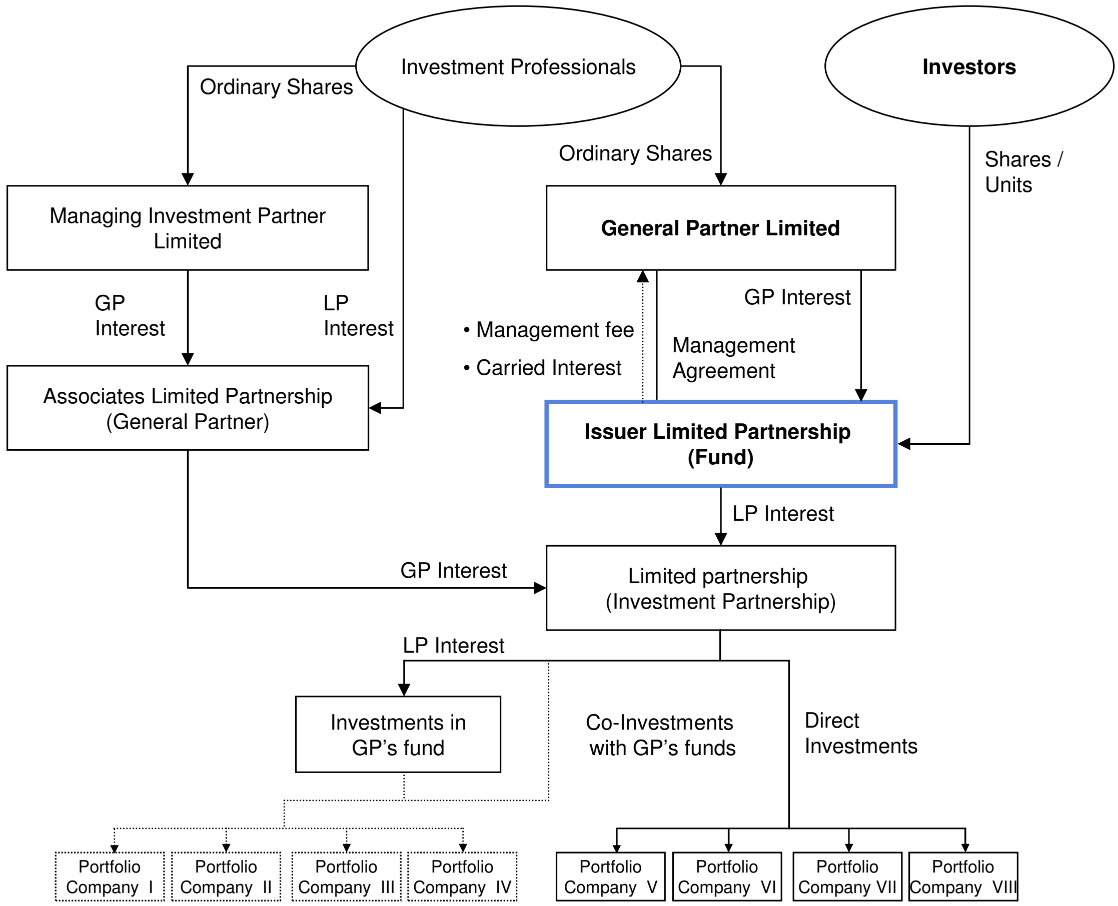

Figure 2.10: Organizational form of listed funds
Source: Adapted from AP Alternative Assets, L.P., Prospectus, July 2006, p. 41; KKR Private Equity Investors, L.P., Prospectus, April 2006, p. 48.

alongside traditional PE funds that are managed by the same general partner (e. g. KKR Private Equity Investors, Apollo Alternative Assets). Most funds focus on specific financing stages, that is, early stage, expansion stage, late stage, buyout or turnaround capital.

The industry standard of reporting fund values are net asset values (NAV) per fund share. Fund value depends on its underlying portfolio value, which, in the absence of market prices, is estimated according to industry guidelines. These are predominantly the International Private Equity and Venture Capital Valuation Guidelines[38] in Europe and the reporting guidelines established by the U.S. Private

[38] Fair value has to be reported, which represents the amount for which an asset may

Equity Industry Guidelines Group[39]. Listed funds should therefore trade close to aggregated net asset values. Market price and NAV often diverge, which can be attributed to a number of possible causes as detailed below.

2.2.2.2 Funds of funds

Funds of funds are externally managed investment vehicles (see figure 2.11). These entities are structured as listed entities (e. g. Ltd., PLC, AG) and pursue investments in traditional PE funds as limited partners. Cash flow is generated from investment activities within the private equity business cycle. Examples include Castle Private Equity and Pantheon International Participations.

Funds of funds are investing their balance sheet and investments are managed by a management company. These fund-of-funds managers are typically paid management fees and carried interest. From an investor's perspective, these fees constitute a second fee layer between the investor and underlying portfolio investments in which the fund of funds participates as a limited partner. However, funds of funds offer access to due diligence expertise, which may enable the selection of better performing funds. In addition, fund-of-funds managers typically are well established players in the market with long-standing relationships to private equity groups and access to top-quartile PE managers.

Funds of funds are broadly diversified on the fund level with respect to financing stages, general partners (PE groups), fund vintage years, and geographical region. This diversification potential can have a substantial impact on performance and risk characteristics. Fund value of listed funds of funds is closely related to the NAV of underlying private equity partnerships, which themselves compile portfolio values according to net asset values derived from valuation guidelines. This multi-layered valuation scheme may result in a time lagged impact of changes in portfolio

be exchanged between knowledgeable, willing parties in an arms' length transaction. In practice, new investments are held at cost for at least twelve months. See http://www.privateequityvaluation.com.

[39] See http://www.peigg.org. For a discussion of reporting standards in private equity funds, see Müller (2007).

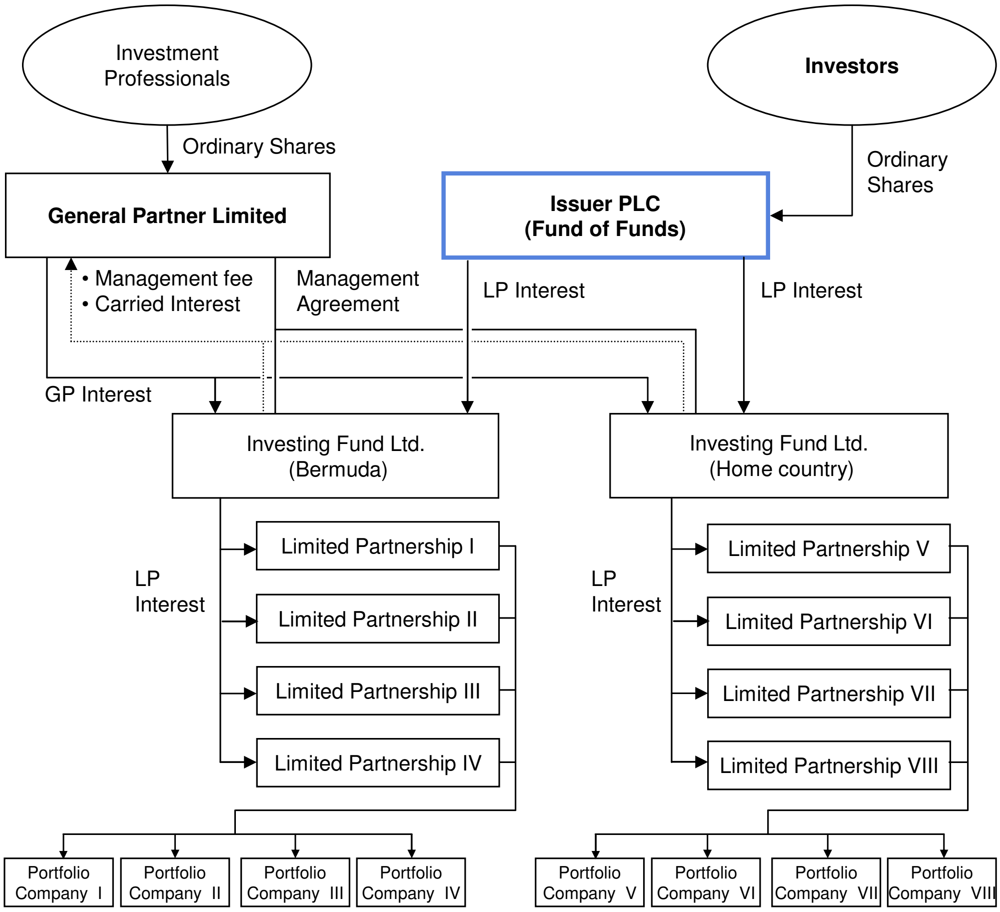

Figure 2.11: Organizational form of listed funds of funds
Source: Adapted from shaPE Capital, Information Memorandum, October 2001, p. 12; Castle Private Equity AG, Listing Memorandum, October 2000, p. 7.

company values. Since most funds report NAVs on a quarterly basis at best, portfolio changes need not show up at the fund of funds' level for a considerable time. If other information about portfolio companies is not available to market participants, this time lag can cause severe autocorrelation in returns as well as an underestimation of correlations with stock markets.

2.2.2.3 Firms

Quoted firms are internally managed vehicles that correspond to the general partner in traditional private equity groups (see figure 2.12). Firms typically take the form of a standard listed company (e. g. PLC, AG, Corp.), whereas partnership structures exist in some cases. These firms hold a GP interest in the private PE vehicles they manage. Examples include Candover Investments and Blackstone. Cash flow is generated primarily through management agreements with private equity funds. Firms are balance sheet-investing to a small extent only with shareholdings of around 1 % in the funds they manage. The firm's main income stream are management fees and performance fees (carried interest). For example, in the case of Blackstone, the public firm owns several management companies, which in turn provide management services to Blackstone's PE funds.

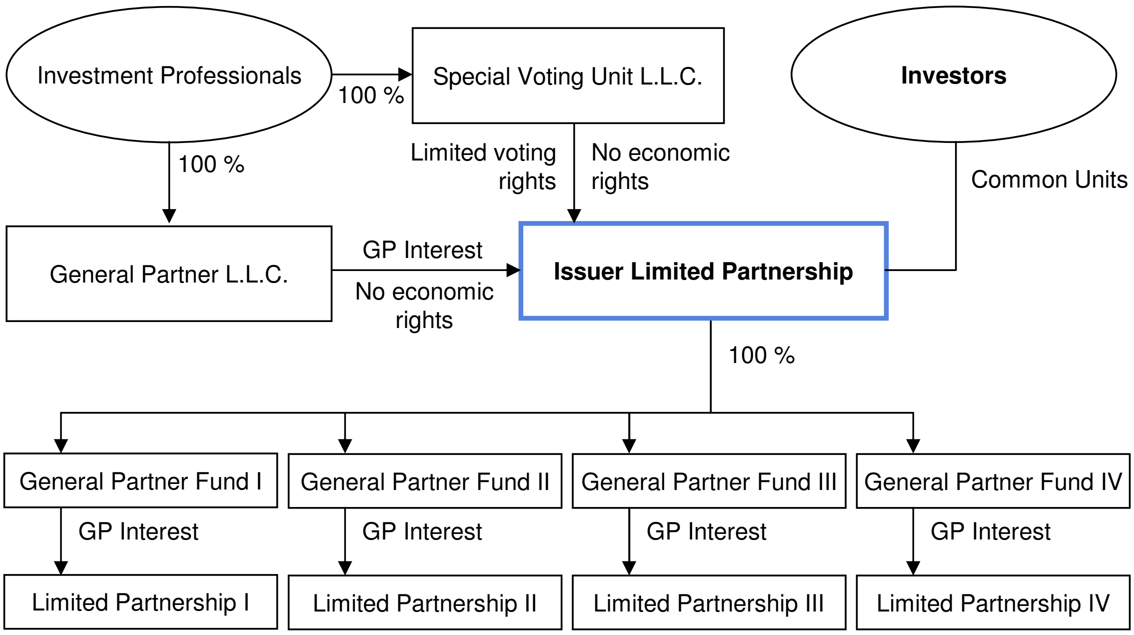

Figure 2.12: Organizational form of listed firms
Source: Adapted from The Blackstone Group, Prospectus, June 2007, p. 16.

Income streams from management activities are quite stable over time, since management fees are predetermined in the limited partnership agreement (LPA) and are typically paid on committed capital. To the contrary, performance fees show higher volatility due to their dependence on successful exits of underlying portfolio companies. The performance-related part can be seen as indirect private investment, since it reflects the firm's ability to create value through PE investments. Investment professionals often own substantial shares in PE firms, which is supposed to lead to an alignment of interest between dispersed shareholders and firm management. Limited partnership stakes in its own funds may be held by the firm as well as direct investments in private companies. Both types generate cash flows related to the success of portfolio companies.

Listed firms provide an opportunity for investors to participate in cash flows from management activities, which is not possible in traditional private equity structures. Firms combine stable returns generated through management activities with more volatile carried interest from indirect participation in PE investments. Because of this diversification of income streams, one might argue that firms have limited downside risk in adverse market environments while being able to exploit favorable environments through huge performance fees. However, firms depend on their ability to raise funds in the future, which is related to their past performance and in turn influences their market value today. The presence of both stable and volatile cash flow components offers no clear indication as to whether firms are subject to higher or lower market risk than funds. I therefore investigate the relation of market risk and organizational forms in chapter 3.

2.2.2.4 Investment companies

Investment companies are internally managed vehicles similar to funds, but do not rely on external management and employ their own investment professionals instead. Consequently, management expenses do not show up as fees on the income statement but as operating expenses. Examples include Eurazeo, Wendel Investissement, and Ratos. Investment companies combine functions in a single entity that are are separated in traditional private equity structures.

Investment companies typically hold a portfolio of direct investments in private companies, but some stacked holding structures may exist within investment companies. Besides their commitment to the PE business model, investment companies often lack features that distinguish them from ordinary holding companies. They

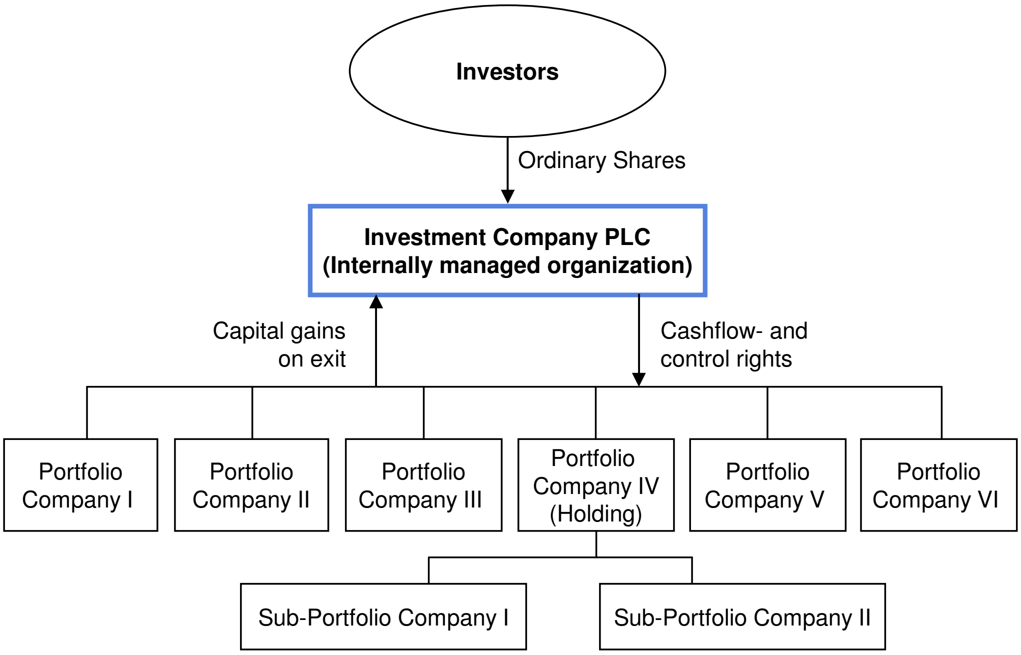

Figure 2.13: Organizational form of investment companies

usually prepare consolidated financial statements but also report a detailed portfolio composition, which is similar to the reporting of fair values of portfolio investments by listed funds. Portfolios held by investment companies are comparable to those of listed funds. However, contrary to listed funds, investment companies take on considerably more debt on their balance sheet, which can influence risk and return characteristics.

Investment companies come in a wide range of local flavors. Many jurisdictions regulate special legal statuses for investment companies, such as Business Development Companies in the U.S. and Venture Capital Trusts in the U.K. Regulations often stipulate tax benefits tied to lock-up periods or investment restrictions. Investment companies also invest in securities of other companies that trade on stock markets, real estate property, or bonds, which can dilute PE portfolios and makes close scrutiny a necessity when classifying vehicles.

2.2.3 Special legal forms

Although the organizational forms described above categorize LPE vehicles according to their economic structure, the underlying legal structures are often quite diverse. Several legal structures have emerged particularly in the U.K. and the U.S., which are well suited for private equity investments.

2.2.3.1 Investment trusts

Investment trusts are a special type of U.K. investment companies, which invest in securities and whose shares are quoted on the London Stock Exchange.[40] Their organizational form classifies them as closed-end fund vehicles. These vehicles have to comply with section 842 of the Income and Corporations Taxes Act 1988, which states that the company's income must be derived wholly or mainly from shares or securities, and no holding in a company other than an investment trust represents more than 15 % of the trust's assets. The distribution of capital gains as dividends must be prohibited by the company's memorandum or articles of association, and the trust must not retain more than 15 % of the income it derives from shares and securities every year.

The main advantages for U.K. investment trusts lie in their exemption from tax on chargeable gains at the company level[41] and the deductibility of management charges. The lack of dividend payments can be seen as a disadvantage, in addition to the fact that management charges are subject to value added tax.

Investment trusts can borrow to purchase additional investments. This ability to take on debt distinguishes them from other collective investment schemes like unit trusts.

[40] See http://www.aitc.co.uk/Guide-to-investment-companies/What-are-investment-companies/How-they-work/ (accessed 2010-03-17).

[41] See s100(1) TCGA 1992.

2.2.3.2 Split capital trusts

Investment companies that issue only one class of shares are commonly known as "conventional" investment companies. Split capital trusts (Splits) were introduced in the U.K. in 1965 and originally had a limited life with a fixed wind-up date and two classes of shares: income shares and capital shares.[42] The different classes of share are designed to meet different investors' needs, as they entitle investors to income generated from the investments (income shares) or the capital value of the company at wind-up (capital shares). Over time, several more share types have developed, such as zero dividend preference shares. At least one share class within a split capital trust is likely to have a limited life (usually between 5–10 years) with a fixed wind-up date. The different share class priorities and entitlements lead to varying risk levels between these classes. Other kinds of collective investment vehicles cannot offer different share classes within one fund.

2.2.3.3 Venture capital trusts (VCTs)

Venture Capital Trusts (VCTs) are a type of company very similar to investment trust companies. They were introduced in the U.K. in 1995 and invest in small, potentially high growth private companies and new shares of companies that are traded on the Alternative Investment Market (AIM) and PLUS Market.[43]

VCTs offer investors income and capital gains tax reliefs, which include income tax relief on the initial investment when subscribing to new VCT share issues, tax-free dividends, and tax-free capital gains. To qualify for income tax relief on subscription, investors must hold VCTs for a minimum time of 5 years. These rules governing the tax benefits of VCTs have, however, changed several times over the past years. VCTs have to adhere to several restrictions with respect to the types of companies

[42] http://www.theaic.co.uk/Documents/Factsheets/AICSplitsFactsheet.pdf (accessed 2010-03-17).

[43] See http://www.theaic.co.uk/Documents/Factsheets/AICVCTFactsheet.pdf (accessed 2010-03-17). A similar structure under Canadian Law are Labour-Sponsored Investment Funds (LSIF) — or Labour Sponsored Venture Capital Corporations (LSVCC) —, which are organized as mutual funds and therefore excluded from my analysis; see Cumming and MacIntosh (2007).

they can invest in. At least 70 % of their investments must be in shares in private U.K. companies which must have pre-money valuations of less than GBP 7 millon, although prior to April 2006, this limit was GBP 15 million. The maximum amount any VCT can invest in a single company in any tax year is GBP 1 million. Because of tax benefits and due to their special statutory governance mechanisms, VCTs are sometimes believed to underperform the market on a share price basis.[44]

2.2.3.4 Business development companies (BDCs)

Business Development Companies (BDC) are publicly traded closed-end companies that are regulated under the U.S. Investment Company Act of 1940, Section 54 (Election to Be Regulated as Business Development Company) and seek to invest in small and mid-sized private companies. They are required by law to provide support and significant managerial assistance to their portfolio companies. To qualify as a BDC, companies must elect to be registered in compliance with the Investment Company Act. A major difference between BDCs and traditional PE funds is that BDCs allow smaller, non-accredited investors to invest in startup companies.

The Investment Company Act imposes certain restrictions on the operations of a BDC. They must hold at least 70 % of their total assets in shares of private companies or securities for which there is no ready market, cash, cash equivalents, U.S. government securities or high quality debt securities maturing in one year or less from the time of investment. Most BDCs have regulated investment company (RIC) status, which requires them to distribute at least 90 % of their taxable income to shareholders every year. No more than 5 % of their assets can be from a single issuer and 10 % is the upper limit BDCs are allowed to own of the outstanding voting securities of any one issuer. BDCs cannot invest more than 25 % of their assets in businesses that they control or businesses that are in similar or related trades or businesses.

[44] See Cumming (2003).

2.2.3.5 Special purpose acquisition companies (SPACs)

Hale (2007) defines a special purpose acquisition company (SPAC) as a shell company (or blank check company) registered with the U.S. Securities and Exchange Commission (SEC) that is formed to raise capital for a yet unidentified business that will be acquired in the future.[45] Similar to internally managed investment companies, SPACs provide investors with potential access to acquisitions of private companies. They have become a popular new investment vehicles, raising more than USD 20 billion since 2003 and comprising 20 % of total funds raised in U.S. IPOs in 2007.[46]

SPAC shares are issued as units consisting of common stock and one or two separate warrants that typically can be exercised only if the SPAC completes an acquisition. The warrants, which are normally callable by the firm at any time during the exercise period, may trade separately from the common stock 90 days after the IPO.

After price manipulations in blank check companies (BCC), the SEC adopted rule 419, which imposes several restrictions on BCCs, prohibiting trading of the BCC's securities by requiring them to be held in an escrow or trust account until consummation of an acquisition.[47] SPACs avoid the application of Rule 419 by not issuing penny stock. However, SPACs voluntarily incorporate a number of Rule 419-type provisions in their IPO terms. For example, SPAC charters usually require an acquisition within 18 to 24 months after the effective date of the offering. Until that date, 90 % of the IPO proceeds must be held in an escrow or trust account. The initial target must have a fair market value of at least 80 % percent of the SPAC's net assets excluding deferred underwriters' discounts and commissions. If management does not find a target within a specified period, the SPAC is liquidated and the firm's net assets are returned to shareholders.

SPACs resemble a risk-free asset in the early stages of their life cycle, yet many

[45] See also Davidoff (2008) for a legal description of SPACs and Berger (2008) for an economic discussion of three case studies.

[46] See Lewellen (2009) and Jenkinson and Sousa (2009).

[47] See Sjostrom (2008) and 17 C.F.R. § 230.419(b)(2)(i) & (vi) (2007).

become single-transaction buyout funds if successful. They trade on stock exchanges and invest in private companies and may therefore be considered listed private equity. In order to qualify as LPE in this thesis, companies must commit to the private equity business model, which includes buying and selling portfolio companies. The selling part is clearly up to the investor. After an acquisition has been consummated, SPACs are very similar to normal holding companies from an economic point of view. I therefore exclude SPACs from my sample, as do most LPE indices.

2.2.3.6 Structured trust acquisition company (STACs)

Structured trust acquisition companies (STACs) are tax-structured corporate entities that initiate offerings to acquire private companies.[48] Similar to traditional private equity fund group structures, investors buy shares in an entity whose sole property are shares in a holding company that invests in private portfolio companies. A management company provides investment services to the holding company. In contrast to SPACs, a STAC identifies its target before going public. Furthermore, STACs enable long-term control-stake ownership of operating companies, and no shareholder approval is necessary for business combinations. They must consolidate financial statements of majority-owned businesses and are subject to "pass-thru" taxation instead of entity level taxation of income and capital gains received from portfolio companies. Two STACs have listed their stock so far: Macquarie Infrastructure Company Trust and Compass Diversified Trust, raising more than USD 700 million, which was immediately used to acquire previously earmarked private companies.[49]

2.2.4 Benefits and disadvantages of listed private equity

Listed private equity vehicles offer several advantages compared to traditional PE funds.[50] These advantages are mainly associated with investors being able to con-

[48] See Davidoff (2008).
[49] See Krus et al. (2006).
[50] See also http://www.lpeq.com.

tinuously trade shares on regulated public markets. However, there are also some drawbacks as detailed below.

2.2.4.1 Company perspective

Several reasons for a company to go public can be identified, which include funding, liquidity, public relations, improved motivation and incentives for management and employees, and an ability to exploit mispricings. Bilo (2002, p. 38) offers some insights into a PE-investing vehicle's motivation to list itself on a stock exchange: A main reason for listing a vehicle is gaining access to a wider range of investors. Before the 1980s, when limited partnerships were emerging as a legal structure for buyout houses, institutional investors had been reluctant to invest in private vehicles, because they either had little knowledge about these or were not allowed to invest. In fact, several investment companies in our sample date back to the 1950s and 1960s. Today, listed vehicles are marketed to institutional investors as a means to temporarily store cash that is about to be invested in traditional funds, thereby avoiding the drag on returns caused by cash holdings. Private investors also entered the scene, partly because of minimum investment requirements in traditional funds, but also for diversification and tax reasons. In the U.K., individual investors profit from tax exemptions when investing in Venture Capital Trusts. Several traditional private equity groups set up listed funds in addition to existing unlisted ones to tap into larger pools of investors.

Bilo (2002) notes that going public conveys a positive signaling effect to the market. If the firm was not successful, it might not be able to fulfill listing requirements or generate enough investor demand for its stock. Listing the vehicle's stock on an exchange brings higher publicity and the opportunity to establish an international brand, as accomplished by the 3i Group. Listing the firm can enhance name recognition and increase the firm's credibility with investors, potential portfolio companies, banks, and other institutions necessary in a successful PE investor's network. It may thus mitigate both sides of the "double sourcing problem".[51] Recognition of a

[51] See Berg, 2005, p. 25.

PE firm may well influence the decision of investors to commit capital to a fund. The same recognition and reputation effect can be used in the sourcing of deals with more favorable transaction terms.

Listed funds and investment companies as well as funds of funds provide pools of capital to the fund manager or investment committee. The management does not have to draw down commitments but can dispose the vehicle's funds at its discretion, which comes with a responsibility to earn a fair return as long as the capital is not invested, of course. Evergreen funds enable their management to concentrate on value creation through the private equity investment cycle instead of tying up resources in cost intensive fund raising and marketing processes.

Another motivation for listing a PE vehicle could be observed in recent years with the listing of several management firms such as Blackstone. Albeit used as a classical means to divest portfolio companies, an IPO offers a possibility for the PE firm's owners to divest their stakes in the firm or to enter the public market in order to sell at a later point in time. These asset disposals are often seen critically, as it is assumed that the key competencies are associated with the senior partners. Theoretically, listing a company's stock offers the possibility of performance-related incentives through company stock or stock options. In practice, most LPE vehicles prefer other contractual agreements when establishing performance-sensitive pay systems.

Capital for listed vehicles can be raised best in times when market sentiment is high. These may not be the best times to invest the IPO proceeds, if some target return is to be achieved. Several studies show that firms go public during periods characterized by high supply of capital and high valuations,[52] which are, of course, two sides of the same medal. This poses a dilemma for PE funds, having to invest in highly valued portfolio companies or deferring investments while parking funds in the money market, thereby diluting returns. Traditional limited partnership structures do not face this difficulty, since they can distribute excess cash to investors. They are, however, under pressure to invest the investor's capital once committed. Listed

[52] See, for example, Ritter (1984) and Gompers and Lerner (2000).

evergreen funds, on the other hand, can try to smooth their exposure to private companies. Once invested, there is no need to divest portfolio companies at a specific point in time, which could otherwise be caused by a limited fund lifetime.

2.2.4.2 Investor perspective

Disadvantages of investments in traditional private equity funds may include difficulty of access, illiquidity, lack of transparency, a high degree of fragmentation, and high transaction costs. Private equity limited partnership funds are often marketed to institutions like pension funds and university endowments, and wealthy individuals only. A minimum investment in excess of USD 1 million is usually required. Investors who want to invest in private companies can either buy shares in them directly or invest through private equity fund intermediaries. Both types of investments may not be salable over short horizons due to missing liquidity in secondary markets. Since capital is provided to the fund until the fund distributes capital gains and is finally wound up, investors in traditional private equity may be locked in for long horizons. In addition, private equity managers charge fees for managing committed capital around 2 % of commitments and performance fees of generally 20 % in excess of hurdle rates.

Listed private equity can provide solutions for some of the drawbacks of traditional private equity investments. Investing in listed private equity vehicles is usually very similar to investments in ordinary stocks. With the exception of some special legal structures, investors buy common shares in entities, which offer the same rights as ordinary equity securities. The investors' commitment is fully drawn when subscribing share issues of LPE vehicles. There is no minimum capital requirement as in traditional private equity funds, but a natural minimum investment corresponding to a single share. Investor rights are sometimes restricted to monitoring, such as observing share prices, obtaining annual reports, and attending annual general meetings. These rights strongly depend on the organizational and legal form chosen by the LPE vehicle.

Since vehicles have to fulfill strict listing requirements and are subject to regulations on the publication of news with potential impact on share prices when listed on a stock exchange, transparency for investors can be substantially improved. Moreover, valuable information about many companies is provided by analyst coverage. This holds mainly for market participants that are not invested yet, because traditional PE funds often provide investors with considerable amounts of timely information about their portfolio, which is not available for outside investors. In contrast to mostly unregulated traditional funds, listed vehicles are subject to shareholder protection laws, which help to curb the risk associated with private investments.

Contrary to traditional fund investments, no cash management is required by the investor during the holding period unless the vehicles pays dividends. The investment process for LPE investments consists of buying and selling shares on public markets. Cash management and administration, which can be complex for traditional LP interests, are provided by the general partner in the case of listed funds. Distribution policies vary between vehicles depending on their structure as limited lifetime or evergreen funds. Some funds, in particular U.K. income trusts, often pay quarterly dividends, whereas some funds retain cash until disbursed at the wind-up date due to favorable taxation of capital gains. For example, capital gains retained within London-listed trusts are not taxed.

The availability of market prices provides an opportunity for performance measurement that is not limited to information provided by the fund management. Investors are able to mark assets to market instead of having to rely on inside information, which can nonetheless be undesirable if true value is believed to be less volatile than market prices. It is sometimes argued that marketability induces extra volatility due to fluctuating demand.[53] With readily available market prices, performance characteristics of LPE entities can be analyzed with methods applied in standard financial asset valuation. Observable market prices allow for a calculation of risk and return as well as parameters used for inclusion of LPE into portfolio management.

A distinct benefit of LPE compared to traditional private equity is that the

[53] For example, Blum (1997).

moment of exiting the investment is at the investor's discretion. Since most vehicles are similar to traded closed-end mutual funds, investors are not bound by limited partnership agreements when selling their stake. Traditional funds often impose transfer restrictions, and fund units cannot be legally offered to the public. LPE entities are listed on public markets and can thus be traded on a daily basis if bid/ask volume suffices. Investments can therefore be liquidated whenever there is someone willing to buy in the market, which can, of course, be difficult in small and illiquid vehicles. For an optimal timing of divestments, market cycles, net asset value discounts and bid-ask spread have to be taken into consideration.

In spite of these advantages, there are some drawbacks of investments in listed private equity. Although LPE vehicles can in principle be bought or sold at any time, a considerable proportion of vehicles is subject to infrequent trading. Many investors hold LPE vehicles as long-term investments, which is especially true for certain investment trusts that enjoy tax benefits after some holding period. This partial illiquidity is reflected by high bid-ask spreads and sometimes no trading activity at all over several days or weeks. Disinvestments of large blocks of shares can thus lead to substantial indirect transaction costs.

An objective of many investors in private equity funds is to indirectly buy shares in private companies. This exposure to private investments can vary considerably in LPE vehicles. One form of variation stems from portfolio investment life-cycles: Initially, LPE funds and investment companies start with cash portfolios, which are invested in portfolio companies over horizons of usually up to three years. These investments generate cash flows when realized, which won't be invested again immediately. Not yet invested capital as well as realized gains produce surplus cash, which, if invested in the money market or other asset classes, may dilute returns. Another form of return dilution is caused by shifts in the vehicle's portfolio. Many vehicles hold portfolios of direct investments in private companies as well as investments in quoted companies or traditional private equity funds. These proportions can vary substantially, which in turn causes (possibly unwanted) variation in the investor's underlying portfolio.

Because the shares of unquoted portfolio companies are not traded on organized public markets, it can be difficult to establish their current market value. Fund managers (or the board of directors) can use valuation methods, such as the International Private Equity and Venture Capital Valuation Guidelines, to estimate the value of each portfolio company. These estimates may or may not correspond to the value realized in a subsequent disinvestment, which depends on finding a buyer and the current market sentiment. LPE vehicles often report net asset values (or book value of equity) on a quarterly or half-yearly basis. These values itself may be lagged, for example, in funds of funds due to their double-layered structure. Net asset value estimates can therefore show substantial autocorrelation, causing the vehicles' market values to be quite volatile compared to underlying net asset values. The relation of net asset values and market prices will be examined in detail below.

2.2.5 The market for listed private equity

2.2.5.1 Index providers

Several stock indices based on varying subsamples of the LPE universe have been developed to measure the performance of this sector. ETFs, certificates and mutual funds tracking these indices are offered by many intermediaries including ALPS Fund Services, BlackRock Advisors, Deutsche Bank, Invesco, Merrill Lynch, RBS, or UBS.

LPX® Listed private equity index family The first and probably the best known provider of LPE indices is LPX GmbH. Since 2004, a family of indices has been developed, which consists of global indices varying in scope (LPX composite, LPX50® and LPX Major Market®), regional indices (LPX Europe, LPX UK and LPX America) as well as style indices (LPX buyout, LPX venture, LPX direct, LPX indirect and LPX mezzanine.[54] A database of over 300 LPE companies listed

[54] See Guide to the LPX Indices, February 2009, available at http://www.lpx-group.com/lpx/fileadmin/images/indices/LPX_Guide_to_the_Equity_Indices.pdf.

worldwide provides the basis for the construction of all LPX indices.[55] In order to be eligible for inclusion, a proportion of net assets greater than 50 % must be private companies. PE investments include direct investments, indirect investments (limited partnerships), the valuation of the PE fund management business as well as cash and cash equivalents. Constituents must fulfil a set of liquidity constraints. Maximum bid-ask spreads have to be 1.5–4.0 %, depending on the index. Minimum market value is USD 20–150 millon, minimum daily trading volume relative to the market capitalization is 0.06–0.10 %, and minimum trade continuity is 75–90 %.

Red Rocks LPE indices Red Rocks[56] provides LPE indices similar to those constructed by LPX GmbH. Their index family consists of three indices with different geographical focus. The Listed Private Equity Index (LPEI) covers the 25–40 largest and most liquid listed private equity companies that are traded on nationally recognized exchanges in the United States. To qualify for inclusion, these companies can invest in, lend capital to, or provide services to privately held businesses. The International Listed Private Equity Index (ILPEI) focuses on 30–50 companies traded outside the U.S., whereas the Global Listed Private Equity Index (GLPEI) comprises the 40–60 most liquid LPE vehicles worldwide.

Index constituents must have, or publicly intend to reach, a majority of their assets invested in equity, loans or services to private companies.[57] Portfolios must consist of at least five unrelated equity investments, loans, or services. Businesses included in the indices are business development companies (BDC), publicly traded limited partnership interests, investment holding companies, special purpose acquisition companies and publicly traded venture capital funds, closed-end funds, financial institutions and even real estate investment trusts (REITs) with a market capitalization in excess of USD 100 million. Funds of funds and other vehicles consisting of interests in pooled investments are excluded in order to avoid additional layers of fees.

[55] Deutsche Bank (2005): DB Platinum V Liquid Private Equity Fonds, Fund Brochure.
[56] See http://www.redrockscapital.com.
[57] See http://www.redrockscapital.com/lpei_meth.html (accessed 2010-03-17).

S&P Listed Private Equity Index The Standard & Poor's Listed Private Equity Index is comprised of 30 large, liquid listed private equity companies trading on exchanges in North America, Europe and the Asia-Pacific region, which meet size, liquidity, exposure and activity requirements.[58] Index constituents are drawn from the Standard & Poor's Capital IQ (CIQ) database and must engage in the private equity business, excluding real estate income and property trusts. Stocks that have an exposure score of 1.0 or 0.5 to PE investments (out of the three assigned values 0, 0.5, and 1.0) are eligible for inclusion. Constituents have to pass several liquidity criteria: They must have a market capitalization above USD 150 million, three-month average daily volume in excess of USD 0.5 million, their stock must trade at least 10,000 shares a day on average for the twelve-month period preceding the appropriate reference date.

Constituent weights are driven by liquidity to reflect the need of product issuers for high basket liquidity. Any single stock's weight is capped at 7.5 %, and the sum of the weights of all stocks with weights of more than 4.0 % must be less than 36 %. Stocks with an exposure score of 0.5 cannot exceed 15 % total index capitalization. An evolutionary algorithm is used with stock weights as input to maximize the size of the index basket that can be traded if 100 % of the market volume is demanded for the smallest volume stock in the index.

SG Private Equity Index (Privex) The Société Générale Private Equity Index includes the 25 most representative stocks of the private equity companies listed on a stock exchange in Western Europe, North America, Singapore, Hong Kong, Japan, South Korea, Australia, and New Zealand. Constituents must be covered by Dow Jones in the Dow Jones World Index and have their largest revenue share in the private equity sector.[59] To be included, companies must be involved in private equity investment activities such as leveraged buyouts, venture capital, or growth capi-

58 See http://www.standardandpoors.com/indices/sp-listed-private-equity-index/en/us/-?indexId=spsal-lpe-usdw---p-rgl--- (accessed 2010-03-17).

59 http://www.sgindex.com/services/quotes/details.php?family=6 (accessed 2010-03-17)

tal. Neither the index brochure[60] nor the general index construction methodology[61] mention other criteria for inclusion, such as liquidity constraints.

DJ STOXX® Europe Private Equity 20 The Dow Jones STOXX® Europe Private Equity 20 index is constructed to reflect the performance of the 20 largest LPE companies in Europe.[62]

Constituents must be classified by the Industry Classification Benchmark (ICB) as either "Specialty Finance" or "Equity Investment Instruments" and/or must have at least 40 % of their investments in private equity assets (e. g. venture capital, mezzanine, buy-out). The investments by constituents in listed companies included in the STOXX® Global 1800 Index are restricted to a maximum of 30 % and index companies must have a free float market capitalization of at least EUR 75 million.

2.2.5.2 Sample generation

Listed private equity vehicles are not easily identified. Public databases like Thomson Reuters or Standard & Poor's Capital IQ sometimes include flags that characterize companies as being private equity investing. These variables are not always accurate, which is why the sample of LPE vehicles in this study is composed from a two-stage search. First, public information from market intermediaries is searched for possible definitions and collections of private equity companies that trade on international stock exchanges. Industry classification codes of these companies can be extracted to search for additional vehicles within these industries. If a large number of vehicles share a common industry classification code, other LPE vehicles are likely to be found under the same code. Companies identified through intermediaries also serve as a test whether other search procedures yield sufficiently many results and identify the whole universe and not just some specific subsample. Second, several Thomson Reuters databases are combined to conduct a systematic search for listed

[60] http://www.sgindex.com/admins/files/other/sgindex/files/4152.pdf (accessed 2010-03-17)
[61] http://www.sgindex.com/admins/files/other/sgindex/files/1633.pdf (accessed 2010-03-17)
[62] http://www.stoxx.com/indices/index_information.html?symbol=SPEP (accessed 2010-03-17).

vehicles that also use the private equity business model. Results from these stages are augmented by an extensive press search and through industry experts. Finally, all vehicles are checked against several criteria to meet the definition of listed private equity.

Two other strategies that come to mind when compiling a sample of LPE companies are a keyword search and looking for companies in specific industries as mentioned above. For example, the S&P Listed Private Equity index is constructed from screening S&P's Capital IQ database for PE-related phrases in their business description, such as Acquisitions, Business Development Company, Buyout, Mezzanine, Recapitalization, Principal Investment, Private Equity, or Venture Capital. I try the keyword approach with Datastream business descriptions, but find a large number of false positives and only a small number of true LPE vehicles as identified by the intermediaries set. The DJ STOXX Private Equity 20 index is constructed in a similar manner. Index constituents must be classified as either "specialty finance" or "equity investment instrument" by the Industry Classification Benchmark (ICB), which corresponds to sub-sectors 8775 and 8985, respectively. Additionally, companies must be invested mainly in private equity (i. e. venture capital, mezzanine and buyout). This search strategy yields substantially better results in terms of the number of false positives, but does not include many vehicles identified by the database search. I provide a review of the method of finding LPE vehicles by their industry classification below.

Identification through LPE market intermediaries The first step of composing a set of LPE vehicles is to examine public information sources, which include private equity indices, related funds and certificates, and LPEQ[63] — a public relations initiative by a group of listed private equity companies. This intermediaries set is based on the LPX 50, LPX Major Market, Privex, Red Rocks LPE index, Red Rocks LPE international index, Red Rocks LPE global index, S&P Listed Private Equity index, DJ STOXX PE 20, Partners Group Listed investments — Listed Pri-

[63] Formerly known as iPEIT.

vate Equity, and PowerShares Listed Private Equity portfolio, which is an exchange traded fund that seeks to replicate the Red Rocks Listed Private Equity index.

Entities identified from these sources are listed by construction but do not need to be private equity vehicles according to my definition, since index providers and fund managers use definitions that differ in some instances. However, it is possible to gain insights into the market participants' understanding of the listed private equity sector and to arrive at a sample that intermediaries consider as typical private equity.

The sample obtained in this step consists of 117 vehicles. I use this set to verify other search procedures and to develop a core definition of listed private equity. After applying the criteria derived from my definition of listed private equity, only 93 of these vehicles remain in the final set. 24 vehicles drop out of the sample mostly because they are holding companies that do not follow the PE business model or because they are pure asset managers that do not invest in private equity assets themselves.

Identification through Thomson Reuters databases The second step consists of combining data from Thomson Reuters databases in such a way that companies satisfying the "listed" criterion as well as the "private equity" criterion can be found. Thomson Datastream includes a set of listed entities, whereas Thomson VentureXpert contains all private equity funds and firms that Thomson considers as such. However, VentureXpert does not provide a variable that indicates whether an entity is listed on a stock exchange. Datastream, on the other hand, covers a large set of listed entities with price data from 1964, which can only in a very few instances be identified as PE vehicles when relying on Datastream data only. Combining these two sources has the advantage of providing many private equity-specific variables such as investment stage focus, which can later be used as grouping variables. This approach does not rely on specific filter criteria applied by index providers and fund managers. I thereby hope to minimize sample selection problems, which could arise from searching in specific industries only.

While Datastream contains several variables identifying companies, such as Datastream codes, ISIN, or SEDOL, no such identifiers exist in the VentureXpert database. Matching those two databases therefore becomes a non-trivial task, which has to rely on matching company names. Due to the noisy nature and different origin of company names within theses databases, matches must be checked whether they are true matches by using additional information.

Variables containing company names in VentureXpert are “fund name” and “firm name”, whereas Datastream records names as “names” (data type “name”) and “expanded names” (“ename”). Some other name variables that are not as successful in identifying companies are data types “cname”, “ecname” and Worldscope item “XWC06001”. These variables have to be preprocessed to obtain company names in a format suitable for matching against both databases. The following corrections are made: VentureXpert names often contain information about a company’s former name (“aka” or “fka”), which is extracted to expand the set of candidates for matching. Legal forms as well as punctuation marks are stripped from the company names, since abbreviation and usage is inconsistent between VentureXpert and Datastream.

To identify matches, I conduct full name matching and sub-string matching, while company names are allowed to differ by up to two characters to account for different spelling. This procedure yields the most matches for both firms and funds when using VentureXpert’s “firm name” or “fund name” in combination with Datastream’s “ename”. If multiple share classes exist, all of them are kept in the sample if they include an equity component. Each share class is limited to one stock exchange. Stocks of LPE vehicles that trade on several exchanges simultaneously are dropped from the sample and only the company’s main exchange remains in the final sample. Since matching by company name produces a large number of duplicates (false positives), screening Worldscope business descriptions — augmented by a press and web search — reduces the set of matches substantially.

Criteria for final inclusion In line with the definition of listed private equity in this study, LPE vehicles must follow the private equity business model and have their assets invested mainly in private equity.

Information regarding the vehicles' asset allocation can be taken from Worldscope or VentureXpert business descriptions, VentureXpert classifications, or company information, such as prospectuses, annual reports and corporate websites. Investments in private equity assets may be conducted directly or indirectly by the vehicle.

Since the private equity business model includes selecting, structuring, monitoring and divesting, these aspects must be mentioned in business descriptions and company documents. This excludes holding companies, which typically do not aim to sell portfolio companies on a regular basis. Furthermore, an investment strategy related to venture capital, mezzanine and/or buyouts must be pursued. This criterion can be checked using the stage focus and stages of interest provided by VentureXpert. If this information is not available, company documents and business descriptions can be analyzed. Vehicles investing mainly in other listed entities are excluded, which applies to many British companies investing in AIM-listed vehicles. Since assets must consist of private companies, real estate investment trusts (REITs) and property trusts do not enter the sample.

Several vehicles cannot be identified as private equity investing in their current condition. These are either misclassifications by Thomson or companies that do not invest in private equity anymore. Since misclassifications are common and companies classified as private equity may not conform to the definition of private equity in the sense of this study, I exclude vehicles that cannot be identified as having followed a private equity strategy at least once in their lifetime.

2.2.5.3 Final sample

The basic sample contains 509 LPE vehicles as of March 2010. It consists of all vehicles found in the last complete screening of data until December 2008 as described above. Whenever I encountered vehicles in the press or industry journals, these were checked against the criteria for inclusion and then added to the sample. Subsamples used in the following chapters may not include all LPE vehicles found so far, since the LPE universe has been updated continuously since these chapters have been written.

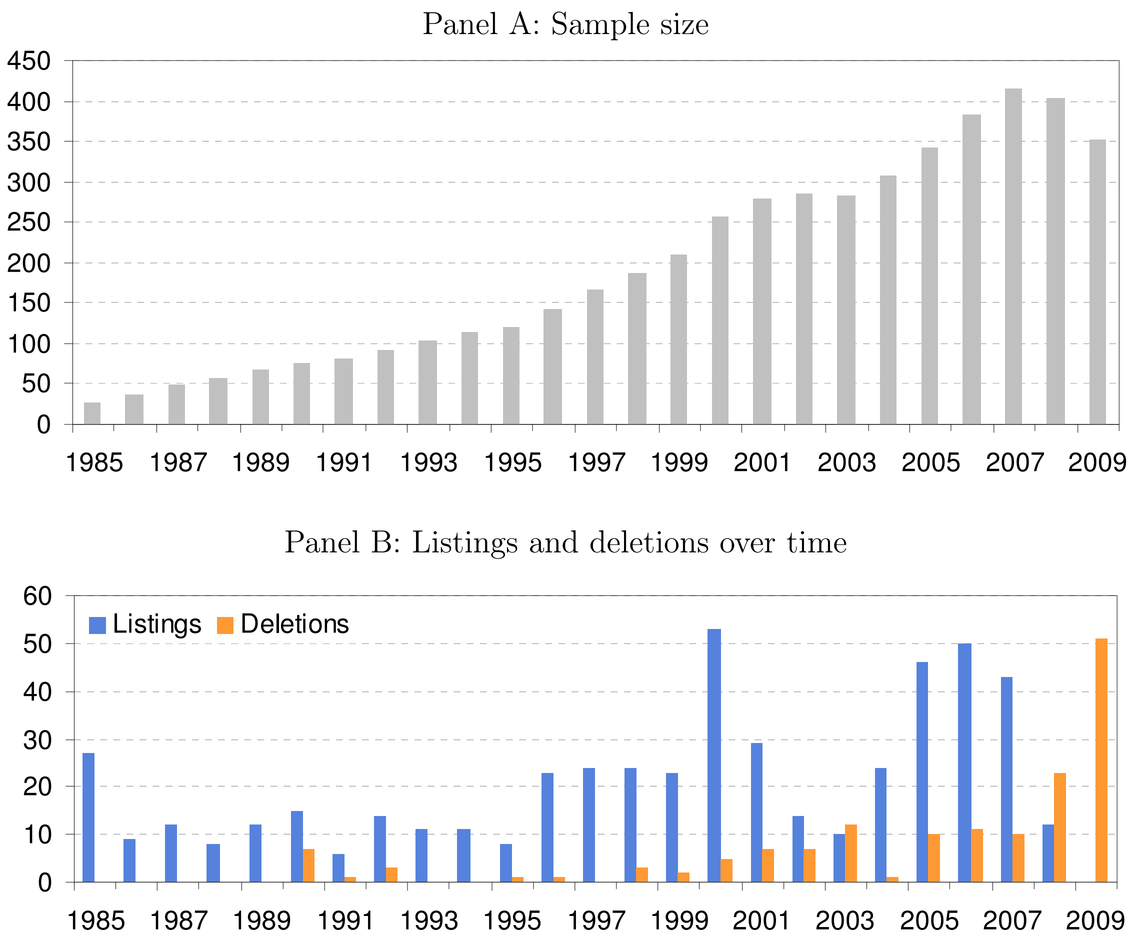

Figure 2.14: Sample

Listings of LPE vehicles prior to and including the year 1985 show up in 1985. New listings in 2009 are likely not zero, for I did the last full screening for LPE vehicles for the year 2008. Deletions are either dates marked as "inactive" by Thomson Datastream, or prices recorded by Datastream did not change after that date. If an inactive date is recorded, this is given priority over inactivity inferred from an absence of price changes. Since stocks have to be inactive for at least 8 weeks, some deletions in 2009 might be erroneous due to illiquidity.

First listings date back to 1964, which is the first recorded date of prices in Datastream. Some investment companies have been founded even earlier.[64] Despite these early occurrences, listed private equity vehicles are a fairly new phenomenon. Two peaks of listing activity are revealed by figure 2.14: Most companies went

[64] For example, Capital Southwest in 1961.

public during the dot-com bubble and from 2005 to 2007. In the year 2000, 53 companies listed their stock on an exchange, while the latest peak occurred in 2006 when 50 companies went public. Listing numbers in general seem to follow the business cycle, which might have pricing implications as argued below in a chapter on net asset value discounts. Listings declined sharply in 2007, along the overall economic climate. Delistings reached their peak in 2008 when 23 vehicles dropped out of my sample. The relative proportion of delistings is highest for IPOs in 2000, of which 37 % were delisted over time. Numbers for 2009 might not reflect the true listing activity, since the listing status of companies had to be inferred from trading activity, which is particularly low in times of weak markets. Between 20 % and 30 % of all vehicles have been delisted over the entire observation period, depending on whether the year 2009 is included. The recent market consolidation left its mark on the total number of vehicles alive, which was highest in 2007.

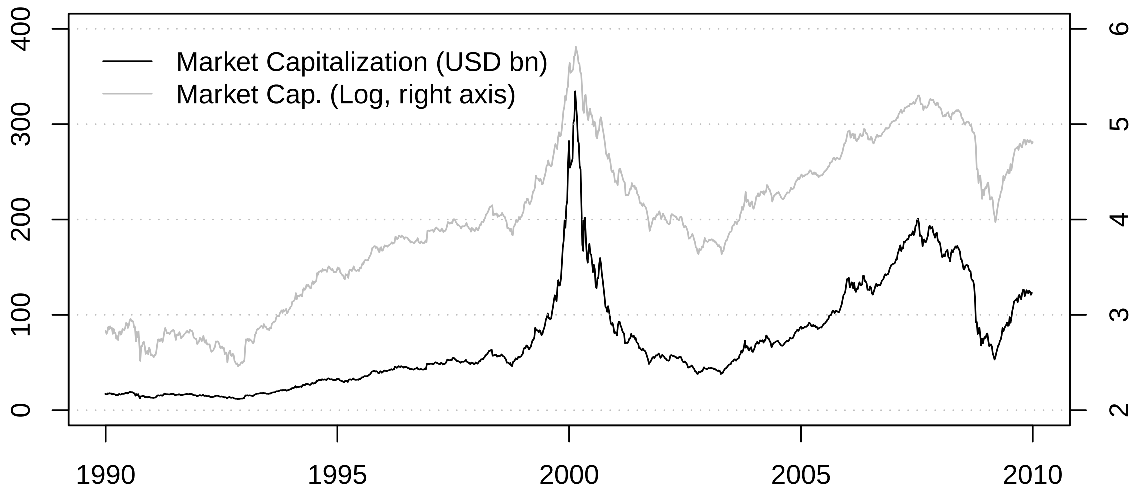

Figure 2.15: Market capitalization of LPE vehicles
Source: Thomson Datastream, author's calculation.

Listed private equity vehicles are mostly located in Europe. 210 (41 %) of all sample vehicles are listed in the U.K., while 67 (13 %) are located in the U.S. and 8 % in Germany. Other relevant markets are Israel (21 vehicles), Australia (20), Canada (19) and Sitzerland (16). The average market capitalization amounts to USD 299.1 million with a median of USD 31.74 million as of 31 December 2009.

Market capitalization is strongly skewed to the right with the largest vehicles being incubators such as Softbank and — temporarily — CMGI. Many vehicles tend to be small and illiquid, which is examined further in chapter 3. Total market capitalization was USD 141 billion at the end of 2009 after it had been almost USD 350 billion in early 2000 as shown in figure 2.15. It shows large swings in excess of equity market movements, which is reflected by the large market betas of listed private equity as shown in chapter 3.

Table 2.1: Industry classifications

Standard Industrial Classification (SIC) codes are primary SIC codes assigned to the companies by Thomson Financial. Industry Classification Benchmark (ICB) codes are from Datastream. If ICB or SIC categories have less than five members, these companies were regrouped into "other" industry codes. ICB codes are 2791 (business support services), 8771 (asset Managers), 8775 (specialty finance), 8777 (investment services), 8985 (equity investment instruments), and 8995 (nonequity investment instruments). SIC codes are 6159 (miscellaneous business credit institution), 6211 (security brokers, dealers & flotation companies), 6282 (investment advice), 6719 (lessors of real property), 6722 (management investment, open-end), 6726 (investment offices), and 6799 (investors). "N/A" entries are vehicles whose industry classification is not available in Thomson Financial databases.

	ICB								
SIC	2791	8771	8775	8777	8985	8995	Other	N/A	Total
6159	0	0	3	0	2	0	0	0	5
6211	0	1	3	0	3	0	1	0	8
6282	0	1	11	1	2	0	2	0	17
6719	0	0	19	0	8	0	1	0	28
6722	0	0	3	0	4	0	0	0	7
6726	0	3	8	2	43	1	1	0	58
6799	1	2	57	2	116	1	2	1	182
Other	4	2	29	1	6	0	20	0	62
N/A	2	1	47	1	63	7	20	1	142
Total	7	10	180	7	247	9	47	2	509

Almost 84 % of all LPE vehicles operate in two industries, according to the Industry Classification Benchmark (ICB): 8985 (equity investment instruments) and 8775 (specialty finance). If Standard Industry Classification (SIC) codes are considered, the two largest groups are 6799 (investors) and 6726 (investment offices), which only make up 47 % of my sample as depicted in table 2.1. The next largest SIC codes are 6719 (lessors of real property) and 6282 (investment advice), which indicates that a distinction between asset management and private equity investing is not always clear.

Industry classification codes might be used to generate a sample of private equity vehicles. Using the six most frequent codes from table 2.1, 92 out of 93 vehicles from the intermediaries set that are LPE according to my definition can be found. If all 117 vehicles from the original intermediaries set (including vehicles that did not turn out to be listed private equity) were to be found, these ICB codes would generate 107 hits. When using SIC codes, only 85 and 106 vehicles can be found, respectively. At least for classification purposes in listed private equity, ICB codes seem to be the superior choice.

Chapter 3

Organizational Forms and Risk of Listed Private Equity[1]

3.1 Introduction

In this chapter, I analyze risk and return characteristics of listed private equity vehicles depending on their organizational structure. Private equity investments are sometimes believed to offer higher risk-adjusted returns than traditional asset classes, mostly due to a small correlation with the market portfolio. Historical correlation estimates of private equity investments to equity markets show low values of 0.5 to 0.6 and a negative correlation of about 0.1 to bond markets.[2] However, these measures are widely discussed and questioned by academic research.[3] While the extent of co-movements with established asset classes is difficult to measure in traditional (i. e. unlisted) private equity, the LPE segment naturally lends itself to studying risk and return patterns. The existence of market prices enables straightforward measurement of idiosyncratic risk expressed through the standard deviation of closing prices as well as correlations with traditional asset classes.

Before estimating the performance of listed private equity, I have to account for

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[1] This chapter has been published in The Journal of Private Equity, Vol. 13(1), 89–99, 2009; Copyright Institutional Investor Journals.

[2] See Bance (2004, p. 6).

[3] See Phalippou (2007).

the greater diversity of this asset class compared to traditional private equity funds. I therefore introduce a new way to classify LPE entities according to their organizational structure as outlined in chapter 2.2.2. Entities are distinguished along two dimensions as to whether they are managed by a third party and whether they set up or invest in more than one fund. Quoted funds or quoted funds of funds are managed externally, whereas investment companies and quoted firms employ their own fund management. The organizational forms of LPE entities should exhibit different risk and return characteristics, since their business models differ substantially. I investigate a comprehensive international sample of 274 liquid LPE entities and find that internally managed entities exhibit higher systematic risk than externally managed ones. Risk-adjusted excess returns are negligible in almost all models tested. The entire sample consists of 446 LPE entities that have to fulfill strict requirements with respect to the underlying assets they invest in as well as the strategy they apply in their investment process.

This chapter builds on work by Bilo, Christophers, Degosciu, and Zimmermann (2005), who developed the highly recognized LPX index[4], which is often referred to in academic as well as practitioner oriented literature (see Kaserer et al. (2007), Diller (2006), Phalippou (2007), Weidig and Mathonet (2005), Ibbotson Associates (2007), and Rodin (2008)). Despite these publications, academic research on the risk and return properties of listed private equity is limited.

Martin and Petty (1983) identify 37 venture capital firms between 1970 and 1980, of which only 11 companies are included in their final sample (8 small business investment companies (SBIC) and three venture capital companies) due to missing price data and inactive trading. The authors analyze risk and reward of the publicly traded venture capital funds in comparison to 20 "maximum capital gain" mutual funds and the S&P 500 index. A back-of-the-envelope calculation of an equally weighted portfolio shows an average annual return of 26.8 %, a standard deviation of 44.8 % and a Sharpe ratio of 0.45. By ranking the funds by Sharpe ratio, Martin and Petty find that seven of the best and the two worst funds are venture capital

[4] See http://www.lpx.ch.

funds. They suggest that that most risk averse investors would invest in individual publicly traded venture capital funds as often as in "maximum capital gain mutual funds" or a S&P 500 portfolio.

Brophy and Guthner (1988) investigate the findings by Martin and Petty (1983) further. Their empirical work is based on a set of 12 publicly traded venture capital companies in the period from 1981 to 1985. Their aim is to provide an explanation of the rationale for institutional investors' fund of funds approach, applying modern portfolio theory. They compute returns of two different portfolios: one equally weighted and one constructed to be mean-variance efficient ex ante with respect to the Capital Asset Pricing Model (CAPM). They achieve mean returns of 19.36 % (24.30 % for the mean-variance efficient portfolio), which are superior to the S&P 500 and to growth-oriented mutual funds, standard deviations of 15.80 % and beta estimates of 0.8 (0.9). They eventually address the issue of "thin market" characteristics and non-synchronous trading and correct for a potential systematic bias by applying the Scholes-Williams beta estimation technique.

Bilo et al. (2005) identify a set of 287 LPE vehicles between 1986 and 2003. After applying liquidity constraints and excluding non-surviving vehicles, they analyze a subset of 114 liquid vehicles by calculating three different portfolio strategies, one value-weighted and two equally weighted, of which is one buy-and-hold and one weekly rebalanced portfolio. They find Sharpe ratios of 0.01 for their value-weighted index and 0.57 and 0.04 on an equally weighted basis for a rebalancing and buy-and-hold strategy, respectively. Betas vary between 0.6 (equally weighted returns) and 1.2 (value weighted). Their equally weighted, rebalanced index seems to outperform the market substantially, even if returns are adjusted for risk.

Bilo et al. (2005) examine potential return biases and suggest corrections for these. Correcting for autocorrelation caused by thin trading leads to lower Sharpe ratios and betas of about one. Costs that are induced by bid-ask spreads lower mean returns and Sharpe ratios even further. Despite the potential selection bias caused by the difficulty to identify dead entities, including non-surviving vehicles in the sample increases the annual mean in almost all observed time intervals.

One objective of this chapter is to replicate the findings of risk-adjusted excess returns in the study by Bilo et al. (2005). I therefore review their index construction methods in the context of private equity indices and general index construction principles. While results of my analysis suggest higher Sharpe ratios of LPE compared to equity markets, which are also documented by Bilo et al. (2005), excess returns in CAPM regressions disappear across the board, except in equally weighted indices of funds of funds and firms. These findings can be partly explained by different index calculation as described in section 3.2.

The remainder of this chapter is organized as follows. Section 3.3 and 3.4 introduce the data set and estimation methods. Section 3.5 provides results for Sharpe ratios and CAPM regression of value-weighted and equally weighted LPE indices. I conduct robustness tests in section 3.6, and section 3.7 concludes this chapter.

3.2 Index construction

This section reviews construction principles of listed private equity indices. I provide an overview of existing indices and point to potential pitfalls in index construction and data quality. Bilo et al. (2005) calculate value-weighted and equally weighted indices. Since listed private equity indices are mostly value-weighted, I first focus on this construction principle and revisit equally weighted indices thereafter. A discussion of how to include transaction costs into value-weighted indices concludes this section.

3.2.1 Value-weighted indices: Laspeyres

The notation used throughout this chapter is based on the definitions used by Deutsche Börse AG[5]:

[5] Guide to the Equity Indices of Deutsche Börse, available at http://deutsche-boerse.com/dbag/dispatch/de/kir/gdb_navigation/market_data_analytics/20_indices/60_publications/20_guidelines.

i	=	Number indicating the entities contained in the index
$i_{t,T}$	=	Set of entities contained in the index at dates t and T
t	=	Date of index calculation
T	=	Date of last chaining (rebalancing) event
I_t	=	Value of the index at time t
c_{it}	=	Current correction factor for entity i at time t
K_T	=	Index-specific chaining factor, valid from chaining date T
ff_{iT}	=	Free float factor for share class i at time T
$p_{i,t}$	=	Share price at time t.
$p_{i,0}$	=	Closing price of entity i for the last trading day prior to index inclusion
$q_{i,t}$	=	Number of shares outstanding at time t for entity i
$q_{i,0}$	=	Number of shares outstanding of entity i at the last trading day before index inclusion
$R_{i,T}$	=	Datastream total return index for entity i at t

3.2.1.1 Index formula

If ordinary index rebalancing (=chaining) occurs at times T and $T+1$, the Laspeyres index is calculated as

$$I_t = \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot \frac{\sum_{i_{T,T-1}} p_{i,T} \cdot q_{i,T-1}}{\sum_{i_{T,T-1}} p_{i,T-1} \cdot q_{i,T-1}} \cdot ... \cdot \frac{\sum_{i_{2,1}} p_{i2} \cdot q_{i1}}{\sum_{i_{2,1}} p_{i1} \cdot q_{i1}} \cdot \frac{\sum_{i_{1,0}} p_{i1} \cdot q_{i0}}{\sum_{i_{1,0}} p_{i0} \cdot q_{i0}} \quad (3.1)$$

and describes changes in prices between two calculation dates while holding quantities constant. All entities that have been index constituents between two chaining dates ($i_{T,T-1}$) are included at each calculation date. If there is no chaining, that is, as long as the weights q and the index composition are not changed, eq. 3.1 reduces to the first term. At each chaining event, a new term is multiplied to the chain, hence the name “chaining”.

There are two ways index weights can change in a chaining event: An ordinary chaining occurs in regular intervals, which are defined at the time of index construction and usually are months or quarters. An extraordinary chaining occurs whenever entities are added to the index or drop out. In an ordinary chaining event, individual weights change according to the market capitalization of individual entities at the chaining date. During an extraordinary chaining, relative weights remain the same for all index constituents. Only market capitalizations of new entities are added (or subtracted for entities deleted from the index).

Extraordinary chaining when adding one new entity at $t+1$:

$$I_{t+1} = \frac{\sum_{i_{t,T}} p_{i,t+1} \cdot q_{i,T} + p_{new,t+1} \cdot q_{new,t}}{\sum_{i_{t,T}} p_{it} \cdot q_{i,T} + p_{new,t} \cdot q_{new,t}} \cdot \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot ... \tag{3.2}$$

Extraordinary chaining when deleting one entity at $t+1$:

$$I_{t+1} = \frac{\sum_{i_{t,T}} p_{i,t+1} \cdot q_{i,T} - 0 \cdot q_{old,t}}{\sum_{i_{t,T}} p_{it} \cdot q_{i,T} - p_{old,t} \cdot q_{old,t}} \cdot \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot ... \tag{3.3}$$

To clarify the relation of ordinary and extraordinary chaining, lets assume an ordinary chaining at time $t+2$:

$$\begin{aligned} I_{t+2} = & \frac{\sum_{i_{t,T+1}} p_{i,t+2} \cdot q_{i,T+1} + p_{new,t+2} \cdot q_{new,T+1}}{\sum_{i_{t,T+1}} p_{i,t+1} \cdot q_{i,T+1} + p_{new,t+1} \cdot q_{new,T+1}} \\ & \times \frac{\sum_{i_{t,T}} p_{i,t+1} \cdot q_{i,T} + p_{new,t+1} \cdot q_{new,t}}{\sum_{i_{t,T}} p_{it} \cdot q_{i,T} + p_{new,t} \cdot q_{new,t}} \cdot \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot ... \end{aligned} \tag{3.4}$$

and thus

$$\begin{aligned} I_{t+2} = & \frac{\sum_{i_{t,T+1}} p_{i,t+2} \cdot q_{i,T+1}}{\sum_{i_{t,T+1}} p_{i,T+1} \cdot q_{i,T+1}} \\ & \times \frac{\sum_{i_{t,T}} p_{i,t+1} \cdot q_{i,T} + p_{new,t+1} \cdot q_{new,t}}{\sum_{i_{t,T}} p_{it} \cdot q_{i,T} + p_{new,t} \cdot q_{new,t}} \cdot \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot ... \end{aligned} \tag{3.5}$$

If an extraordinary chaining event coincides with an ordinary one, chaining has to be done only once, as the ordinary chaining also includes the change in index constitution by adjusting the weights of all old and new index constituents. One of the advantages of calculating a value-weighted index according to the Laspeyres formula is that only current prices and quantities must be known and no historic information needs to be gathered or re-evaluated. If no chaining event occurs, the index formula is simply one term. At each chaining event, a new term is multiplied with all prior terms, which become constants and can be accumulated into a chaining factor K_T as described below. The new factor that is multiplied from the left is always one of two cases: 1) ordinary chaining or 2) changes in index composition (extraordinary chaining).

Deutsche Börse The index formula used by Deutsche Börse is a variation of Laspeyres' formula, which, however, results in the same index value. Denominators in eq. 3.1 are shifted one term to the right, so as to yield a ratio of current index market capitalization to the market capitalization at the index base date, multiplied by a chaining factor K_T.

$$\begin{aligned} I_t &= \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{1,0}} p_{i0} \cdot q_{i0}} \cdot \frac{\sum_{i_{T,T-1}} p_{i,T} \cdot q_{i,T-1}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot \ldots \cdot \frac{\sum_{i_{2,1}} p_{i2} \cdot q_{i1}}{\sum_{i_{3,2}} p_{i2} \cdot q_{i2}} \cdot \frac{\sum_{i_{1,0}} p_{i1} \cdot q_{i0}}{\sum_{i_{2,1}} p_{i1} \cdot q_{i1}} \\ &= \frac{\sum_{i_{t,T}} p_{it} \cdot q_{i,T}}{\sum_{i_{1,0}} p_{i0} \cdot q_{i0}} \cdot K_T \end{aligned} \tag{3.6}$$

Deutsche Börse's index formula takes into account only freely available and tradable shares (free float) by including a free float factor (ff):

$$I_t = \frac{\sum_i p_{it} \cdot q_{iT} \cdot ff_{iT} \cdot c_{it}}{\sum_i p_{i0} \cdot q_{i0} \cdot ff_{i0}} \cdot K_T. \tag{3.7}$$

The resulting chaining factor is

$$K_{T+1} = \frac{\sum_i p_{it} \cdot q_{iT} \cdot ff_{iT} \cdot c_{it}}{\sum_i p_{it} \cdot q_{i,T+1} \cdot ff_{i,T+1}} \cdot K_T, \tag{3.8}$$

which is the ratio of index values at the chaining date computed with old and new weights. Because $t = T + 1$ on the day the chaining factor is calculated, the index formula eq. 3.6 can be seen to be identical to eq. 3.7 and 3.8.

Dow Jones STOXX PE 20 The capitalization weighted version of Dow Jones' DJ STOXX PE 20[6] is calculated as

$$I_t = \frac{\sum_i (p_{i,t} \cdot q_{i,t} \cdot ff_{i,t} \cdot cf_{i,t} \cdot x_{i,t})}{D_t} \tag{3.9}$$

where

$$D_{t+1} = D_t \cdot \frac{\sum_i (p_{i,t} \cdot q_{it} \cdot ff_{i,t} \cdot cf_{i,t} \cdot x_{i,t}) \pm \Delta MC_{t+1}}{\sum_i (p_{i,t} \cdot q_{i,t} \cdot ff_{i,t} \cdot cf_{i,t} \cdot x_{i,t})}, \tag{3.10}$$

$D_0 = 1$ and

$cf_{i,t}$	=	Cap limit for entity i at time t
$x_{i,t}$	=	Exchange rate between local and index currency
ΔMC_{t+1}	=	Difference between index capitalization and adjusted market capitalization. Market capitalization is adjusted because of capital actions in $t+1$ as follows: The market capitalization at t using closing prices, number of shares, and free float factor at t is subtracted from the market capitalization at $t+1$ calculated with adjusted closing price, new number of shares, and free float factor at $t+1$.

New index constituents and deletions as well as capital actions are accounted for by daily adjustments to the market capitalization (ΔMC). This index formula is thus equivalent to the general Laspeyres formula (3.1) with chaining (3.2) and (3.3).

Calculation with data from Datastream There is no individual adjustment factor c_{it} available from Datastream. It can be calculated using Datastream data, however, if the relation between individual return indices and prices is considered:

$$R_{i,t} = \frac{p_{i,t} \cdot c_{i,t}}{p_{i,T}} R_{i,T}. \tag{3.11}$$

where

[6] Dow Jones STOXX® Index Guide Version 12.0, February 2008.

$R_{i,t}$ = Return index for entity i at the calculation date

$R_{i,T}$ = Return index at the last chaining date.

If we substitute (3.11) into the index formula (3.7), it becomes computable using Datastream data only:

$$I_t = K_T \frac{\sum_i q_{i,T} \cdot ff_{i,T} \cdot \frac{R_{i,t}}{R_{i,T}} \cdot p_{i,T}}{\sum_i p_{i,0} \cdot q_{i,0} \cdot ff_{i,0}} \tag{3.12}$$

The same goes for the chaining factor:

$$K_{T+1} = K_T \frac{\sum_i q_{i,T} \cdot ff_{i,T} \cdot \frac{R_{it}}{R_{i,T}} \cdot p_{i,T}}{\sum_i p_{it} \cdot q_{i,T+1} \cdot ff_{i,T+1}} \tag{3.13}$$

For practical applications it is more convenient to use a recursive formula to compute index values, which is augmented by individual adjustment factors $c_{i,t}$ to account for dividends and capital actions:

$$I_t = \frac{\sum_{i_{t,T}} p_{i,t} \cdot q_{i,T} \cdot c_{i,t}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \cdot \frac{\sum_{i_{T,T-1}} p_{i,T} \cdot q_{i,T-1} \cdot c_{i,T}}{\sum_{i_{T,T-1}} p_{i,T-1} \cdot q_{i,T-1}} \cdot \ldots \cdot \frac{\sum_{i_{1,0}} p_{i,1} \cdot q_{i,0} \cdot c_{i,1}}{\sum_{i_{1,0}} p_{i,0} \cdot q_{i,0}} \tag{3.14}$$

We finally substitute eq. 3.11 in eq. 3.14 to obtain the index formula with Datastream data

$$I_t = \frac{\sum_{i_{t,T}} q_{i,T} \cdot \frac{R_{it}}{R_{iT}} \cdot p_{iT}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \frac{\sum_{i_{T,T-1}} q_{i,T-1} \cdot \frac{R_{iT}}{R_{i,T-1}} \cdot p_{i,T-1}}{\sum_{i_{T,T-1}} p_{i,T-1} \cdot q_{i,T-1}} \ldots \frac{\sum_{i_{1,0}} q_{i0} \cdot \frac{R_{i1}}{R_{i0}} \cdot p_{i0}}{\sum_{i_{1,0}} p_{i0} \cdot q_{i0}}. \tag{3.15}$$

Daily chaining The index formula reduces to a simpler version, if the index is chained on a daily basis. Using the relation between returns and prices

$$R_{i,t} = \frac{p_{it} \cdot c_{i,t}}{p_{i,t-1}} R_{i,t-1} \tag{3.16}$$

from above, we get

$$c_{i,t} = \frac{R_{i,t}}{R_{i,t-1}} \frac{p_{i,t-1}}{p_{i,t}}. \tag{3.17}$$

If we substitute this into the index formula (3.7) and let $T = t-1$ (daily chaining), it follows that

$$I_t = K_{t-1} \frac{\sum_i q_{i,t-1} \cdot ff_{i,t-1} \cdot \frac{R_{i,t}}{R_{i,t-1}} \cdot p_{i,t-1}}{\sum_i p_{i,0} \cdot q_{i,0} \cdot ff_{i,0}}. \tag{3.18}$$

The chaining factor (3.8) is obtained by

$$K_t = K_{t-1} \frac{\sum_i q_{i,t-1} \cdot ff_{i,t-1} \cdot \frac{R_{i,t}}{R_{i,t-1}} \cdot p_{i,t-1}}{\sum_i p_{i,t} \cdot q_{i,t} \cdot ff_{i,t}}. \tag{3.19}$$

Calculating the chaining factor on a daily basis is somewhat cumbersome but can be simplified. It is possible to compute daily index returns and to construct the index time series from these without having to calculate chaining factors. The daily index return is

$$\frac{I_{t+1}}{I_t} = \frac{K_t}{K_{t-1}} \frac{\sum_i q_{i,t} \cdot ff_{i,t} \cdot \frac{R_{i,t+1}}{R_{i,t}} \cdot p_{i,t}}{\sum_i q_{i,t-1} \cdot ff_{i,t-1} \cdot \frac{R_{i,t}}{R_{i,t-1}} \cdot p_{i,t-1}}. \tag{3.20}$$

If we plug in the daily chaining factor (3.19), we get a more practical recursive index formula:

$$\frac{I_{t+1}}{I_t} = \frac{\sum_i q_{i,t} \cdot ff_{i,t} \cdot \frac{R_{i,t+1}}{R_{i,t}} \cdot p_{i,t}}{\sum_i p_{i,t} \cdot q_{i,t} \cdot ff_{i,t}}. \tag{3.21}$$

3.2.1.2 Laspeyres vs. Bilo et al. (2004)

Results for listed private equity returns found by Bilo et al. (2004) are potentially biased because of differences in computing index values between their index formula and the general Laspeyres formula. Bilo et al. use prices at the end of return periods, whereas the Laspeyres formula uses prices at the beginning of each return period. Two problems arise: First, the Bilo et al. method leads to an overestimation of true returns. Second, such an index is not investible. This difficulty can be shown as follows.

Bilo et al. calculate their index[7] by

$$I_{t+1} = I_t \cdot \sum_i \frac{M_{i,t+1}}{M_{t+1}} \frac{(p_{i,t+1} + D_{i,t+1}) Adj_{i,t+1}}{p_{i,t}} \tag{3.22}$$

[7] See Bilo et al. (2004, p. 10). Bilo et al. (2005) seem to use the same methodology, since both papers report identical results.

where

$M_{i,t}$	=	Market capitalization of entity i at time t
M_t	=	Index capitalization at time t
D_{it}	=	Dividends paid by entity i at time t
Adj_{it}	=	Adjustment factor for capital actions (e. g. stock split).

The last term is the ratio of two individual return indices on two consecutive days (see eq. 3.16). It follows that

$$r_{i,t+1} = \frac{R_{i,t+1}}{R_{i,t}} = \frac{(p_{i,t+1} + D_{i,t+1})Adj_{i,t+1}}{p_{i,t}}. \tag{3.23}$$

Therefore, eq. 3.22 can be written as

$$I_{t+1} = I_t \cdot \sum_i \frac{M_{i,t+1}}{M_{t+1}} \cdot r_{i,t+1} \tag{3.24}$$

and expanding market values yields

$$I_{t+1} = I_t \cdot \frac{1}{\sum_i p_{i,t+1} \cdot q_{i,t+1} \cdot ff_{i,t+1}} \sum_i p_{i,t+1} \cdot q_{i,t+1} \cdot ff_{i,t+1} \cdot r_{i,t+1}. \tag{3.25}$$

To compare eq. 3.25 to the Laspeyres formula, we use eq. 3.23 and rewrite the Laspeyres index (3.21):

$$I_{t+1} = I_t \cdot \frac{1}{\sum_i p_{i,t} \cdot q_{i,t} \cdot ff_{i,t}} \sum_i p_{i,t} \cdot q_{i,t} \cdot ff_{i,t} \cdot r_{i,t+1}. \tag{3.26}$$

Tomorrow's prices $p_{i,t+1}$ are weighted by tomorrow's market capitalizations in eq. 3.25, but by today's capitalizations in 3.26. Because the Laspeyres index employs current capitalizations, an investor can replicate this index without future information. By contrast, an investor trying to compose a portfolio following the index described by eq. 3.25 would need to know tomorrow's (unknown) weights.

Moreover, Bilo's index formula[8] can be interpreted as daily re-weighting according

[8] Bilo et al. (2004, p. 10).

to the new market values, which is contrary to their statement "The index basically represents an unbalanced strategy, except if a new listing occurs: capital is taken out of the existing vehicles and reinvested in the new portfolio constituent." This inconsistency can be resolved if one assumes that the index formula (3.22) is valid only on chaining dates, that is, $t = T$.

Similarly, a re-weighting changing all weights according to current market capitalizations occurs whenever an entity is added to the index. This corresponds to an ordinary chaining in Laspeyres-type indices instead of an extraordinary one, which is a rather unusual index design. Consider the economic interpretation of such a chaining rule: The index portfolio is rebalanced completely if and only if a new entity is added or an index constituent drops out. Bilo et al. do not specify what happens if an entity is deleted from the index portfolio.

3.2.1.3 Laspeyres vs. LPX

The guide to the listed private equity indices provided by LPX GmbH[9] contains ambiguities in some places as outlined below. Their index formula on page 13 is apparently based on the Laspeyres formula, which is augmented by currency adjustments to include international listed private equity entities in their index portfolios.

Index formula Since 15 June 2005, the LPX Major Market Index is computed with a Laspeyres formula. Since 14 December 2005, all other LPX indices are computed using this formula except the LPE Composite, which is based on a recursive formula.[10] This suggests that this recursive formula was used for all other indices prior to 2005, which can lead to biases when comparing different time series.[11]

Adjustment factors An inconsistency to the Laspeyres method can be found in the LPX manual for calculating individual adjustment factors ($C_{i,t}$). According to

[9] Guide to the LPX Indices, Version 2.6.

[10] See Guide to the LPX Indices, Version 2.6, p. 13.

[11] The LPX Composite is based on the works by Bilo et al.; see index formulas by Bilo et al. (2004) above.

page 15 in the manual, they are calculated as a product of individual factors for a number of reasons, of which especially dividend adjustments and adjustments for stocks splits seem a little odd. The factor for stock splits is equal to unity only on index day 1 ($t = 1$), although all individual adjustment factors are usually set to unity on chaining dates (which is the objective of chaining). The same curiosity can be found in the formula for dividend adjustments.

Individual dividend adjustment factors between two chaining dates are added instead of multiplied, which is uncommon:

$$a_{i,t} = \left(1 + \frac{(1-Q)D_{i,t}}{p_{i,t-1} - (1-Q)D_{i,t}}\right) \cdot a_{i,t-1}, \tag{3.27}$$

where Q is the tax rate applicable to dividends. However, this method leads to the same correction factors as in the general Laspeyres formula, which is shown below. First, I deduce a general dividend adjustment factor which is then compared to the factor computed by the LPX method.

Let us assume without loss of generality that a company pays dividends on two consecutive days between chaining dates and that no new information arrives that could influence share prices.[12] Shares prices for this company are

$$P_{t+1} = P_t - D_{t+1} \tag{3.28}$$

and thus

$$P_{t+2} = P_t - D_{t+1} - D_{t+2}. \tag{3.29}$$

The individual adjustment factor for this company is

$$c_{t+2} = \frac{P_t}{P_{t+2}} = \frac{P_t}{P_t - D_{t+1} - D_{t+2}}. \tag{3.30}$$

[12] Dividend payments must occur between two chaining dates, payments on two consecutive dates merely simplify notation.

Ignoring taxes, the adjustment factor according to the LPX method (3.27) is

$$c_{t+2} = \left(1 + \frac{D_{t+2}}{P_{t+1} - D_{t+2}}\right) \cdot c_{t+1}. \tag{3.31}$$

Since the adjustment factor at $t = 0$ is unity, it follows that

$$c_{t+2} = \left(1 + \frac{D_{t+2}}{P_{t+1} - D_{t+2}}\right) \cdot \left(1 + \frac{D_{t+1}}{P_t - D_{t+1}}\right). \tag{3.32}$$

Using P_{t+1} from eq. 3.28 in eq. 3.32 and expanding yields

$$c_{t+2} = 1 + \frac{D_{t+1}}{P_t - D_{t+1}} + \frac{D_{t+2}}{P_t - D_{t+1} - D_{t+2}} + \frac{D_{t+2}D_{t+1}}{(P_t - D_{t+1})(P_t - D_{t+1} - D_{t+2})}, \tag{3.33}$$

which reduces to

$$c_{t+2} = \frac{P_t}{P_t - D_{t+1} - D_{t+2}}. \tag{3.34}$$

The index formula used by LPX indices (3.34) and the general formula (3.30) are therefore equivalent.

3.2.2 Equally weighted index

In order to enable a robustness test for capitalization-weighted indices, I compute an equally weighted index. With daily rebalancing to equal weights, this index is calculated as

$$I_{t+1} = I_t \cdot \frac{1}{n_{t+1}} \sum_i \frac{R_{i,t+1}}{R_{i,t}}. \tag{3.35}$$

Although Bilo et al. (2004) use this index formula, they state in their index description that there is weekly rebalancing to equal weights. If this is true, weights vary according to changes in the entities' individual market capitalization between two rebalancing dates T and $T + 1$. Correspondingly, their index formula should read

$$I_{t+1} = I_T \cdot \frac{1}{n_{t+1}} \sum_i \frac{R_{i,t+1}}{R_{i,T}}, \tag{3.36}$$

which is the equally weighted return since the last (weekly) rebalancing date.

If we assume daily rebalancing or if returns are measured weekly, it follows that $T = t$ in eq. 3.36, which leads to index formula eq. 3.35. Still, it is not clear how to incorporate new listings or deletions between two rebalancing dates. One solution would be to wait until the next rebalancing date and to add new entities then. A difficulty with this procedure can arise if index constituents delist between two rebalancing dates or drop out of the index portfolio for some other reason. This leads to the question whether the appropriate denominator in eq. 3.36 is n_T or n_{t+1}. If neither additions nor deletions occur, then $n_T = n_{t+1}$. If the portfolio composition changes, index values might be biased, for instance, if weighting is done by n_T and new listings occur in $t + 1$, or if returns are weighted by n_{t+1} but some entity is deleted between T and $t + 1$.

To allow for portfolio changes, rewrite the index formula 3.36 as

$$I_{t+1} = I_t \cdot \frac{\sum_i \frac{R_{i,t}}{R_{i,T}} \frac{R_{i,t+1}}{R_{i,t}}}{\sum_i \frac{R_{i,t}}{R_{i,T}}} = I_t \cdot \frac{\sum_i \frac{R_{i,t+1}}{R_{i,T}}}{\sum_i \frac{R_{i,t}}{R_{i,T}}}. \tag{3.37}$$

If an entity is added now, index calculation at time $t + 1$ changes similar to eq. 3.2 to

$$I_{t+1} = I_t \cdot \frac{\sum_i \frac{R_{i,t+1}}{R_{i,T}} + \frac{R_{new,t+1}}{R_{new,t}}}{\sum_i \frac{R_{i,t}}{R_{i,T}} + 1}. \tag{3.38}$$

To ensure consistency of calculation until the next rebalancing date $T + 1$, let $R_{new,T} = R_{new,t}$. By means of this construction, the new entity is incorporated into the denominator in eq. 3.37 from time $t + 2$.

Á deletion from the index portfolio is constructed in an analogous manner:

$$I_{t+1} = I_t \cdot \frac{\sum_i \frac{R_{i,t+1}}{R_{i,T}}}{\sum_i \frac{R_{i,t}}{R_{i,T}} - 1}. \tag{3.39}$$

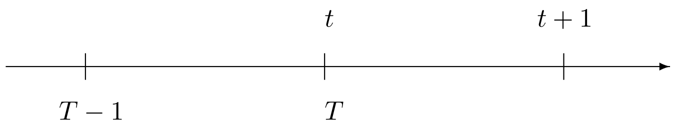
3.2.3 Transaction costs

Indices provide information about market movements, but should also be investible. Transactions costs are usually not considered in index construction, since market participants face different magnitudes of costs, which would lead to a large number of investor-specific indices. The drawback of not considering costs is that index returns overstate investor returns, which complicates the use of indices as return benchmarks. Transaction costs in the listed private equity market are generally non-trivial. In particular, implicit transaction costs such as large bid-ask spreads (BAS hereafter) in illiquid entities necessitate an adjustment to obtain fair benchmark returns. The following calculation assumes costs that amount to half the bid-ask spread for each trade that occurs during chaining, which reduce index returns over the next period. An adjustment procedure is shown for equally weighted indices.

An equally weighted index can be computed according to eq. 3.37:

$$I_{t+1} = I_t \cdot \frac{\sum_i \frac{R_{i,t+1}}{R_{i,T}}}{\sum_i \frac{R_{i,t}}{R_{i,T}}}. \tag{3.40}$$

Assume that ordinary chaining is scheduled for time t, which results in the following series of event dates.



Transaction costs are assumed to accrue at time t due to changes in weights caused by rebalancing. Costs are assumed to be deducted at the beginning of each time period. Consequently, they reduce index returns over the subsequent time period between t and $t+1$. An index return in eq. 3.40 can be seen as a return prior to transaction costs. If transaction costs are to be considered at the period's beginning at time t, this return must be weighted by the initial investment less costs at time t. The sum of all weights (= market capitalization) at t is the number of entities n. We therefore face the question which proportion of the market capitalization to deduct at t:

$$I_{t+1} = I_t \cdot \frac{\sum_i \frac{R_{i,t+1}}{R_{i,T}}}{\sum_i \frac{R_{i,t}}{R_{i,T}}}(1 - BAS). \tag{3.41}$$

Costs per entity are the difference between its index weight before rebalancing at time t and its weight $1/n$ after rebalancing, multiplied by half its bid-ask spread.

$$BAS = \sum_i \left(\left| \frac{\frac{R_{i,t}}{R_{i,T-1}}}{\sum_i \frac{R_{i,t}}{R_{i,T-1}}} - \frac{1}{n} \right| \cdot \frac{1}{2} BAS_i \right). \tag{3.42}$$

Example

Let a and b be two listed entities and

$R_{a,t} = 20,\ R_{a,T-1} = 15,\ BAS_a = 0.02$

$R_{a,t} = 10,\ R_{a,T-1} = 5,\ BAS_a = 0.03$

It follows that $\frac{R_{a,t}}{R_{a,T-1}} = 1.\bar{3}$ and $\frac{R_{b,t}}{R_{b,T-1}} = 2$ with weights

$$\frac{\frac{R_{a,t}}{R_{a,T-1}}}{\sum_i \frac{R_{i,t}}{R_{i,T-1}}} = \frac{1.\bar{3}}{3.\bar{3}} = 0.4 \text{ and } \frac{\frac{R_{b,t}}{R_{b,T-1}}}{\sum_i \frac{R_{i,t}}{R_{i,T-1}}} = \frac{2}{3.\bar{3}} = 0.6.$$

The new weight is $1/n = 0.5$. The index investor therefore has to buy 0.1 times a's market capitalization and sell 0.1 times b's market capitalization. According to eq. 3.42, the investor incurs costs of $BAS = 0.1\frac{1}{2}BAS_a + 0.1\frac{1}{2}BAS_b = 0.1 \cdot 0.01 + 0.1 \cdot 0.015 = 0.0025$. This corresponds to the *proportion* of the market capitalization at time t that must be deducted as costs in t.

3.3 Data

I identify 446 LPE entities between 1 January 1986 and 31 March 2008 using the Thomson Financial databases VentureXpert and Datastream as well as an extensive press search. The majority of these entities is listed in Europe, particularly in the U.K., where I find a large number of small trusts. Table 3.1 shows that the number of listed entities has been increasing since the beginning of my sample period with a short flat period between 2002 and 2004 when new listings were balanced by delisted entities. Market value reached a peak in 2000, which is mainly due to the inclusion of incubators such as Softbank or CMGI in my sample.

Table 3.1: Sample composition over time

The numbers of LPE vehicles include new listings as well as delistings, which is why the number of vehicles differs from my sample size.

	United Kingdom	Europe ex UK	North America	Rest of World	Total	Market cap in $bn
1 Jan 1986	11	4	7	1	23	3.9
1 Jan 1988	17	11	14	3	45	7.3
1 Jan 1990	19	20	14	6	59	17.1
1 Jan 1992	22	27	17	9	75	17.5
1 Jan 1994	22	35	26	15	98	23.2
1 Jan 1996	29	38	31	18	116	42.7
1 Jan 1998	41	49	37	29	156	48.3
1 Jan 2000	58	62	45	33	198	274.0
1 Jan 2002	95	81	50	37	263	62.1
1 Jan 2004	99	84	53	39	275	71.6
1 Jan 2006	123	92	65	48	328	142.2
1 Jan 2008	154	119	78	50	401	179.4
31 Mar 2008	155	121	79	50	405	163.0

Many LPE entities are rather small and tend to be illiquid. Since an LPE index should be replicable and comparable to other investment indices, such as stock market indices, I apply a set of quantitative liquidity constraints. Virtually all providers of private equity indices and stock market indices use one or more criteria such as minimum market capitalization or average daily trading volume. I focus on the criteria used by Bilo et al. (2005):

- *Number of price observations*: a minimum of 30 weekly observations over the entity's lifetime is required in order to ensure accuracy of parameter estimates.
- *Trade continuity* is measured by the percentage of weeks over the entity's lifetime within which at least one transaction occurs. It must be at least 15 %.
- *Market capitalization*: the instruments are required to exhibit a minimum average market capitalization of USD 2 million.
- *Trading volume*: A minimal trading activity is intended to be assured by imposing a minimum average trading volume of 0.1 % per week. The relative

trading volume is defined by

$$\text{Relative Volume}_t = \frac{\text{Trading Volume (USD)}_t}{\text{Market Value}_t} \tag{3.43}$$

- A maximum average *bid-ask spread* of 20 % is required, defined by the spread of bid and ask price relative to the arithmetic average of the bid and ask quotes.

  $$\text{Bid-Ask-Spread}_t = \frac{\text{Ask}_t - \text{Bid}_t}{\text{Mid price}_t} \tag{3.44}$$

  This corresponds to the approach by Elleswarapu (1997) who states that for each stock the spread in a month is calculated by averaging the daily relative bid-ask spreads, where the relative spread of a day is the dollar bid-ask spread divided by the average of the closing bid and ask prices for the day.

Liquidity constraints and missing data for calculating these liquidity criteria reduce the sample size to 274 entities, of which are 109 funds, 116 investment companies, 30 firms, and 19 funds of funds.

3.3.1 Adjustments to data obtained from Datastream

Ince and Porter (2006) describe some precautions that must be taken when dealing with Datastream data.[13] Therefore, some adjustments must be made to time series data for listed private equity entities:

- I identify dead entities by filtering entities that have substrings {*dead, delisted, merger*} in their names and missing bid-ask spread data at the end of their time series. Alternatively, price observations can be deleted backwards from the end, if returns are zero over some predetermined time period (this procedure is only applicable for times series in local currency, since times series in some other currency would include changes in exchanges rates, which would mask true zero returns).

[13] See Ince and Porter (2006, p. 472 ff.).

- Correcting time series data for missed stock splits and other capital actions: These would be indicated by exceptionally large returns and changes in market capitalization. A press search for corporate events is necessary in each case.

- Prices of small absolute value can exhibit jumps due to rounding in decimal places. Since market capitalization is likely small for these entities, errors caused by rounding should be small in value-weighted indices. Value-weighted indices thus do not need to be adjusted for penny stocks. Special care must be taken when interpreting equally weighted indices, as large return errors in small-cap entities are not reduced by small weights.

- Non-trading can be identified by missing trading volume, but not by missing closing prices, since Datastream uses padded prices in time series.

- A potential survivorship bias in Datastream data must be kept in mind: Since entities are sometimes lost because of mergers or delistings, those cases must be included when searching for listed private equity time series.

Another potential cause of bias are *Open Offers* in British companies. Espenlaub et al. (2008) find that Datastream does not calculate price adjustment factors for these offers during the 1990s, which may lead to downward biased returns at the day the offer is effective. I find some open offers for listed private equity entities that have market capitalizations of USD >100 Mio. in an extensive press search, but none within my sample period.

3.3.2 Risk-free rate

The risk-free rate used for calculations in this chapter is computed from annualized yields to maturity provided by the Federal Reserve Board.[14] Since the Fed uses a bank year with 360 days to annualize yields, the log daily return on 3-month T-Bills (r_{3M}) is given by

[14] See http://www.federalreserve.gov/releases/h15/data.htm (accessed 2009-06-07).

$$r_{D_t} = ln\left((1 + r_{3M,D_{t-1}})^{\frac{D_t - D_{t-1}}{360}}\right), \tag{3.45}$$

where D_t are calendar dates and t are bank days. Therefore, the corresponding weekly risk-free rate of return is the sum of seven daily log returns

$$r_{D_t,week} = \sum_{i=1}^{B} ln\left((1 + r_{3M,D_{t-i}})^{\frac{D_{t-i+1} - D_{t-i}}{360}}\right), \tag{3.46}$$

where B is the number of bank days in a given week — which may or may not correspond to five calendar days — and $D_t - D_{t-B} = 7$.

3.4 Methodology

3.4.1 LPE indices

To measure risk and return of LPE entities and subsamples, I construct one value-weighted and two equally weighted indices which are rebalanced on a weekly basis and whenever delistings occur.

Value-weighted index

For the first portfolio strategy, the weights of the individual index constituents are computed by their market capitalization in relation to the market capitalization of all instruments. Hence the value of the index at time t is determined by the Laspeyres formula

$$I_t = \frac{\sum_{i_{t,T}} q_{i,T} \cdot \frac{R_{i,t}}{R_{i,T}} \cdot p_{i,T}}{\sum_{i_{t,T}} p_{i,T} \cdot q_{i,T}} \frac{\sum_{i_{T,T-1}} q_{i,T-1} \cdot \frac{R_{iT}}{R_{i,T-1}} \cdot p_{i,T-1}}{\sum_{i_{T,T-1}} p_{i,T-1} \cdot q_{i,T-1}} \ldots \frac{\sum_{i_{1,0}} q_{i,0} \cdot \frac{R_{i,1}}{R_{i,0}} \cdot p_{i0}}{\sum_{i_{1,0}} p_{i,0} \cdot q_{i,0}} \tag{3.47}$$

where

I_t	=	Value of the Index at time t
T	=	Chaining (rebalancing) date
$i_{t,T}$	=	Set of companies contained in the index at dates t and T
T	=	Rebalancing day
$R_{i,T}$	=	Datastream total return index for entity i at t
$q_{i,t}$	=	Number of shares outstanding at time t
$p_{i,t}$	=	Share price in USD at time t.

Rebalancing to market capitalization weights occurs whenever a new entity is listed. The new entity's market value is added to the existing index portfolio. Between listings, individual index constituent weights change according to their change in market capitalization with respect to the overall change in market capitalization of all index constituents. Capital changes are accounted for at each balancing date.

Equally weighted index

While value-weighted indices are a proxy for the listed private equity industry as a whole, results might be driven by only a few large-cap index constituents such as Softbank. As a first robustness check, I compute an equally weighted index. At the beginning of the time series an equal fraction of wealth is invested in the individual instruments. In order to maintain equal weights the index is rebalanced on a weekly basis. The index is calculated recursively as

$$I_{t+1} = I_t \frac{\sum_{i_{t+1,T}} \frac{R_{i,t+1}}{R_{i,T}}}{\sum_{i_{t+1,T}} \frac{R_{i,t}}{R_{i,T}}}. \tag{3.48}$$

New index constituents are considered at the first rebalancing day after their listing. Weights of single constituents develop according to their performance between two rebalancing days.

Many small sample vehicles exhibit large bid-ask spreads, up to 20 % on average. This would cause an enormous cost, if one was to replicate the underlying index investment strategy. Therefore, I construct a second equally weighted index where transaction costs due to weekly rebalancing are considered. I do not adjust the value-weighted index for bid-ask spreads, because these amount to only 1.5 % on average for the vehicles representing 90 % of the total index capitalization.

3.4.2 Performance measures

Risk-adjusted returns can be estimated by a variety of measures. I focus on Jensen's Alpha and calculate Sharpe ratios mainly for historical comparisons. While both measures are widely used in theory and practice, they must be applied with some caution in the context of partially illiquid assets such as LPE. Listed private equity returns sometimes trade thinly which may lead to autocorrelated returns. These cause the return variance to be downward biased and in turn increase the Sharpe ratio. The capital asset pricing model or arbitrage pricing models can be misspecified due to autocorrelated error terms.

Sharpe ratio

The "reward-to-variability"-ratio which is better known under the name *Sharpe ratio* (Sharpe, 1966) relates the excess return of an investment over the risk-free rate to the standard deviation of its return and is determined by

$$SR = \frac{r_p - r_f}{\sigma_p} \tag{3.49}$$

where r_p is the total return of a portfolio p, r_f is the risk-free rate of return, and σ_p is the standard deviation of the portfolio returns.

A major source of bias in return variances is the tendency for prices recorded at the end of a time period to represent the outcome of a transaction that occurred earlier in or prior to the period in question. Fisher (1966) points out that this causes an index constructed from such share price data to be an average of the temporally ordered underlying values of the shares. Consequently, positive serial correlation is induced into returns which are calculated from the index and the estimated variance of returns on the index is biased downward. Shares that suffer from non-trading also have their covariance with the market substantially underestimated. French et al. (1987) also find non-synchronous trading of securities to cause portfolio returns to be autocorrelated. In order to overcome the impact of autocorrelation, they estimate the variance of the monthly return to the S&P portfolio as the sum of the squared daily returns plus twice the sum of the products of preceding returns,

$$\sigma_{mt}^2 = \sum_{i=1}^{N_t} r_{it}^2 + 2 \sum_{i=1}^{N_t - 1} r_{it} r_{i+1,t} \tag{3.50}$$

where σ_t^2 is the return variance in month t, N_t is the number of daily returns, and r_{it} is the return on day i in month t. Since this covariance estimator need not be positive semidefinite in finite samples, I use a Newey-West estimator

$$\sigma_{mt}^2 = \sigma_{t,t} + 2 \sum_{j=1}^{p} \left(1 - \frac{j}{p+1}\right) \sigma_{t,t+j} \tag{3.51}$$

where $\sigma_{t,t+j}$ is the j^{th} return autocovariance and p is the lag truncation parameter. I employ this method using 20 lags[15], since my data show autocorrelated returns at a high number of lags.

Jensen's Alpha

Returns of LPE indices have two properties that have to be accounted for when estimating their risk and excess return component: an international scope by construction and an extensive autocorrelation structure as described above. Therefore, I cannot use a traditional (national) Capital Asset Pricing Model (CAPM) to estimate Alpha and sensitivity to market risk. Instead, I employ a combination of the international CAPM and a Dimson regression to address these issues.

For non-synchronously traded shares the estimated variance of returns is biased downward (Dimson, 1979). Moreover, these shares have their covariance with market underestimated and thus also possess beta estimates that are biased downward.

[15] 20 lags are used by Bilo et al. (2005), which is not chosen based on any particular metric. I follow Bilo et al. for comparability reasons. Robustness checks should be conducted with regard to the appropriate number of lags.

Dimson presents an approach to obtain an unbiased estimate of risk in the case where the stock and some of the constituents in the market are subject to infrequent trading. He develops a method based on a market model regression, called the aggregated coefficients (AC) method. The underlying assumption is that since shares are subject to infrequent trading, an observed price may represent the actual transaction price in the observed period or a price established in a preceding period. To account for this, Dimson suggests running a multiple regression of observed returns against preceding, synchronous and subsequent market returns.

The multinational nature of my sample vehicles introduces a currency risk, if one replicates the index and holds index constituents in local currency while consuming the proceeds in his home currency. However, this currency risk has not been included in prior studies of LPE returns (Bilo et al., 2005). Several theoretical models of international asset pricing incorporate this additional source of risk (see Solnik (1974), Stulz (1981), Anderson and Danthine (1981), Adler and Dumas (1983), Dumas and Solnik (1995), De Santis and Gérard (1998), and Capiello and Fearnley (2000), and for a survey see Stulz (1995)). They mostly find that the price of currency risk is significantly different from zero. Therefore, models of international asset pricing that only include market risk are misspecified.

Based on the international Capital Asset Pricing Model, the equation for the regression is given by

$$R_t = \alpha + \sum_{k=0}^{7} \beta_k M_{t-k} + \gamma_1 GBP_t + \gamma_2 EUR_t + \gamma_3 JPY_t + \epsilon_t, \qquad (3.52)$$

where R_t and M_{t-k} are the respective observed logarithmic (excess) index and market returns at time t and t-k, whereas k corresponds to the respective lag, α, β and γ are the slope coefficients and ϵ_t is an error term. I include seven lagged market returns, since this number of lags turns out to be statistically significant for equally weighted indices. GBP, EUR and JPY are the weekly log returns of currency portfolios to account for exchange rate fluctuations and movements in local interest rates. They are constructed as (excess) returns on short-term deposits denominated in local currency and measured in the reference currency. All returns are continuously compounded. Since market return autocorrelations are relatively small compared to autocorrelations in my LPE indices, I exclude leading market returns to avoid look-ahead bias. The risk-free rate of return was estimated by averaging the monthly averages of three-month Treasury bill returns over the observed period (see Brophy and Guthner (1988)) and taking logs.

3.5 Results

Performance measurement is conducted for two different portfolio strategies: a value-weighted index and an equally weighted strategy, both rebalanced on a weekly basis. From 1986 to 2008, the value-weighted index yields a weekly log return of 0.265 %, while the equally weighted index performs much better with an average 0.326 % return per week. Standard deviations are substantial for investment companies and firms compared to market returns, as depicted in table 3.2. This corresponds to an arithmetic return of 14.8 % and 18.5 % per year for value-weighted and equally weighted indices, respectively. Though the value-weighted index is dominated by only a few large-cap vehicles like CMGI and Softbank, equally weighted spread-adjusted returns are similar to value-weighted returns. The mean weekly equally weighted return is 0.33 %, which is reduced to 0.24 % (13.2 % per year) by spread costs.

Among the different organizational structures of LPE, investment companies and firms achieve the highest returns at a correspondingly high standard deviation. This suggests higher risk for vehicles with these two organizational forms – a finding that is confirmed by an estimation of systematic risk. Externally managed vehicles (funds and funds of funds) offer slightly higher mean returns compared to the market while having similar standard deviations.

All returns except equally-weighted firm returns are slightly skewed and show large excess kurtosis, though similar to that of MSCI World returns. The LPE

Table 3.2: Summary statistics of weekly index returns

All figures refer to weekly log index returns. Spread-adjusted indices are calculated by subtracting half the average bid-ask spread from the amount being rebalanced during weekly index chaining. All values in percent except skewness and kurtosis. $N = 1160$.

	Min	Median	Mean	Max	SD	Skewness	Kurtosis
Value-weighted indices							
All LPE	-22.706	0.310	0.254	19.409	3.512	-0.615	9.527
Fund	-15.398	0.347	0.172	9.934	2.175	-0.869	7.798
Investment Company	-27.834	0.325	0.272	22.328	4.564	-0.421	7.839
Fund of Funds	-19.570	0.226	0.197	15.999	2.042	-0.074	18.002
Firm	-20.065	0.417	0.287	15.857	3.187	-0.381	7.044
Equally weighted indices							
All LPE	-14.472	0.426	0.322	8.556	1.874	-0.906	9.026
Fund	-15.567	0.267	0.226	12.129	1.857	-0.419	11.329
Investment Company	-14.672	0.447	0.365	10.122	2.316	-0.540	7.230
Fund of Funds	-19.570	0.280	0.229	15.999	2.052	-0.168	17.867
Firm	-13.789	0.386	0.381	17.161	2.687	0.284	6.917
Equally weighted indices, spread-adjusted							
All LPE	-14.537	0.324	0.238	8.350	1.877	-0.914	8.969
Fund	-15.583	0.219	0.170	12.118	1.858	-0.424	11.246
Investment Company	-14.750	0.344	0.252	9.939	2.317	-0.581	7.279
Fund of Funds	-19.570	0.265	0.216	15.999	2.052	-0.159	17.863
Firm	-13.824	0.312	0.309	17.080	2.687	0.271	6.916
MSCI World	-14.059	0.309	0.121	9.414	1.977	-0.744	7.385

indices are constructed using padded prices if no price is available for an entity within a particular week, which could lead to excess kurtosis, especially in small funds. However, there does not seem to be additional kurtosis on top of that induced by the market.

Listed private equity stocks seem to be influenced by illiquidity in the short run and imperfect informational efficiency over longer time periods. I find significant autocorrelations at up to three weeks, which is possibly caused by LPE stocks not being traded each week (see table 3.3). Equally weighted indices show larger and longer autocorrelations, possibly because of thinner trading. Surprisingly, funds of funds do not seem to have autocorrelations from week two or higher. Even though funds of funds are supposed to have the slowest dissemination of information from underlying investments, they have the smallest bid-ask spread on average. High liquidity might therefore help to facilitate informational efficiency in the LPE market. Significant partial autocorrelations at higher lags show no clear pattern and might be random occurrences.

Table 3.3: Partial autocorrelations

All figures refer to weekly log index returns. Spread-adjusted indices are calculated by subtracting half the average bid-ask spread from the amount being rebalanced during weekly index chaining. P-values are calculated using the Box-Jenkins critical value. The Ljung-Box test statistic at 7 lags is significant at the 1-%-level for all indices except for the value-weighted firm index, where it is significant at $p < .05$. MSCI World returns are autocorrelated at $p < .05$, Yen-returns at $p < .1$. $N = 1160$.

Lag	1	2	3	4	13	26	52
Value-weighted indices							
All LPE	0.123 ***	0.037	0.064 **	-0.047	0.051 *	0.065 **	0.020
Fund	0.108 ***	0.115 ***	0.084 ***	0.003	0.048	0.056 *	-0.019
Investment Company	0.119 ***	0.016	0.048	-0.039	0.054 *	0.066 **	0.026
Fund of Funds	0.113 ***	0.065 **	-0.012	0.030	0.076 ***	0.006	-0.034
Firm	0.020	0.087 ***	0.006	-0.056 *	0.051 *	-0.013	0.023
Equally weighted indices							
All LPE	0.171 ***	0.138 ***	0.082 ***	0.025	0.075 **	0.052 *	0.021
Fund	0.141 ***	0.125 ***	0.066 **	0.001	0.020	0.029	0.040
Investment Company	0.179 ***	0.126 ***	0.098 ***	0.025	0.057 *	0.059 **	0.009
Fund of Funds	0.136 ***	0.028	-0.014	-0.005	0.050 *	0.022	-0.042
Firm	0.112 ***	0.043	0.021	0.008	0.075 **	0.051 *	0.029
Equally weighted indices, spread-adjusted							
All LPE	0.168 ***	0.140 ***	0.083 ***	0.026	0.076 ***	0.053 *	0.022
Fund	0.134 ***	0.126 ***	0.067 **	0.003	0.020	0.030	0.039
Investment Company	0.174 ***	0.127 ***	0.099 ***	0.026	0.059 **	0.060 **	0.010
Fund of Funds	0.136 ***	0.029	-0.013	-0.005	0.050 *	0.023	-0.041
Firm	0.107 ***	0.045	0.021	0.008	0.075 **	0.052 *	0.029
MSCI World	-0.051 *	0.068 **	0.052 *	-0.049 *	-0.004	0.004	0.016
GBP	0.040	0.051 *	-0.043	-0.010	0.009	0.028	-0.018
EUR	0.001	0.033	0.012	0.029	-0.013	-0.033	0.004
JPY	0.033	0.097 ***	0.015	0.004	0.014	-0.028	-0.001

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

Traditional private equity funds usually publish their net asset values quarterly. With portfolio companies being mostly opaque to the market, fund management has the potential to smooth earnings. I find that partial autocorrelations peak at three months and after half a year, whereas there is no significant one-year partial autocorrelation observable. Because market returns are not autocorrelated at these lags, this effect indicates that funds or portfolio companies are able to withhold information that the market would otherwise price immediately.

From an investor's point of view it might also be interesting if LPE stocks offer attractive risk-adjusted returns. I calculate Sharpe ratios based on weekly index and T-bill returns. All unadjusted Sharpe ratios (see columns "SR" in table 3.4) are higher than the MSCI World Sharpe ratio, which is not surprising after observing the huge mean returns in table 3.2. Funds of funds and firms show the highest unadjusted Sharpe ratios in value-weighted indices, while investment companies and firms perform better in equally weighted indices.

Table 3.4: Sharpe ratios

Sharpe ratios are calculated using 3-month T-Bill returns. I report the standard measure (column "SR") and an autocorrelation-adjusted measure, where I use 20 lagged returns to estimate the standard deviation of returns with a Newey-West estimator. All figures refer to weekly log index returns. Spread-adjusted indices are calculated by subtracting half the average bid-ask spread from the amount being rebalanced during weekly index chaining. $N = 1160$.

	Value-weighted		Equally weighted		Equally weighted spread-adjusted	
	SR	adj.	SR	adj.	SR	adj.
All LPE	0.049	0.037	0.129	0.084	0.082	0.054
Fund	0.035	0.028	0.077	0.053	0.047	0.032
Investment Company	0.041	0.031	0.122	0.079	0.073	0.047
Fund of Funds	0.080	0.064	0.105	0.091	0.096	0.083
Firm	0.062	0.058	0.110	0.085	0.082	0.063
MSCI World	0.019	0.019				

Standard deviations are underestimated – and therefore Sharpe ratios overstated – if returns are autocorrelated and if one considers an investment horizon longer than one week. An adjustment of standard deviations due to thin trading effects leads to higher standard deviations for all subsamples. Unadjusted standard deviations are biased down about 20 % on average compared to values calculated from equations 3.51 and equation 3.50. On an adjusted basis, all indices still show higher Sharpe ratios than the MSCI World, though the gap is narrower.

CAPM estimates differ substantially among portfolio strategies in general as well as among organizational structures in particular, as can be seen in tables 3.5, 3.6 and 3.7. LPE shows Dimson betas of 1.8 for the value-weighted index and 1.2 for the equally weighted index. The large difference can be attributed to heavy-weight index constituents. Autocorrelation is clearly present across all index styles, as several lagged returns become significant predictors of current index returns. Currency risk factors behave nicely in showing the right direction and loading. The LPE sample is mainly composed of UK and other European vehicles, as can be seen in table 3.1, a fact that is also documented by the large GBP factor for "All LPE" and "Fund" LPE returns.

Alpha for the value-weighted portfolio is slightly above zero, but amounts to a highly significant 7.5 % annually for the equally weighted index. There seems to be a small-firm or liquidity effect driving these results. After adjusting for bid-ask spread costs, alpha reduces to an insignificant 2.9 % annually. Still, there might be some economic significance in excess returns. While funds tend to display negative excess returns, investment companies, funds of funds and firms perform better than predicted by risk factors, though not statistically significant.[16] This finding is even more pronounced in equally weighted indices. Adjusted R^2 values for indices of all LPE vehicles are a moderate 0.41 to 0.62. This suggests that LPE entities to a large extent are exposed to specific risk in the short run.

The most remarkable feature of LPE returns is their different exposure to market risk depending on organizational forms. Externally managed LPE vehicles show substantially lower exposure to systematic risk than internally managed entities. For value-weighted indices, Dimson beta estimates for investment companies and firms are 2.0 and 1.5, respectively. These figures differ from beta estimates of 1.3 for funds and quite low 0.8 for funds of funds. In equally weighted spread-adjusted indices, these betas are 1.4 for investment companies and firms, but 1.0 and 0.7 for funds and funds of funds. The different betas for value- and equally weighted indices indicate the impact of a few large volatile investment companies on LPE returns. When estimated for each entity individually, beta coefficients differ significantly between groups of organizational forms. An ANOVA model for Dimson betas weighted by their estimation error is highly significant ($F_{(3,270)} = 37.83, p < .001$) and individual

[16] Jegadeesh et al. (2009) also find small excess returns for a sample of LPE funds of funds.

Table 3.5: Value-weighted indices

The international CAPM was estimated by $R_t = \alpha + \sum_{k=0}^{7} \beta_k M_{t-k} + \gamma_1 GBP_t + \gamma_2 EUR_t + \gamma_3 JPY_t + \epsilon_t$ using OLS, where R_t is the weekly excess index return between January 1986 and March 2008, M_t are the (lagged) excess market returns, GBP_t, EUR_t and JPY_t are excess returns of currency portfolios. ϵ_t is the error term. All returns are in logs. "MSCI World" sums beta from lag 0 to lag 7. Standard errors are not adjusted for heteroskedasticity, since this yields more conservative estimates for confidence intervals for index excess returns (α).

	All LPE	Fund	Investment Company	Fund of Funds	Firm
MSCI World	1.777***	1.271***	1.981***	0.756***	1.495***
Lag 0	1.140***	0.720***	1.275***	0.345***	0.988***
Lag 1	0.224***	0.200***	0.256***	0.182***	0.104***
Lag 2	0.128***	0.085***	0.143**	0.111***	0.138***
Lag 3	0.070	0.096***	0.082	0.031	0.040
Lag 4	0.036	0.046*	0.034	-0.013	0.049
Lag 5	0.041	0.033	0.043	0.025	0.105***
Lag 6	0.054	0.053**	0.059	0.051**	0.009
Lag 7	0.085**	0.039	0.089	0.026	0.062*
GBP	0.276***	0.601***	0.119	0.753***	0.536***
EUR	0.282***	0.097*	0.356***	0.111**	0.206**
JPY	0.243***	0.064	0.367***	0.004	0.003
Constant	0.0007	-0.0002	0.0007	0.0006	0.0009
95% upper CI	0.0023	0.0008	0.0029	0.0015	0.0023
95% lower CI	-0.0010	-0.0012	-0.0014	-0.0002	-0.0005
Const. annualised	0.0356	-0.0084	0.0379	0.0319	0.0471
adj. R^2	0.405	0.481	0.326	0.437	0.427
Durbin-Watson	1.814	1.759	1.832	1.716	1.998

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance. Dimson betas ("MSCI World") are tested by Wald tests.

means are different ($p < .001$) except for *funds* vs. *funds of funds* ($p > .1$) and *investment companies* vs. *firms* ($p > .1$).

Different risk characteristics can arise for three reasons: Operating activities might induce business risk, leverage could transform this business risk, and tax regimes can be different between companies. Income tax relief and capital gains tax relief for investments in British venture capital trusts might help explain the small underperformance of my fund sample, but do not seem a plausible cause for the huge differences in market risk. For differences in operating businesses to be the reason, betas should not be equal after correcting for leverage and tax system, i. e. unlevering betas.

Table 3.6: Equally weighted indices

The international CAPM was estimated by $R_t = \alpha + \sum_{k=0}^{7} \beta_k M_{t-k} + \gamma_1 GBP_t + \gamma_2 EUR_t + \gamma_3 JPY_t + \epsilon_t$ using OLS, where R_t is the weekly excess index return between January 1986 and March 2008, M_t are the (lagged) excess market returns, GBP_t, EUR_t and JPY_t are excess returns of currency portfolios. ϵ_t is the error term. All returns are in logs. "MSCI World" sums beta from lag 0 to lag 7. Standard errors are not adjusted for heteroskedasticity, since this yields more conservative estimates for confidence intervals for index excess returns (α).

	All LPE	Fund	Investment Company	Fund of Funds	Firm
MSCI World	1.225 ***	1.043 ***	1.435 ***	0.732 ***	1.381 ***
Lag 0	0.614 ***	0.499 ***	0.744 ***	0.318 ***	0.668 ***
Lag 1	0.213 ***	0.195 ***	0.252 ***	0.180 ***	0.203 ***
Lag 2	0.111 ***	0.098 ***	0.122 ***	0.113 ***	0.093 ***
Lag 3	0.055 ***	0.048 *	0.058 **	0.042 **	0.087 ***
Lag 4	0.032 *	0.048 *	0.038	-0.023	0.045
Lag 5	0.086 ***	0.065 ***	0.109 ***	0.030	0.110 ***
Lag 6	0.068 ***	0.049 **	0.071 ***	0.038 **	0.102 ***
Lag 7	0.046 ***	0.041 *	0.040 *	0.034 *	0.075 **
GBP	0.362 ***	0.665 ***	0.213 ***	0.783 ***	0.270 ***
EUR	0.330 ***	0.162 ***	0.424 ***	0.093 **	0.370 ***
JPY	0.053 **	-0.014	0.072 **	0.027	0.105 **
Constant	0.0014 ***	0.0006	0.0018 ***	0.0010 **	0.0021 ***
95% upper CI	0.0021	0.0015	0.0027	0.0017	0.0034
95% lower CI	0.0008	-0.0004	0.0009	0.0002	0.0008
Const. annualised	0.0750	0.0309	0.0938	0.0498	0.1095
adj. R^2	0.619	0.425	0.529	0.509	0.331
Durbin-Watson	1.766	1.668	1.749	1.625	1.922

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance. Dimson betas ("MSCI World") are tested by Wald tests.

Leverage influences market risk substantially in the firm and investment company sample. For 2007, I observe a simple mean market value leverage of 0.47 for investment companies and 0.36 for firms. Unlevering would decrease beta to 1.5 and 1.2 when using the Hamada equation with an assumed 3 % interest, if 2007 leverage is representative for the whole observation period. Leverage in funds and funds of funds is 0.18 and 0.06, respectively, which is plausible given the usual fund terms. Debt need not be accumulated at the fund level except in portfolio companies, so there might still be substantial leverage left to drive betas.

Even if leverage is the correct explanation for different risk, then the different levels of debt are still to be explained. A natural explanation would be the stage

Table 3.7: Equally weighted indices, spread-adjusted

The international CAPM was estimated by $R_t = \alpha + \sum_{k=0}^{7} \beta_k M_{t-k} + \gamma_1 GBP_t + \gamma_2 EUR_t + \gamma_3 JPY_t + \epsilon_t$ using OLS, where R_t is the weekly excess index return between January 1986 and March 2008, M_t are the (lagged) excess market returns, GBP_t, EUR_t and JPY_t are excess returns of currency portfolios. ϵ_t is the error term. All returns are in logs. "MSCI World" sums beta from lag 0 to lag 7. Standard errors are not adjusted for heteroskedasticity, since this yields more conservative estimates for confidence intervals for index excess returns (α).
I account for bid-ask spreads by subtracting half the average spread from the amount being traded during weekly index rebalancing.

	All LPE	Fund	Investment Company	Fund of Funds	Firm
MSCI World	1.232***	1.050***	1.440***	0.736***	1.396***
Lag 0	0.615***	0.499***	0.744***	0.318***	0.670***
Lag 1	0.214***	0.198***	0.252***	0.180***	0.204***
Lag 2	0.112***	0.099***	0.121***	0.113***	0.095***
Lag 3	0.056***	0.047*	0.059**	0.042**	0.089***
Lag 4	0.034*	0.050**	0.040*	-0.022	0.048
Lag 5	0.088***	0.067***	0.111***	0.031	0.112***
Lag 6	0.069***	0.050**	0.071***	0.039**	0.102***
Lag 7	0.047***	0.041*	0.041*	0.035*	0.075**
GBP	0.362***	0.666***	0.212***	0.784***	0.270***
EUR	0.332***	0.163***	0.425***	0.092**	0.372***
JPY	0.053**	-0.015	0.073**	0.027	0.104**
Constant	0.0006	-0.0001	0.0007	0.0008**	0.0013**
95% upper CI	0.0012	0.0009	0.0016	0.0015	0.0026
95% lower CI	-0.0001	-0.0010	-0.0003	0.0001	0.0001
Const. annualised	0.0289	-0.0030	0.0348	0.0409	0.0695
adj. R^2	0.621	0.428	0.530	0.509	0.334
Durbin-Watson	1.789	1.698	1.774	1.629	1.943

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance. Dimson betas ("MSCI World") are tested by Wald tests.

focus of my sample funds. Since buyout transactions are frequently financed using more debt than early-stage transactions, buyout vehicles should exhibit a higher-than-average market risk. This seems to be true for the firm sample, which is predominantly composed of firms with a focus on buyout and balanced-stage funds (see table 3.8). This argument should also hold for funds of funds that invest in buyout funds, but it does not. Funds of funds have the lowest of all market risks. To the contrary, investment companies show higher market risk than funds, although both have roughly the same stage distribution. There must be some source of market risk other than leverage.

Table 3.8: LPE entities by investment stage focus

	Fund	Investment Company	Firm	Fund of Funds	Total
Seed Stage	1	3	0	0	4
Early Stage	21	37	1	3	62
Development	0	3	0	0	3
Expansion	14	3	0	0	17
Balanced Stage	33	30	7	15	85
Generalist	5	7	0	4	16
Later Stage	5	5	2	0	12
Buyouts	23	22	9	7	61
Turnaround	1	2	0	0	3
Mezzanine Stage	6	4	0	1	11
Total	109	116	19	30	274

Management activities in firms and investment companies could provide such a source of risk. Both types of LPE vehicles own their fund management, which usually generates two types of cash flow: management fees and carried interest. The interesting part is the carried interest. As a general partner of private equity funds, investment companies and firms may be entitled to a share in capital gains larger than their share in the fund. At the same time, "clawback" provisions in fund partnership agreements require the general partner to return, typically at the end of the fund's life, distributions with respect to its carried interest to the extent that such distributions exceed a fixed percentage over the life of the fund. Both arrangements tie the general partner's cash flow to the success of its portfolio companies, but with a disproportionately high risk.

3.6 Robustness tests

Limitations of the results presented above could arise mainly for three reasons: sample selection, data quality and model specification. The greatest difficulty in composing a representative sample lies in identifying entities that ceased to exist early in my sample period. The VentureXpert database includes inactive vehicles but is less accurate in early years. Bilo et al. (2005) find no selection bias in 287 vehicles they identify between 1986 and 2002, where I find 285 in the same period. Over the whole sample period, 32 vehicles delisted or stopped trading for some other reason (15 in Bilo et al. (2005)). I included vehicles that were classified as private equity by VentureXpert. However, 11 vehicles that changed businesses were excluded because no specific date of business change could be obtained. An additional 17 vehicles were classified as holdings, specialty funds or royalty trusts and were therefore excluded. Bilo et al. (2005) report 18 business changes. To test for remaining sample selection issues, I check the results by excluding data prior to 2001. Results depicted in table 3.9 show no substantial change in betas but significant alphas for funds of funds. Within these indices, R^2 values increase to $0.53 - 0.59$.

Inaccurate data might be another source of unstable results. Espenlaub et al. (2008) report that Datastream failed to correct time series of prices for open offers in the UK. I conduct an extensive press analysis for vehicles affected in my sample, but find no open offers during the sample period. Price movements might not reflect the true underlying change in value, especially in penny stocks, where tick size is large with respect to the share price (see, for example, Ince and Porter (2006)). Furthermore, Datastream sometimes misses capital actions or other corporate events that require price adjustments. Therefore, I checked all returns outside an $[-40\,\%, +80\,\%]$ interval for errors.

Results might be driven by the specific liquidity constraints chosen. Stronger liquidity constraints could, for example, lower the excess returns in firms and funds of funds, if there is some liquidity risk left that is not priced in my model. I limit the average bid-ask spread to less than 5 % instead of 20 % as before. Results shown in table 3.9 indicate no change in excess returns for firms, funds and funds of funds but a strong increase in equally-weighted investment company excess returns. Stronger liquidity constraints may lead to a sample selection bias, since large — and therefore more liquid — vehicles enter the sample more often than small ones. Large vehicles usually become large by growing at rates in excess of the average industry return, which is reflected in the results in table 3.9. Risk factors, however, remain essentially the same.

Table 3.9: Results for changes in liquidity and time period

Average bid-ask spread for LPE vehicles is constrained to less than 5 % which reduces the sample size to 183 vehicles (upper panel) and observations are restricted to the time period 2001 - 2008 (lower panel). Beta estimates represent Dimson betas from the OLS regression $R_t = \alpha + \sum_{k=0}^{7} \beta_k M_{t-k} + GBP_t + EUR_t + JPY_t + \epsilon_t$, where R_t is the weekly excess index return between January 1986 and March 2008, M_t are the (lagged) excess market returns, GBP_t, EUR_t and JPY_t are excess returns of currency portfolios. ϵ_t is the error term. All returns are in logs.

	All LPE	Fund	Investment Company	Fund of Funds	Firm
Max. 5 % bid-ask spread					
MSCI World Dimson beta					
Value-weighted	1.792***	1.252***	1.993***	0.767***	1.501***
Equally weighted	1.255***	1.133***	1.400***	0.776***	1.391***
Equally weighted, adjusted	1.257***	1.136***	1.401***	0.779***	1.394***
Annualized alpha					
Value-weighted	0.0385	-0.0059	0.0402	0.0312	0.0481
Equally weighted	0.0903***	0.0471	0.1212***	0.0463**	0.0880***
Equally weighted, adjusted	0.0731***	0.0323	0.1021***	0.0393**	0.0692**
Data from 2001 – 2008					
MSCI World Dimson beta					
Value-weighted	1.835***	1.190***	2.170***	1.032***	1.568***
Equally weighted	1.270***	0.792***	1.666***	0.991***	1.560***
Equally weighted, adjusted	1.282***	0.808***	1.671***	0.995***	1.581***
Annualized alpha					
Value-weighted	-0.0701	-0.0029	-0.0783	0.0301	0.0233
Equally weighted	0.0928***	0.0359	0.1330***	0.0723***	0.1280**
Equally weighted, adjusted	0.0338	-0.0085	0.0548	0.0603**	0.0732

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

One could ask if results change if the model is specified differently. This seems not to be the case for several plausible alternative specifications. First, the number of currency factors was chosen arbitrarily to represent only the four largest LPE subsamples by market capitalization. Results are similar if the Yen factor is excluded. I therefore choose clarity over completeness and do not include additional currency portfolios.

Second, if Fama-French factors are included, only the small-minus-big factor becomes significant in some cases. Since inclusion of those factors does not change results much (alphas are only slightly higher) and factors are only available for the United States, I do not include them.

Third, estimation errors for most indices are autocorrelated at least at lag one, which is indicated by the Durbin-Watson test statistic in tables 3.5, 3.6 and 3.7. Further inspection shows that most indices show long autocorrelation structures. Since standard errors of parameter estimates might not be correct in this case, one way to deal with autocorrelated errors would be to include them explicitly. I estimate several modified models with ARMA errors but find only minor changes in parameters and two changes in significance levels: for funds of funds and firms, alpha is no longer significant at the 5 % level.

3.7 Conclusion

This chapter investigates the risk and return characteristics of listed private equity vehicles, which are grouped into subsamples according to their organizational structure. I identify 446 vehicles in the period from 1986 to 2008 and obtain a sample of 274 vehicles after imposing liquidity constraints. Listed private equity vehicles show a Dimson beta of 1.7 without any substantial excess return on a value-weighted basis. An equally weighted portfolio which is adjusted for spread costs has a beta of 1.2 and does not outperform the market either.

Listed private equity vehicles offer a wider range of entities to invest in than traditional unlisted private equity. While investors usually participate in traditional private equity *funds*, LPE entities can be funds, management companies or a combination of both, i. e. investment companies. I therefore propose a classification of LPE vehicles along the two dimensions *participation in fees and carried interest* and *degree of diversification*. Traditional funds and funds of funds are managed externally and are thus directly comparable to the listed private equity subsamples. In addition to externally managed vehicles, I identify companies that employ their own management or are management companies of unlisted funds. Since these two subsamples use business models distinct from those of normal funds, their market risk might be different.

As expected, value-weighted indices for different organizational forms exhibit a wide range of systematic risk. Dimson beta is 1.2 for funds, 0.6 for funds of funds, 1.5 for firms, and 2.0 for investment companies. Although leverage differs substantially between organizational forms, a back-of-the-envelope calculation shows that leverage is probably not the only explanation for these huge differences in market risk. I find internally managed vehicles being more sensitive to market movements than externally managed ones, which could be due to their different sources of cash flow. Since internally managed vehicles usually generate cash from carried interest in addition to capital gains, their cash flow streams should be more risky than cash flows of externally managed vehicles.

Jensen's alpha varies strongly depending on the estimation period and which organizational form is measured. I find no excess returns for value-weighted indices. On an equally weighted basis, firms show a slightly significant 5.8 % annual excess return even if returns are corrected for bid-ask spreads. Alphas in equally-weighted indices increase if I apply stronger liquidity criteria, which induces a selection bias favoring large vehicles with exceptionally high growth (and returns) in the past. If small vehicles that never become big enough to be identified are not included in my sample, equally weighted indices could be upward biased.

Economic causes and effects of differences between LPE's organizational forms should be subject to further research. Leverage in portfolio companies, liquidity risk and small firm effects in individual vehicles could help explaining risk characteristics in listed private equity. Answers to these questions could also foster our understanding of traditional private equity funds and firms.

Chapter 4

The Time-Varying Risk of Listed Private Equity[1]

4.1 Introduction

Performance measurement and portfolio allocation are notoriously difficult when dealing with private equity assets due to the nontransparent nature of this asset class. To evaluate the success of an investment, its risk premium as derived from factor pricing models can serve as a benchmark for required returns in excess of the risk-free rate. Private equity's market risk, albeit hard to measure in traditional private equity funds, can be obtained from listed private equity vehicles. In this chapter, I extend the results in chapter 3 and measure the time-series variability of aggregate and individual market risk.

Private equity investors can benefit from a quantification of private equity market risks and their variability, since this asset class represents a substantial share of international investment opportunities. The private equity sector had more than USD 2.5 trillion of capital under management in 2008 according to the International Financial Services London (2009). This large volume demands for a time variation analysis of systematic risks. In addition, industry-specific characteristics caused

[1] The main results of this chapter have been published in the Journal of Financial Transformation, Vol. 28, 87–93, 2010.

by the private equity business model shape the evolution of risk within this asset class: Acquisitions and divestments of portfolio companies constantly rebalance fund portfolios, which should lead to highly unstable market risk.

Several authors have focused on non-constant risk premia in equities, bonds, and REITs. Early papers discussed the impact of risk variability on portfolio decisions.[2] Later work developed the conditional capital asset pricing model and similar models using mostly public market data.[3] Time-varying risk properties of private equity, however, have not been examined by empirical research.

The difficulty with risk measurement in traditional (unlisted) private equity vehicles lies in the opacity of their price formation. Time series of returns are hardly observable, which renders estimation of market risk nearly impossible. Many attempts at measuring systematic risk are based on voluntarily reported returns of private equity funds, internal rate of return (IRR) distributions[4], cash flows[5], transaction values of portfolio companies[6], or the matching of portfolio companies to public listed companies with similar risk determinants[7].

Private equity vehicles that are listed on international stock exchanges provide a natural alternative to unlisted ones when estimating their risk. Return data are readily available and can be used to answer risk-related questions: What are the market risk patterns of listed private equity throughout the life of the security? How stable are the market risks of the listed private equity companies?

I first analyze the market risk structure of listed private equity. For this purpose, I measure market risk in an international capital asset pricing model (CAPM) using Dimson (1979) betas. While chapter 3 measures constant betas over the lifetime of listed private equity vehicles, I now take a step further in considering their time series properties. In this chapter, market risk is measured over a rolling window to

2 See Levy (1971) and Blume (1971).

3 See Lettau and Ludvigson (2001), Ghysels (1998), De Santis and Gérard (1997), Jagannathan and Wang (1996), Bollerslev et al. (1988), and Ferson et al. (1987).

4 See Kaplan and Schoar (2005).

5 See Driessen et al. (2008).

6 See Cochrane (2005) and Cao and Lerner (2009).

7 See Ljungqvist and Richardson (2003) and Groh and Gottschalg (2009).

generate a continuous set of beta observations, which describes the aggregate asset class risk over time.

Second, I examine the stability of individual betas. Correlations of cross-sections for consecutive years can offer insights into relative changes of risk within the asset class. I find that market risk of listed private equity is quite unstable if time periods longer than two years are considered. In a second step, I compute transition probabilities between risk classes. My results reflect the instability of risk in general, but highlight a moderate persistence of exceptionally high and low risks.

4.2 Stability of market risk

A broad picture of how market risk evolves in listed private equity can be seen from yearly cross-sections. In this section, I show the main properties of market risk measurement for the listed private equity sample for different time horizons: a rolling windows of one and two years, and total lifetime.

The sample of listed private equity vehicles is based on the data in chapter 3. This sample consists of a comprehensive list of listed private equity companies, which I extend to account for recent listings. My final sample includes 278 vehicles, the largest proportions being investment companies and funds that are managed externally. The time horizon chosen for this analysis is 1986 to 2009, although not all companies have return data during the whole time period due to new listings and delistings.

To measure the market risk of my sample vehicles, I use individual return indices from Thomson Datastream in U.S. Dollar, the 3 month Treasury bill rate as a proxy for the risk-free rate and MSCI World index returns in U.S. Dollar as a proxy for market returns. All return data are converted to logarithmic returns. During the time period studied in this chapter, 33 companies were delisted. All companies enter the analysis when return data becomes available and drop out if they delist or if trading volume is zero after some date.

4.2.1 Market risk estimation

To obtain market risks I regress excess LPE stock returns on excess market returns (MSCI World). I employ a Dimson regression to account for autocorrelation in asset returns caused by illiquidity in LPE vehicles. Early studies showed that in similar settings autocorrelation on the portfolio level can be a problem.[8] I use the results of Dimson (1979) and incorporate 7 lagged market returns in the estimation model to adjust for autocorrelation. In a second step I aggregate the lags as proposed by Dimson to obtain a measure of market risk. Since my sample consists of vehicles traded on international exchanges, I account for currency risk by introducing risk factors for Euro, Yen, and the British Pound, which represent excess returns of currency portfolios in U.S. Dollar. The international capital asset pricing model is thus given by

$$r_{i,t} = \alpha_i + \sum_{k=0}^{7} \beta_{i,k} r_{m,t-k} + \gamma_{i,1} GBP_t + \gamma_{i,2} EUR_t + \gamma_{i,3} JPY_t + \epsilon_{i,t}, \tag{4.1}$$

where $r_{i,t}$ and $r_{m,t-k}$ are the respective observed logarithmic (excess) individual vehicle and market returns at time t and t-k, whereas k corresponds to the respective lag. The intercept α_i represents a vehicle-specific constant excess return, and β_i and γ_i are the slope coefficients and $\epsilon_{i,t}$ is an error term. I use this regression equation to calculate the market risks for different time periods: one year, two years, and lifetime market risks.

4.2.2 Yearly cross-sections and aggregate market risk

I first illustrate the behavior of aggregate market risk in a time series context before taking a closer look at individual risk stability. Time series of aggregate risk can be constructed from measures of market risk in rolling windows. I define two such rolling windows: The first spans 52 weekly observations and the second has 104

[8] See Fisher (1966) and French et al. (1987).

observations. Similar windows are used by Bilo (2002), who measures historical return variances but does not examine the time series properties of systematic risk.

Table 4.1 summarizes the main market risk statistics for different observation windows. Mean one-year betas range from a minimum of –0.07 in 1986 to a maximum of 1.97 in 2000. Two-year betas are highest for the periods ending in 1987, 2001, and 2009. One-year betas as well as two-year betas vary around an average that is close to one. All periods and estimation windows exhibit a large cross-sectional variation in market risk. This might be caused by the huge diversity within the listed private equity asset class, which includes many small vehicles with strongly differing business models. Interestingly, mean betas are positively correlated to their standard deviation. This suggests that mean betas are driven by vehicles with huge betas as indicated by a skewed distribution of betas.

Figure 4.1 shows a more detailed picture over time. Listed private equity betas are first estimated for each vehicle in rolling windows. These individual betas are then weighted equally over all vehicles for which I was able to calculate a beta at a given point in time. Figure 4.1 reveals the volatile nature of private equity market risk. Even mean betas vary widely over time. Beta variability is smaller for two-year betas due to smoothing but higher at the beginning of the observation period. This higher variability could be caused by the smaller number of vehicles compared to later years, which makes the sample mean a less efficient estimator for the true mean. The one-year beta time series exhibits a mean-reverting behavior, oscillating between low values around zero during the early 1990s and peaks in 1996 and 2000. Its long term average, however, is a moderate 0.99. Two-year betas behave similarly around a time series mean of 1.11. They are lower than the market average during the 1990s and again from 2006 through 2008 with a large hike during the financial crisis. Both charts have more or less pronounced peaks during the Asian Financial Crisis (1997–1998), the Dot-Com Bubble (1999–2001), the year 2004, and the recent financial crisis (2007–2009).

Exogenous shocks and extreme market movements are possible causes for beta variability. The green lines in figure 4.1 show market return variances for the cor-

Table 4.1: Summary statistics for beta cross-sections from 1986 to 2009

Total values include $N = 4560$ single observations for one-year betas and $N = 2484$ observations for two-year betas in an unbalanced panel structure.

	One-year betas						Two-year betas					
Period ending	Mean	Med.	SD	Min	Max	N	Mean	Med.	SD	Min	Max	N
1986	-0.07	-0.11	1.57	-4.32	2.47	20						
1987	1.52	1.45	0.57	0.81	3.07	23	1.47	1.32	0.54	0.60	2.69	21
1988	0.58	0.55	0.92	-0.68	2.78	29						
1989	0.47	0.28	1.42	-1.93	3.53	34	0.55	0.62	0.81	-0.78	2.07	29
1990	0.89	0.69	0.92	-0.92	3.36	41						
1991	0.80	0.97	1.34	-2.70	3.52	49	0.95	0.88	0.73	-0.32	2.51	41
1992	0.40	0.28	1.64	-2.33	6.85	52						
1993	0.07	-0.11	1.48	-3.59	4.95	55	0.53	0.40	1.09	-1.12	5.98	52
1994	1.05	1.03	1.51	-3.42	4.70	59						
1995	0.63	0.30	2.03	-3.47	9.70	67	0.84	0.76	1.31	-1.64	6.94	59
1996	1.24	0.85	3.85	-5.46	27.06	74						
1997	0.86	0.43	2.12	-2.21	14.03	87	0.83	0.44	2.00	-2.02	12.40	74
1998	1.19	0.83	1.28	-0.78	6.18	101						
1999	1.46	1.10	2.06	-1.79	7.83	120	1.31	1.10	1.24	-0.78	5.10	101
2000	1.97	1.10	2.49	-3.14	14.46	135						
2001	1.26	0.99	1.37	-2.06	7.68	160	1.43	1.11	1.37	-2.17	6.10	135
2002	1.16	0.99	1.47	-3.13	6.74	178						
2003	1.14	0.80	1.99	-6.78	8.77	181	1.15	0.85	1.14	-1.75	4.96	175
2004	1.50	0.88	2.58	-3.39	19.64	184						
2005	1.00	0.76	2.46	-8.45	9.73	190	1.35	0.88	1.94	-2.75	14.51	179
2006	1.01	0.76	1.54	-6.27	6.29	204						
2007	1.00	0.77	1.90	-6.96	12.84	229	1.19	1.01	1.30	-2.22	7.35	201
2008	1.25	0.99	1.34	-3.94	9.04	235						
2009	1.35	1.19	1.67	-5.97	8.79	190	1.40	1.25	0.97	-0.39	5.33	207
Total	1.14	0.85	1.95	-8.45	27.06		1.19	0.97	1.37	-2.75	14.51	

responding rolling windows (one-year and two-year) for weekly MSCI World return data. Betas and the market return variance are moderately correlated with a coefficient of 0.57 (p=0.055) in two-year betas, which is surprising, since betas are inversely related to the market's variance in a CAPM context by definition. This result suggests a large increase in covariance between listed private equity vehicles and the market in times of uncertainty. If systematic risk of private equity is about the same as the market's risk and, even worse, rises in times when investors seek portfolio insurance, the often purported benefits of this asset class might turn out to be hard to achieve.

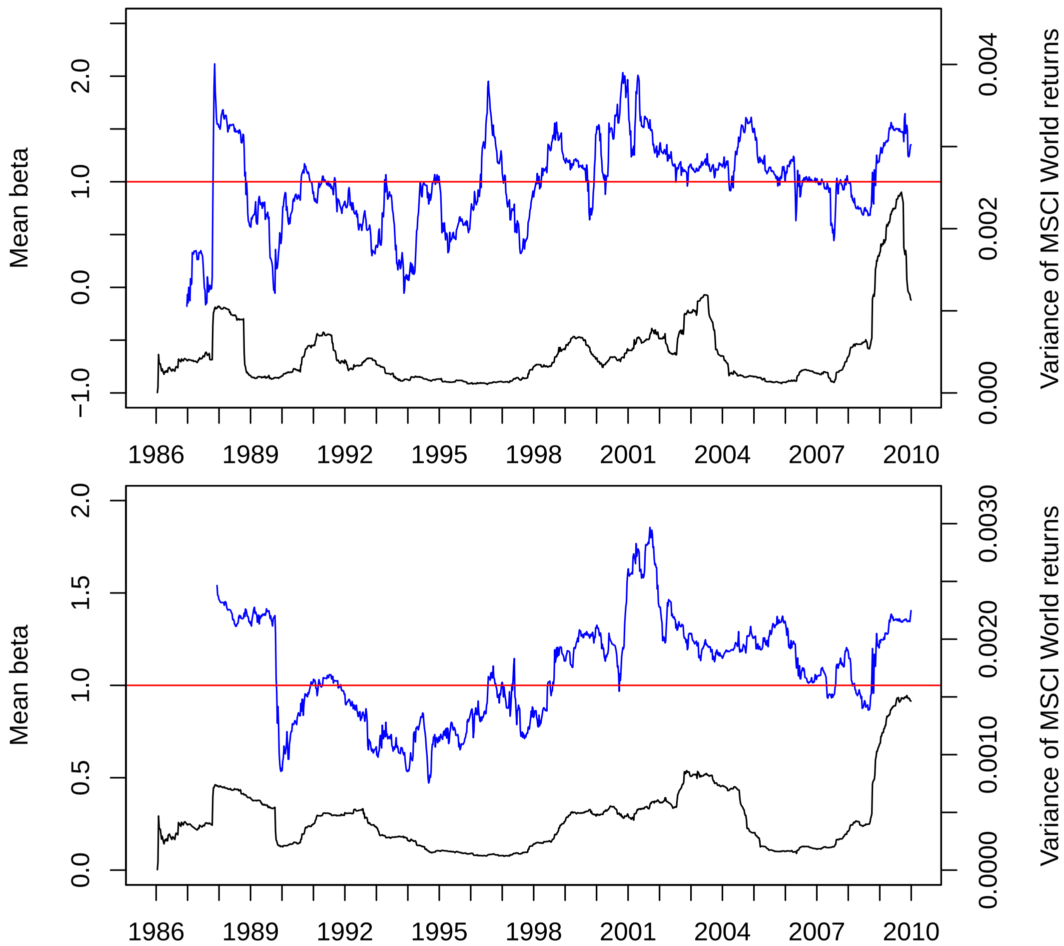


Figure 4.1: Mean one-year beta (upper panel) and two-year beta (lower panel) Betas (blue line) are measured on the left scale, return variance (black line) on the right scale. Betas and MSCI World return variance are estimated over rolling windows of 52 and 104 weeks for one-year and two-year horizons, respectively.

4.3 Do risks move together?

Although aggregate market risk seems to be rather unstable over medium to long time periods, individual risks might still move parallel to the general mean. There could thus be considerable relative stability within the listed private equity asset class despite its apparent irregular behavior. I measure risk stability relative to the listed private equity asset class by estimating Pearson correlation coefficients. Betas can be huge in magnitude, which can strongly influence linear estimators such as Pearson correlation coefficients. Spearman's rank correlation coefficient can provide a robust measure of relative beta stability.

I first calculate the Pearson correlation to capture beta movements between two points in time. Correlation coefficients are calculated from all vehicles with a risk estimate available for two consecutive years. Figures 4.2 and 4.3 show that one-year betas are correlated especially at lags one and two, but only for observation periods after 1993. Betas prior to 1994 seem to behave randomly. Significant correlations of one-year betas at lag one vary between 0.15 and 0.43. Interestingly, betas are not always significantly correlated even for recent years. There is, for example, almost no correlation between betas from 2004 to 2007. An explanation for weak relations in general could be mean reversion. LPE vehicles tend to have a beta around an individual mean. If market risk deviates from this mean in a given year due to an exogenous shock affecting an individual vehicle, it tends to drift back to the individual mean after some time. This would reduce the correlation between individual betas.

Another explanation are real changes in the vehicles' underlying businesses, which cause beta variability. Private equity funds buy portfolio companies to realize capital gains and management fees over some holding period, which is usually less than ten years, depending on the funds' focus. Portfolio turnover is thus higher than in other companies that grow organically or merge with newly acquired subsidiaries. If the portfolio companies' market risk is diverse across portfolio acquisition, private equity betas experience jumps according to the market risk of the often substantial amounts of assets acquired or sold.

The portfolio companies' risk itself might not be constant either. Private equity funds and firms that specialize in turnaround management and venture capital in particular can show large swings in market risk. Restructuring can affect operational risk as well as market risk, while rapid growth of successful companies causes changes in portfolio risk even if individual portfolio company risk remains constant. This effect also depends on portfolio size. Acquisitions and divestments must be large relative to portfolio size to cause substantial risk changes on the portfolio level. It seems reasonable to expect such a rebalancing effect over the medium to long term.

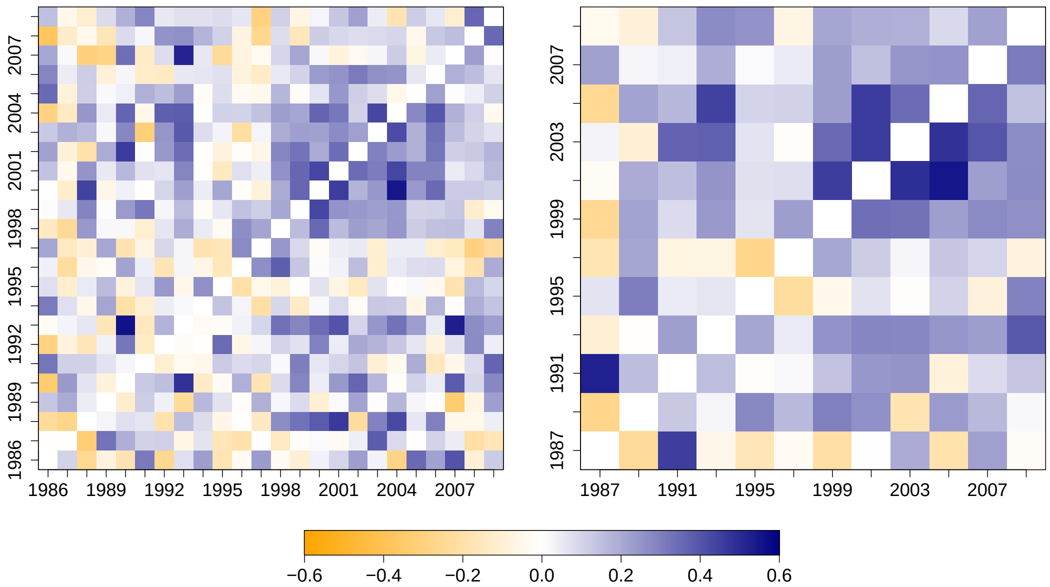


Figure 4.2: Correlation of cross-sectional betas between observation periods
Pearson correlation coefficients are displayed above the main diagonal, Spearman rank correlation coefficients are below. Left panel: one-year betas. Right panel: two-year betas.

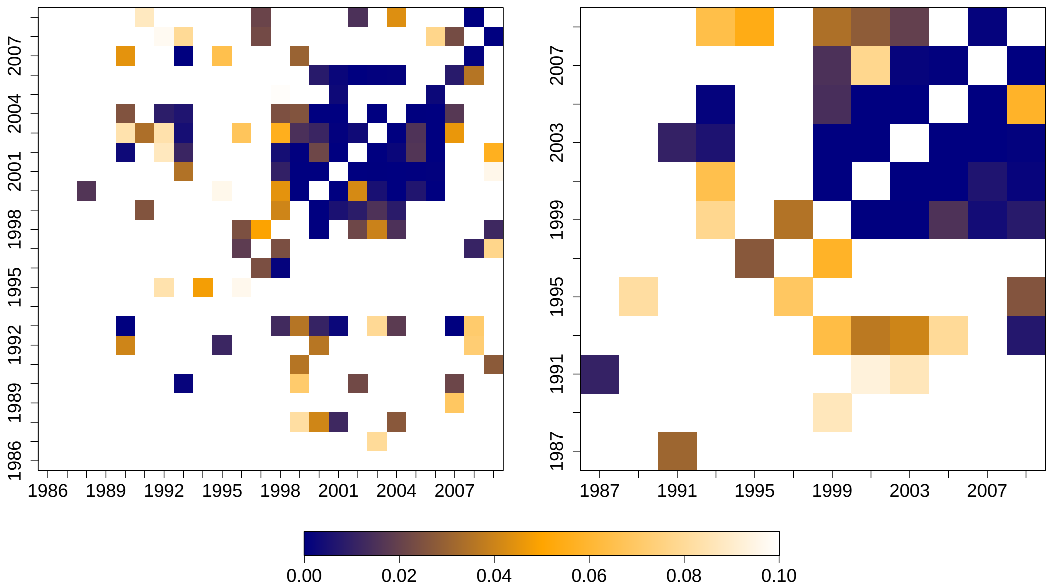


Figure 4.3: Significance levels for correlations of cross-sectional betas between observation periods
P-values are displayed for Pearson correlation coefficients (above the main diagonal) and Spearman rank correlation coefficients (below). Left panel: one-year betas. Right panel: two-year betas.

Short-term beta variability is likely caused by estimation errors, which in turn arise for primarily two reasons. First, listed private equity vehicles are often quite small by market capitalization and illiquid. The low informational quality of prices in thinly traded stocks - although mitigated by the Dimson regression - can carry over to insignificant or unstable beta coefficients. Second, the nontransparent structure and characteristics of portfolio companies can reduce informational efficiency. Since most portfolio companies are not listed and investors in private equity must rely on the information provided by the fund manager, this information can sometimes be as scarce as unreliable. If company betas are seen as a moving average of partially unreliable information about true market risk, betas become increasingly unstable over short horizons.

4.3.1 Rank correlations

As a robustness check for the Pearson correlation matrices, I calculate the Spearman rank correlation to capture the relative rank movements. Instead of correlating betas directly, the Spearman correlation computes a coefficient based on the ranks of individual betas in two consecutive time periods. This calculation yields a matrix with yearly entries from 1990 to 2008 in the one-year case and with two-year intervals where betas are estimated over 104 weeks. Estimation of correlations is based on all vehicles with observable betas in two consecutive periods, which leads to a changing number of degrees of freedom.

The entries below the main diagonal in both panels in figure 4.2 show rank correlation coefficients for one-year and two-year betas. Similar to the one-year Pearson correlation matrix, betas are correlated at the first few lags in the one-year case. The highest correlation for one-year betas is 0.43 at the first lag. Betas begin to be significantly correlated from 1996 on, which is partly due to their higher magnitude and partly due to increasing degrees of freedom.

Results are different in the two-year case but similar to Pearson correlations. Coefficients are slightly higher than in the one-year beta case. This is likely the result of better estimates due to the increasing degrees of freedom when estimating beta over 104 weeks, which makes estimates less sensitive to outliers in the return distribution. If betas are measured more accurately, correlations increase as well.

Results suggest that opacity in portfolio companies and illiquidity lead to estimation error on the short run, while portfolio rebalancing changes individual betas over the medium to long term. Estimated market risk seems to be most stable over horizons spanning 2-3 years. The two-year beta correlations are slightly higher than in the one-year case, while significant correlations can be observed over the last decade only.

4.4 Evolution of risk over time

The time series perspective can be combined with an assessment of cross-sectional stability if one assumes that individual betas are generated by a Markov process common to all vehicles. I estimate an empirical Markov transition matrix under the assumption that future betas depend only on their current value. Transition probabilities from one risk class to another within the empirical Markov Transition Matrix (MTM) are calculated as the relative frequency of moving from one risk class to another in the next observation period. For this purpose, I construct risk classes in two different ways: betas deciles and fixed beta classes.

4.4.1 Persistency in beta deciles

The deciles-oriented MTM is based on quantiles of the distribution of individual company market risk. All companies in a decile are assigned to one risk class. As a result of changes in aggregate beta over time, decile boundaries may change as well. Since betas are measured with error, boundaries of upper and lower deciles fluctuate most. Quantiles around the median are more stable.

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result of changes in aggregate beta over time, decile boundaries may change as well. Since betas are measured with error, boundaries of upper and lower deciles fluctuate most. Quantiles around the median are more stable.

Because a company's risk class is assigned by the decile function, its risk class depends on the risk exposure of the entire listed private equity market. An increase in beta, however, does not change the risk class if all companies are affected by this increase to the same extent. This property has an important influence on the interpretation of my results. The probability of a transition from one risk class into another does not reflect changes of absolute risk exposure but gives insight into how the risk of one company behaves compared to the risk of all other companies. If, for example, a flat transition matrix is found, betas are equally likely to move from one risk class to any other. In other words, the relative risk structure would be completely random over time. This could hold for companies in the venture capital market in particular, whose risks are driven by real options and less by fundamental data. If, to the contrary, only positive entries along the main diagonal exist, relative risks within the industry do not change over time.

When interpreting results, we have to take care of the fact that new companies get listed and some become delisted. If we allow companies to move in and out of the sample, decile boundaries can change even without any variation in risks, which may force a company to change its risk class. This can be a problem if the sample is not random. Transitions probabilities shown in figure 4.4 confirm the results for cross-sectional rank correlations. Betas are moderately stable relative to the listed private equity sector over short time periods. Interestingly, high risk companies remain in the highest risk class with a 21 % (one-year) and a 31 % (two-year) probability. This suggests that there might be companies that have a persistently higher risk than other companies. The same result can be seen for low risk classes. For both observation horizons, risk is comparably stable (17 % for the one-year betas and 15 % for two-year betas). Note that in both cases a relatively high proportion of companies switches from the highest risk class into the lowest risk class from one period to the next and vice versa. These companies are most likely outliers, whose beta cannot be estimated reliably and therefore is unstable compared to the industry as a whole. Considering the almost random correlation structure prior to 1994 in figure 4.2, I calculated transition matrices excluding these early betas, but find similar results.

The flat probability structure in deciles 5 and 6 can be observed for several reasons: First, it can be driven by listings and delistings. These changes in the underlying sample can influence decile boundaries, if newly added companies do not follow the same risk distribution as existing ones. A second explanation could be that the risk of private equity changes fast. Companies having extremely high or low risk remain in the respective risk classes if their risk changes not too much, whereas medium-risk companies switch between deciles more often for similar beta changes. Incomplete and noisy information about portfolio companies might not allow the market to generate stable betas over short time periods.

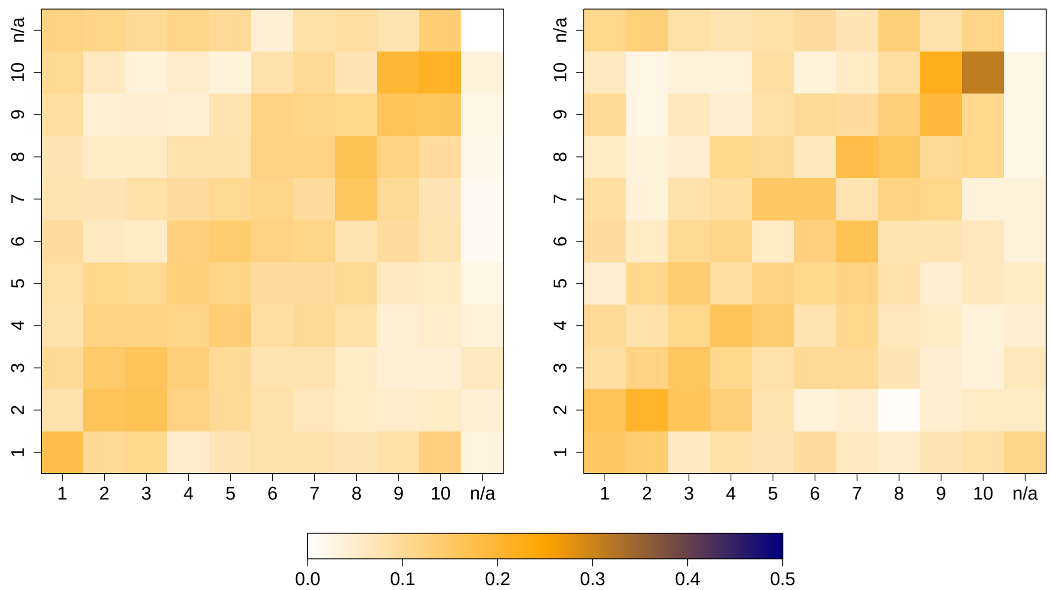

Figure 4.4: Markov transition matrices with risk classes constructed from deciles
The vertical axis shows risk classes at time t and the horizontal axis at time $t+1$ (entities move from row classes to column classes each period). Left panel: one year betas; Right panel: two year betas.

Moderately stable ranks are good news for private equity investors. If private equity vehicles remain in their risk deciles over periods of two years and even longer (results for three and four years not shown here), investors can base their portfolio allocation decisions on betas relative to the private equity sector. Although betas exhibit large absolute swings, which will be shown below, long-term investors can still target specific high or low risk vehicles for inclusion in their portfolio.

4.4.2 Persistency in fixed beta classes

Absolute persistency of market risks can be examined by using fixed risk classes. In this case, I do not measure the behavior of company risk relative to other companies but absolute risk change. I define the following ten risk classes for individual betas $\beta_{i,t}$ for vehicle i at time t: $q_{k-1} < \beta_{i,t} \leqslant q_k$ with $\{q_0, ..., q_{10}\} = \{-\infty, -3, -2, -1, 0, 1, 2, 3, 4, 5, \infty\}$, where each class is denoted by its upper boundary. If risks were stable in this sense, we would expect matrix entries along the main diagonal. If risks change their size randomly, each row should reflect the limiting (unconditional) distribution of betas.

The MTM with fixed risk classes in figure 4.5 yields a different impression of market risk. When using fixed class boundaries, transition matrices cannot be used to reach conclusions about risk movements within the listed private equity sector anymore. Instead, transition probabilities reflect the behavior of individual risks, which include changes in market risk as well as idiosyncratic exogenous factors. As expected from the correlation analysis, betas show a highly mean-reverting behavior. This effect can be seen from classes five and six (representing the industry general mean market risk), which have the highest transition probability from almost every other risk class. Transition probabilities seem to converge to the stationary distribution after a short time, which again indicates that betas become unstable due to portfolio rebalancing and time-varying risk within portfolio companies.

The suspicion that extreme betas are due to estimation error is confirmed by the fact that one-year betas in risk classes 1 and 10 behave quite randomly between two observation periods. An economic reason for unstable negative betas could be that private equity has no short selling strategies. Although results are similar for

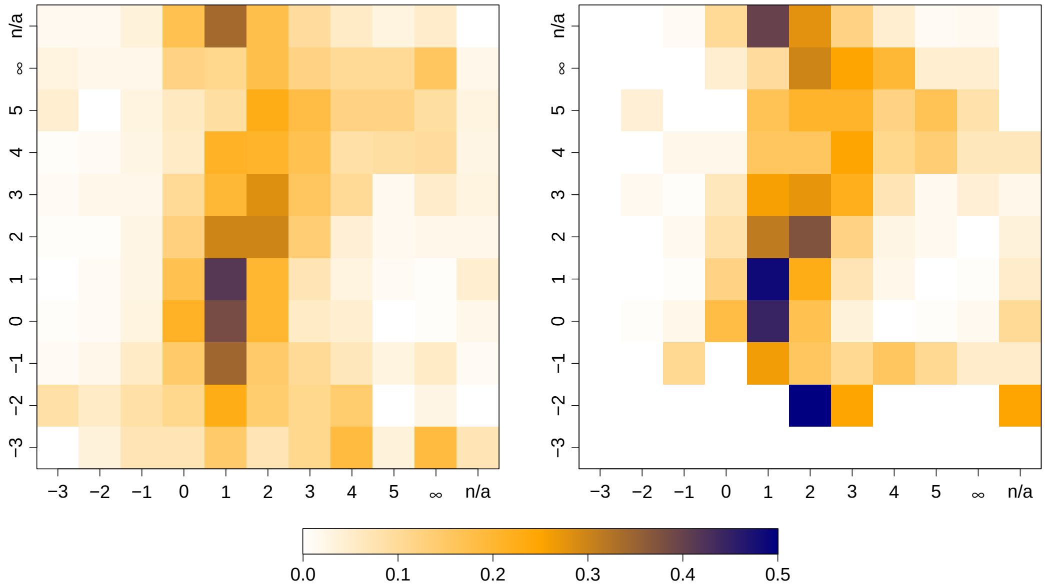

Figure 4.5: Markov transition matrices with fixed risk classes
The vertical axis shows risk classes at time t and the horizontal axis at time $t+1$ (entities move from row classes to column classes each period). Left panel: one year betas; Right panel: two year betas.

one-year and two-year betas, there are a few differences. The lowest risk class for two-year betas does not contain any entries. High risks are more persistent than medium risks, as can be seen from risk classes 9 and 10, whose transition probabilities are shifted to the right. This effect is strongest in one-year betas in the high risk classes, which are more stable than two-year betas.

4.5 Conclusion

Aggregate market risk of listed private equity vehicles varies strongly over time and is positively correlated with the market return variance. Individual CAPM betas are highly unstable, whereas ranks of individual vehicles within a cross-section change slightly less over time. Individual CAPM betas are predictable only up to 2-3 years into the future and quickly converge to a stationary distribution when measured in fixed risk classes in an empirical Markov transition matrix. High and low risk companies, however, remain in their decile risk classes more likely than medium-risk companies. The probability that a company can be found in the same decile in the next year is about 21 % for high-risk companies and 18 % for low-risk ones.

I suspect that market risk of private equity is affected by factors unique to this sector: acquisitions and divestments that constantly rebalance portfolios, scarcity of information about portfolio companies, and rapid changes within portfolio companies. Unstable market risk seems to be a fundamental characteristic of private equity assets, which must be incorporated in the valuation process and which casts doubt on diversification benefits of private equity in times of crisis. Particularly important, investors usually hold traditional private equity shares to maturity, which can be up to 10 years. Unpredictable changes in market risk pose a challenge for portfolio allocation, since investors would be buying assets that behave entirely different from what they were supposed to when first included in the investor's portfolio. However, targeting vehicles with specific risks relative to the asset class might be a feasible strategy for long-term private equity investors.

Chapter 5

Net Asset Value Discounts in Listed Private Equity Funds

5.1 Introduction

Since the emergence of exchange traded private equity[1] funds (i. e. listed private equity) as an asset class in the 1990's, these vehicles have constantly been trading at a discount to their respective net asset value (NAV). If listed private equity funds were similar to holding companies, they should trade at a premium on average. Historically, book-to-market ratios in stocks have been well below one (see, for example, Loughran (1997) and Kothari and Shanken (1997)). This translates into an average NAV premium for stocks, not into a discount. One can also view listed private equity funds as traded portfolios of unlisted companies. If this was the correct perspective, these funds would be more similar to mutual funds which also represent a portfolio, albeit of securities instead of unlisted shares. The cross-sectional average NAV discount in closed-end mutual funds is almost always positive and has been moving in the range between 5 % and 15 % over the past 20 years. (Cherkes et al. (2009), Dimson and Minio-Kozerski (1999)). During the same time, listed private equity funds showed an average discount to NAV of about 15 %.

[1] I use the term "private equity" to refer to venture capital funds and buyout funds.

This chapter investigates the causes and consequences of discounts in listed private equity funds. I will refer to the ratio of market value to the fund's net asset value as its "premium". The importance of listed private equity funds is that they bridge the gap between closed-end mutual funds, unlisted private equity funds and listed holding companies. It is thus not immediately clear which theories apply. If premia could be successfully explained, my results would have implications for the pricing of private equity funds and in particular secondary transactions, since there are usually no market prices observable for traditional private equity funds.

I find many similarities between premia in listed private equity funds and closed-end funds but also several striking differences. LPE funds do not start with a premium like closed-end mutual funds but show a negative premium of -2.5 % instead. This premium takes about 2 years to adjust to the long-term average of -21 %. This behavior is very similar to traditional private equity funds. Premia predict future stock returns, what I interpret as mean reversion following Pontiff (1995). I document a U-shaped seasonality in fund returns with higher-than-average returns in the first quarter and lower returns in the second and third. This pattern cannot be explained by the usual arguments involving tax effects to account for the January effect, but to a substantial extent by publication dates of annual reports.

The drop in NAV premia during the first two years cannot be explained directly by economic causes but has only small explanatory power. One likely reason why I observe decreasing premia is a market mechanism when participants learn about management ability, as proposed by Berk and Stanton (2007). Cash holdings can proxy for a fund's investment degree, which should provide some information about successful or unsuccessful portfolio acquisitions. The fund's investment degree has no significant effect on premia, which casts doubt on managerial ability being the only explanation for declining premia. Variables related to investor sentiment, on the other hand, offer some insight into cross-sectional and time-series properties of premia. Premia that are 10 % lower than in closed-end mutual funds across the board could be an indication of higher noise trader risk in listed private equity. Sensitivity to small-cap indices and proxies for hot markets lends further support to the investor sentiment hypothesis.

I find a positive relation between the fund's bid-ask spread and premia. Surprisingly, infrequently traded funds have exceptionally high premia. Private equity fund valuations seem to depend on credit markets, since premia are inversely related to the long-term credit spread between government and corporate bonds. Moreover, premia are higher in funds with low systematic risk, which suggests that systematic risk is not fully reflected in net asset values. Another new effect in listed private equity funds is the apparent underperformance of buyout funds following their IPO. Buyout funds exhibit premia that are 10–11 % lower than premia in other funds, which is almost entirely attributable to poor stock performance over their first few years of trading.

The remainder of the chapter is organized as follows. In section 5.2, I review theories explaining fund premia and account for the specifics of private equity funds. I motivate the empirical analysis by combining theories from the closed-end fund literature with empirical phenomena in private equity funds. In section 5.3, I provide detailed information on private equity net asset values and variables used to estimates premia. In Section 5.4, I discuss the results on the predictability of fund returns and fund premia and their implications. Section 6.6 contains a summary and conclusions.

5.2 Premia in (private equity) funds

Several theories have been put forward to explain the difference between NAV and market price of a listed fund. On the one hand, the extant literature focuses on closed-end funds that invest in securities. The description as a "closed-end fund puzzle" in the literature highlights the difficulty of investigating NAV premia in these vehicles. On the other hand, there are private equity-specific explanations, which take account of the fact that private equity funds invest in unlisted companies.

5.2.1 The closed-end fund puzzle

Most of the theories dealing with NAV premia concern closed-end mutual funds, which invest only in securities. The fact that these funds are traded at premia to NAV is even more surprising, since such premia should be eliminated by arbitrage in perfect markets. Closed-end investment funds are usually issued with a premium of up to 10 %. Within a few months, they trade at a discount. If the fund is converted into an open-end fund (open-ending), merged with an open-end fund, liquidated, or if the fund's portfolio is sold as a whole, the fund price rises and the discount vanishes (Brauer (1984), Brickley and Schallheim (1985), Kadapakkam et al. (2005)). I discuss the relevant theories trying to explain the closed-end fund puzzle and highlight the similarities to listed private equity.

Management fees

Several scholars have proposed theories why management fees of a fund should correlate with NAV premia. Their results are, nevertheless, contradictory. Boudreaux (1973) argues that fees might imply a NAV discount, if the fund's charges are too high. Malkiel (1977) finds no significant relationship between fund returns or NAV premium and fees. Ammer (1990), however, shows that the fees usually charged by UK funds explain the discounts well. His model is criticized by Dimson and Minio-Kozerski (1999), because it neither explains the variance of NAV premia in different types of closed-end funds nor the variance in different countries. Lee et al. (1991) argue that fees are not responsible for the large fluctuations in premia, since they are typically calculated as a fixed percentage of NAV. Thus the present value of future fees varies mainly because of changing interest rates. According to their study, there is no correlation between NAV premia and interest rates and thus not with management fees. Furthermore, they state that fees cannot explain why closed-end funds typically start with a premium. Kumar and Noronha (1992) use a larger dataset than Malkiel (1977). Taking account of control variables, they find a significant correlation between NAV premia and fees. The small part of total variance explained by their regression suggests that there may be other determining factors.

Management fees in private equity funds are usually determined as a fixed percentage of net assets as well. All arguments put forward to explain closed-end mutual fund premia should therefore carry over to private equity funds.

Managerial ability and performance persistence

The theory of managerial ability posits that many closed-end funds have higher costs than the expertise of investment managers could justify. Shares of those funds should therefore trade at discounts while offering comparably low returns (Dimson and Minio-Kozerski, 1999). Both Malkiel (1977) and Thompson (1978) find no evidence for this hypothesis in their analysis. Going a step further, this theory suggests that a large NAV discount is followed by low future NAV returns (Dimson and Minio-Kozerski, 1999). According to Chay (1992) and Chay and Trzcinka (1999), there is a significant correlation between high discounts and low future NAV returns. Lee et al. (1990) as well as Pontiff (1995) do not find this correlation in their analyses. They demonstrate the opposite, namely that large NAV discounts lead to better future NAV returns. In the most recent model involving managerial ability, Berk and Stanton (2007) argue that discounts change over time as investors change their beliefs about the manager's ability. If managers cannot be fired, poor managerial performance leads to discounts. Premia are short-lived, because managers learn about their above-average performance and negotiate a pay increase.

Taking previous returns as an indicator of the management's skills in closed-end funds, future NAV returns could be inferred from past observed NAV returns. Premia and discounts could be explained by this performance persistence. Dimson and Minio-Kozerski (2001) analyze British closed-end funds but find no evidence for the existence of performance persistence in their data. Bleaney and Smith (2003) consider the relationship between past returns and NAV premia. They examine closed-end funds in the US and UK that invest either in bonds or stocks. Past returns are shown to have a positive impact on NAV premia, but only in equity funds. The performance persistence explanation should also apply to listed private equity. Kaplan and Schoar (2005), for example, show that it exists at least for traditional non-listed private equity funds.

Private benefits

If closed-end funds can be opened or liquidated, discounts should tend to zero. However, if managers own very little of the fund, they do not benefit substantially from opening the fund, but would run a risk of losing their job. Therefore, managers resist open-ending proposals and discounts persist. Larger managerial stock ownership should lead to an incentive to open the fund and to declining discounts.[2] Barclay et al. (1993) find exactly the opposite relation. The greater the managerial stock ownership in closed-end funds, the larger are the discounts to net asset value. The average discount for funds with blockholders is 14 %, whereas the average discount for funds without blockholders is only 4 %. They argue that blockholders receive private benefits such as management fees or payments for financial research that do not accrue to other shareholders. Therefore, they veto open-ending proposals to preserve these benefits. The situation in listed private equity funds is somewhat more complicated. While venture capital trusts generally allow the fund's dissolution by shareholder resolution, shareholder (or unitholder) rights differ in funds with a partnership structure. Limited partners in these funds typically have no right to terminate and dissolve the fund (e. g. KKR Private Equity Investors). I suspect that the legal structure has an influence on private benefits extraction and may interact with the proportion of block ownership.

Tax timing

Following Constantinides (1984), capital gains tax can be reduced by skillfully timed purchases and sales of shares. According to this theory, investors forgo their chance to minimize taxes through managing their portfolio by investing in externally managed funds. If investors replicate the fund's portfolio instead, they have better

[2] See Kaserer and Moldenhauer (2008) for an investigation of the relation between insider ownership and corporate performance in listed companies.

control over their tax payments (Kim, 1994). Brickley et al. (1991) support this theory with their findings. Kim (1994) shows that tax issues have a significant influence on the NAV premium of closed-end funds. Tax timing, however, cannot explain why funds are occasionally traded at a premium. Contrary to investment funds, LPE funds invest in rather illiquid assets that cannot be bought and sold as easily as stocks. The replication argument does not hold, since there is no precise control of tax payments possible.

Country funds and market segmentation

Closed-end funds that invest in a specific country or a particular region outside their home country are called country funds (Charitou et al., 2006). The theory is that restrictions on direct foreign investment are a possible explanation for NAV premia (Dimson and Minio-Kozerski, 1999). Bonser-Neal et al. (1990) test whether there is a correlation between announcements of changes in international investment restrictions and changes in NAV premia. In four out of five funds they find a reduction in premia whenever a liberalization of investment restrictions is announced. The average premium reduction is 6.8 %. A study by Malkiel (1977), however, shows no significant correlation between the proportion of foreign shares in the fund portfolio and its NAV premium. Country effects cannot explain the up to 100 % premia of country funds which invested in Germany during the reunification, since Germany is a free market without investment barriers (Hardouvelis et al., 1993). This theory is hardly applicable for listed private equity funds, since private equity funds with an explicit country focus do not exist yet. Nevertheless, the German example shows the overreactions which may occur in the market.

Low sales incentives

Malkiel (1977) points out that investors usually do not *buy* mutual funds. They are rather *sold* to investors by brokers, but brokers sell those products that promise the highest commission. Open-end funds usually pay higher commissions. According to

Pratt (1966), this is the reason for an imbalance of sales efforts between open and closed funds. NAV discounts are thus caused by a weaker demand for closed-end funds. Weiss (1989) adds that the higher NAV premium at the moment of listing could be due to higher sales commissions in IPOs of closed-end funds. There is no reason to believe that sales efforts are higher or lower for LPE funds than for other closed-end funds, but the overall effect is hard to measure, since there are no LPE funds comparable to open-end investment funds.

Investor sentiment

Because the previously mentioned theories cannot sufficiently explain NAV discounts, the rationality of the market is called into question. A visible sign of this irrationality could be decreasing NAV discounts in times of bull markets and declining premia when stock prices are falling. Zweig (1973) argues that premia in closed-end funds mirror the expectations of private investors. De Long et al. (1990) investigate the impact of these investors and the possibility to reduce premia by arbitrage. They suggest the existence of two different groups of investors: rational and irrational investors. Rational investors have unbiased expectations of future returns, but irrational investors' predictions are systematically biased in either direction. Rational investors are assumed risk averse and having finite investment horizons. Because of their unpredictable behavior, irrational investors prevent rational investors from eliminating premia by arbitrage. If irrational investors expect positive stock returns and drive the stock price up, future expectations by irrational investors could be even higher, thus making an arbitrage strategy partially infeasible. If a rational investor pursuing such a strategy cannot hold his position any longer, he must liquidate it at a loss. Fear of this loss should discourage at least investors that have a short investment horizon from arbitrage. According to this theory, the reason for the existence of NAV premia is that irrational investors directly cause deviations of market value and NAV and indirectly lead to higher discounts or lower premia. Market price inflations on their own cause market values to deviate from NAV in closed-end funds because of infeasible arbitrage.

In addition to this direct but symmetric effect, there is a second, indirect reason for discounts caused by noise trader risk. It is not due to the general pessimism of irrational investors that closed-end funds are traded at a discount most of the time. Noise traders rather induce discounts because of a non-predictable risk of stochastically acting irrational investors (Lee et al., 1991). Investors wanting to sell their investment in finite time have to be compensated for this noise trader risk, resulting in NAV discounts. Note that both rational and irrational investors are affected by this additional risk. In this way, irrational investors with unpredictable changing return expectations cause stochastic changes in the demand for the shares of closed-end funds, which in turn lead to stochastic changes in the NAV premia. Lee et al. (1991) support this theory with their analysis based on the similar ownership structures of closed-end funds and small listed companies and show a high correlation of NAV premia and stock returns of small companies.

There are, however, conflicting results. Ammer (1990) compares the closed-end funds in the US with the closed-end funds in the UK. He concludes that in both countries similarly high NAV premia can be observed, although British funds have a much higher proportion of institutional investors (which is 70–75 % during the time period Ammer studies). Since institutional investors are seen as rational, this finding contradicts the investor sentiment theory. According to Lee et al. (1991), there is sufficient evidence that shares of closed-end funds are owned and traded to a large extent by irrational investors. They estimate the proportion of irrational investors in closed-end funds much higher than their share in the fund's portfolio companies. In her study of 64 funds investing in stocks or bonds, Weiss (1989) shows that three months after an IPO only 3.5 % of all outstanding shares of a closed-end fund are held by institutional investors. The proportion of small and possibly irrational investors is presumably high in listed private equity funds. We can safely assume that their share of the fund's individual portfolio companies is much lower, since funds typically own large stakes in unlisted portfolio companies. Consequently, even listed funds can be affected by noise trading and investor sentiment.

5.2.2 Private equity-related explanations

In addition to explanations focusing on mutual funds and the closed-end fund puzzle, there are several explanations of NAV premia which apply to LPE-specific characteristics. These are the dependence on credit markets in buyout funds, illiquidity of portfolios and listed funds, stale pricing and the J-Curve effect.

Dependency on credit markets

Private equity transactions and predominantly those in the buyout sector typically involve large amounts of debt. Between 1990 and 2006, the average equity contribution in buyout transactions was constantly about 30 % of transaction value (Guo et al., 2008). Although it is not immediately clear how changes in the cost of debt affect equity valuations, two direct mechanisms that work in LPE are conceivable. Kaplan and Strömberg (2009) argue that private equity funds may take advantage of systematic mispricings in the debt and equity markets. When the cost of debt is relatively too low compared to an appropriate level, private equity funds can arbitrage or benefit from the difference by overleveraging. A similar argument is put forward by Baker and Wurgler (2000) and Baker et al. (2003) for public companies. The validity of this argument, however, relies on market frictions which cause a segmentation of debt and equity markets.

Axelson et al. (2009) propose a different hypothesis based on the observation that private equity firms pursue large transactions relative to their fund sizes. Private equity firms might be constrained in the amount of equity they can invest in a given deal. Therefore, they must use leverage to fund their investments. Both theories imply a dependence on credit markets. Based on Kaplan and Stein's (1993) observation that overly favorable terms from high yield bond investors could have fueled the 1980s buyout wave, Kaplan and Strömberg (2009) find a cyclicity in debt levels. They also document lower debt levels of about 30 % in the second buyout wave from 2005 through mid-2007 compared to 10–15 % during the first wave in the 80s, which they interpret as evidence for Kaplan and Stein's argument that debt investors might have been too optimistic. More transactions should be undertaken by LPE funds if interest levels are unusually low. Excess value creation by funds during these periods could be anticipated by fund investors, which in turn increases NAV premia.

Liquidity

Liquidity can play a role on two levels. On one hand, it is important to investigate whether the portfolio companies' liquidity have an influence on the fund's NAV premium. On the other hand, the liquidity of the fund itself might affect premia. Lee et al. (1990) show that the liquidity of the securities the fund holds cannot be responsible for the NAV discount in investment funds, because only a few funds have illiquid securities in their portfolio.

LPE funds, however, mostly hold illiquid shares in portfolio companies. Cherkes et al. (2009) find that closed-end funds that hold illiquid securities are traded at higher premia. They justify this by the additional liquidity these funds offer their investors compared to direct investments in these portfolio companies. While the funds's stock is listed on an exchange, shares in the portfolio companies are highly illiquid. Since the illiquidity of an investment is not taken into account when calculating the NAV, investors of such a fund pay an additional liquidity premium. Note that this argument is directly opposed to the arbitrage argument that premia should be lower if the liquidity of the fund's underlying portfolio is high and arbitrage strategies are thus easier to implement.

On the fund level, Datar et al. (1998) and Chordia et al. (2001) show that the illiquidity of an investment is generally related to a higher rate of return, as investors want to be compensated for the higher risk in illiquid investments. Many LPE vehicles are rather small and illiquid. Thus, the illiquidity both at the level of the fund as well as on the level of the portfolio companies might have an impact on NAV premia.

Stale pricing

The quality of net asset values is highly dependent on the choice of parameters and the method used for their calculation. Therefore, a PE fund or the management company can act with relatively high flexibility in pricing those portfolio companies for which there is no market price available (Anson, 2002). Since many PE firms accept the International Private Equity and Venture Capital Valuation Guidelines developed by the industry organizations AFIC, BVCA and EVCA and based on the notion of fair value, valuation methods are largely the same across funds. However, many free parameters can be chosen at the firm's discretion. Many management companies are reluctant to change valuations in the absence of value-determining events such as a change of ownership. There can be long periods without such events, which can lead to NAVs containing less and less current information. Whenever the net asset value does not contain all available information, this situation is called stale pricing. This leads to a delay between net asset value and observable market value. Therefore, the NAV will only occasionally coincide with the market value of portfolio companies measured by the hypothesized transaction value on a free market.

An inconsistency of NAV and market value or lagged book values can also be caused by managed pricing (Anson, 2002). The management company has certain leeway in calculating NAVs that can be exploited in the way most useful to fund management, that is, fast appreciation and slow depreciation of NAVs to boost performance-related compensation. Those fair values which are based on international valuation guidelines could be biased due to stale pricing. Since the guidelines advocate rapid depreciation to ensure conservative valuation, managed pricing should rather play a minor role.

Stale pricing and managed pricing are no longer a problem as soon as the portfolio company is sold and the investment is realized by the fund. The final return could be observed at this point in time. Emery (2003) analyzes quarterly NAV returns by regressing them on stock index returns and finds a coefficient of determination of 35 % when using NASDAQ returns as an independent variable and 56 % when using lagged NASDAQ returns. These results suggest a delay in the adjustment of net asset values to new information about portfolio companies. When using annual rather than quarterly data, the lag effect is less pronounced. However, Emery does not explore whether the delay is caused by stale pricing or managed pricing.

Anson (2002) finds a similar lag structure between NAV returns and stock index returns. In addition, he tests whether the delays are attributable to stale pricing or managed pricing. He examines how fast NAVs appreciate in rising stock markets and depreciate in bear markets. Managed pricing should be indicated by quickly appreciating and slowly depreciating NAVs. He notes that appreciation occurs slower than depreciation, which is in line with the international guidelines on valuation but contrary to NAV-based incentive schemes.

Since listed funds employ the same business model as traditional private equity funds and their portfolio companies are valued according to the same standards, results should be similar for listed funds. In listed funds, however, it is possible to construct incentive schemes based on the stock price, which should reduce managed pricing to some extent.

The J-Curve effect

A well established empirical phenomenon is the J-shaped relationship between a fund's age and its lifetime NAV return (see Phalippou and Gottschalg (2009), Kaplan and Schoar (2005), Artus and Teiletche (2004), Kaserer and Diller (2004)). Reported net asset values of most funds drop during the first few years and grow steadily until the end of the fund's lifetime. Several explanations can account for this phenomenon. First, management fees that are not offset by realized profits during the first years can push NAV below par. This effect is even more pronounced in funds where management fees are calculated as a percentage of committed capital and not paid-in capital. Second, most investments are made at the beginning of the fund's lifetime. Therefore, the majority of investment costs accrue over this time. Finally, the J-curve can be the result of asymmetric depreciation policies. Many PE firms depreciate aggressively if investments turn out worse than expected but write up only if the portfolio company is sold or some other valuation event occurs. This creates a downward pressure on net asset values during the first few months or years when no such value-determining event occurs. This pressure can be amplified, if the fund management is able to identify underperforming portfolio companies earlier than outperforming ones.

All these effects also apply to listed private equity with the exception of management fees, where the magnitude of the J-curve is supposedly lower than in traditional PE funds. Listed funds are usually paid in at once and thus no discrepancy between committed capital and paid-in capital can exist. More than half of the European institutional investors surveyed by LPEQ believe that listed private equity offers less management fees compared to limited partnership private equity and an attractive way to invest in private equity after the “J-curve”, avoiding low returns on investment in initial periods (Cumming et al., 2010).

In efficient stock markets, price changes reflect changes in the expectations of shareholders in net cash flows available for distribution to the shareholders and also in the interest rate used to discount future cash flows. Since the J-Curve effect is well known, it should be taken into account in rational capital markets and should thus have no impact on share price movements. If the fund’s NAV shows a J-Curve effect but the share price does not, then NAV discounts should depend on the fund’s age. This theory could, if confirmed, explain only a small part of NAV discounts shortly after the fund’s IPO and does not explain premia at the IPO or late in the fund’s lifetime.

5.3 Data and methodology

5.3.1 Net asset values and premia

Fund data were compiled from several sources. Net asset values per share between 1992 and 2008 were collected from the funds’ financial reports. Share prices were obtained from Datastream. Practitioners usually define a fund's premium as the ratio of the fund's price per share to the book value of their portfolio per share minus one. In this chapter, I compute premia as the natural logarithm of price to net asset value per share. Since one ratio can be transformed into the other, we do not lose information but are able to specify regression models correctly. A fund's premium can be expressed as $PREM_t = \ln(P_t/NAV_t)$ where P_t is the fund's price per share and NAV_t is defined as the fund's net asset value or, equivalently, book value of equity per share. I collected 1727 premia from 100 funds, not all of which can be analyzed in all models due to missing data on covariates. My sample comprises 79 ordinary funds and 21 listed private equity funds of funds (FoF) that invest in traditional private equity funds. Since funds of funds turn out to behave similarly to directly investing funds, I do not treat them as special, but address relevant FoF issues below. Most funds (64) are headquartered in the UK, 11 are based in the US, 20 in continental Europe and 5 in other countries.

Figure 5.1 shows the average premium over time. Most observations are from the last 5 years when many funds went public. Funds usually report NAVs quarterly, but sometimes change reporting frequency or business year. 48 funds report more than 3 NAVs per year on average, 26 report more often than twice per year. My data thus have an unbalanced panel structure with gaps. I record NAVs in March, June, September and December. If business years are off by on leading or lagging month, NAVs are treated as being reported in the nearest quarter (for example, if the fund reports in May, I record this NAV in June). 79 funds report at the end of the quarter, 12 one month before and 9 one month later.

5.3.2 Covariates

Table 5.1 reports summary statistics of the net asset value premia and covariates. The average ratio of NAV to market value is 84.2 %, which corresponds to an average premium of -20.7 %. One NAV below zero is observed but is excluded from further analyses when taking logs. 85.7 % of all premia are below zero, only 3.1 % are greater

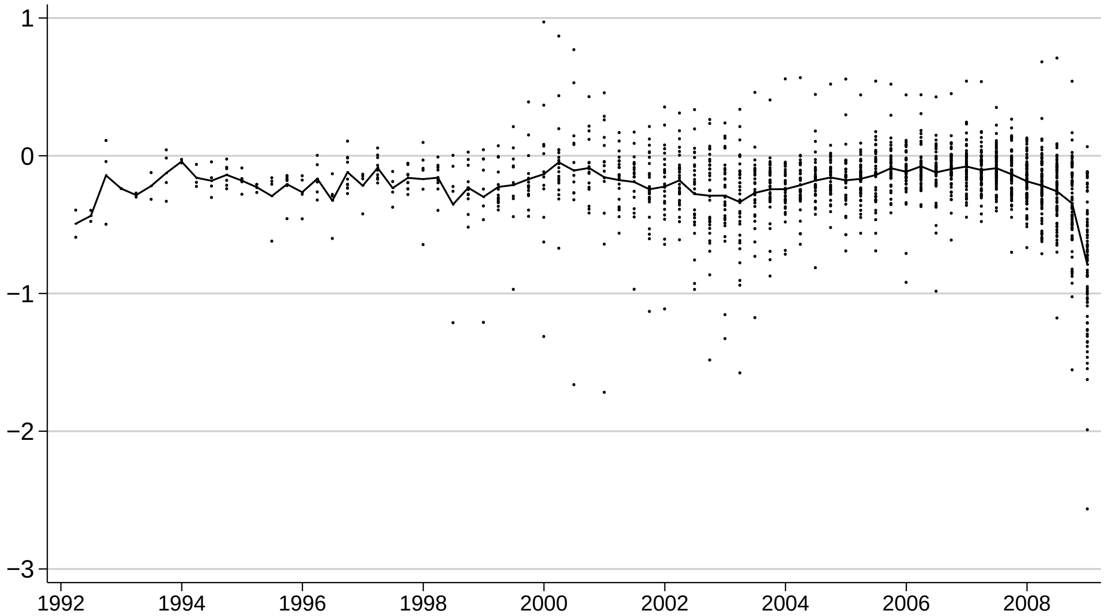

Figure 5.1: Premium in calendar time
Dots represent premium observations, the solid line is an equally weighted average of NAV premia.

than 20 %. The average fund age is 6.6 years, which documents the recent growth in this asset class.

- *Cash / Total Assets:* The funds' cash position and total assets in each quarter are taken from Worldscope and augmented by figures from the funds' financial reports. I define the cash position as cash and cash equivalents to total assets. I also compute a cash position relative to market capitalization but do not use it to explain premia. Since most of this measure's variation is due to changes in market value, including it in a regression for premia would cause spurious correlation. The average cash position is 11.3 % with a median of 5.8 %. Compared to market value, funds hold 18.0 % cash on average (Median 8.4 %).

- *Bid-ask spread (Log):* Bid-ask spreads are calculated for each fund as its share price's bid-ask spread averaged over each quarter. The average bid-ask spread is 2 %. Two implausible negative values could not be verified, but are excluded

Table 5.1: Summary statistics of independent and dependent variables

The "Panel" column denotes if data is available for cross-sections (i), time series (t), or both (p).

	Panel	Mean	SD	Min	25 %	Median	75 %	Max	N
NAV premium	p	-0.201	0.283	-2.564	-0.294	-0.154	-0.055	0.972	1792
Fund age (Ln)	p	6.571	5.511	0.005	2.295	5.466	9.096	32.619	1784
Bid-ask spread	p	0.020	0.031	-0.004	0.005	0.011	0.022	0.487	1792
Trading days	p	0.617	0.381	0.000	0.212	0.848	0.955	1.000	1785
Beta	p	0.653	1.893	-47.041	0.000	0.474	1.162	39.321	1792
Common law	i	0.701	0.458	0.000	0.000	1.000	1.000	1.000	1792
Venture capital trust	i	0.220	0.414	0.000	0.000	0.000	0.000	1.000	1792
Managment fee	i	0.017	0.005	0.004	0.014	0.018	0.020	0.035	1787
Cash / Total assets	p	0.111	0.153	0.000	0.015	0.052	0.141	1.000	1380
Cash / Market value	p	0.174	0.249	0.000	0.020	0.077	0.217	1.515	1377
Inst. ownership	p	0.319	0.255	0.005	0.112	0.254	0.500	1.150	877
Ownership conc.	p	0.048	0.090	0.000	0.003	0.017	0.050	0.766	977
Commitments (USD bn)	t	76.80	46.17	0.65	35.06	74.62	108.81	167.53	1792
Commitments change	t	0.121	0.898	-0.835	-0.239	-0.074	0.272	21.786	1790
MSCI excess return	t	-0.016	0.083	-0.211	-0.047	0.002	0.041	0.175	1790
Interest rate UK %	t	4.888	0.905	3.290	4.440	4.740	5.090	9.720	1792
Interest factor	t	-0.772	0.477	-1.696	-0.994	-0.834	-0.617	1.548	1792
Spread UK %	t	1.582	1.359	0.160	0.840	1.090	1.610	6.370	1792
Spread factor	t	0.553	1.208	-1.022	-0.252	0.169	1.075	4.562	1792
IPO volume (USD bn)	t	90.71	52.69	9.13	52.91	78.89	113.27	214.34	1792
IPO volume change	t	-0.127	0.691	-1.924	-0.586	-0.114	0.436	1.489	1790

when taking logs.

- *Trading days (Log):* In each quarter, I count the number of days Datastream reports a trading volume for and take its natural log. The average number of trading days is 41, but most funds traded on 56 or more days each quarter. The variable that enters the regression is the percentage of trading days in each quarter in logs.

- *Age (Log):* At the end of each quarter, each fund's age is calculated as the natural logarithm of the number of years from its IPO date.

- *Institutional ownership (Log):* Ownership data is obtained from Thomson Financial for the years 1997 to 2008. The Thomson ONE Ownership database reports the institutional ownership for equities at the end of each year based on various sources, such as 13(f) filings by institutions or mutual fund data. I sum all shares held by investors other than individual investors to obtain the institutional ownership fraction and take logs. Average institutional ownership is 32 %. Two funds have more than 100 % institutional ownership in one year, which could not be resolved.

- *Ownership concentration (Log):* To measure the extent of blockholdings, I construct a Herfindahl index for each fund-year from the ownership data obtained from Thomson ONE Ownership for my sample. This measure does not only include institutional investors but also individual ones. Holdings in listed private equity funds are diversified to a large extent, indicated by a median Herfindahl index of 0.017.

- *Beta:* Systematic risk is estimated by a time-series regression with Dimson (1979) betas over a one-year rolling window. I use this variable to proxy for systematic business risk associated with portfolio companies. Based on the international Capital Asset Pricing Model, the equation for the regression is given by

$$R_t = \alpha + \sum_{k=0}^{7} \beta_k M_{t-k} + \gamma_1 GBP_t + \gamma_2 EUR_t + \gamma_3 JPY_t + \epsilon_t, \qquad (5.1)$$

Beta is the sum of β_k. R_t and M_{t-k} are the respective observed logarithmic (excess) weekly index and market returns at time t and *t-k*, whereas k corresponds to the respective lag, α, β and γ are the slope coefficients and ϵ_t is an error term. Asset and market returns are in US dollars. I include seven lagged market returns, since this number of lags turns out to be statistically significant for equally weighted indices of listed private equity (see chapter 3 and Lahr and Herschke (2009)). GBP, EUR and JPY are the weekly log returns of currency portfolios to account for exchange rate fluctuations and movements in local interest rates. They are constructed as (excess) returns on short-term deposits denominated in local currency and measured in the reference currency. All returns are continuously compounded. Since market return autocorrelations are relatively small compared to autocorrelations in my LPE indices, I exclude leading market returns to avoid look-ahead bias. The risk-free rate of return was estimated by averaging the monthly averages of three month Treasury bill returns over the observed period and taking logs.

- *Management fee:* Private equity funds usually charge two types of fees. Management fees typically are a fixed percentage of NAV whereas performance-related fees can depend on income or capital gains. Performance fees of 20 % of NAV gains combined with an 8 % hurdle rate are most common in my sample. Since different performance fee provisions across funds cannot easily be concentrated in one variable, I choose to retain only nominal management fees as a covarite. Management fees range from 0.4 % to 3.5 %. The median fee is 1.8 %.

- *Market and small cap indices:* The concurrent quarterly MSCI World index return is used to control for the market risk factor in equity markets. To test the investor sentiment theory, the FTSE Small Cap, DJ Stoxx Small and MSCI US Small Cap index returns are included for the UK, Europe and the US, respectively. Because of high collinearity, I construct a small-cap factor from these indices.

- *Commitments:* Cash inflows to private equity funds may well indicate hot markets according to the money-chasing-deals argument (Gompers and Lerner, 2000) and therefore influence premia. I obtain quarterly worldwide fund commitments in U.S. Dollars from Thomson VentureXpert to measure both level and changes in fund commitments.

- *IPO volume:* A second variable to proxy for investor sentiment in hot markets is the volume of international initial public stock offerings in U.S. Dollars. I obtain quarterly worldwide IPO volume from Thomson SDC.

- *Interest rates and spread:* I decompose long-term interest rates on corporate debt into 10-year government bond yield and the spread between long-term government and corporate bonds. UK and US interest rates are represented by their respective government bond yield, continental European interest rates are approximated by German 10-year benchmark bond yields.

- *Fund focus:* To account for possibly different business risk and organizational structures, I separate funds according to their stage focus. I only distinguish between venture funds (41) and buyout funds (38) because of the limited number of funds. The 21 funds of funds in my sample constitute a third category.

5.3.3 Estimation

Net asset value premia in listed private equity funds show considerable autocorrelation at lag one. I therefore employ estimation techniques that account for this autocorrelation. Returns in tables 5.3 and 5.8 are estimated by pooled OLS with inference using Newey-West standard errors. A more direct method to deal with autocorrelation is to adjust the variables previous to the estimation, which is done in tables 5.4 and 5.7. Variables are first purged of first-order autocorrelation by a Cochrane-Orcutt transformation. After that, I use the GLS method by Baltagi and Wu (1999) to handle unbalanced panel data. To identify coefficients for variables that are constant within each panel, the Baltagi and Wu random effects estimator is employed. I also report fixed effects estimates for comparison for some models.

Collinearity among independent variables can make it hard to assign effects to specific variables. Spurious significance or no significance at all could be the result of negatively or positively correlated variables, respectively. There is a large amount of common variation among the market index returns, interest rates, and (lagged) interest spreads. I try to overcome these issues by constructing factors from groups of variables by performing factor analyses and using the common factors in regressions instead of the original variables. Small capitalization index returns for U.S., U.K., and continental European stocks are aggregated into a small-cap factor. I also construct factors for interest rates on government bonds and for yield spreads between government and corporate bonds in these markets.

5.4 Empirical results

I record the first observation for one fund two days after its IPO. The average premium for this day is -2.58 %. If extrapolated linearly from this first observation, the IPO premium is -2.5 % (see table 5.2 and figure 5.2). This is considerably less than the premia reported for U.K. and U.S. closed-end funds. The average investment trust issue is quoted at an effective premium of 5.72 % above its net asset value at the end of the first day of trading (Levis and Thomas, 1995). U.S. stocks still trade at 4.8 % premium 5 weeks after the IPO (Weiss, 1989). Considering an initial return of -6.48 % over the first 30 days, as reported by Weiss (1989), U.S. stocks sell at an even higher premium. According to Lee et al. (1991), first day premia are generally attributed to investor sentiment, which issuing firms are able to use to their advantage. If first day premia occur in hot issue markets due to positive investor sentiment, we observe less irrational behavior in listed private equity funds. This argument must be taken with a grain of salt, however, since not premia per se may be seen as an indication of investor sentiment but rather the large drop in premia after a fund's IPO, as I will argue below.

After the first slightly negative premium on the first trading day, premia decrease to the long-run average of -21 %. The drop in premia is fairly linear and reaches its bottom after 2–2.5 years as depicted in figure 5.3. Weiss (1989) finds that within 24 weeks of trading, closed-end equity funds in the U.S. trade at a significant average discount of 10.02 %. Levis and Thomas (1995) find that after 200 trading days, equity funds in the U.K. fall in value by 5 %. The qualitative behavior of premia is thus very similar to closed-end funds but displays a time pattern like in traditional private equity funds where returns measured by IRRs usually turn around after 2–3 years and break even after 5–6 years. However, the pattern is actually *reversed* compared to what we should expect if the J-curve phenomenon was driving premia. If NAV returns were low over the first quarters but shares earned some risk-adjusted return, premia should *rise* first and then remain at an equilibrium. I find no correlation between NAV returns and age, but higher stock returns in older funds. This

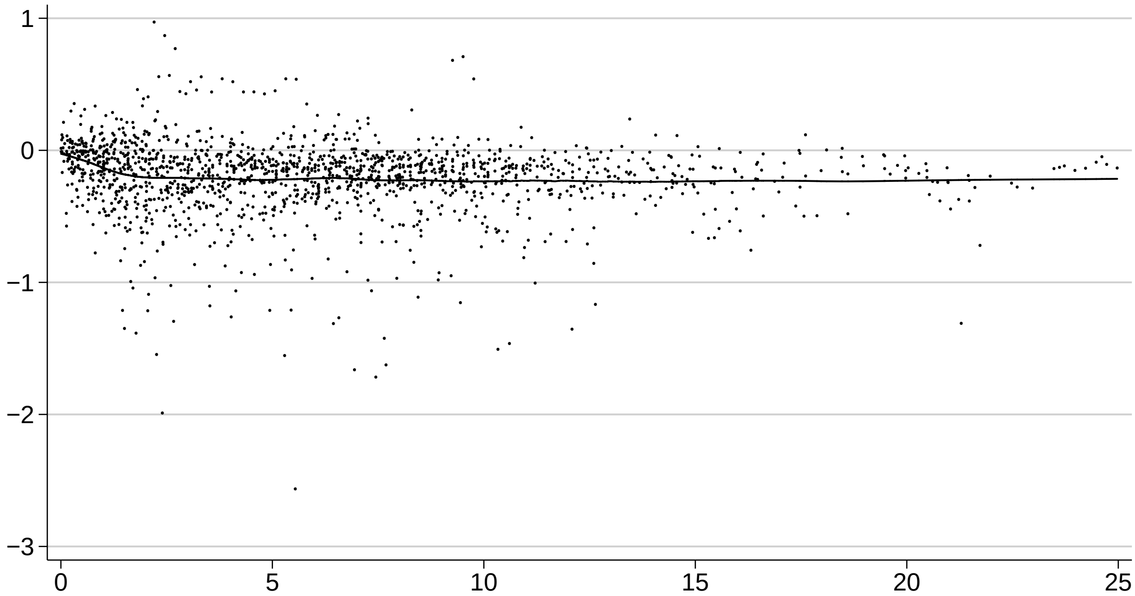

Figure 5.2: Premium in event time (years from IPO)
The solid line represents the average premium estimated by locally weighted regression (Lowess) with bandwith 0.25.

suggests that the age effect is driven by stock returns rather than net asset values.

Table 5.2: Post-IPO premia
A locally weighted regression with bandwith 0.25 is performed on log premiums. The initial premium at day 0 is a linear extrapolation from 2 days after the IPO when the first premium observation occurred.

Years from IPO	0	0.5	1	1.5	2	3	4	5
Premium	-0.025	-0.073	-0.132	-0.181	-0.205	-0.210	-0.217	-0.223

An explanation for discounts in line with Berk and Stanton's (2007) management ability hypothesis is that the market needs some time to learn about the management's quality. This argument works for private equity funds, since it takes much longer in private equity funds to invest the IPO proceeds than in closed-end mutual funds. If, for example, management ability can be assessed based on the acquisitions during this initial investment period rather than the portfolio's subsequent performance, the largest changes in premia should be observed in this early post-IPO period. Consistent with this explanation, premia in venture capital funds take

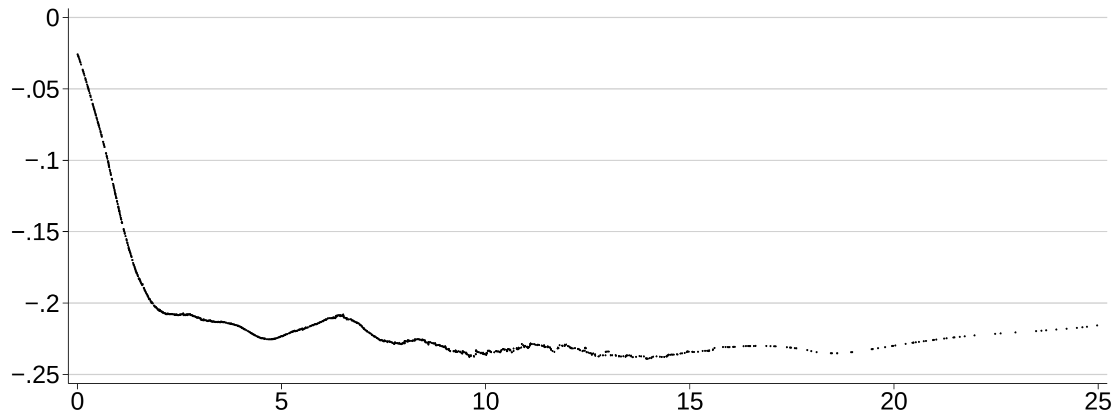

Figure 5.3: LOWESS prediction of premia (years from IPO)
Locally weighted regression is performed with bandwith 0.25.

about four years to settle whereas premia in buyout funds and funds of funds reach their long-term average two years after their IPO. Initial changes in fund premia could therefore be an indication of managerial ability.

A post-IPO decline in premia can be explained by both investor sentiment and managerial ability. While consequences are similar, causes and mechanism of both hypotheses could hardly be more different. Positive investor sentiment, and therefore high premia, should be observed in markets when other indicators for investor sentiment, such as the volume of initial public offerings, are also high. Movements in premia due to discoveries of managerial ability should be correlated with indicators of information flow, such as a fund's investment degree. If premia reflect fund investors' assessment of managerial ability, it should be reflected in returns. Berk and Stanton (2007) point out that today's premium should be related to past returns, since high NAV and stock returns indicate high ability. Premia should also be related to future NAV returns but not to future stock returns, because better managers generate higher NAV returns relative to the fees charged. These arguments hold only if funds have a limited life. Since most listed private equity funds do not have specific wind-up provisions in their charters, bounded premia would require stock returns and NAV returns net of costs to match in the long run. If funds have infinite lives, premia would rather reflect barriers to arbitrage or other variables than managerial ability. I therefore test the relation between returns and premia empirically before examining the determinants of premia.

5.4.1 Return predictability

Listed private equity NAV premia predict future stock performance in almost all of my sub-samples (see tables 5.3 and 5.4). The negative relation is stable across different specifications and independent from the Fama-French HML factor.

In rational markets, sensitivity of returns to book-to-market ratios represents some financial risk associated with high (or low) book-to-market firms. The book-to-market effect is a well documented phenomenon across different markets. Fama and French (1992, 1993, 1998) document a strong positive relation between average cross-sectional returns and book-to-market equity. Empirical studies find that book-to-market ratios are inversely related to future firm performance (Fama and French (2004), Fama and French (1995)) and growth (Lakonishok et al., 1994) and are positively related to leverage (Chen and Zhang, 1998). Petkova and Zhang (2005) show that the value premium itself tends to covary positively with the expected market risk premium. These results suggest that high book-to-market firms are more financially distressed than low book-to-market firms, and therefore at least some of the documented stock performance is an artifact of expected returns for financial risk factors (Piotroski, 2007).

Contrary to these explanations, Lakonishok et al. (1994) argue that the subsequent returns to the book-to-market strategy represent a reversal of past valuation errors. The predominant finding in closed-end funds is a negative correlation between fund premia and future returns, which is the opposite of the negative relation between book-to-market ratios and returns. Pontiff (1995) finds that funds with 20 % discounts have expected twelve-month returns that are 6 % greater than nondiscounted funds (0.7 % per month). Thompson (1978) finds that annual contrarian strategies based on this finding yield abnormal risk-adjusted returns of about 4 % per year. Pontiff (1995) attributes this correlation to premium mean-reversion, not to anticipated future portfolio performance. Economically motivated explanations such as bid-ask spread or tax considerations do not account for this effect.

Table 5.3: Return predictability

Reported are pooled OLS regressions of quarterly total stock returns with Newey-West standard errors using 4 lags. Model 3 is a pooled OLS regression with autocorrelation-adjusted variables using the Prais-Winsten transformation. "1st quarter" is a dummy variable equal to one if an observation is recorded in the first quarter of a calendar year, "Q1 after AR" is a dummy variable equal to one in the first quarter after annual reports are published.

	All		All, AR(1)	Buyout	Venture	FoF
Model	1	2	3	4	5	6
MSCI World	0.769***	0.768***	0.774***	0.746***	1.122***	0.630***
MSCI World Lag 1	-0.141	-0.139	-0.150	-0.131	-0.314	-0.056
MSCI World Lag 2	0.232***	0.234***	0.230***	-0.086	0.516**	0.277**
MSCI World Lag 3	0.267***	0.269***	0.264***	0.105	0.497**	0.286**
SMB	0.544***	0.542***	0.546***	0.287	1.240***	0.326*
SMB Lag 1	0.115	0.117	0.127	0.028	0.237	0.096
HML	0.019	0.018	0.019	0.122	-0.236	0.100
HML Lag 1	-0.353***	-0.351***	-0.358***	-0.117	-0.693***	-0.326**
GBP	-0.712***	-0.713***	-0.720***	-0.362	-1.360**	-0.684**
EUR	-0.188	-0.188	-0.193	-0.321	0.090	-0.215
JPY	0.229	0.231	0.232	0.455	0.101	0.148
NAV premium Lag 1	-0.074***	-0.074***	-0.068***	-0.042**	-0.120**	-0.068
NAV return Lag 1	0.091*	0.091*	0.107**	0.064	0.072	0.091
1st quarter	0.025**	0.007	0.007	0.054***	0.028	0.003
2nd quarter	-0.003	-0.007	-0.008	0.019	-0.038	0.004
3rd quarter	-0.020	-0.027**	-0.027*	-0.017	-0.014	-0.025
Q1 after AR		0.035**	0.035**			
Q2 after AR		0.010	0.010			
Q3 after AR		0.016	0.016			
Constant	0.007	-0.001	0.000	0.001	0.003	0.010
adj. R^2	0.295	0.299	0.318	0.233	0.419	0.286
N	967	967	967	320	260	387
Funds	67	67	67	23	23	21

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

Results for listed private equity fund returns displayed in table 5.3 show both effects. Fund returns can be explained by the book-to-market factor but also by past premia. Funds trading at a 20 % discount yield a quarterly return 1.5 % higher than those without such a premium. The effect is least in buyout funds and most pronounced in venture funds. Since returns are autocorrelated at lag one ($p < 0.05$), I perform the same regressions on adjusted variables and find similar results for all sub-samples (see table 5.4).

Table 5.4: Return predictability – adjusted for autocorrelation

Reported are fixed effects regressions of quarterly total stock returns for Cochrane-Orcutt transformed variables. The column "All, AR(0)" shows results of a fixed effects regression without transformation.

Model	All	Buyout	Venture	FoF	All, AR(0)	All w/o lags
Lag 1	0.038	-0.286***	0.021	0.060	0.062	
Lag 2	0.129***	0.034	0.092	0.178***	0.149**	
MSCI World	0.493***	0.373***	0.707***	0.361***	0.527***	0.529***
MSCI World Lag 1	-0.020	0.098	-0.094	0.006	-0.054	-0.053
MSCI World Lag 2	0.059	-0.123	0.145	0.246**	0.087	0.210***
SMB	0.774***	0.540***	1.531***	0.348**	0.702***	0.768***
SMB Lag 1	0.123	0.392**	0.152	0.022	0.136	0.217*
HML	-0.298***	-0.110	-0.722***	0.075	-0.249**	-0.228***
HML Lag 1	-0.237***	-0.106	-0.545**	-0.044	-0.204*	-0.243***
NAV premium Lag 1	-0.178***	-0.060	-0.210*	-0.309***	-0.186***	-0.191***
NAV premium Lag 2	0.043	0.025	0.093	0.053	0.036	0.069*
NAV return Lag 1	0.049	0.181*	-0.002	0.021	0.029	0.033
1st quarter	0.029**	0.044**	0.016	0.024	0.027**	0.029**
2nd quarter	-0.032**	0.002	-0.078**	-0.011	-0.037**	-0.035***
3rd quarter	-0.019	-0.028	-0.016	-0.005	-0.015	-0.011
Constant	0.011	0.021*	0.022	-0.014	0.008	0.015*
R^2 within	0.304	0.319	0.449	0.375	0.293	0.289
R^2 total	0.285	0.293	0.445	0.261	0.263	0.262
ρ	0.036	0.096	-0.128	-0.092		0.101
N	731	281	218	232	796	758
Funds	64	23	20	21	65	64

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

Additionally, I observe a U-shaped seasonal pattern in returns. Quarterly returns are highest in the first quarter and lowest in the second and third (see table 5.3). This would be a violation of market efficiency if no economic cause were to be found. In a three-factor CAPM world, the January effect in returns should disappear, if returns are regressed on risk factors that also show this effect (Fama and French, 1992). This is not the case in my data. The seasonality is robust to alternative model specifications as shown in tables 5.4 and 5.5. Explanations of this "January effect", which are put forward in the literature, are mostly tax-related.

Pontiff (1995) argues that different taxation of dividends and capital gains can cause a transitional effect on returns and premia. When stocks go ex-dividend,

Table 5.5: Return predictability – variable CAPM coefficients

Reported are pooled OLS regressions of residuals from fund-specific three-factor CAPM regressions on seasonal dummy variables. Standard errors are Newey-West errors using 4 lags. Fama-French CAPM regressions are estimated by $R_t = \alpha + \sum_{k=0}^{3} \beta_k M_{t-k} + \lambda_1 SMB_t + \lambda_2 SMB_{t-1} + \lambda_3 HML_t + \lambda_4 HML_{t-1} + \gamma_1 GBP_t + \gamma_2 EUR_t + \gamma_3 JPY_t + \phi_1 PREM_{t-1} + \phi_2 RNAV_{t-1} + \epsilon_t$ where R_t and M_t are the respective excess fund and market returns, SMB and HML are size and book-to-market factors, GBP, EUR, and JPY are excess returns on currency portfolios, $PREM$ is the NAV premium and $RNAV$ is the NAV return. Model 3 is a pooled OLS regression with autocorrelation-adjusted variables using the Prais-Winsten transformation. "1st quarter" is a dummy variable equal to one if an observation is recorded in the first quarter of a calendar year, "Q1 after AR" is a dummy variable equal to one in the first quarter after annual reports are published.

	All		All, AR(1)	Buyout	Venture	FoF
Model	1	2	3	4	5	6
1st quarter	-0.007	-0.023	-0.018	0.025	-0.049	-0.007
2nd quarter	-0.044***	-0.048***	-0.048***	-0.034**	-0.104***	-0.011
3rd quarter	-0.023**	-0.033**	-0.034**	-0.014	-0.076***	0.004
Q1 after AR		0.031*	0.032**			
Q2 after AR		0.009	0.010			
Q3 after AR		0.020	0.022			
Constant	-0.002	-0.009	-0.010	-0.009	0.037	-0.020*
adj. R^2	0.011	0.013	0.017	0.017	0.042	-0.006
N	967	967	967	320	260	387
Funds	67	67	67	23	23	21

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

their prices fall by an amount less than the dividend. This affects both the fund and its portfolio. In periods in which a fund collects dividends on its portfolio, its premium decreases, because its net asset value increases. When the fund passes on these dividends to its shareholders, its stock will decrease less than the drop in NAV, thus increasing the premium. There are several difficulties with this argument in the context of listed private equity funds. First, higher NAV returns in periods when the fund is collecting dividends depend on the fund's ability to revalue its portfolio according to the difference between dividends received and the change of the portfolio company's share price. This can be difficult if there is no market price for portfolio companies, as is the case with private equity funds. In regressions similar to the ones shown in table 5.3, I do not find a seasonality in NAV returns. Second, dividends would have to be simply too large to account for the difference in returns, which is about 4 % between the first and third quarter.

The second explanation could be tax-loss-selling. This theory holds that at the end of the year, investors sell stocks which have experienced losses to realize these losses and thereby reduce their taxable income. Brauer and Chang (1990) document a "January effect" in closed-end funds, which they interpret as evidence of tax-loss selling. They show that fund prices increase in January, although their net asset values do not. I also find significantly higher January returns in listed private equity funds. However, tax-loss-selling does not account for the surprisingly low returns in the second and third quarter.

Bilo (2002, p.63) finds a similar return pattern in her sample of listed private equity funds, investment companies and other organizational structures. Stock returns are highest in the first two quarters and below-average from July to December. She argues that information about underlying portfolios is mainly disseminated by annual reports, which are published within the first few months of each year. Fund investors then use this information to update their valuation. In private equity, there is usually no other way for investors to gain knowledge about the fair value of the fund's portfolio companies.

Such an effect would suggest a fundamental difference of audited annual reports compared to interim reports. The U-shaped pattern of returns can be explained to a large extent by reporting dates. 47 % of my sample funds report in the last quarter, 27 % in the first quarter and 13 % in the second and third quarter each. If reports are published in the quarter following the balance sheet date, we should expect impact on returns in the first and second quarter, which is exactly what I find.

To test this hypothesis, I construct a variable that measures the time distance of an observation from the last reporting date. Tables 5.3, 5.4 and 5.5 reveal that stock returns of listed private equity funds are 3.1 % to 3.9 % higher in quarters when annual reports are published. Even if information was generated by annual reports only, their impact on returns should be symmetric. This pattern of returns thus indicates some informational inefficiency, whose causes I can only speculate about.

5.4.2 Determinants of listed private equity premia

Premia and global equity markets seem to move together as indicated by figure 5.1. While it could be fruitful to regress premia on market indices, the difficulty of non-stationarity arises. Premia are stationary over the medium term for economic reasons, but index levels have no upper boundary. The aim is to test cross-sectional as well as time-series properties of premia. Econometric solutions to non-stationarity problems usually involve first differencing of dependent and independent variables. I follow this approach and include first differenced variables where appropriate to explain changes in premia. Unfortunately, variables that are constant over time (most fund-specific attributes) drop out of the equation when differencing. To keep these variables, I estimate models for premia levels explained by levels of market indices. Although clearly not stationary over longer terms, market indices might nevertheless be stationary over time periods spanning only a few years. Variables that are almost integrated of order one are strongly autocorrelated, which must be taken into account in estimation and considered carefully when interpreting results.

Regressions using differenced and original variables as shown in tables 5.6 and 5.7 yield largely similar results.

The age effect found in the descriptive analysis is also present in multivariate analyses. During the first year after the IPO, funds show a 9.9 % above-average premium which declines to 5.7 % above the long-term average in the second year. This two-year adaptation period might be caused by the long investment period of private equity funds, which go public with a portfolio consisting almost entirely of cash that is invested in portfolio companies over time. Cash levels can therefore act as a proxy for the fund's investment degree. There is, however, no influence of the fund's investment degree on its premium in my data (see model 3 in tables 5.6 and 5.7). If I construct a cash ratio based on market value instead of total assets, I find a negative relation between cash and premia where there should be a positive one. Since market value enters the equation on both sides, the effect is likely caused

Table 5.6: Regression of differenced premia

The dependent variable is logarithmic premium returns. Models 1 to 4 are pooled OLS regressions, where model 1 includes all variables where sufficient data is available and model 2 includes only significant variables. Pooled OLS models 5 to 7 use padded values for net asset values if they are missing in some quarters. Model 8 to 11 are random effects regressions assuming AR(1) errors. The estimated error correlation is reported as ρ. Small-cap residuals are residuals from a regression of a small-cap factor that is composed of UK-, US-, and European small capitalization indices, regressed on MSCI World returns.

	Pooled OLS				Padded NAV, pooled OLS			AR(1)		Padded NAV, AR(1)	
Model	1	2	3	4	5	6	7	8	9	10	11
MSCI World	0.378 ***	0.325 ***	0.418 ***	0.386 ***	0.308 ***	0.207 ***	0.474 ***	0.394 ***	0.340 ***	0.316 ***	0.221 ***
Small-cap residuals	0.042 *	0.047 **	0.046 *	0.042	0.026 *	0.017	0.013	0.044 *	0.049 **	0.025	0.016
SMB	0.270	0.186	0.214	0.314	0.012	0.084	0.359 **	0.261	0.173	0.016	0.077
SMB Lag 1	-0.372 ***	-0.390 ***	-0.378 ***	-0.427 ***	-0.300 ***	-0.354 ***	-0.347 ***	-0.359 **	-0.385 ***	-0.295 ***	-0.367 ***
HML	0.152	0.156	0.169	0.241 *	0.138 *	0.085	0.079	0.156	0.160 *	0.137 *	0.098
HML Lag 1	-0.548 ***	-0.455 ***	-0.459 ***	-0.506 ***	-0.350 ***	-0.238 ***	-0.292 **	-0.549 ***	-0.450 ***	-0.352 ***	-0.241 ***
1st quarter	0.002	-0.005	-0.003	-0.015	0.033	0.030 **	0.037	0.000	-0.006	0.033 *	0.028 **
2nd quarter	0.052 ***	0.045 ***	0.032 **	0.036 **	0.046 ***	0.029 ***	0.027 *	0.052 ***	0.045 ***	0.047 ***	0.030 ***
3rd quarter	0.006	0.004	0.001	-0.017	0.024	0.020	0.018	0.005	0.004	0.023	0.019
Age (Log)	0.011 **	0.010 ***	0.006	0.006	0.012 ***	0.010 ***	0.008 *	0.011	0.010 *	0.012 **	0.010 **
Δ IPO volume (Log)	0.029	0.045 ***	0.029	0.039 *	0.030 **	0.040 ***	0.031	0.029	0.045 ***	0.031 ***	0.040 ***
Δ IPO volume Lag 1	0.070 ***	0.068 ***	0.046 **	0.074 ***	0.030 **	0.028 ***	0.028 *	0.071 ***	0.069 ***	0.032 **	0.030 ***
Δ Cash / Total assets			0.006								
Δ Ownership factor				-0.032 *			-0.018				
Δ Commitments (Log)	0.030				0.030 **			0.030		0.030 **	
Δ Beta	-0.006 *	-0.004 ***	-0.004 ***	-0.006 **	-0.008 *	-0.005 ***	-0.008 **	-0.007 **	-0.004 ***	-0.008 ***	-0.005 ***
Δ Interest factor	-0.040				-0.036			-0.046		-0.043	
Δ Spread factor	-0.078 ***	-0.060 ***	-0.051 ***	-0.064 ***	-0.075 ***	-0.066 ***	-0.059 ***	-0.079 ***	-0.059 ***	-0.076 ***	-0.064 ***
Δ Bid-ask spread (Log)	0.005				0.014			0.006		0.016	
Δ Days traded (Log)	0.006				-0.004			0.006		-0.005	
Constant	-0.031 *	-0.027 **	-0.017	-0.013	-0.050 ***	-0.038 ***	-0.037 **	-0.029	-0.025 *	-0.050 ***	-0.038 ***
R^2 within								0.382	0.369	0.218	0.178
R^2 total	0.388	0.375	0.312	0.397	0.238	0.196	0.289	0.388	0.375	0.238	0.196
ρ								0.034	0.031	-0.064	-0.096
N	849	1012	781	623	1788	2362	1018	849	1012	1788	2362
Funds	66	68	52	43	99	99	59	66	68	99	99

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

by endogeneity. Although the age effect can be explained by managerial ability (discovery of ability over the first few years) as well as investor sentiment (price deterioration after hot issue markets), the missing relation between premia and the fund's investment degree challenges managerial ability as the sole explanation.

Investor sentiment as an explanation for premia plays a dominant role in the literature on closed-end fund discounts. Funds issued at premia and rising premia in hot markets as well as a general discount on closed-end funds are all attributed to the presence of irrational investors. I find partial support for this hypothesis in listed private equity funds. Premia are related to market indices, small-cap indices, IPO volume, and commitments to traditional private equity funds. However, the age effect cannot be explained entirely by these variables, and ownership structure does not seem to determine NAV premia either.

Average discounts in listed private equity funds are similar in shape to the time pattern observed in closed-end mutual funds. While U.K. and U.S. closed-end mutual funds are issued at a premium, the average IPO premium in my sample is negative. This should not be interpreted as a smaller sensitivity to investor sentiment, since premia are about 10 % lower over the funds' lifetime, not just shortly after its IPO. If investor sentiment was a driver of premia, they would be correlated with small-cap indices. If funds are issued when investor sentiment is positive, the resulting decline in premia would simply be a consequence of market timing. Any unexplained age effects would then have to be attributed to some other cause.

Movements in equity markets are strongly related to NAV premia in all subsamples and all models. MSCI World returns are the last variable to lose significance if the sample size is reduced. If small-cap indices for U.K., U.S., and continental European markets are added to the regressions, they have no individual power in explaining premia (regressions not reported here). A factor constructed from these indices is, however, significantly but negatively correlated with premia. At the same time, the market index is significant with the opposite sign, which is an indication of collinearity ($\rho = 0.63$). I therefore construct a factor from small-cap indices to eliminate collinearity between them. Residuals from regressions of this small-cap factor on market returns capture the variation in small-cap stocks not already incorporated in market returns. Significant coefficients for these small-cap residuals in my results suggest the presence of investor sentiment in listed private equity funds.

I use commitments to unlisted private equity funds and the volume of international IPOs as proxies for hot markets that indicate positive investor sentiment. Coefficients for both variables are both statistically and economically significant in most models. Despite their common variation, fund commitments and IPO volume add individual explanatory power to my models. Although the number of listed private equity fund IPOs follows the general trend, adding these two sentiment indicators does not seem to reduce the age effect.

Institutional ownership, which can also proxy for noise trader risk, does not seem to determine premia. The concentration of ownership is similar, but also proxies for the potential of owners to extract private benefits. Although there is some correlation with premia (ρ=–10.5, p<0.01), I find no influence on premia in a multivariate setting. Institutional ownership and ownership concentration share a large part of their variation, which can lead to collinearity problems if both are included in a model. A single factor constructed from both variables becomes slightly significant as shown in table 5.6. Ownership information is not available for all funds in my sample, which leaves us in doubt about the influence of ownership structures on NAV premia.

While independent variables indicate investor sentiment to some degree, simply the premium's size could reflect the greater importance of investor sentiment in private equity funds compared to closed-end mutual funds. Average premia are about 10 % lower than in closed-end mutual funds over the funds' lifetimes. It is unlikely that these larger discounts can be explained by the illiquidity of the fund's holdings. The opportunity to trade portfolios of illiquid assets should rather be accompanied by higher premia as is the case in closed-end mutual funds that offer access to foreign (segmented) markets. Instead, lower premia in listed private equity funds possibly are a sign of higher arbitrage costs. Most portfolios are not only held

Table 5.7: Regression results for NAV premia

This table reports regressions logarithmic NAV premia. Models 1 to 7 are random effects regressions using the Baltagi and Wu (1999) GLS method. Model 8 and 9 are OLS random effects and fixed effects regressions, and model 10 is a pooled OLS regression with Prais-Winsten transformed variables to account for AR(1) errors. "Small-cap residuals" are residuals from regressing a small-cap factor on MSCI World excess returns. This small-cap factor is constructed from U.K., U.S., and European small-cap index excess returns. "Interest factor" and "Spread factor" are the main common factors of U.K., U.S., and Euro interest rates and yield spreads, respectively.

	GLS							RE, AR(0)	FE, AR(0)	Pooled, AR(1)
Model	1	2	3	4	5	6	7	8	9	10
Age < 1 year	0.099***	0.080***	0.083**	0.095**	0.104**		0.103***	0.132***	0.183***	0.081***
1 year ⩽ Age < 2 years	0.057**	0.042*	0.064**	0.071*	0.073**		0.058**	0.090***	0.131***	0.050**
2 years ⩽ Age < 3 years	0.025	0.011	0.038*	0.036	0.028		0.027	0.047**	0.074***	0.020
Age (Log)						-0.030***				
Bid-Ask Spread (Log)	-0.055***	-0.081***	-0.049***	-0.072***	-0.073***	-0.057***	-0.057***	-0.073***	-0.076***	-0.049***
Days traded (Log)	-0.038***	-0.030***	-0.031***	-0.027	-0.033**	-0.036***	-0.037***	-0.057***	-0.052***	-0.039***
Beta	-0.006**	-0.007***	-0.005*	-0.012***	-0.012***	-0.006**	-0.006**	-0.003	-0.002	-0.008***
Common law	0.139***	0.151***	0.135***	0.158***	0.152***	0.132***	0.141***	0.131***		0.176***
VCT	-0.020	-0.001	-0.006	-0.014	0.028		-0.016	-0.027		-0.054*
Venture fund	0.105**	0.127***	0.089*	0.095	0.103*	0.099***	0.105**	0.104**		0.141***
Fund of funds	0.106**	0.109***	0.103**	0.132**	0.127**	0.098**	0.107**	0.122***		0.106***
Management fee	1.776	1.695	0.751	0.467	-0.510		1.824	2.164		0.336
Cash / Total assets			0.044							
Inst. ownership (Log)				-0.002						
Ownership conc. (Log)					-0.005					
Commitments (Log)	0.065***		0.060***	0.063**	0.054**	0.066***	0.054***	0.075***	0.078***	0.066***
IPO volume (Log)	0.041***		0.032**	0.037*	0.042**	0.041***	0.044***	0.048***	0.052***	0.033**
MSCI World	0.020	0.163**	0.103	0.088	0.080		0.175**	0.004	0.027	0.031
Small-cap residuals	0.072***	0.061***	0.066***	0.107***	0.094***	0.072***	0.078***	0.071***	0.065***	0.083***
Interest factor	0.080***	0.085***	0.073***	0.089**	0.091**	0.077***		0.070***	0.060***	0.087***
Interest UK							0.041***			
Spread factor	-0.079***	-0.083***	-0.064***	-0.092***	-0.077***	-0.080***		-0.078***	-0.073***	-0.080***
Spread UK							-0.060***			
Constant	-1.776***	-0.694***	-1.579***	-1.752***	-1.714***	-1.698***	-1.909***	-2.077***	-1.987***	-1.682***
R^2 within	0.400	0.331	0.321	0.461	0.428	0.391	0.402	0.408	0.411	
R^2 total	0.339	0.289	0.271	0.379	0.362	0.334	0.341	0.333	0.256	0.345
ρ	0.528	0.556	0.581	0.557	0.553	0.536	0.526			0.685
N	1458	1458	1211	720	812	1463	1458	1458	1458	1458
Funds	98	98	80	58	64	99	98	98	98	98

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

privately – which is the very nature of private equity – but are also majority-owned by the private equity fund, making arbitrage almost impossible. Rational investors facing these obstacles cannot easily buy the listed private equity vehicle at a discount and sell the portfolio. Noise trader risk is thus amplified, which increases discounts.

I conclude that investor sentiment seems to influence premia, although decreasing post-IPO premia cannot be explained entirely by changes in investor sentiment. If fund age is excluded from the regressions, however, R^2 drops by less than 0.5 %. Albeit small, the unexplained age effect lends some support to the management ability hypothesis by Berk and Stanton (2007).

Pontiff (1995) finds a positive relation between bid-ask spreads and expected returns, which is dominated by the even stronger ability of premia to predict returns. This effect of both variables predicting returns could be the result of collinearity between premia and bid-ask spreads, which is indicated by the results in table 5.7. If low premia represent financial risk that is only in part explained by bid-ask spread, premia could be a more reliable predictor of returns than bid-ask spreads. However, bid-ask spreads could still be the economic cause of premia, as I propose here. This direction of causality seems more plausible than a causation of bid-ask spread by premia or by a third unobserved variable.

As another proxy for liquidity, I include in my analysis the percentage of active trading days within each quarter. The expected relation is positive, if illiquidity causes discounts. However, I find a negative relation across all model specifications in table 5.7. Although bid-ask ratios and trading days are negatively correlated ($\rho = -0.56$), one of them remains significant with the same sign as before, if the other is excluded from the regression. It turns out that the effect becomes insignificant if I exclude severely illiquid observations with less than 5 trading days per quarter. If we assume that zero trades are data errors and impute the sample average of 41 trading days instead, the effect for trading days disappears. To the contrary, the effect does not disappear if I impute 4 trading days (4 days maximize the significance of trading activity). The negative trading activity effect thus appears to be nonlinear and strongest in quarters with only a couple of trades. Adding a dummy variable that measures if there are up to 15 trading days per quarter yields a small, but positive coefficient ($b = 0.031$), which is only partially significant ($p = 0.071$). I do not find a reasonable explanation for this negative effect of trading activity within my dataset, which suggests that results might be due to data errors or an unobserved variable.

Interest rates have a mixed effect on premia, whereas the yield spread between government and corporate debt contributes inversely to NAV premia. I observe a positive relation between U.K. long term interest rates and premia. Because interest rates are strongly correlated between U.S., U.K. and continental European markets, their common variation can be used to construct a replacement variable by factor analysis. When used instead of individual interest rates, the interest factor is significant in models explaining premia levels (see table 5.7). Changes in interest rates, however, are negatively related to changes in premia but remain insignificant.

The effect of yield spread on premia is consistently negative. This result could imply that changes in spreads have a stronger influence on market prices than on net asset values. Pontiff and Schall (1998) provide an explanation built on arguments put forward by Ball (1978) and Berk (1995). Berk reminds us that a firm's market value does not cause its capital cost to be high but that rising discount rates lead to a lower lower market capitalization. Pontiff and Schall argue that book value proxies for future cash flows and therefore dividing a cash flow proxy by a concurrent market price produces a variable that is correlated with future returns. This is because dividing an expected cash flow proxy (net asset values in our case) by a price level (market value) yields a discount rate proxy. This approach is very general, since it holds whether or not discount rates are generated by a specific model or are influenced by stochastic or irrational factors. However, Pontiff and Schall's explanation depends on the ability of book value to proxy for cash flow. Turning this argument around, the common variation in premia and yield spread in my results supports the hypothesis that book value proxies for cash flow.

It seems to be the difference in yield between corporate debt and government debt that shows a relation to premia, not the interest level. This suggests that changes in interest rates are reflected in both net asset values and market prices. My result is consistent with the hypotheses by Kaplan and Strömberg (2009) and Axelson et al. (2009) who suggest a dependence of private equity valuations particularly on yields of high-yield bonds.

Moreover, I document an inverse relation between premia and systematic risk, represented by Dimson beta in an international capital asset pricing model. Since portfolio betas are just the weighted sum of its assets' betas, net asset values and fund prices should move together. The difference between the two should therefore not depend on systematic risk. The effect I observe in my data is suggestive of mispricing of net asset values or fund prices. The former is more likely because of the management's discretionary power when estimating net asset values. For high-beta funds, net asset values seem too high, and vice versa.

Further insights into the nature of fund premia might come from grouping funds according to legal systems. In particular, private benefits could be extracted more easily in some jurisdictions than in others. I use the exchange where a fund's stock is traded to distinguish between common law and other legal systems. There are 76 funds in common law countries whose premia are about 10 % higher on average. Since there are 25 venture capital trusts in my sample, which offer tax advantages, I control for this fact, but find no different results. This result is consistent with the view that protection of investors in publicly listed companies is higher in countries of English legal origin (La Porta et al., 1998).

Fund focus shows a surprisingly large effect in my sample. Venture capital funds and funds of funds have premia that are 10–11 % higher than in buyout funds. Could it be that there is less value creation in buyout funds? If funds are issued at net asset value, there must be either a faster appreciation of net asset values in buyout funds or a drop in fund prices after the IPO. Interestingly, buyout funds start with a premium of 3.04 %, whereas venture capital funds and funds of funds are issued at premia of –6.85 % and –6.64 %, respectively. This suggests that buyout fund prices depreciate even faster relative to their NAVs. I perform a regression of fund returns

Table 5.8: Age effect in buyout fund returns

Reported are OLS-coefficients for quarterly total stock returns with Newey-West standard errors using 4 lags. Only buyout funds are included.

MSCI World	0.698***	NAV return Lag 1	0.049	adj. R^2	0.237
MSCI World Lag 1	-0.093	1st quarter	0.060***	N	320
SMB	0.266	2nd quarter	0.012	Funds	23
HML	0.084	3rd quarter	-0.012		
GBP	-0.231	Age $<$ 1 year	-0.036***		
EUR	-0.407	1 year $\leqslant$ Age $<$ 2 years	-0.012		
JPY	0.446	2 years $\leqslant$ Age $<$ 3 years	-0.015		
NAV premium Lag 1	-0.036*	Constant	0.009		

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance.

on the usual risk factors and fund age and find a negative abnormal return for the first year (see table 5.8). The sum of the year dummies is significant at the 5 %-level. There is no such effect in venture capital fund or fund of funds returns. If not for high investor sentiment, it remains a puzzle why investors should be willing to participate in buyout fund IPOs under these circumstances.

In line with the arguments by Lee et al. (1991), I find no correlation between management fees and premia. It might be argued that fund of funds' fees are double-layered because of the fees charged both at the portfolio fund level and by the fund of funds. Nevertheless, there is still no effect, if the average management fee of funds is added to the funds of funds' fee.

5.5 Conclusion

This chapter investigates the causes and consequences of discounts in listed private equity (LPE) funds. LPE funds share characteristics of closed-end mutual funds and traditional unlisted private equity funds and can therefore offer insights into both. The purpose of this chapter is twofold: First, I test the hypotheses developed to solve the "closed-end fund puzzle" against the newly established LPE asset class. Second, I improve the understanding of premia in traditional private equity funds, whose market prices are typically unobservable.

In contrast to mutual funds, I find that LPE funds do not trade at a premium immediately after their IPO. They start with a negative premium of –2.5 % instead. This premium takes much longer than in mutual funds — over 2 years — to adjust to the long-term average of –21 %. Premia predict future stock returns after controlling for the book-to-market factor. I interpret the negative correlation as mean reversion following Pontiff (1995).

I find a U-shaped seasonality in fund returns across different investment styles, which can neither be explained by different taxation of dividends and capital gains nor by tax-loss-selling. A substantial part of this pattern seems to be related to the fund's fiscal year. Returns are exceptionally high in quarters where annual reports are published, which is puzzling, since tax reasons offer no satisfactory explanation for the 3.5 % return differential.

The fund's cash divided by total asset can proxy for its investment degree, but shows no relation to premia. If a fund's investment degree conveys information about the quality of its management by making it possible to judge the management by recent portfolio acquisitions, the missing relation between cash holdings and premia casts doubt on the management ability hypothesis. Investor sentiment, however, finds support in my results, in which proxies for small-cap stocks and hot IPO markets become significant.

I further confirm the positive relation between the fund's liquidity, measured by its bid-ask spread, and premia. Surprisingly, infrequently traded funds have exceptionally high premia. I find evidence that some information about the fund's portfolio is not reflected in net asset values but in market prices. Fund valuations depend on the long-term credit spread between government and corporate bonds. Premia are also higher in funds with low systematic risk, which suggests that systematic risk is not fully reflected in net asset values. This lends support to the hypothesis that net asset values proxy for future cash flow, which, if divided by discount rate proxies like beta or credit spread, yields a market price.

Another new effect in listed private equity funds is the apparent under-performance of buyout funds following their IPO. Buyout funds exhibit premia that are 10–11 % lower than premia in other funds, which is almost entirely attributable to poor stock performance over the first few years of the funds' lifetime. These findings suggest that future research on fund premia might benefit from examining the drop in first-year premia and the informational content of private equity net asset values.

Chapter 6

Loss Aversion in Listed Private Equity

6.1 Introduction

Do private equity funds manage earnings to avoid posting losses? Private equity funds could be able to manage earnings due to the nontransparent nature of their business.[1] Since information about portfolio companies is hard to gather by market participants, private equity management companies hold some kind of monopoly on this information. Within the framework defined by mandatory reporting standards and voluntary industry-wide valuation guidelines, private equity fund management thus has, at least in theory, an opportunity to pursue its own agenda. Private equity net asset value (NAV) returns are often said to exhibit less volatility than comparable traded securities, which is attributed to earnings smoothing.[2] Fund managers that have not yet established a track record may aggressively price unlisted assets to gain a marketing edge or avoid reporting losses in difficult times.[3] The quality of

[1] See Phalippou and Gottschalg (2009), Cumming and Walz (2010) and Anson (2002).

[2] See chapter 2.1.6 for an overview of performance-related literature, private equity funds' reluctance to reassess values of portfolio companies in the absence of price-determining events, and the smoothed NAV returns that result from this behavior.

[3] See Gompers and Lerner (1996) and Blaydon and Wainwright (2005).

reported earnings[4] and net asset values is thus crucial to establishing confidence in performance measures (such as the internal rate of return) and pricing relations (such as NAV premia).[5]

Another sign of managerial discretion could be an aversion to small losses in order to avoid negative shareholder reactions. These small losses could be present in real changes of net asset values or in yearly net income. If management chooses to smooth these losses, the distribution of NAV returns or standardized earnings should exhibit a discontinuity at zero, since small losses are turned into small gains, leading to less observations of small losses than expected. I therefore test these hypotheses, first by examining NAV returns and second by testing the distribution of standardized earnings for discontinuities. The main part of this chapter develops a procedure to find evidence for earnings management, which is then applied to listed private equity.

Earnings benchmarks are widely used in the literature investigating earnings management. Burgstahler and Dichev (1997) and Degeorge et al. (1999) identify three main benchmarks that indicate earnings management: Firms avoid small losses, earnings decreases, and earnings that fall short of analysts' forecasts. All of these benchmarks use arguments based on their respective variables' distribution to derive conclusions about the existence of earnings management. For example, the deviation of earnings from analyst forecasts could be skewed or discontinuous[6] at zero, which would indicate that earnings or analyst forecasts are managed.[7] If firms have incentives to achieve earnings above some threshold, the distribution of reported earnings will have fewer-than-expected observations for earnings just below this threshold and more just above. The emerging consensus is that the earnings distribution has a discontinuity around zero and is not symmetric.[8]

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4 For a discussion of the term *earnings quality* in its general context of accounting theory and practice, see Francis et al. (2006) and Penman (2002).

5 See Gompers and Lerner (1997) and Cumming and Johan (2007).

6 More precisely, a discontinuity in the sense of this study is a point at which a density function is discontinuous and jumps without being discontinuous in a neighborhood of this point.

7 See Degeorge et al. (1999), Burgstahler and Eames (2006), and Burgstahler and Eames (2003).

8 See Cohen and Lys (2003), Dechow et al. (2003), McNichols (2000), Beaver et al. (2003), and Burgstahler and Dichev (1997).

Burgstahler and Dichev (1997) (hereafter BD) develop a statistical measure of a distribution's smoothness based on histograms. Their test statistic is the difference between the expected and observed number of observations in a histogram bin, divided by its standard deviation. A similar test statistic is proposed by Degeorge et al. (1999). There is a large and steadily growing number of studies which make use of the BD method.[9] However, the BD method has several shortcomings, which reduce its validity under some circumstances. As noted by Glaum et al. (2004), the choice of histogram interval width is a critical consideration, which is often neglected. Holland (2004) demonstrates that if the peak of the distribution falls adjacent to a threshold, the BD method will not provide statistically reliable and robust results. The BD method does not locate the exact point of discontinuity and gives no hint at the structure of earnings management. Even if a plausible bin width can be determined, the researcher can arbitrarily shift the histogram's location to the left or right. From a statistical point of view, the BD method only tests specific intervals and not the whole distribution, that is, if there is earnings management *at all*. The classical problem with multiple tests arises with BD tests for each bin, which should be significant as a whole and not just individually. A Bonferroni or Šidák correction would be necessary in this case. It can be shown that the test statistic's rejection region in this case is also strongly dependent on the data and BD's assumption of local linearity in the data's density.

This chapter proposes a method to identify discontinuities in distributions that corrects most of these shortcomings. My approach consists of two stages: First, a kernel density estimate is constructed such that it cannot be distinguished globally from the data by a Kolmogorov-Smirnov (KS) test and by a bootstrap test. This density is used as a non-parametric reference distribution instead of BD's assumption of local linearity. Second, the KS test yields the location at which I conduct a

[9] For a cross-section of different earnings management benchmarks, such as standardized earnings, earnings per share, earnings increases, or analyst forecast errors, see Beatty et al. (2002), Burgstahler and Eames (2003), Beaver et al. (2003), Cohen and Lys (2003), Dechow et al. (2003), Glaum et al. (2004), Brown and Caylor (2005), Coulton et al. (2005), Durtschi and Easton (2005), Burgstahler and Eames (2006), Gore et al. (2007), Pinnuck and Lillis (2007), Talha et al. (2008), Tung et al. (2008), and Charoenwonga and Jiraporn (2009).

binomial test for a local discontinuity. This second stage is similar to BD's method. However, it is not constructed from adjacent bins but from the same interval of the empirical density and the kernel density estimate. Kernel density estimation can be used for a wide range of distributions and is not limited to a linear relationship in the number of observation in adjacent histogram bins. My test procedure works well around the center of a distribution, where earnings management is usually supposed to occur.

A binomial test on the difference between the data and a carefully constructed kernel density estimate can also be an alternative to the test by Bhattacharya et al. (2003), who measure loss aversion by the ratio of the number of firms with small positive earnings minus the number of firms with small negative earnings divided by their sum. Their test has the disadvantage of an a priori selected point of discontinuity and may be biased, if the distribution of (unmanaged) standardized earnings is not symmetric in the neighborhood of the discontinuity.

The remainder of this chapter is organized as follows: Section 6.2 reviews Burgstahler and Dichev's test and introduces some notation. Section 6.3 outlines the test procedure. Section 6.4 describes results for German earnings data and section 6.5 applies the procedure to listed private equity.

6.2 Burgstahler and Dichev's test

Burgstahler and Dichev's (1997) method uses histograms to construct a test statistic for the expected number of observations in each bin. Let X_1, ..., X_N be N independent random variables with distribution function F. Construct a histogram with equally spaced bin boundaries $-\infty = c_0 < c_1 < ... < c_m = \infty$, where $(c_j - c_{j-1} = h)$ for $j = 2, ..., m-1$. The number of observations in bin i is then defined as

$$n_i \equiv \sum_{i=1}^{N} \mathbf{1}\left(X_k \in (c_{i-1}, c_i]\right), \quad i = 1, ..., m, \tag{6.1}$$

with **1** as the indicator function. The number of observations n_i follows a multinomial distribution with $p_i \equiv P(X \in (c_{i-1}, c_i])$.

The test statistic constructed by Burgstahler and Dichev (1997) is

$$BD = \frac{(n_{i-1} + n_{i+1})/2 - n_i}{\sqrt{Var\left((n_{i-1} + n_{i+1})/2 - n_i\right)}} \tag{6.2}$$

where

$$Var\left(\frac{n_{i-1} + n_{i+1}}{2} - n_i\right) = Np_i(1-p_i) + \frac{N}{4}(p_{i-1}+p_{i+1})(1-p_{i-1}-p_{i+1}) + Np_i(p_{i-1}+p_{i+1}), \tag{6.3}$$

N is the total number of observations, n_i is the number of observations in bin i and $p_i = n_i/N$. Burgstahler and Dichev ignore the last term in eq. 6.3, as noted by Takeuchi (2004). Even more important, they assume that $E((n_{i-1}+n_{i+1})/2) - n_i) = 0$ to derive eq. 6.3 (see Appendix B). This linearity can be overly restrictive when applied to multimodal or skewed densities.

6.3 Test procedure

There are two closely related sides to the problem of identifying a discontinuity in a given empirical distribution: it has to be defined what constitutes a discontinuity and there must be a statistical test of significance. Although a discontinuity in density functions is well defined, empirical densities lack an unambiguous definition. Is there an anomaly, if we do not count a single observation in a certain histogram bin but many in adjacent bins? All we have is a sample of observations, which is, by its nature, discontinuous. To make inferences about the underlying density function, this function has to be estimated in a most general way. Burgstahler and Dichev (1997) do not explicitly assume a specific distribution but implicitly assume a linear relationship between the number of observations in a bin and its adjacent bins, which translates into a locally linear density function. This can be overly restrictive. A more flexible and non-parametric method to define a reference distribution is to construct it from the data by kernel density estimation, which is a commonly used method if a continuous density function is needed. For example, Bollen and Pool (2009) apply kernel density estimation to the detection of loss aversion in hedge funds, but use predetermined estimation parameters instead of globally fitted ones, as is proposed here. A further advantage of the method proposed in this chapter is the reduced number of degrees of freedom, since the functional form of the kernel is the only parameter the researcher can adjust.

The reference distribution must be chosen carefully, since its shape will determine the level of statistical significance. The idea is to estimate a kernel density that globally fits the empirical distribution and to locally test for discontinuities based on the density estimate. If the kernel density estimate is not a good approximation of the data, tests of discrepancies between the estimate and the data produce spurious inferences. Two tests can be employed to construct a density estimate that corresponds to the data in a statistical meaningful way. First, the data should be a plausible realization of the estimated kernel density. A Kolmogorov-Smirnov test should thus find no difference between the integrated kernel density estimate (IKDE) and the empirical cumulative distribution function (ECDF). Second, the kernel density estimate should be a plausible distribution considered that the data is just a single realization of some unknown density. Bootstrap errors for the difference between the ECDF and the IKDE as described in Scott (1992, chap. 9.3.2) can yield a test for this purpose.

After a reference distribution is established, there must be a measure of statistical significance. Burgstahler and Dichev calculate the standardized difference between the expected and observed number of observations in each bin. They test for a discontinuity at a location determined by a-priori considerations. Their method is therefore not a test of discontinuities *somewhere* in the distribution but at a specific location. The method proposed in this chapter takes a different approach to finding and testing the discontinuity: A test should be conducted at the point of maximum difference between the empirical cumulative distribution and the integrated kernel density estimate. The test should then be based on the expected number of observations within a reasonable interval around this point of maximum difference.

The test procedure is as follows:

1. Select an optimal bandwidth h calculated from the data to produce a starting point for bandwidth selection.

2. Construct a kernel density estimate and calculate the maximum difference to the ECDF. Denote the point of maximum difference as d_{max}.

3. If a Kolmogorov-Smirnov test on the maximum difference is significant, reduce bandwidth h and proceed from (2).

4. Estimate kernel densities from bootstrap samples from the original data and construct a confidence interval for the integrated kernel density estimate at d_{max}.

5. If the ECDF at d_{max} is outside this confidence interval, reduce bandwidth h, calculate the new d_{max} between the new density estimate and the ECDF, and proceed from (4).

6. Test the expected number of observations within the intervals $(d_{max} - h, d_{max}]$ and $(d_{max}, d_{max} + h]$ simultaneously against the observed number using a binomial test or t-test.

Kernel density estimation

This study focuses on kernel density estimators as introduced by Rosenblatt (1956) and Parzen (1962). This family of density estimators $\hat{f}_h$ is defined by

$$\hat{f}_h(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{6.4}$$

where h is called the bandwidth and K, the kernel, is some smoothing density function. The Epanechnikov kernel is used to compute the results in this chapter:

$$K(z) = \begin{cases} \frac{3}{4}(1 - \frac{1}{5}z^2)/\sqrt{5} & \text{if } |z| \leqslant \sqrt{5} \\ 0 & \text{otherwise} \end{cases}. \tag{6.5}$$

The Gaussian kernel

$$K(z) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}z^2\right) \tag{6.6}$$

provides a robustness check and offers some insights into the relatively small importance of selecting the "right" kernel compared to choosing the optimal bandwidth h.

Bandwidth selection

The choice of the bandwidth h is a key aspect of a practical implementation of kernel density estimation. Choosing h small leads to an estimator with a small bias and large variance, whereas a large h causes lower variance at the expense of concealing features that might be present in the data. Techniques for bandwidth selection include Silverman's (1986) rules of thumb, oversmoothing, cross-validation, direct plug-in methods, the solve-the-equation method, and the smoothed bootstrap (Jones et al., 1996).

To estimate the earnings density in step 2, a bandwidth can be selected by the most commonly used rule of thumb, which is optimal for normally distributed data and a Gaussian kernel (see Silverman (1986), p. 45, eq. 3.28).

$$h_{opt} = 1.06\sigma n^{-1/5} \tag{6.7}$$

where

$$\sigma = \min\left(\sqrt{\hat{\sigma}_X}, \frac{Q_X}{1.349}\right) \tag{6.8}$$

and $\hat{\sigma}_X$ is the sample standard deviation and Q is the interquartile range. This bandwidth selector is sensitive to heavily skewed data but not much to kurtosis of the underlying empirical distribution. Silverman therefore proposes a variation using a factor of 0.9 instead of 1.06, which provides robust bandwidth estimation for a wide range of t-, log-normal and normal mixture distributions (see Silverman (1986), p. 48, eq. 3.31):

$$h_{opt} = 0.9\sigma n^{-1/5} \tag{6.9}$$

Standardized earnings in my sample are moderately skewed with $s = 1.37$ but show excess kurtosis of $k = 35.79$. Equation 6.9 should therefore provide a good approximation of the optimal bandwidth. However, I also provide robustness tests for alternative fractions of this bandwidth. Further robustness tests are obtained by the *solve-the-equation* and *plug-in* bandwidth selectors by Sheather and Jones (1991).

Note that optimal bandwidth depends on sample size, which may lead to different estimates of the extent of earnings management, measured by the difference between ECDF and IKDE, for the same empirical distribution but different sample size. In fact, the difference between the estimated and empirical distributions can be made arbitrarily small for large samples, since the estimated density becomes more and more fine-grained. A direct consequence is that the extent of earnings management cannot be measured without making further assumptions about the distribution of unmanaged earnings. This feature is also inherent in the BD method where optimal bin width must be determined. The number of companies that manage earnings as found by Burgstahler and Dichev (1997) depends on their assumption of a locally linear density and can be made smaller or larger by employing different assumptions.

Kolmogorov-Smirnov test statistic

To test if the data match the estimated kernel density, a simple Kolmogorov-Smirnov (KS) test can be used. Specifically, the KS test's null hypothesis is that the sample is generated by that distribution. Its test statistic is based on the empirical distribution and the density estimate, which are both defined at each observation, not only for a number of bins. The test statistic can therefore pick the observation at which the discontinuity occurs.

The method proposed in this chapter is based on the empirical cumulative distribution and a density estimate, which is less arbitrary than BD's method, since it does not involve a specification of histogram bin boundaries. The Kolmogorov-Smirnov test statistic is defined by

$$D = \max_{X} |S_N(X) - F(X)| \tag{6.10}$$

where $F(X)$ is the theoretical population cumulative distribution derived from the kernel density estimate and $S_N(X)$ is the empirical cumulative distribution. This test statistic follows the distribution given by Massey (1951).

If the researcher had some prior knowledge about the true distribution underlying the data, this test could be used to identify the location as well as the extent of the discontinuity. The null hypothesis of no earnings management would be rejected whenever the KS-test is significant. If the "true" distribution is estimated from the data instead of using some a priori-distribution, a significant KS-test can indicate that either the data has an abnormal discontinuity or the kernel density estimate is simply oversmoothed and thus missing this discontinuity. I therefore use the KS-test as a global measure of *no* discontinuity and aim at constructing a density estimate that is globally indistinguishable from the data.

Bootstrap intervals for a kernel density estimate

In addition to testing whether the sample could have been generated by the kernel density estimate, it is desirable to have a density estimate that is plausible given that the data is just one realization of some underlying true distribution.

Scott (1992, chap. 9.3.2) proposes a technique for constructing confidence intervals for the density estimate. A large number of samples with size equal to the original sample size is drawn with replacement from the data. For each sample, a kernel density is estimated using a predetermined bandwidth. This initial bandwidth is the result of the prior step in my procedure. I use these density estimates to construct pointwise bootstrap confidence intervals for the integrated kernel density estimate at the KS-test's maximum.

If the ECDF lies outside the confidence interval for a predetermined confidence level, it is unlikely that the density estimate derived from the original data describes the data well. Bandwidth must be reduced until the ECDF is inside the interval. Except near the distribution's boundaries, this technique leads to reasonable bandwidths and reduces the researcher's degrees of freedom to selecting the kernel function.

Testing the discontinuity

After a plausible kernel density estimate (KDE) has been constructed, the discontinuity itself can be tested using this density estimate as a reference distribution. The discontinuity is likely to be located at d_{max}, the maximum difference between the integrated KDE and the empirical CDF. This result is shown for a uniform distribution in Appendix B.2.1. The key is to compare the expected number of observations under the null hypothesis of being generated by the KDE with the actual number on both sides of the discontinuity. Since the number of observations that fall within a specific interval follows a binomial distribution, the test statistic is

$$t = \frac{p - \hat{p}}{\sqrt{\hat{p}\,(1-\hat{p})}}\sqrt{N}, \tag{6.11}$$

if the normal approximation to the binomial distribution is used and if independence of observations is assumed. p is the actual number of observations in this interval divided by sample size N. For small pN, the binomial distribution should be used instead of the normal approximation. The expected number of observations in terms of the integrated KDE, $\hat{F}_h$, over the interval of interest is

$$\hat{p} = \hat{F}_h(d_{max}) - \hat{F}_h(d_{max} - h) \tag{6.12}$$

for the interval to the left of the discontinuity and

$$\hat{p} = \hat{F}_h(d_{max} + h) - \hat{F}_h(d_{max}) \tag{6.13}$$

for the interval to the right. Since two hypotheses are tested simultaneously, the test's rejection region must be adjusted, for example, by the Bonferroni correction. If the true density shows a positive jump at the discontinuity, the test statistic is negative to the left and positive to the right, which can indicate the discontinuity's shape in an empirical setting (see Appendix B.2.2).

6.4 Application to German earnings data

In this section, I apply the methodology outlined above to earnings data from listed German firms. This section's main purpose is to demonstrate the test procedure and to replicate findings of loss aversion in earnings management studies. An application to listed private equity follows in section 6.5.

Data

Accounting data was collected from Worldscope for 10 180 valid firm-years from 1991 to 2008 on total assets (Worldscope item 02999) and net income available to common shareholders (Worldscope item 01751), which is used by Worldscope to calculate earnings per share. Firms are included if they were CDAX index constituents at some time between 1995 and 2006. Following Burgstahler and Dichev, financial institutions are eliminated on the basis of their ICB codes. Net income is scaled by lagged total assets. The resulting ratio is referred to as "standardized earnings" hereafter. Using same-year total assets yields almost identical results. However, a ratio of same-year variables might cause endogeneity problems but has the advantage of an additional 1 091 observations. Standardized earnings less than -1 or greater than 3 are excluded, since these are likely to be data errors. The remaining earnings have a mean of $\mu = 0.0129$, standard deviation of $\sigma = 0.171$, skewness of $s = 1.369$, and kurtosis of $k = 38.79$.

Results

Standardized earnings of German firms show the pattern presented in the international literature.[10] They are skewed to the right and heavy-tailed, as can be seen in figure 6.1, which depicts a histogram of earnings as the starting point for BD's method. A large spike is clearly visible at the smallest positive interval. The kernel density estimate, which is the reference distribution for my test procedure, mirrors the histogram's skewness and kurtosis. The objective of the following analysis is to test whether the observations seemingly missing under the curve to the left from zero and the additional ones to the right constitute a significant irregularity. As outlined above, it is not possible to measure the extent of earnings management without making additional distributional assumptions.

Figure 6.2 shows the integrated kernel density estimate and the empirical cumulative distribution of standardized earnings. While the reference distribution is smooth around zero, the empirical distribution has an S-shape at this point. It deviates negatively from the reference distribution in the interval [–0.0036, 0.002]. This reproduces the results reported by Burgstahler and Dichev (1997), who find unusually low frequencies of small losses and unusually high frequencies of small positive income in cross-sectional distributions of earnings. There are 22 earnings of exactly zero in my sample, which contribute to the additional tiny jump at zero. Since these are probably the result of rounding but do not alter any of my results, I keep these observations.

Prior studies assumed rather than showed that the discontinuity is at zero. The maximum difference between the integrated kernel density estimate and the empirical distribution is at earnings of –0.0009.61 %, which is the largest observation smaller than zero in my sample (see figure 6.3). As shown in table 6.1, this location is independent of the choice of kernel function or bandwidth. This result suggests that regardless of the method for testing the discontinuity's significance, its location

[10] See section 6.1.

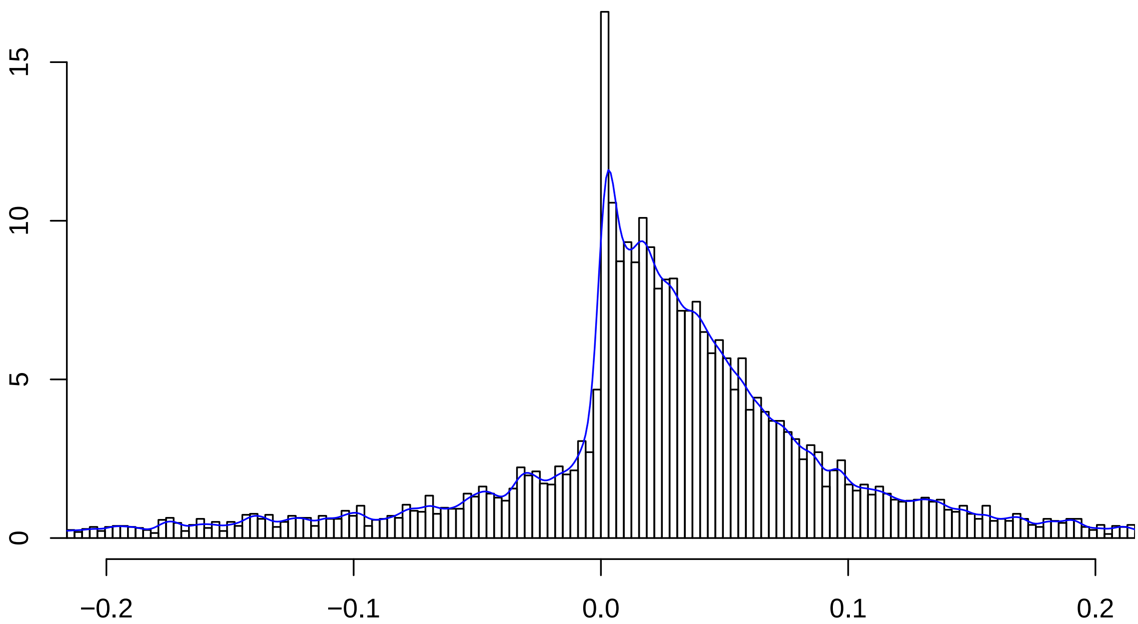

Figure 6.1: Density of standardized earnings
Standardized earnings are calculated as net income divided by lagged total assets. Bars show the density of earnings at bin width 0.00309, the solid line is an Epanechnikov kernel density estimate with bandwidth 0.00309. Values outside the interval [-0.2,0.2] are not displayed.

can be established with high precision. The next highest peak occurs at 0.003220 with a difference of 0.0047. The highest peak for negative earnings is at -0.0679 with a 0.000716 difference and at 0.0203 with a difference of 0.002046 for positive standardized earnings greater than 0.005.

The discontinuity at zero is highly significant for all three kernels used. Using a Gaussian kernel yields the lowest significance, which can be attributed to the weight this kernel places on observations outside an interval $\pm h$ from the center. Both the uniform kernel and the Epanechnikov kernel consider observations only within this definite interval, which might be superior to using the Gaussian kernel when looking for irregularities in the neighborhood of some point. This can further be seen from the bootstrap bandwidth, which needs to be much smaller for the Gaussian kernel to produce a density estimate which is not significantly different from the data.

The range of small losses appears to be roughly twice as wide as the range of

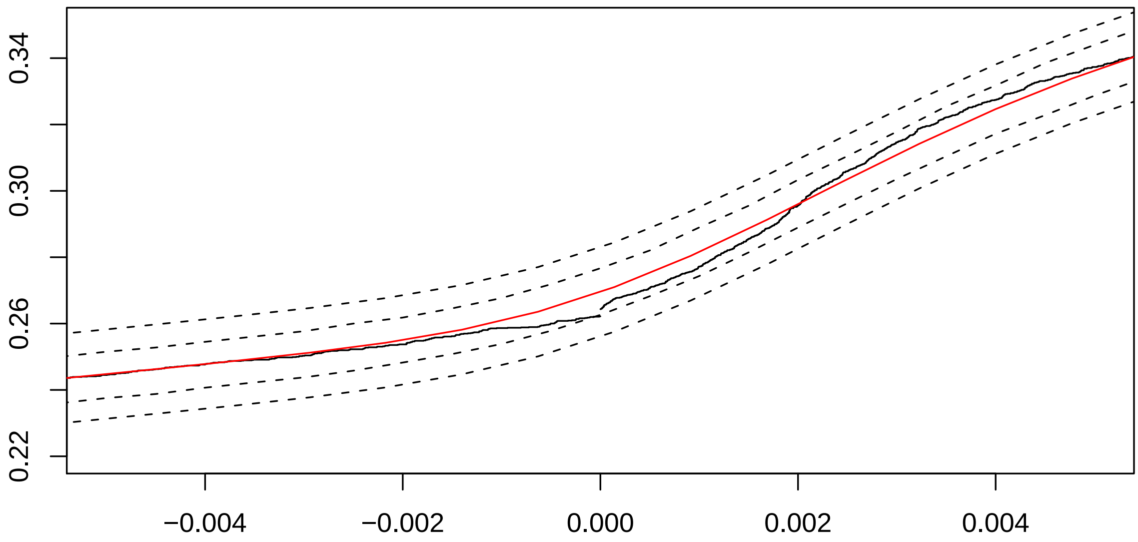

Figure 6.2: Distribution of standardized earnings
Standardized earnings are calculated as net income divided by lagged total assets. The solid black line is the empirical cumulative distribution of standardized earnings, the red line shows an integrated kernel density estimate with bandwidth 0.00309. The outer dashed lines are the Kolmogorov-Smirnov confidence bands at the 5 % level and the inner dashed lines are the pointwise bootstrap confidence bands for the integrated kernel density estimate at the 10 % level.

small profits, which could be a sign of firms trying to just clear zero without posting a substantial profit. This feature is present in the whole sample as well as in yearly subsamples. Figure 6.4 shows the difference between expected and observed earnings numbers in the years 1998 and 2003. These two years were chosen for their difference in significance (see table 6.2), yet both show a slow buildup and sharp decrease in effect size.

Degeorge et al. (1999) argue that the discontinuity reported by BD might be due to scaling of earnings per share (EPS) by market value per share when EPS are rounded to the nearest penny. Since I do not use per-share data but net income as posted by the firm, my analysis does not suffer from this potential problem.

Another explanation is provided by Durtschi and Easton (2005), who observe that price per share is smaller for loss firms than it is for profit firms. They argue that when earnings are standardized by this variable, the smaller denominator for loss firms drives small losses away from some benchmark. This explanations seems

Table 6.1: Discontinuity for alternative kernels

The upper panel shows four bandwidth selectors, the point of maximum difference, and the Kolmogorov-Smirnov test statistic for three alternative kernel functions. “RoT” is Silverman’s (1986) rule of thumb with a factor of 0.9 and “SJ” are Sheather and Jones’ (1991) *direct plug-in* and *solve-the-equation* bandwidth selection methods. RoT and SJ bandwidths are calculated once per bandwidth but might be more appropriate for specific kernels. For example, the RoT bandwidth assumes normally distributed data. Results for d_{max} are the same for all four bandwidths and are therefore displayed only once per kernel. The lower panel shows the expected number of observations calculated from the kernel density estimate (KDE) and the actual number. Significance levels were calculated by performing a t-test on eq. 6.11 and a binomial test on the number of observations.

	Optimal kernel bandwidth					
Kernel	Bootstrap	RoT	SJ (DPI)	SJ (STE)	d_{max}	$\sqrt{N}D$
Epanechnikov	0.00309	0.00686	0.00376	0.00253	-0.00000961	-0.728
Gaussian	0.00143	0.00686	0.00376	0.00253	-0.00000961	-0.725
Uniform	0.00231	0.00686	0.00376	0.00253	-0.00000961	-0.717

	Left interval				Right interval			
	Observations		P-value		Observations		P-value	
Kernel	KDE	Actual	normal	binomial	KDE	Actual	normal	binomial
Epanechnikov	190	125	0.000	0.000	434	542	0.000	0.000
Gaussian	114	57	0.000	0.000	184	222	0.004	0.006
Uniform	162	95	0.000	0.000	319	406	0.000	0.000

unlikely for two reasons: If there is a relation between earnings and market price, this relation must have a highly nonlinear form in order to stretch the earnings distribution at zero while compressing it at some points on both sides of zero to produce the discontinuity. Second, the discontinuity’s asymmetric shape suggests a cause other than a scaling effect.

A recent study by Beaver et al. (2007) suggests that asymmetric effects of income taxes and special items for profit and loss firms contribute to a discontinuity at zero in the distribution of earnings. Even if there is no discretionary management behavior, income taxes draw positive observations toward zero while negative special items push negative observations away from zero. My results strongly support this argument, since an asymmetry around zero is what one would expect under this hypothesis. However, earnings management cannot be distinguished from a mere income tax effect by using standardized net income alone. In combination with

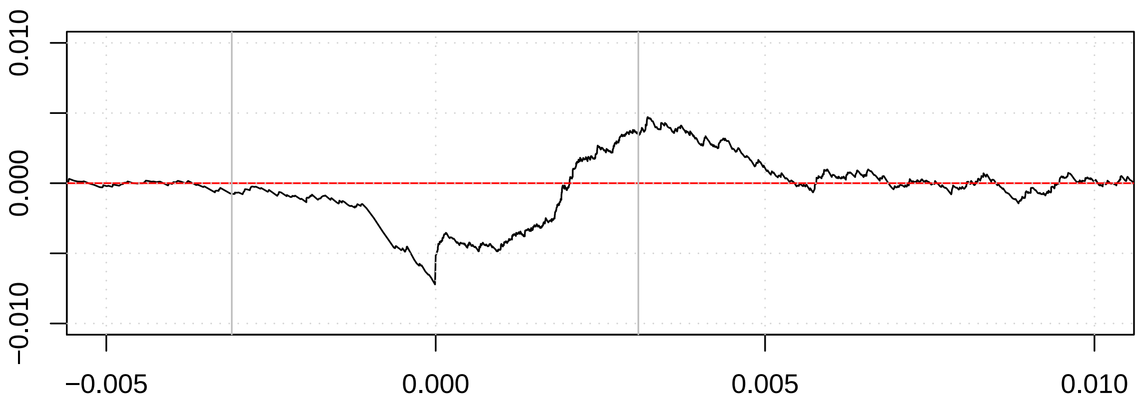

Figure 6.3: Difference of empirical cumulative distribution and reference distribution ($S_N(X) - F(X)$) for standardized earnings
Left and right kernel boundaries at the point of maximum difference are shown by the gray solid lines.

other variables such as pretax income and income before extraordinary items, the distributional approach can shed some light on the causes of the discontinuity.

I estimate loss aversion over the period 1991–2008 by calculating the kernel density for each year separately using the individually appropriate bandwidth and then applying a t-test and binomial test at d_{max}. Discontinuities exist in almost all yearly subsamples shown in table 6.2 and are insignificant only in 1998, 2006, and 2008. These less-than-significant results could by explained by smaller than optimal bandwidths and thus undersmoothing, which could cause discontinuities to disappear. However, bandwidths obtained from Silverman's rule of thumb for 2006 and 2008 are also in agreement with the bandwidths obtained from the bootstrap step. A wrong bandwidth size is thus not a likely cause of reduced loss aversion in these years.

Another explanation could be changes in reporting standards. Publicly traded German corporations were allowed to prepare company accounts under international financial reporting standards (IFRS or US GAAP) instead of German GAAP for the first time in 1998. Several studies find that income smoothing, which is similar to loss aversion, decreases under voluntary IFRS adoption.[11] These studies also find

[11] See Van Tendeloo and Vanstraelen (2005), Barth et al. (2008), and Christensen et al. (2008).

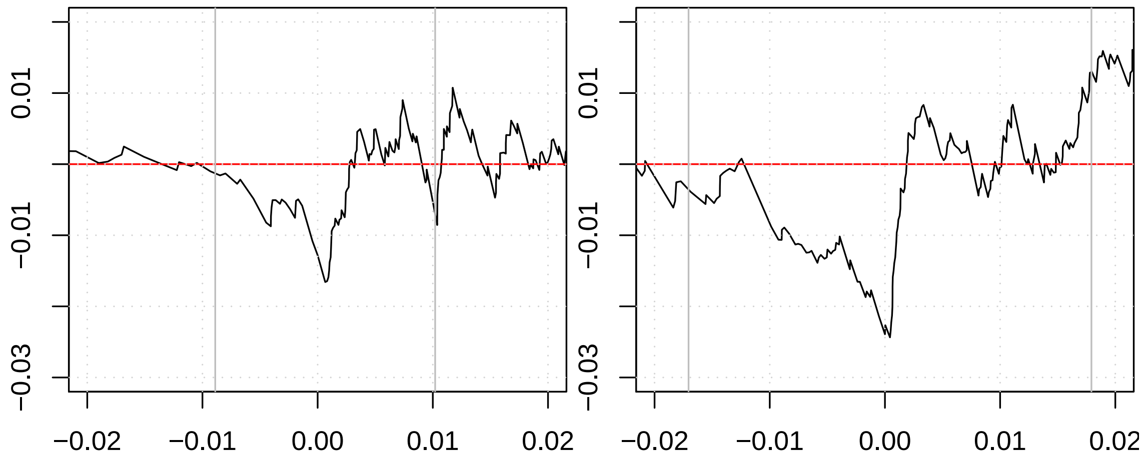

Figure 6.4: Difference of empirical cumulative distribution and reference distribution for standardized earnings in 1998 (left) and 2003 (right)
Left and right kernel boundaries at the point of maximum difference are shown by the gray solid lines.

that earnings smoothing does not change after mandatory IFRS adoption. International accounting standards became mandatory for German companies — with a few exceptions — in 2005, but the significance of loss aversion has been decreasing, which either contradicts these prior findings or points at some unobserved variable.

There is no clear trend in the degree of loss aversion over my sample period. Despite the drop in significance since 2000, t-statistics indicate that there is some cyclicality in loss aversion rather than an overall trend. Loss aversion decreases until 1998, but reaches its highest significance in 2000 and 2001 and decreases again thereafter. If a Bonferroni correction for multiple hypothesis tests is applied, discontinuities during the periods 1996–1998 and 2006–2008 are insignificant. This pattern resembles stock market movements over the period 1991–2008, which is supported by evidence provided by Günther et al. (2009): They suggest that neither voluntary nor mandatory IFRS adoption unambiguously leads to higher earnings quality and that capital market phases are an important determinant of earnings quality.

Empirical evidence suggests that the tendency to meet or beat analysts' forecasts has gained importance over avoiding small losses or earnings decreases in recent years

Table 6.2: Discontinuities in yearly subsamples

The upper panel shows optimal and bootstrapped bandwidth, the point of maximum difference (d_{max}), and the Kolmogorov-Smirnov test statistic. "RoT" is Silverman's (1986) rule of thumb with a factor of 0.9. The lower panel shows t-test statistics and the proportion of actual observations within an interval of one bandwidth to the left and right of d_{max}. The rightmost column is the lower of the two binomial test P-values.

	Descriptives			Bandwidth			
Year	N	Mean	SD	RoT	Bootstrap	d_{max}	$\sqrt{N}D$
1991	343	0.030	0.069	0.0081	0.0077	0.00126	-0.544
1992	357	0.017	0.064	0.0094	0.0058	-0.00043	-0.720
1993	385	0.014	0.066	0.0077	0.0077	0.00126	-0.638
1994	424	0.026	0.130	0.0086	0.0086	0.00122	-0.584
1995	434	0.030	0.094	0.0094	0.0053	-0.00043	-0.720
1996	435	0.021	0.072	0.0094	0.0094	-0.00044	-0.471
1997	551	0.047	0.189	0.0114	0.0112	-0.00072	-0.560
1998	677	0.054	0.210	0.0132	0.0095	0.00066	-0.431
1999	730	0.020	0.181	0.0123	0.0123	0.00000	-0.581
2000	717	-0.006	0.205	0.0136	0.0136	0.00107	-0.578
2001	761	-0.051	0.185	0.0247	0.0106	-0.00061	-0.603
2002	687	-0.052	0.231	0.0318	0.0258	-0.00335	-0.767
2003	659	-0.017	0.200	0.0175	0.0175	0.00044	-0.631
2004	659	0.015	0.184	0.0147	0.0147	-0.00029	-0.552
2005	653	0.038	0.198	0.0150	0.0150	0.00021	-0.544
2006	634	0.042	0.188	0.0162	0.0162	0.00050	-0.467
2007	613	0.041	0.176	0.0165	0.0165	0.00067	-0.404
2008	448	0.019	0.140	0.0157	0.0157	-0.00253	-0.415

	Left interval			Right interval			
		% observations			% observations		P-value (binom.)
Year	t	expected	actual	t	expected	actual	Left & Right
1991	-2.50**	5.8	2.6	2.35**	10.2	14.0	0.010
1992	-2.24***	3.6	1.2	2.20**	9.7	12.9	0.004
1993	-2.42**	7.1	3.9	1.72*	14.3	17.4	0.013
1994	-2.17**	5.1	2.4	1.80*	14.2	17.0	0.008
1995	-2.45**	3.2	1.2	2.38**	9.3	12.7	0.009
1996	-2.20**	6.2	3.7	1.13	12.5	14.3	0.028
1997	-2.18**	5.1	3.1	1.87*	10.1	12.5	0.026
1998	-1.76*	4.9	3.4	0.74	9.4	10.2	0.088
1999	-2.62***	4.6	2.6	1.64	10.2	12.1	0.006
2000	-2.89***	5.9	3.3	2.31**	11.9	14.6	0.002
2001	-2.75***	5.8	3.0	2.33***	8.7	12.0	0.000
2002	-1.95*	10.4	8.2	2.50**	17.3	21.0	0.015
2003	-1.71*	9.8	7.9	2.60***	15.3	18.9	0.012
2004	-2.43**	7.0	4.6	2.19**	12.5	15.3	0.014
2005	-2.04**	5.3	3.5	2.39**	11.6	14.5	0.020
2006	-1.80*	5.0	3.5	1.36	9.7	11.4	0.083
2007	-1.96**	4.4	2.8	1.00	9.0	10.1	0.048
2008	-1.60	6.0	4.2	0.85	10.4	11.6	0.135

*** $p < .01$; ** $p < .05$; * $p < .1$ two-side significance, without adjustment for testing joint hypotheses.

(Burgstahler and Eames (2006), Brown (2001), Degeorge et al. (1999)). Brown and Caylor (2005) show that since the mid-1990s, managers seek to avoid either small losses or earnings decreases less than to avoid negative earnings surprises. They argue that the economic rationale for this shift in hierarchy is that since the mid-1990s, investors unambiguously rewarded firms for reporting earnings meeting analysts' estimates more than they did for meeting the other two thresholds. Since the method presented in this chapter can be applied to distributions of analyst forecast errors as well, it could be worthwhile to investigate earnings management practices other than loss aversion.

6.5 Application to listed private equity

A high quality of reported book values is a necessary prerequisite when pricing private equity vehicles on the basis of net asset values. I therefore apply the procedure developed above to earnings data of listed private equity vehicles. Since manipulations of earnings are likely to carry over to next year's net asset values, I test distributions of standardized earnings for indications of loss aversion. In addition to earnings variables, I use net asset values reported by LPE funds to directly examine the extent of loss aversion in NAV returns.

Data

Accounting data was collected from Worldscope for 2 101 valid firm-years between 1990 and 2009 on earnings before interest, taxes, depreciation and amortization (EBITDA, Worldscope item WC18198), earnings before interest and taxes (EBIT, item WC18191), pretax income (WC01401), net income before extraordinary items and preferred dividends (WC01651) and net income (WC01751). These earnings variables are deflated by lagged total assets (WC02999), net sales (WC01001), common equity (WC03501) and market capitalization, which I obtained from Datastream. Resulting ratios are referred to as "standardized earnings" hereafter.

Accounting data is available for 288 listed private equity vehicles, of which are

115 investment companies, 29 firms, 129 funds, and 15 funds of funds. There are 915, 223, 818, and 145 firm-year observations, respectively.

Net asset values (NAVs) were collected from annual report and interim reports of 69 listed private equity funds on a quarterly basis from 1992 to 2008. A total of 1 042 quarterly ratios of a fund's NAV to last quarter's NAV was calculated.

Results for net asset value returns

Results for NAV returns are shown in figures 6.5 and 6.6. The distribution of NAV returns in figure 6.5 is approximated fairly closely by the integrated kernel density estimate. The empirical distribution function is well within the 10 % interval that was chosen to indicate the range where 90 % of the bootstrapped density estimates can be found. From a global perspective, we can thus use the empirical distribution and its kernel density estimate interchangeably.

The local test for discontinuities yields a maximum difference between the empirical and estimated distribution of 0.977 % at a NAV return of 2.32 %. Binomial tests to the left and to the right of this maximum are insignificant. I document 18 zero returns, which do not influence my results if excluded from the sample. The difference at NAV returns of zero is 0.666 % but insignificant. In addition, differences do not show the typical J-shaped pattern around zero, which is a further indication that net asset value returns are not subject to deliberate manipulation.

To check alternative specifications, arithmetic NAV returns can be replaced by continuous (log) NAV returns or arithmetic and log returns of NAV premia. Distributions of these variables do not show discontinuities either.

One might argue that NAV returns do not measure the variable of interest to shareholders, that is, total shareholder return. Fund management could rather try to avoid small losses in the the sum of net asset value returns *and* dividends to shareholders. If that was the case, the distribution of NAV returns and dividends would exhibit a discontinuity at zero. While it is possible that the distribution of dividends reduces the discontinuity at zero when subtracted from the distribution of total shareholder returns, it seems unlikely that funds incur disproportionately

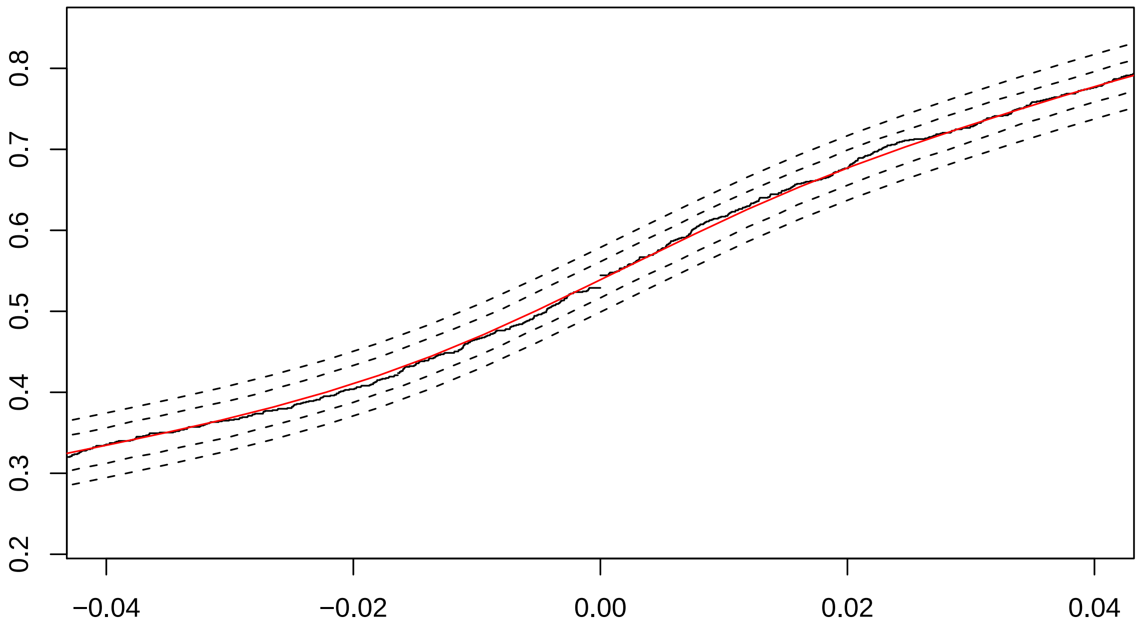

Figure 6.5: Distribution of net asset value returns
The solid black line is the empirical cumulative distribution, the red line shows an integrated kernel density estimate with bandwidth 0.0137. The outer dashed lines are the Kolmogorov-Smirnov confidence bands at the 5 % level and the inner dashed lines are the pointwise bootstrap confidence bands for the integrated kernel density estimate at the 10 % level.

many small NAV losses just to pay dividends.

The International Private Equity and Venture Capital Valuation Guidelines that are used by the private equity and venture capital industry for valuing investments and monitoring the value of existing investments thus seem to work quite well, providing shareholders with unbiased information about the fund's portfolio. In fact, these guidelines are based on the notion of "fair value" in order to be consistent with IFRS and US GAAP.

Results for income statement variables

Manipulation of income statement variables is somewhat harder to detect, since there is a host of different items that can be deflated by several other balance sheet items or off-balance sheet items such as total assets or market capitalization,

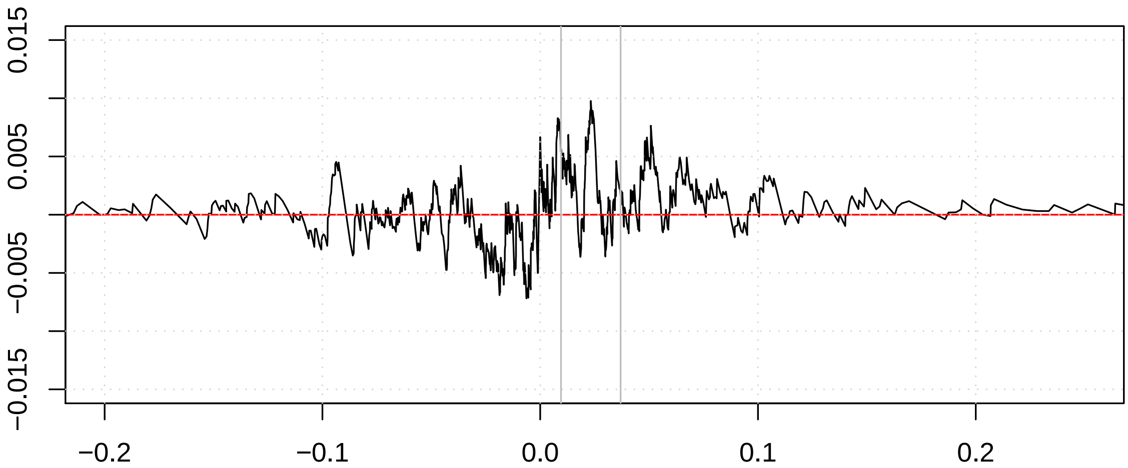

Figure 6.6: Difference of empirical cumulative distribution and reference distribution ($S_N(X) - F(X)$) for net asset value returns
Left and right kernel boundaries at the point of maximum difference are shown by the gray solid lines.

producing a large number of distributions that can be tested for discontinuities. I concentrate on items that can be defined in much the same way across different reporting standards and that offer some insight into the nature of what might seem to be loss aversion. The first variable to test for a discontinuity are earnings before interest, taxes, depreciation and amortization (EBITDA), which act as a rough proxy for the firm's cash flow. The net steps down the income statement are EBIT and pretax income, with intermediate items being the items that could be managed. Net income to common shareholders is the variable that most often is found to be managed. I therefore include several measures of net income before and after extraordinary items or preferred dividends.

Results indicate that discontinuities in earnings distributions can be found for investment companies and for certain earnings deflators only. Earnings deflated by total assets for LPE entities except investment companies in figure 6.7 do not indicate any loss aversion. The difference function shown in the right panel stays close to zero with a peak at earnings of 2.6 %, which is significant but probably coincidental, since the difference function looks quite irregular around zero where

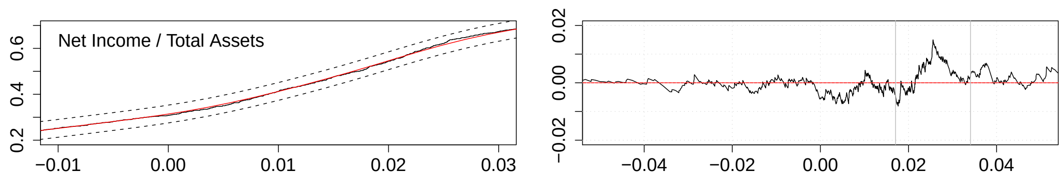

Figure 6.7: Cumulative distribution and difference between actual and estimated CDF for funds, funds of funds, and firms, deflated by total assets.
The difference at 0.026 is significant at the 5 % level. Other variables (not shown here) or loctions remain insignifcant at this level.

the peak would be expected.

The difference function's characteristic shape that indicates loss aversion shows up if earnings variables are deflated by sale revenue. From EBITDA to net income, the dent at zero increases and even becomes slightly asymmetric as in the German accounting data above. Although not significant, the difference function looks fairly different around zero comparing pretax income and after-tax income in figure 6.8. Beaver et al. (2007) suggests that asymmetric effects of income taxes and special items for profit and loss firms contribute to a discontinuity at zero, because income taxes draw positive observations toward zero while negative special items push negative observations away from zero. My results support the tax hypothesis. While the earnings distribution to the left of zero remains largely the same after taxes, positive earnings are drawn towards zero, establishing the difference function's asymmetric shape. Funds usually do not post large special items, which is likely the reason for the absence of large effects to the left of zero, which can also be seen in figure 6.10. They further prepare financial statements under different rules than investment companies, which leads to different balance sheets and revenue/cost structures. Funds that designate financial assets through the profit and loss account at fair value usually do not have substantial revenues, whereas investment companies prepare consolidated statements. These different accounting rules due to the vehicle's organizational form could explain why we do not observe loss aversion in the fund subsample.

The dent at zero is also visible for investment company earnings deflated by sales, but much stronger than in fund earnings. There is even a significant effect for pretax

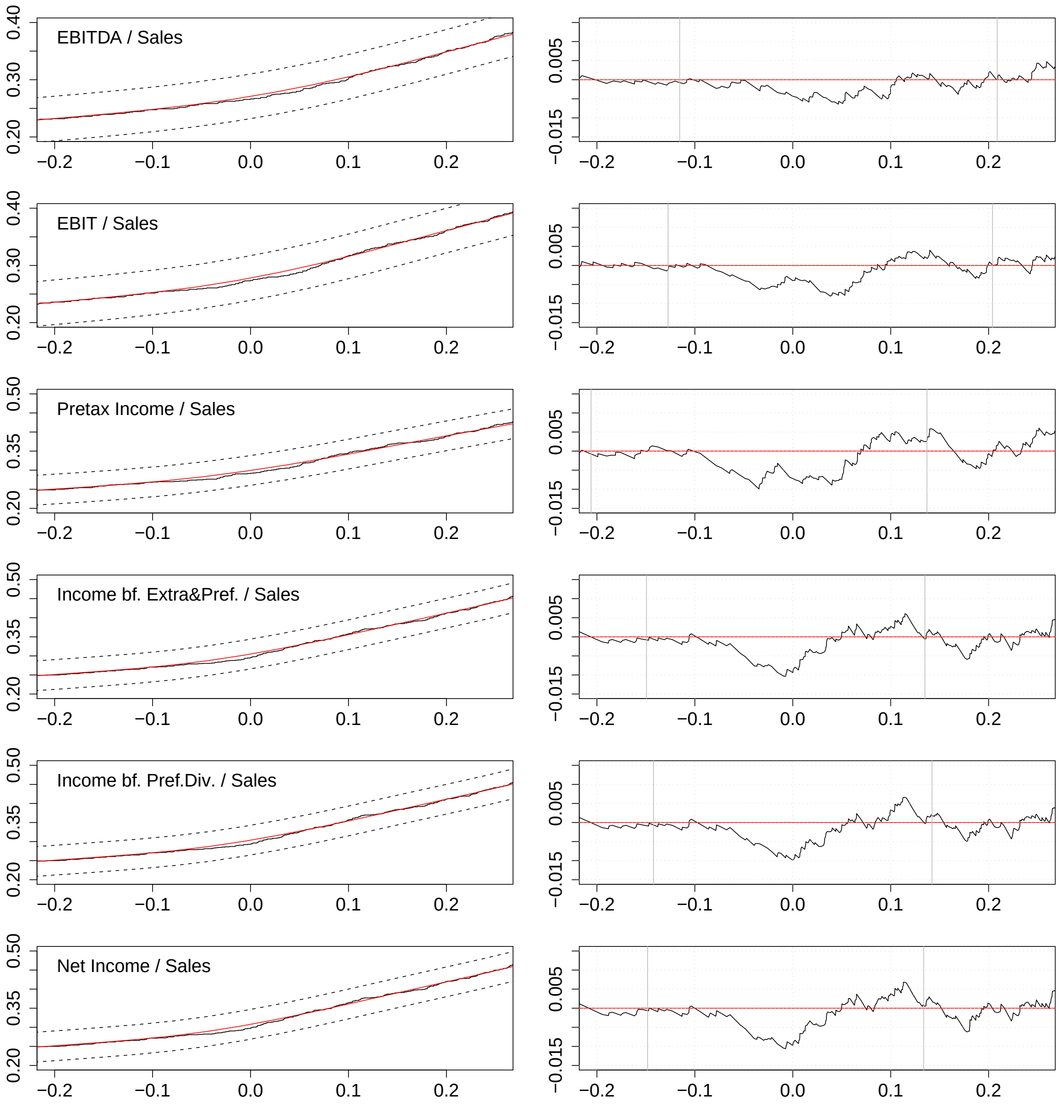

Figure 6.8: Cumulative distribution and difference between actual and estimated CDF for funds, funds of funds, and firms, deflated by sales
None of the differences are significant at the 10 % level.

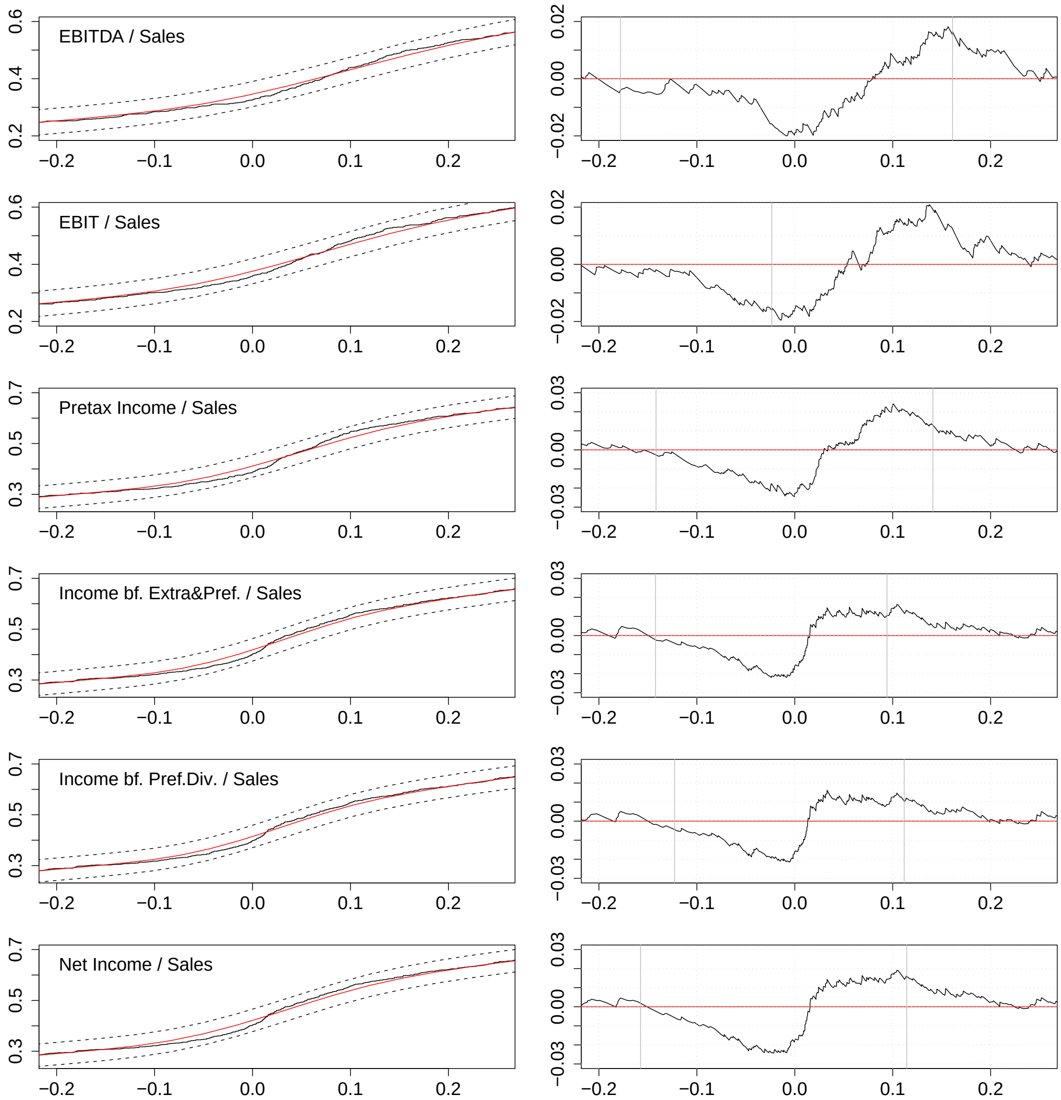

Figure 6.9: Cumulative distribution and difference between actual and estimated CDF for investment company earnings, deflated by sales
All differences are significant at the 1 % level.

income and sales. Figure 6.9 reveals an asymmetric discontinuity at zero for pretax income, which is inconsistent with the hypothesis that the discontinuity is caused by income taxes and special items. This finding hints at a problem of standardizing earnings by the wrong variable, which I also document for earnings deflated by total assets in figure 6.11. The discontinuity is significant for income items after tax but also for pretax income. This suggests that in addition to taxes, interest payments influence the distribution of standardized earnings. Financial income having an effect on the distribution of earnings is not surprising, since net income represents income to shareholders, but net income is deflated by total assets, which represent total firm capital. Therefore, leverage in funds and investment companies cannot be neglected, and total assets are probably not the right variable to deflate earnings.

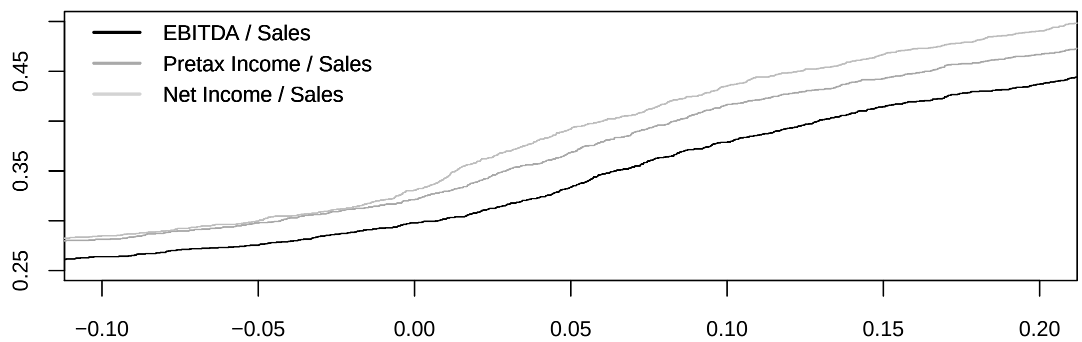

Figure 6.10: Influence of income taxes on distributions of standardized earnings
This graph shows cumulative distributions of pre- and post-tax earnings deflated by sales for all listed private equity vehicles in my sample. N=2625 for EBITDA, N=2740 for pretax income, and N=2744 for net income.

An assumption of studies examining the distribution of earnings for many companies simultaneously is that standardized earnings can be compared across companies, that is, they have the same distribution for all companies. This assumption is clearly violated if leverage is not being accounted for when dividing by total assets. A solution is to deflate net income by common equity to match stakeholders in the numerator and denominator. Net income standardized by common equity as shown in figure 6.12 does not show a significant discontinuity for investment companies anymore but for other organizational forms, albeit not at zero. If I divide net income by market capitalization, no loss aversion can be found in any subsample.

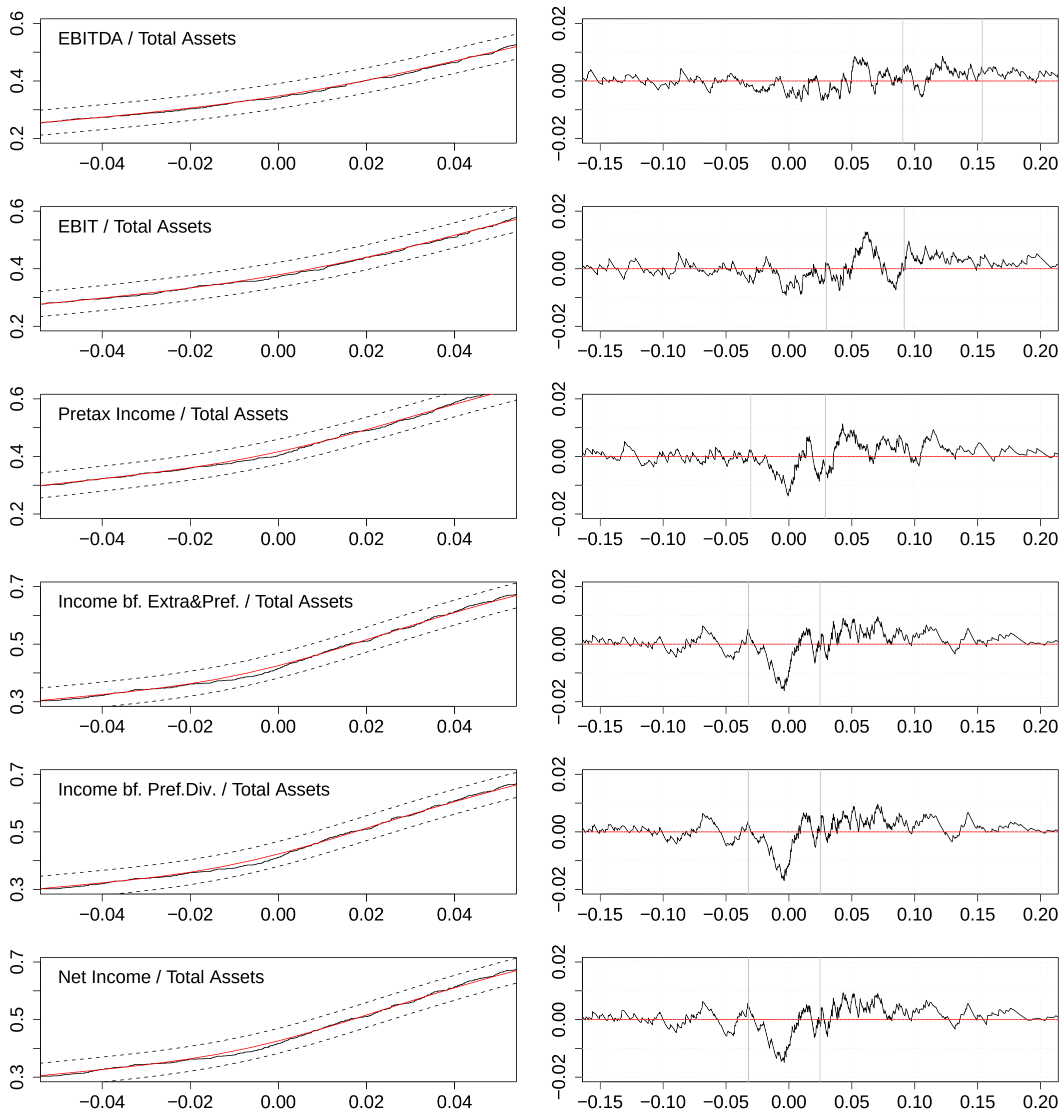

Figure 6.11: Cumulative distribution and difference between actual and estimated CDF for investment company earnings, deflated by total assets
Differences for pretax income to net income are significant at the 5 % level. EBITDA and EBIT remain insignificant.

I conclude that the apparent loss aversion in listed private equity vehicles is mainly due to tax effects, which produce a pattern that might be mistaken for loss aversion. Scaling of income variable by wrong denominators is another reason why discontinuities can falsely be attributed to loss aversion. Total assets or sales probably are the wrong variables to standardize earnings with, since total assets are the

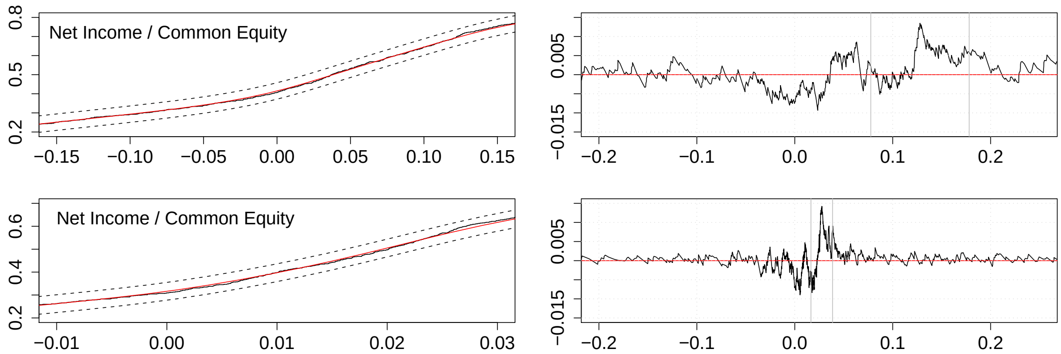

Figure 6.12: Cumulative distribution and difference between actual and estimated CDF, deflated by common equity

Differences are not significant at the 10 % significance level for investment company earnings (upper panels), but significant at the 5 % level for other organizational forms (lower panels).

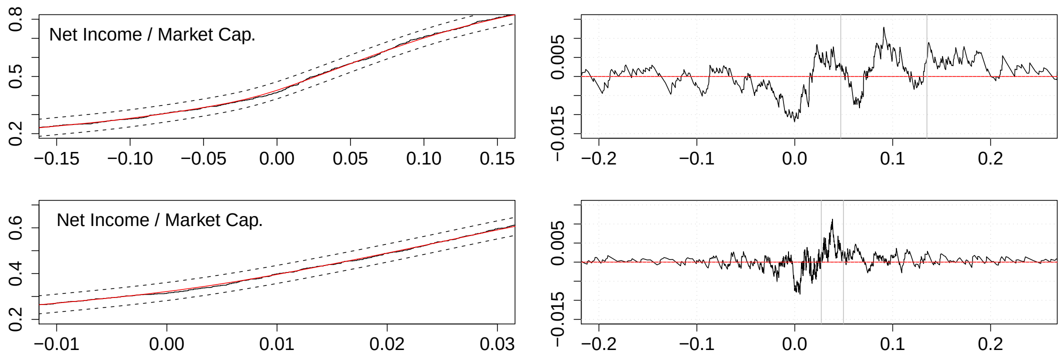

Figure 6.13: Cumulative distribution and difference between actual and estimated CDF, deflated by market capitalization

Differences are not significant at the 10 % significance level for neither investment company earnings (upper panels) nor other organizational forms (lower panels).

same regardless of leverage, whereas net income is not. If income is scaled by market capitalization, all discontinuities disappear. In an asset pricing context, earnings standardized by market capitalization reflect the cost of capital to shareholders. If we assume constant earnings that are distributed as dividends, it follows that market price is $P = \frac{NI}{r_e}$ where NI is net income and r_e is the cost of equity. The variable $\frac{NI}{P}$ thus represents the cost of capital, which is still not equal for all companies. If prices reflect net income discounted by the cost of equity and some pricing error, the correct way to arrive at a comparable earnings distribution would be to scale standardized earnings by the cost of equity. More formally, if $P_t = \frac{NI_t}{r_e} \cdot \epsilon_t$, then $\epsilon_t = \frac{NI_t}{P \cdot r_e} \cdot$, which can be more safely assumed to have the same distribution for all companies. Standard procedures such as the one outlined above can then be applied to this scaled version of standardized earnings.

6.6 Conclusion

This chapter proposes a new test procedure to detect discontinuities in empirical distributions, which I use to examine the quality of listed private equity net asset value returns and earnings. This procedure is based on kernel density estimation and a Kolmogorov-Smirnov test statistic and overcomes several shortcomings of Burgstahler and Dichev's (1997) method. My more general test is able to identify the exact location of discontinuities in distributions and can be used for a wide range of empirical data such as standardized earnings, earnings changes, or forecast errors relative to analysts' predictions. Degrees of freedom for the researcher are reduced to choosing a kernel function, which is a substantial improvement over existing methods.

In order to demonstrate the test procedure, I use a representative sample of listed German firms between 1991 and 2008. Earnings data for these firms show a discontinuity at zero. The range of small losses is more than twice as wide as the range of small profits, which could be a sign of loss aversion. The only plausible alternative interpretation is an explanation by Beaver et al. (2007), which employs asymmetric effects of income taxes and special items for profit and loss firms. Discontinuities exist in all yearly subsamples except in 1998, 2006, and 2008. Although other studies suggest an increasing importance to meet or beat analysts' forecasts compared to avoiding small losses or earnings decreases, I find no clear trend in my data.

Findings of loss aversion in listed private equity vehicles seem to be mainly due to tax effects, which produce a pattern that might be mistaken for loss aversion. If income is scaled by market capitalization, all discontinuities disappear. The distribution of net asset value returns does not show any sign of loss aversion. These results suggest that listed private equity vehicles do not engage in earnings management by manipulating earnings and net asset values to a substantial extent. Consequently, changes in net asset values are likely not systematically biased, which lends some credibility to the quality of net asset values for pricing purposes.

Chapter 7

Conclusion

7.1 Summary and implications

One fundamental difficulty when dealing with private equity markets is that market prices of funds and firms are mostly unobservable. Consequently, performance and risk properties of investments are hard to measure, and obtaining price multiples for transactions involving fund shares can be challenging. This thesis aims for the solution of these difficulties by investigating a sample of listed private equity vehicles for which market prices are available. My results can be grouped into a) risk and return properties of listed private equity, b) the relation between market and book values, and c) the quality of book values of LPE vehicles.

Systematic risk and return: Listed private equity vehicles show an aggregate Dimson beta of 1.7 without any substantial excess return on a value-weighted basis. An equally weighted portfolio which is adjusted for spread costs has a beta of 1.2 and does not outperform the market either.

While investors usually participate in traditional private equity *funds*, LPE vehicles can be funds, management companies, a combination of both (i. e. investment companies), or funds of funds. I therefore propose a classification of LPE vehicles along the two dimensions *participation in fees and carried interest* and *degree of diversification*. Traditional funds and funds of funds are managed externally and are thus directly comparable to the listed private equity subsamples. In addition to externally managed vehicles, I identify internally managed investment companies and management companies of unlisted funds.

Since internally managed vehicles usually generate cash from carried interest in addition to capital gains, their cash flow streams should be more risky than cash flows of externally managed vehicles. As expected, value-weighted indices for different organizational forms exhibit a wide range of systematic risk. Dimson beta is 1.2 for funds, 0.6 for funds of funds, 1.5 for firms, and 2.0 for investment companies. A back-of-the-envelope calculation shows that leverage is likely not the only explanation for these huge differences in market risk. Higher risks measured for firms and investment companies support the hypothesis that internally managed vehicles are substantially different from externally managed ones. As a result, organizational forms should be are taken account of when comparing traditional PE funds or firms to LPE.

Jensen's alpha varies strongly depending on the estimation period and which organizational form is measured. I find no excess returns for value-weighted indices. On an equally weighted basis, firms show a slightly significant 5.8 % annual excess return even if returns are corrected for bid-ask spreads, which might be caused by liquidity risk that is not accounted for in the capital asset pricing model.

Aggregate market risk of listed private equity vehicles varies strongly over time and across vehicles. CAPM betas of LPE vehicles are highly unstable, whereas ranks of individual vehicles within a cross-section change slightly less over time. I suspect that market risk of private equity is affected by factors unique to this sector: acquisitions and divestments that constantly shift portfolios, scarcity of information about portfolio companies, and rapid changes within portfolio companies. Unstable market risk should be incorporated in the valuation process and portfolio decision and casts doubt on diversification benefits of private equity in times of crisis. Since investors usually hold traditional private equity shares for long time periods, unpredictable changes in market risk pose a challenge for strategic portfolio allocation. However, targeting vehicles with specific risks *relative* to the LPE asset class might be a feasible strategy, as market risks of LPE vehicles tend to move together.

Market value and book value: To arrive at a market value for fund shares, the unlisted assets on the fund's balance sheet can be used as a source of information. If pairs of market price and book value can be observed for some funds, their characteristics could be used to infer market prices of other funds. In a broader economic context, net asset value returns are also related to share price returns, which is reflected in the closed-end fund literature. I therefore investigate the causes and consequences of net asset value discounts in listed private equity funds.

NAV discounts in LPE funds display many of the features that are present in closed-end mutual funds. Discounts in LPE funds are even larger, which I attribute to higher noise trader risk due to the nontransparent nature of private equity portfolios and the impracticability of short-selling portfolios. Investor sentiment seems to play a dominant role in LPE funds, of which I find evidence in NAV discounts. These depend on small-cap index returns and indicators of hot markets, such as the volume of initial public offerings and the cash flow to traditional PE funds. A major explanation for the time-variability of discounts therefore seems to be market timing by LPE funds, which leads to decreasing premia over the first few years of the funds' lifetimes. This drop in premia is particularly strong in buyout funds, which might depend more on market timing than venture funds, since buyout funds engage in value generation by multiple trading and financial engineering more often.[1]

The discovery of managerial ability as a cause of time-varying premia plays a less important role in LPE. The fund's cash holdings divided by total assets can proxy for its investment degree, which should indicate an information flow to fund investors, but shows no relation to premia. However, the initial drop in premia after a fund's IPO cannot be completely explained by proxies for investor sentiment. The remaining variation in premia that is explained by year dummies is only about one percent, which could still be supportive of the managerial ability hypothesis.

Furthermore, I find evidence that some information about the fund's portfolio is not reflected in net asset values but in market prices: Fund valuations depend on the

[1] See Achleitner et al. (2010), Kaserer et al. (2007), and Berg and Gottschalg (2005) for a discussion of value generation in private equity.

long-term credit spread between government and corporate bonds. Premia are also higher in funds with low systematic risk, which suggests that systematic risk is not fully reflected in net asset values. These two findings lend support to the hypothesis that net asset values proxy for future cash flow. Dividing a cash flow proxy by a discount rate proxy, such as beta and credit spread, yields a market price.

Finally, fund returns show a U-shaped seasonality across different investment styles, which can neither be explained by different taxation of dividends and capital gains nor by tax-loss-selling. A substantial part of this pattern seems to be related to the fund's fiscal year. Returns are exceptionally high in quarters where annual reports are published, which is puzzling, since tax reasons offer no satisfactory explanation for the 3.5 % return differential.

Quality of book values: For net asset values to be a valid source of information to price fund shares, the quality of net asset values has to be measured. I develop a procedure to test earnings management that is characterized by discontinuities in distributions of earnings-related variables. For example, distributions of standardized earnings can indicate loss aversion, and distributions of net asset value returns can indicate an aversion to posting capital losses.

This procedure is based on kernel density estimation and a Kolmogorov-Smirnov test statistic and overcomes several shortcomings of Burgstahler and Dichev's (1997) method. My more general test is able to identify the exact location of discontinuities in distributions and can be used for a wide range of empirical data such as standardized earnings, earnings changes, or forecast errors relative to analysts' predictions. Degrees of freedom for the researcher are reduced to choosing a kernel function, which is a substantial improvement over existing methods.

Apparent findings of loss aversion in listed private equity vehicles seem to be mainly due to tax effects, which produce a pattern that might be mistaken for loss aversion. If income is scaled by market capitalization, all discontinuities disappear. The distribution of net asset value returns does not show any sign of loss aversion. These results suggest that listed private equity vehicles do not engage in earnings management by manipulating earnings or net asset values to a substantial extent. Consequently, changes in net asset values are likely not systematically biased, which lends some credibility to the quality of net asset values for pricing purposes.

7.2 Outlook

Observing the listed private equity universe can offer unique insights into unlisted vehicles. Although the results I present in this thesis have undergone several robustness checks, other tests and extensions are conceivable.

The economic causes and effects of differences between LPE's organizational forms could be subject to future research to further our understanding of the economics of private equity firms and funds. For example, operational and other determinants of systematic risk, such as the nature and frequency of portfolio investments and divestments, could be investigated to estimate the risk components that drive stock returns. Information at the portfolio company level should be able to explain some proportion of the variation in individual LPE vehicle risk. In particular, leverage in portfolio companies and liquidity risk might help to clarify the cause of the small excess returns found in equally weighted LPE indices for funds of funds and firms. On the econometric side of the problem, the remarkably low systematic risk and high excess return of funds of funds could be subject to further investigation through alternative model specifications. Funds of funds are different from other LPE vehicles, since information about their underlying investments becomes available rather slowly because of an additional reporting layer.

Timing and scarcity of information appear as a strong central theme in all areas related to the pricing of LPE stocks. Informational inefficiencies seem to influence net asset value premia in LPE funds. Seasonal patterns in stock returns and the dependency of premia on systematic risk might both be explained by variables related to the disclosure of information about portfolio companies. Another avenue of research into NAV discounts could be an estimation of portfolio betas from fundamentals to proxy for underlying business risk. Finally, an important open question from a theoretical point of view is the mechanism by which initially decreasing NAV premia can be explained. Looking for variables that better proxy for investor sentiment or managerial ability could help us distinguishing the impact of these competing theories.

Listed private equity vehicles do not seem to avoid posting losses on their income statement. Although examining bottom line results captures a wide range of earnings management practices, net asset values and earnings might be biased in other ways. Future research could therefore address other dimensions of earnings management in LPE, such as income smoothing and discretionary accruals. Conditional conservatism[2] and the timeliness of conditional loss recognition are likely greater in portfolio companies of private equity funds due to the PE governance model.[3] Listed PE companies are therefore good candidates to exhibit a similarly high degree of earnings quality, which can also be reflected in the persistence and predictability of earnings and cash flows. However, it is a controversial issue in the literature, whether smooth earnings signal high earnings quality.[4] Smooth and thus predictable earnings can indicate a stable underlying business. But they can also be an indication of the management's efforts to pretend stability where there is none. In the latter case, the informational content of earnings for pricing purposes would rather be reduced. If all information available at a time was incorporated in earnings figures, earnings *changes* would not be predictable. Additional studies of accounting variables could thus improve our understanding of price formation in private equity.

The scope of interesting questions to ask in the field of private equity greatly exceeds the scope of this thesis. For example, research could be worthwhile to conduct particularly with respect to event studies that examine share price reactions around corporate or external events.

[2] Basu (1997) defines conditional conservatism as the accountant's tendency to require a higher degree of verification for recognizing good rather than bad news in earnings.

[3] See Beuselinck et al. (2009).

[4] For a cross-section of definitions of earnings quality and interpretations of persistent and predictable earnings, see Bernstein et al. (1999), Revsine et al. (1999), Penman and Zhang (2002), McNichols (2002), Bernstein and Siegel (1979), and Richardson (2003).

Appendix A

Appendix Chapter 5

A.1 Correlation matrix

Table A.1: Correlation between premia and covariates

Figures are Pearson product-moment correlation coefficients. P-values are in parentheses.

		1	2	3	4	5	6	7	8
1	NAV premium (Ln)								
2	Fund age (Ln)	-0.157							
		(0.00)							
3	Bid-ask spread (Ln)	-0.057	-0.115						
		(0.02)	(0.00)						
4	Trading days (Ln)	-0.078	0.161	-0.563					
		(0.00)	(0.00)	(0.00)					
5	Beta	-0.142	0.057	-0.095	0.156				
		(0.00)	(0.00)	(0.00)	(0.00)				
6	Common law	0.178	0.062	0.317	-0.288	-0.047			
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
7	VCT	0.081	-0.065	0.599	-0.693	-0.088	0.324		
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)		
8	Managment fee	-0.015	-0.025	0.262	-0.263	-0.076	-0.071	0.419	
		(0.53)	(0.17)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
9	Cash / Total Assets	0.037	-0.273	0.087	-0.069	-0.019	0.009	-0.044	0.124
		(0.17)	(0.00)	(0.00)	(0.00)	(0.35)	(0.65)	(0.03)	(0.00)
10	Cash / Market value	-0.099	-0.164	0.092	-0.030	-0.002	0.056	-0.035	0.140
		(0.00)	(0.00)	(0.00)	(0.18)	(0.91)	(0.01)	(0.09)	(0.00)
11	Inst. Ownership (Ln)	0.030	0.122	-0.379	0.385	0.018	-0.097	-0.664	-0.305
		(0.37)	(0.00)	(0.00)	(0.00)	(0.49)	(0.00)	(0.00)	(0.00)
12	Ownership conc. (Ln)	-0.105	0.069	-0.393	0.487	0.093	-0.272	-0.687	-0.361
		(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
13	Commitments (Ln)	0.063	0.088	-0.211	0.023	0.108	0.000	0.000	0.000
		(0.01)	(0.00)	(0.00)	(0.24)	(0.00)	(1.00)	(1.00)	(1.00)
14	Commitments change	0.061	-0.018	0.001	0.039	-0.037	0.000	0.000	0.000
		(0.01)	(0.32)	(0.98)	(0.05)	(0.00)	(1.00)	(1.00)	(1.00)
15	Small cap residuals	0.108	-0.001	0.112	-0.040	0.002	0.000	0.000	0.000
		(0.00)	(0.97)	(0.00)	(0.04)	(0.86)	(1.00)	(1.00)	(1.00)
16	MSCI World	0.297	-0.048	0.042	0.022	-0.076	0.000	0.000	0.000
		(0.00)	(0.01)	(0.03)	(0.26)	(0.00)	(1.00)	(1.00)	(1.00)
17	Interest rate UK	0.160	-0.106	-0.060	0.126	-0.133	0.000	0.000	0.000
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(1.00)	(1.00)	(1.00)
18	Interest factor	0.172	-0.131	-0.027	0.138	-0.129	0.000	0.000	0.000
		(0.00)	(0.00)	(0.16)	(0.00)	(0.00)	(1.00)	(1.00)	(1.00)
19	Spread UK	-0.408	0.112	-0.086	-0.048	0.123	0.000	0.000	0.000
		(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(1.00)	(1.00)	(1.00)
20	Spread factor	-0.387	0.097	-0.067	-0.049	0.153	0.000	0.000	0.000
		(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(1.00)	(1.00)	(1.00)
21	IPO volume (Ln)	0.361	-0.007	-0.165	0.089	0.017	0.000	0.000	0.000
		(0.00)	(0.69)	(0.00)	(0.00)	(0.17)	(1.00)	(1.00)	(1.00)
22	IPO volume change	0.247	-0.035	0.022	0.023	-0.031	0.000	0.000	0.000
		(0.00)	(0.05)	(0.25)	(0.24)	(0.01)	(1.00)	(1.00)	(1.00)

Continued on next page

Table A.1 – continued from previous page

		9	10	11	12	13	14	15	16
9	Cash / Total Assets								
10	Cash / Market value	0.878							
		(0.00)							
11	Inst. Ownership (Ln)	-0.039	-0.080						
		(0.24)	(0.02)						
12	Ownership conc. (Ln)	0.056	0.068	0.889					
		(0.06)	(0.03)	(0.00)					
13	Commitments (Ln)	0.028	0.019	0.138	0.089				
		(0.17)	(0.35)	(0.00)	(0.00)				
14	Commitments change	-0.032	-0.031	0.002	-0.009	0.006			
		(0.11)	(0.14)	(0.95)	(0.73)	(0.65)			
15	Small cap residuals	0.039	0.027	-0.057	-0.021	0.034	0.108		
		(0.05)	(0.19)	(0.03)	(0.40)	(0.01)	(0.00)		
16	MSCI World	0.007	-0.018	0.014	-0.001	-0.094	0.105	0.000	
		(0.74)	(0.39)	(0.59)	(0.97)	(0.00)	(0.00)	(1.00)	
17	Interest rate UK	-0.120	-0.124	-0.063	-0.061	-0.784	0.236	-0.110	0.155
		(0.00)	(0.00)	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)
18	Interest factor	-0.120	-0.130	-0.124	-0.086	-0.762	0.250	-0.078	0.142
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
19	Spread UK	-0.028	0.042	0.053	0.040	0.205	-0.019	-0.026	-0.499
		(0.16)	(0.04)	(0.05)	(0.11)	(0.00)	(0.12)	(0.03)	(0.00)
20	Spread factor	-0.010	0.049	0.024	0.026	0.412	-0.122	-0.012	-0.625
		(0.63)	(0.02)	(0.38)	(0.29)	(0.00)	(0.00)	(0.34)	(0.00)
21	IPO volume (Ln)	-0.004	-0.047	0.050	0.035	0.603	-0.106	-0.022	0.168
		(0.83)	(0.02)	(0.06)	(0.16)	(0.00)	(0.00)	(0.07)	(0.00)
22	IPO volume change	0.014	-0.019	-0.004	-0.005	0.064	0.171	-0.126	0.392
		(0.50)	(0.37)	(0.87)	(0.83)	(0.00)	(0.00)	(0.00)	(0.00)

		17	18	19	20	21
17	Interest rate UK					
18	Interest factor	0.983				
		(0.00)				
19	Spread UK	-0.270	-0.288			
		(0.00)	(0.00)			
20	Spread factor	-0.517	-0.489	0.893		
		(0.00)	(0.00)	(0.00)		
21	IPO volume (Ln)	-0.364	-0.330	-0.229	-0.057	
		(0.00)	(0.00)	(0.00)	(0.00)	
22	IPO volume change	0.044	0.052	-0.324	-0.304	0.582
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Appendix B

Appendix Chapter 6

B.1 Proof of equation 6.3

Assume that $E\left(\frac{n_{i-1}+n_{i+1}}{2}-n_i\right)=0$ where E is the expectation operator with respect to the sampling population.

Then

$$
\begin{aligned}
Var\left(\frac{n_{i-1}+n_{i+1}}{2}-n_i\right) &= E\left(\left(\frac{n_{i-1}+n_{i+1}}{2}-n_i-E\left(\frac{n_{i-1}+n_{i+1}}{2}-n_i\right)\right)^2\right)\\
&= E\left(\left(\frac{n_{i-1}+n_{i+1}}{2}\right)^2-2n_i\frac{n_{i-1}+n_{i+1}}{2}+n_i^2\right)\\
&= \frac{1}{4}E\left(n_{i-1}^2+2n_{i-1}n_{i+1}+n_{i+1}^2\right)-E\left(n_in_{i-1}+n_in_{i+1}\right)+E\left(n_i^2\right) \qquad \text{(B.1)}\\
&= \frac{1}{4}\left(Np_{i-1}(1-p_{i-1})-2Np_{i-1}p_{i+1}+Np_{i+1}(1-p_{i+1})\right)+\\
&\quad + Np_ip_{i-1}+Np_ip_{i+1}+Np_i(1-p_i)\\
&= Np_i(1-p_i)+\frac{N}{4}(p_{i-1}+p_{i+1})(1-p_{i-1}-p_{i+1})+Np_i(p_{i-1}+p_{i+1}).
\end{aligned}
$$

B.2 Results for uniform distribution and uniform kernel

B.2.1 Maximum difference

Let t be some variable that follows a uniform distribution. Assume without loss of generality that t's density is positive over the interval $[0, d]$. The boundary points constitute a discontinuity in the sense of this study. The uniform density is $g(x) = 1/d$. The uniform kernel is $K(x) = \frac{1}{2h}\mathbf{1}(-h \leqslant x \leqslant h)$, where $\mathbf{1}(\cdot)$ is the indicator function, which is 1 if the condition in parentheses is true and 0 otherwise. Then, by convolution of $g(x)$ and $K(x)$, the density estimate is

$$\begin{aligned} f(t) &= \int_{-\infty}^{\infty} g(x)K(t-x)dx \\ &= \frac{1}{2dh}\int_{-\infty}^{\infty} \mathbf{1}(0 \leqslant x \leqslant d)\mathbf{1}(-h \leqslant t-x \leqslant h)dx \\ &= \frac{1}{2dh}\int_{-\infty}^{\infty} \mathbf{1}((0 \leqslant x \leqslant d) \cap (-h \leqslant t-x \leqslant h))dx. \end{aligned} \tag{B.2}$$

Assume that $2h \leqslant d$, that is, the true distribution is wider than the kernel. Evaluating the indicator function yields the density estimate

$$f(t) = \frac{1}{2dh}\begin{cases} 0 & , t < -h \\ h+t & , -h \leqslant t \leqslant h \\ 2h & , h \leqslant t \leqslant d-h \\ d-h-t & , -h+d \leqslant t \leqslant h+d \\ 0 & , t > d+h. \end{cases} \tag{B.3}$$

The integrated kernel density estimate is

$$F(t) = \begin{cases} 0 & ,t < -h \\ \int_{-h}^{t} f(x)dx = x\frac{h+\frac{1}{2}x}{2dh}\Big|_{-h}^{t} & ,-h \leqslant t \leqslant h \\ \frac{h}{d} + \int_{h}^{t} f(x)dx = \frac{h}{d} + \frac{1}{d}x\Big|_{h}^{x} & ,h \leqslant t \leqslant d-h \\ 1 - \frac{h}{d} + \int_{d-h}^{t} f(x)dx = 1 - \frac{h}{d} + x\frac{d+h-\frac{1}{2}x}{2dh}\Big|_{d-h}^{t} & ,-h+d \leqslant t \leqslant h+d \\ 1 & ,t > d+h. \end{cases} \tag{B.4}$$

To find the point of maximum absolute difference between the integrated kernel density estimate and the empirical cumulative distribution, denote by $\hat{F}(t)$ the empirical cumulative distribution and define

$$D(t) = \hat{F}(t) - F(t) \tag{B.5}$$

on the interval $[-h \leqslant t \leqslant h]$. Since $\hat{F}(t) = 0$ for $t \leqslant 0$, but $\hat{F}(t) \leqslant F(t)$ on this interval, we are looking for a *minimum* of $D(t)$ for the two cases $[-h \leqslant t \leqslant 0]$ and $[0 \leqslant t \leqslant h]$.

The first case is

$$\begin{aligned} D(t) = \hat{F}(t) - F(t) &= \frac{1}{d}t - \int_{-h}^{t} f(x)dx = \frac{1}{d}t - x\frac{h+\frac{1}{2}x}{2dh}\Big|_{-h}^{t} \\ &= \frac{2hx - \frac{1}{2}(t+h)^2}{2dh} \end{aligned} \tag{B.6}$$

The first order condition for a maximum follows directly:

$$\frac{dD(t)}{dt} = \frac{1}{2dh}(2h - t - h) = -\frac{t-h}{2dh} > 0 \;\forall\; (0 \leqslant t \leqslant h). \tag{B.7}$$

Thus

$$-\frac{t-h}{2dh} = 0 \rightarrow t = h, \tag{B.8}$$

which is a maximum, because

$$\frac{d^2D(t)}{dt^2} = -\frac{1}{2dh} < 0. \tag{B.9}$$

Since the first derivative is negative, the minimum we are looking for is a boundary solution at $t = 0$. For the second case $[-h \leqslant t \leqslant 0]$, the first and second order conditions are

$$\frac{dD(t)}{dt} = \frac{d}{dt}\left(\hat{F}(t) - F(t)\right) = 0 - f(t) = -\frac{h+t}{2dh} < 0 \; \forall \; (-h \leqslant t \leqslant 0) \tag{B.10}$$

and

$$\frac{d^2D(t)}{dt^2} = -\frac{1}{2dh} < 0. \tag{B.11}$$

There is a maximum at $t = -h$ and a minimum at $t = 0$. Since the kernel density estimate is symmetric and $D(t) = 0$ on $[h \leqslant t \leqslant d - h]$, the points of maximum difference are at $t = 0$ and $t = d$, which are indeed the true locations.

B.2.2 Test statistic

The test statistic at $t = 0$ for the left interval $[-h, 0]$ is

$$s_l = \frac{\hat{p} - p}{\sqrt{p(1-p)}}\sqrt{N}, \tag{B.12}$$

where $\hat{p} = \int_{-h}^{0} \hat{f}(t)dt = 0$ and

$$p = \int_{-h}^{0} f(t)dt = F(0) = \frac{h}{4d}. \tag{B.13}$$

Therefore,

$$s_l = -\frac{h}{2d\sqrt{\frac{h}{d}\left(1 - \frac{h}{4d}\right)}}\sqrt{N} = -\frac{h\sqrt{N}}{\sqrt{4hd - h^2}}. \tag{B.14}$$

Bandwidth usually depends on sample size through $h = cN^{-1/5}$ with some constant c (see Silverman, 1986, chap. 3.4; Scott, 1992, chap. 6.2). Therefore, the test statistic is

$$\begin{aligned} s_l &= -\frac{cN^{3/10}}{\sqrt{4dcN^{-1/5} - c^2N^{-2/5}}} \\ &\geqslant -\frac{cN^{3/10}}{\sqrt{4dcN^{-1/5} - c^2N^{-1/5}}} \\ &= -\frac{c}{\sqrt{4dc - c^2}} N^{2/5} = O(N^{2/5}) \end{aligned} \tag{B.15}$$

The test statistic tends to minus infinity more slowly than at the usual rate $O(N^{1/2})$.

Using the same logic as above, the test statistic for the right interval $[0, h]$ is

$$s_r = \frac{h\sqrt{N}}{\sqrt{12hd - 9h^2}} \tag{B.16}$$

using the results above, that is,

$$\hat{p} = \int_0^h \hat{f}(t)dt = \frac{h}{d} \tag{B.17}$$

$$p = \int_0^h f(t)dt = F(h) - F(0) = \frac{h}{d} - \frac{h}{4d} = \frac{3h}{4d}. \tag{B.18}$$

At $t = 0$, the left test statistic's absolute value is larger than the right one's, that is, $|s_l| > |s_r|$, whenever

$$\left| -\frac{h\sqrt{N}}{\sqrt{4hd - h^2}} \right| > \left| \frac{h\sqrt{N}}{\sqrt{12hd - 9h^2}} \right| \tag{B.19}$$

$$d > h.$$

This condition is always true, because we assumed that $2h \leqslant d$. Comparing the magnitude of s_l and s_r can therefore indicate the discontinuity's shape.

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