Review of Finance (2012) 16: 799–835
doi: 10.1093/rof/rfr011
Advance Access publication: May 27, 2011

Private Equity Fund Size, Investment Size, and Value Creation*

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Abstract. This paper examines why large private equity (PE) funds earn lower returns. The article argues that large PE funds are suited to making large investments and small PE funds are suited to nurturing start-ups. Thus, the suboptimal investment in small companies is one driver of the size effect in PE. A theoretical model and empirical results from a sample of 1,222 funds in the USA support this prediction. The largest 25% of PE funds earn internal rates of return of 5.17% when they invest in the largest 25% of companies but only −2.98% when they invest in the smallest 25%. This suggests that investment size is a driver of the size effect in PE.

JEL Classification: G11, G24, G34

1. Introduction

Large private equity (PE) funds have several advantages: they have better connections, are more able to diversify, and should be able to obtain better financing terms. However, prior evidence suggests that large PE funds earn lower returns. The literature has not shown why this is so. Thus, I analyze the relationship between fund size, investment size, and returns. I present a model that shows (1) large PE funds should earn lower returns than do small PE funds and (2) large PE funds earn especially lower returns when they invest outside their area of competitive advantage by investing in small companies. Empirical results from 1,222 funds that invest in the USA support this, showing that large PE funds earn lower returns on average, especially when they invest in small companies.

Large PE funds have several advantages over small PE funds. First, they may be more connected with other financial institutions. This might facilitate better deal terms from investment banks (following Hochberg, Ljungqvist, and Lu, 2007; Hellman, Lindsey, and Puri, 2008; Hege, Palomino, and Schwienbacher, 2009; Demiroglu and James, 2010). Second, large PE funds are more likely to

* For their valued input, I thank the editor (Holger Mueller), Mark Carnegie, Deon Joubert, Joseph McCahery, Cyril Pham, Ronan Powell, Jo-Ann Suchard, Asfandyar Uppal, Karyn West, Jason Zein, and the anonymous reviewer.

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diversify internationally (Cumming and Dai, 2010b). Different countries offer differently favorable investment environments (Hege, Palomino, and Schwienbacher, 2009; Cumming and Walz, 2010). Thus, large PE funds might be able to optimally choose their investment environment.

Despite these competitive advantages, Lopez-de Silanes, Phalippou, and Gottschalg (2009) find that large PE funds perform worse than small PE funds do.[1] The issue is then why large funds earn lower returns. There are four interlinked reasons to think that it is due to suboptimal investments in small companies for which small PE funds are better suited.

First, small investments could cause large PE funds to spread staff too thinly. Large PE funds can generate economies of scale by reducing the number of staff per dollar of investment. Thus, if large PE funds invest in small companies, they reduce the number of staff per company. This can destroy value by reducing the attention that each PE professional gives to each company (following Cumming, 2006; Lopez-de Silanes, Phalippou, and Gottschalg, 2009; Cumming and Dai, 2011). This appears especially problematic for small companies, which rely on "nurturing" and management expertise to generate value (Cumming, Fleming, and Suchard, 2005).

Second, large PE funds argued that advantages lie mainly in using connections to obtain better financing terms (Hochberg, Ljungqvist, and Lu, 2007; Hellman, Lindsey, and Puri, 2008). This favors investments in large companies because the benefit of finance-related connections increases with the amount of financing needed. While small companies also benefit from this, small PE funds can also be well connected and provide reputation effects for initial public offerings (IPO) and financing (Pollock *et al.*, 2010).

Third, small funds might have a first-mover advantage when investing in small companies. A small PE fund faces capital and location constraints. These constraints limit the small fund's set of potential investments. Appraising investments is time consuming (Tang, Kacmar, and Busenitz, 2010). Thus, small funds might find the best investments in the set of small companies before large funds can do so.

Fourth, given the above three factors, large funds are likely to invest in small companies when they have excess cash, which might induce Harford (1999) type agency conflicts. This could destroy value. Supporting this, prior literature shows a negative relation between PE fund performance and the amount of cash flowing into the PE industry (Ljungqvist and Richardson, 2003; Diller and Kaserer, 2009).

These factors combine to suggest that large PE funds should lose when they invest in small companies. Therefore, this paper generates a model that predicts (1) large PE funds should earn lower returns on average; however, (2) large PE

[1] Similarly, Cumming and Dai (2011) show a *U*-shaped relationship between firm valuations and fund size.

funds especially lose (gain) when they invest in small (large) portfolio companies. Thus, investments in small companies should partially explain why large PE funds perform poorly.

Empirical results from a sample of 1,222 PE funds confirm the model's predictions. Large funds earn lower returns on average. They especially earn lower returns if they invest in small companies. However, they earn higher returns when they invest in large companies. Thus, investments in small companies are a key, but not necessarily sole, avenue of loss for large PE funds. This finding is economically significant. Large funds earn internal rates of return (IRRs) of 5.17%, whereas investments in the largest 25% of companies but only −2.98% when they invest in the smallest 25% of companies.

This paper makes a significant contribution to the literature. Prior literature documents a size effect in PE fund returns. However, it does not explain why the size effect exists. Thus, this paper's main contribution is to show how large PE funds destroy value. It provides a model to explain the relation between PE fund size, PE investment size, and PE returns. This helps explain why large PE funds might earn lower returns despite their competitive advantages. Furthermore, it provides additional empirical evidence of the factors that influence the fund returns. This helps clarify the avenues of value creation (or destruction) for PE funds.

The paper also makes some collateral contributions. (1) I show that this size effect exists for both buyout funds and venture funds. (2) I document the factors that influence a fund's investment size. (3) I provide a method to compute "proxy" PE fund fees when only anonymous fee data are available and document that such fees reduce IRRs, in a similar vein to Officer (2007). (4) I show a significant "state effect"; in particular, funds from California and New York have significantly higher returns.

The balance of this paper proceeds as follows. Section 2 outlines the theoretical model that predicts that large PE funds should earn lower returns when they invest in small companies. Section 3 contains empirical results that support these predictions. Section 4 concludes that large PE funds earn lower returns and that this is at least partially due to suboptimal investments in small companies.

2. Why Might Large Funds Earn Lower Returns When They Invest in Small Companies?

This section outlines an argument for why large PE funds might lose when they invest in small companies. The model results rely on three key assumptions. The assumptions may not hold for all PE firms but should hold on average. To the extent that the assumptions are arguable, the empirical section, which tests model, implicitly tests these assumptions.

First, small funds invest before large funds. The rationale is that capital constraints prevent small funds from investing in large companies and are more geographically constrained. Thus, have a smaller set of investments to analyze. This focus gives a first-mover advantage. This should enable competitive small funds to drive up the returns earned on small investments to an equilibrium level.

Second, small funds have a lower cost structure when investing in small companies. The rationale is that small funds have fewer fixed overheads. Furthermore, due to lower free cash flow and cash holdings, they are less likely to engage in Jensen (1986) and Harford (1999) type value destruction. This quadrates with the implication from Moeller, Schlingemann, and Stulz (2004) that large corporations are more likely to have agency conflicts and make value-destroying investments.

Third, small funds are more likely to "nurture" start-up and seed companies. The rationale is that large PE funds have fewer staff per investment. This implies that large funds are less able to contribute management expertise. Furthermore, if large funds act do on agency conflicts of free cash flows, then the fund likely has agency conflicts. These agency conflicts indicate that the fund might not generate value in the invested company.

It is important to acknowledge that some aspects of large funds might reduce small funds' advantages. Large funds do have some advantages. Large funds may have market power and this may ameliorate the small fund's first-mover advantage. Furthermore, large funds may be better connected. These connections can drive-down costs (Hellman, Lindsey, and Puri, 2008) and can improve IPO returns (following Kaplan and Schoar, 2005; Nahata, 2009). However, these are not directly related to nurturing or managerial expertise. Thus, these assumptions may be contentious. However, empirical tests analyze the model and thus implicitly test the model's assumptions.

The modeling section proceeds as follows: Section 2.1 outlines the model and Section 2.2 solves the model.

2.1 SETUP

There are two classes of PE fund. First, there is a "large" or "big" fund (denoted "B"). Second, there is a small fund (denoted "S"). There is sufficient competition within these classes such that the firm's returns tend toward an "equilibrium" or a "reserve" return (consistent with Trester, 1993; Keuschnigg, 2003; Riyanto and Schweinbacher, 2006).

The market is segmented such that there are two classes of PE investment. First, there are large safe investments in the set $\mathcal{Y} = \{y_1, \ldots, y_n\}$. Second, there are small but risky investments in the set $\mathcal{X} = \{x_1, \ldots, x_m\}$. The big fund can invest in both

$\mathcal{X}$-type assets and $\mathcal{Y}$-type assets. However, the small fund is capital constrained and cannot afford to invest in large $\mathcal{Y}$-type investments. This quadrates with evidence of capital constraints in the PE and venture capital (VC) sectors (see, e.g., Gompers and Lerner, 1997; Pissarides, 1999; Di Gregorio and Shane, 2003).[2] Furthermore, consistent with the capital-constraint literature, there are more profitable investment opportunities than there are funds willing to invest.

The returns on the large assets are normally distributed with the expected return vector μ_y and variance $\mathbf{y}^{\mathrm{T}}\Sigma_y\mathbf{y}$. But, there may be estimation error vis-à-vis the return vector and the variance matrix. Thus, while the assets have expected value μ_y, the measurement is between the lower bound $\underline{\mu}_y$ and the upper bound $\bar{\mu}_y$ and thus $\underline{\mu}_y \leq \mu_y \leq \bar{\mu}_y$. Furthermore, Σ_y is between the lower bound $\underline{\Sigma}_y$ and the upper bound $\bar{\Sigma}_y$. Similarly, the small assets are normally distributed with expected return vector μ_x and variance $\mathbf{x}^{\mathrm{T}}\Sigma_x\mathbf{x}$. Due to measurement error, $\underline{\mu}_x \leq \mu_x \leq \bar{\mu}_x$ and $\underline{\Sigma}_x \leq \Sigma_x \leq \Sigma_x$. This induces the uncertainty sets:

$$\mathcal{U}_x = \left\{\mu_x : \underline{\mu}_x \leq \mu_x \leq \bar{\mu}_x, \underline{\Sigma}_x \leq \Sigma_x \leq \bar{\Sigma}_x\right\} \tag{1}$$

$$\mathcal{U}_y = \left\{\mu_y : \underline{\mu}_y \leq \mu_y \leq \bar{\mu}_y, \underline{\Sigma}_y \leq \Sigma_y \leq \bar{\Sigma}_y\right\}. \tag{2}$$

The costs have three important traits. First, investing is costly in general. The cost vector for the small fund of investing in $\mathcal{X}$-type assets is $\mathbf{c}_x^{\mathrm{S}}$. There is no $\mathcal{Y}$-type vector since the small fund cannot invest in $\mathcal{Y}$-type assets. The cost vectors for the big fund are $\mathbf{c}_x^{\mathrm{B}}$ and $\mathbf{c}_y^{\mathrm{B}}$, reflecting investments in $\mathcal{X}$-type assets and $\mathcal{Y}$-type assets, respectively.

Second, investing is more costly for the large fund than it is for the small fund. This is because small funds have lower costs than do large funds due to their lower fixed overheads and tendency to build a specialized expertise (Gupta and Sapienza, 1992; Audretsch, 1998; Dimov, Shepherd, and Sutcliffe, 2007). Furthermore, due to lower free cash flows and cash holdings, they are less likely to experience Jensen (1986) and Harford (1999) type agency conflicts.

Third, large funds benefit from economies of scale, so have lower per unit costs when investing in large assets. A key competitive advantage is the ability to utilize their reputation to reduce financing costs (following Demiroglu and James, 2010). This is especially important for large deals that are costly.

Overall, this means that the costs are such that $c_{x_i}^{\mathrm{S}} < c_{y_j}^{\mathrm{B}} < c_{x_i}^{\mathrm{B}}$ for all $\mathcal{Y}_j \in \mathcal{Y}$ and $x_i \in x$. In words, (1) small funds have the lowest cost, and this arises for investments in

[2] The data, presented in Section 3.1, also suggest that small funds avoid investing in large firms. The results in "Do large funds invest in large companies?" section confirm that small funds are significantly less likely to invest in large companies.

$\mathcal{X}$-type assets. (2) Large funds have higher costs than small funds do. (3) For large funds, the cost of investing in $\mathcal{X}$-type assets is higher than it is for $\mathcal{Y}$-type assets since $\mathcal{Y}$-type assets allow the large fund to exploit economies of scale.

The return earned depends on the investment type and the fund type. For small $\mathcal{X}$-type investments, small funds earn higher returns than do large funds. This is because $\mathcal{X}$-type investments are small and rely on nurturing (following Cumming, Fleming, and Suchard, 2005; Bottazzi, Da Rin, and Hellmann, 2008; Hellman, Lindsey, and Puri, 2008; Ivanov and Xie, 2010). Large funds typically have fewer professionals per investment (Lopez-de Silanes, Phalippou, and Gottschalg, 2009; Cumming and Dai, 2011) and are less able to nurture.

The order of play is as follows. Preliminarily, nature sets the uncertainty sets $\mathcal{U}_x$ and $\mathcal{U}_y$. The small fund invests first since (1) it can invest only in $\mathcal{X}$-type assets, so has fewer assets to appraise and (2) smaller PE funds tend to focus more on nurturing and the use of specialist knowledge (Gupta and Sapienza, 1992; Audretsch, 1998; Dimov, Shepherd, and Sutcliffe, 2007). This specialist knowledge grants a first-mover advantage. The small funds invest in $\mathcal{X}$-type assets to generate the nonnegative vector of investments $\mathbf{x}^{\mathrm{S}}$. The total fund size is $[1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{S}}]$ and the total fund performance is $[\mu_x\mathbf{x}^{\mathrm{S}} - (\mathbf{c}_x^{\mathrm{S}})^{\mathrm{T}}\mathbf{x}^{\mathrm{S}}]$.

Furthermore, note that because the small funds are competitive, they will drive the return on asset $x_i \in \mathcal{X}$ to a "baseline," "reserve," or "equilibrium" return, denoted $\mu_{x_i}^{\mathrm{R}}$. This generates the vector of reserve returns, μ^{R}. But small firms have fewer staff, smaller premises, and lower overall costs (following Cumming, 2006). Thus, small funds are willing to accept lower returns than large funds are. Therefore, the reserve return is sufficiently low such that, for the large firm, the return on large investments always exceeds the return on small investments. Thus, for all $x_i \in \mathcal{X}$ and $y_j \in \mathcal{Y}$, $[\mu_{y_j}^{\mathrm{B}} - c_{y_j}^{\mathrm{B}}] > [\mu_{x_i}^{\mathrm{R}} - c_{x_i}^{\mathrm{B}}]$.

The large funds invest second. Large funds invest in a set of $\mathcal{X}$-type investments and a set of $\mathcal{Y}$-type investments, inducing investment vectors $\mathbf{x}^{\mathrm{B}}$ and $\mathbf{y}^{\mathrm{B}}$, respectively. These investments incur costs $\mathbf{c}_x^{\mathrm{B}}$ and $\mathbf{c}_y^{\mathrm{B}}$, respectively. For the big fund, type-$\mathcal{Y}$ investments are less costly than are type-$\mathcal{X}$ investments since the big fund typically focuses on large assets. Thus, $c_{y_i}^{\mathrm{B}} < c_{x_j}^{\mathrm{B}}$ for all $y_j \in \mathcal{Y}$ and $x_j \in \mathcal{X}$. The investment in each asset must be nonnegative. Thus, the fund has total size $[1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} + 1_y^{\mathrm{T}}\mathbf{y}^{\mathrm{B}}]$, where $\mathbf{1}_x$ and $\mathbf{1}_y$ are vectors of ones. The total performance is $[\mu 1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} - (\mathbf{c}_x^{\mathrm{B}})^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} + \mu 1_y^{\mathrm{T}}y - (\mathbf{c}_y^{\mathrm{B}})^{\mathrm{T}}\mathbf{y}^{\mathrm{B}}]$.

The compensation scheme is linear in the size of the fund and in the performance of the fund. This is standard practice in the PE industry (Kaplan and Schoar, 2005; Phalippou and Gottschalg, 2009).[3] However, the large PE fund has market power. Thus, it is able to extract superior compensation terms. The size-of-fund

[3] Data from Preqin Fund Terms Advisor confirm this. Information on this database is here: http://www.preqin.com/item/private-equity-fund-terms-advisor/1/1346.

compensation parameters are β^{S} and β^{B}, for the small and large funds, respectively. The performance compensation parameters are γ^{S} and γ^{B} for the small and large funds, respectively. The total compensation for the big and small funds is thus,

$$\text{Return to big} = \beta^{\mathrm{B}}[1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} + 1_y^{\mathrm{T}}y^{\mathrm{B}}] + \gamma^{\mathrm{B}}[\mu 1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} - (\mathbf{c}_x^{\mathrm{B}})^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} + \mu 1_y^{\mathrm{T}}y - (\mathbf{c}_y^{\mathrm{B}})^{\mathrm{T}}\mathbf{y}^{\mathrm{B}}]. \tag{3}$$

$$\text{Return to small} = \beta^{\mathrm{S}}1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{S}} + \gamma^{\mathrm{S}}[\mu 1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{S}} - (\mathbf{C}_x^{\mathrm{S}})^{\mathrm{T}}\mathbf{x}^{\mathrm{S}}]. \tag{4}$$

Here, β^{B} and β^{S} are the fund size compensation parameters and γ^{B} and γ^{S} are the performance compensation parameters. The terms μ_x and μ_y are the returns to the $\mathcal{X}$-type and $\mathcal{X}$-type investments, respectively. The vectors $\mathbf{x}^{\mathrm{B}}$ and $\mathbf{x}^{\mathrm{S}}$ are the investments in $\mathcal{X}$-type assets by the big and small fund, respectively. Similarly, $\mathbf{y}^{\mathrm{B}}$ and $\mathbf{y}^{\mathrm{S}}$ are the investments in $\mathcal{Y}$-type assets by the big and small fund, respectively. The vectors $\mathbf{c}_x^{\mathrm{B}}$, $\mathbf{c}_y^{\mathrm{B}}$, and $\mathbf{c}_x^{\mathrm{S}}$ are cost-vectors. Since the large firm has greater fixed overheads than the small firm does, the costs are such that $c_{x_i}^{\mathrm{S}} < c_{y_j}^{\mathrm{B}} < c_{x_i}^{\mathrm{S}}$ for all $y_j \in \mathcal{Y}$ and $x_i \in \mathcal{X}$

2.2 RESOLUTION

The resolution proceeds in several steps. The first step is to generate the objective function and constraints. Note that because the problem involves uncertainty sets, this is a robust optimization problem. The resolution of the robust aspect of the problem follows the approach in Tütüncü and Koenig (2004) and Cornuejols and Tütüncü (2007).

First, set the fund's objective function. The fund's objective is to maximize its compensation. The optimization procedure bases itself upon the portfolio optimization literature. Here, the big fund adjusts its investment parameters $\mathbf{x}^{\mathrm{B}}$ and $\mathbf{y}^{\mathrm{B}}$ in order to maximize its total compensation. The constraints are that (1) $\mathbf{x}^{\mathrm{B}}$ and $\mathbf{y}^{\mathrm{B}}$ are nonnegative, (2) the small fund earns at least its reservation utility, (3) the small fund's investment $\mathbf{x}^{\mathrm{S}}$ is nonnegative, and (4) the total investment in $\mathcal{X}$-type assets, and $\mathcal{Y}$-type assets is no greater than the total amount of available assets. This induces the robust optimization problem:

$$\begin{aligned} f = \max_{\mathbf{x},\mathbf{y}} \Bigg\{ \min_{\mu_x,\Sigma_x \in \mathcal{U}_x, \mu_y,\Sigma_y \in \mathcal{U}_y} & \beta\left[1_x^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} + 1_y^{\mathrm{T}}\mathbf{y}^{\mathrm{B}}\right] + \gamma\Big[\mu_x^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} + \mu_y^{\mathrm{T}}\mathbf{y}^{\mathrm{B}} - (\mathbf{c}_x^{\mathrm{B}})^{\mathrm{T}}\mathbf{x}^{\mathrm{B}} \\ & - (\mathbf{c}_y^{\mathrm{B}})^{\mathrm{T}}\mathbf{x}^{\mathrm{B}}\Big] - \frac{\theta}{2}(\mathbf{x}^{\mathrm{B}})^{\mathrm{T}}\Sigma_x\mathbf{x}^{\mathrm{B}} - \frac{\theta}{2}(\mathbf{y}^{\mathrm{B}})^{\mathrm{T}}\Sigma_y\mathbf{y}^{\mathrm{B}} \Bigg\} \end{aligned} \tag{5}$$

$$\text{s.t.} = \min_{\mu_x, \Sigma_x \in \mathcal{U}_x} \left\{ \gamma^{\text{S}} \left(\mu^{\text{S}} \mathbf{x}^{\text{S}} - \left(\mathbf{c}_x^{\text{S}} \right) \mathbf{x}^{\text{S}} \right) - \frac{\eta}{2} \left(\mathbf{x}^{\text{S}} \right)^{\text{T}} \Sigma_x \mathbf{x}^{\text{S}} \right\} \geq \left(\mu^{\text{R}} \right)^{\text{T}} \mathbf{x}^{\text{S}}. \quad (6)$$

$$\mathbf{x}^{\text{B}} + \mathbf{x}^{\text{S}} \leq \text{total}_{\text{x}}. \quad (7)$$

$$\mathbf{y}^{\text{B}} \leq \text{total}_y. \quad (8)$$

$$\mathbf{x}^{\text{B}}, \mathbf{y}^{\text{B}}, \mathbf{x}^{\text{S}} \geq 0. \quad (9)$$

Second, transform the robust problem into an ordinary quadratic problem. The transformation follows the approach in Tütüncü and Koenig (2004). Here, recognize that the big fund's objective function in Equation (5) is convex and the small fund's objective function, which is in the constraint in Equation (6), is convex. Thus, they both achieve a minimum at the set of values $\{\underline{\mu}_x, \underline{\mu}_y, \bar{\Sigma}_x, \bar{\Sigma}_y\}$. Thus, the reformulated optimization problem is as follows:

$$f = \max_{\mathbf{x},\mathbf{y}} \beta[1_x^{\text{T}} \mathbf{x}^{\text{B}} + 1_y^{\text{T}} \mathbf{y}^{\text{B}}] + \gamma[\underline{\mu}_x^{\text{T}} \mathbf{x}^{\text{B}} + \underline{\mu}_y^{\text{T}} \mathbf{y}^{\text{B}} - (\mathbf{c}_x^{\text{B}})^{\text{T}} \mathbf{x}^{\text{B}} + (\mathbf{c}_y^{\text{B}})^{\text{T}} \mathbf{x}^{\text{B}}] - \frac{\theta}{2} \left(\mathbf{x}^{\text{B}} \right)^{\text{T}} \bar{\Sigma}_x \mathbf{x}^{\text{B}} - \frac{\theta}{2} \left(\mathbf{y}^{\text{B}} \right)^{\text{T}} \bar{\Sigma}_y \mathbf{y}^{\text{B}}. \quad (10)$$

$$\text{s.t.} = \underline{\mu}^{\text{S}} \mathbf{x}^{\text{S}} - \frac{\eta}{2} \left(\mathbf{x}^{\text{S}} \right)^{\text{T}} \bar{\Sigma}_x \mathbf{x}^{\text{S}} - (\mathbf{c}_x^{\text{S}}) \mathbf{x}^{\text{S}} \geq \left(\mu^{\text{R}} \right)^{\text{T}} \mathbf{x}^{\text{S}}. \quad (11)$$

$$\mathbf{x}^{\text{B}} + \mathbf{x}^{\text{S}} \leq \text{total}_x. \quad (12)$$

$$\mathbf{y}^{\text{B}} \leq \text{total}_y. \quad (13)$$

$$\mathbf{x}^{\text{B}}, \mathbf{y}^{\text{B}}, \mathbf{x}^{\text{S}} \geq 0. \quad (14)$$

Third, recall that there is an oversupply of potential investments. Thus, the constraints in Equations (12) and (13) do not bind in the optimum.

Fourth, recall that the small funds are competitive. Thus, the small funds drive down the return on $\mathcal{X}$-type investments such that the marginal return on $\mathcal{X}$-type investments equals the reservation return (following Clark, 1940; Caplin and Nalebuff, 1991). Therefore, the amended optimization problem becomes

$$f = \max_{\mathbf{x},\mathbf{y}} \beta[1_x^{\text{T}} \mathbf{x}^{\text{B}} + 1_y^{\text{T}} \mathbf{y}^{\text{B}}] + \gamma[\left(\mu^{\text{R}} \right)^{\text{T}} \mathbf{x}^{\text{B}} + \underline{\mu}_y^{\text{T}} \mathbf{y}^{\text{B}} - (\mathbf{c}_x^{\text{B}})^{\text{T}} \mathbf{x}^{\text{B}} + (\mathbf{c}_y^{\text{B}})^{\text{T}} \mathbf{x}^{\text{B}}] - \frac{\theta}{2} \left(\mathbf{x}^{\text{B}} \right)^{\text{T}} \bar{\Sigma}_x \mathbf{x}^{\text{B}} - \frac{\theta}{2} \left(\mathbf{y}^{\text{B}} \right)^{\text{T}} \bar{\Sigma}_y \mathbf{y}^{\text{B}}. \quad (15)$$

$$\mathbf{x}^{\mathrm{B}}, \mathbf{y}^{\mathrm{B}}, \mathbf{x}^{\mathrm{S}} \geq 0. \tag{16}$$

Fifth, differentiate with respect to $\mathbf{x}^{\mathrm{B}}$ and $\mathbf{y}^{\mathrm{B}}$ to yield a $1 \times (m + n)$ row vector. Partition the vector into two row vectors: a $1 \times m$ vector that corresponds to the derivative with respect to the $\mathbf{x}$ assets and a $1 \times n$ vector that corresponds to the derivative with respect to the $\mathbf{y}$ assets. That is,

$$\left[\frac{\mathrm{d}f}{\mathrm{d}\mathbf{x}} \quad \frac{\mathrm{d}f}{\mathrm{d}\mathbf{y}}\right] = \left[\left(\beta 1_x^{\mathrm{T}} + \gamma\left(\mu^{\mathrm{R}}\right)^{\mathrm{T}} - \frac{\theta}{2}\bar{\Sigma}_x \mathbf{x}^{B} - \gamma^{B}\mathbf{c}_x\right)\left(\beta 1_y^{\mathrm{T}} + \gamma\underline{\mu}_y^{\mathrm{T}} - \frac{\theta}{2}\bar{\Sigma}_y \mathbf{y}^{\mathrm{B}} - \gamma^{\mathrm{B}}\mathbf{c}_y^{\mathrm{B}}\right)\right] \tag{17}$$

Sixth, examine the derivatives. Note that the big firm will invest in the assets that have the greatest derivative since these assets increase the return the most. To examine the returns on individual $\mathcal{X}$-type assets generate the indicator vector $\mathbf{e}_i$ of length m that has 1 in the ith entry and 0 elsewhere. Similarly, for $\mathcal{Y}$-type assets generate the indicator $\mathbf{f}_j$ that has 1 in the jth entry and 0 elsewhere. Now, denote the derivative for individual $\mathcal{X}$-type assets and $\mathcal{Y}$-type assets as $\mathrm{d}/\mathrm{d}x_i$ and $\mathrm{d}/\mathrm{d}y_j$, respectively. This induces the individual derivatives:

$$\frac{\mathrm{d}f}{\mathrm{d}x_i} = \mathbf{e}_i\left(\beta 1_x^{\mathrm{T}} + \gamma\left(\mu^{\mathrm{R}}\right)^{\mathrm{T}} - \frac{\theta}{2}\bar{\Sigma}_x \mathbf{x}^{\mathrm{B}} - \gamma^{\mathrm{B}}\mathbf{c}_x^{\mathrm{B}}\right) \tag{18}$$

$$\frac{\mathrm{d}f}{\mathrm{d}y_j} = \mathbf{f}_j\left(\beta 1_y^{\mathrm{T}} + \gamma\underline{\mu}_y^{\mathrm{T}} - \frac{\theta}{2}\bar{\Sigma}_y \mathbf{x}^{\mathrm{B}} - \gamma^{\mathrm{B}}\mathbf{c}_y^{\mathrm{B}}\right) \tag{19}$$

Seventh, recall the following: (1) For all assets $x_i \in \mathcal{X}$ and $y_j \in \mathcal{Y}$, the return earned on asset y_j exceeds the baseline (or reserve) return on x_i. That is, $(\mu_{y_j}) > (\mu_{x_i}^{\mathrm{R}})$. (2) For large funds, the per unit cost of investing in large assets is below that of investing in small assets. Thus, the cost y_j, denoted $c_{y_j}^{\mathrm{B}}$, is strictly below the cost of x_i, denoted $c_{x_i}^{\mathrm{B}}$, for all $y_j \in \mathcal{Y}$ and $x_i \in \mathcal{X}$. (3) The large assets are less risky than the small assets. Thus, $\mathbf{y}^{\mathrm{T}}\bar{\Sigma}_y\mathbf{y} < \mathbf{x}^{\mathrm{T}}\bar{\Sigma}_x\mathbf{x}$. Now, this implies that $(\beta 1_y^{\mathrm{T}} + \gamma\underline{\mu}_y^{\mathrm{T}} - \frac{\theta}{2}\bar{\Sigma}_y\mathbf{x}^{\mathrm{B}} - \gamma^{\mathrm{B}}\mathbf{c}_y^{\mathrm{B}}) > (\beta 1_x^{\mathrm{T}} + \gamma(\mu^{\mathrm{R}})^{\mathrm{T}} - \frac{\theta}{2}\bar{\Sigma}_x\mathbf{x}^{\mathrm{B}} - \gamma^{\mathrm{B}}\mathbf{c}_x^{\mathrm{B}})$. Thus, (1) the big fund should prefer to invest in y-type assets to $\mathcal{X}$-type assets and (2) will only invest in $\mathcal{X}$-type assets if it consumes all profitable opportunities to invest in $\mathcal{Y}$-type assets. Therefore, it is the suboptimal investment in small companies that reduces large funds' returns.

To draw this together: this model predicts that (1) large funds should earn lower returns on average; however, (2) large firms will earn especially low returns if they invest in small companies and earn normal to high returns if they invest in large companies. Therefore, if a large fund invests in small companies, it should have

lower returns. Thus, suboptimal investments in small companies should partially, but not necessarily completely, explain that large funds perform worse than small funds do.

The issue is whether the empirical evidence supports this prediction that large funds earn lower returns and that this is especially so for investments in small companies. A collateral issue is to test the assumption that small (large) firms invest in small (large) companies on average (or in equilibrium). The remainder of the paper empirically tests these issues.

3. Empirical Analysis

This section contains the empirical analysis. Section details the data source, variables, and methodology. Section 3.2 contains the results. "Fund size and fund performance" section tests whether large funds earn lower returns in general. "Fund size, investment size, and returns" section examines whether investments in small companies might drive this result. "Examining buyout versus VC funds" section then examines if this result holds for both buyout and venture funds. "Do large funds invest in large companies?" section ensures that the assumption that large funds generally invest in large companies holds. "Robustness tests" section ensures that the results are robust to model specification issues.

3.1 METHODS AND MATERIALS

The goal is to examine whether large funds earn lower returns and whether this is especially the case for large funds that invest in small companies. I first broadly outline the empirical approach. Then, I detail the data sources and the variables. Table I summarizes the variables.

3.1.a Empirical approach

There are four over-arching issues: (1) do large funds earn lower returns, (2) how does the interaction of fund size and investment size influence returns, (3) does the relation hold for both venture and buyout funds, and (4) do large funds generally invest optimally by investing in large companies.[4]

I analyze the first three issues using a broadly similar model. The dependent variable is a measure of the fund's performance. The main control variables

[4] This is an issue because it is an implicit assumption of the model in Section 2.

Table I. Variable definitions

Variable	Definition
Fund size variables	
Fund Size	The total amount of capital that the fund raises, as reported by Preqin.
1n(Fund Size)	The natural log of the fund's size (''fundSize'').
Investment size variables	
Investment Size	The average size of the fund's investments, as obtained from Thomson VentureXpert.
ln(Investment Size)	The natural log of the fund's average investment size (''investSize'').
1/ln(Investment Size)	The inverse of the natural log of the fund's average investment size.
Control variables	
Seed	A dummy variable that equals 1 if the firm states a preference for making ''seed'' investments, as reported in Preqin.
Expertise	The total claimed expertise. Calculate as follows: First, generate dummy variables that equal 1 if the firm claims to have expertise in (1) types of industry, (2) management, (3) marketing, (4) networking, (5) operations, (6) recruiting, (7) strategic direction, and (8) technical aspects. Second, sum these dummy variables to generate a claimed expertise index. The maximum is 7 (if the firm claims all types of expertise) and the minimum possible is 0 (if the firm claims no type of expertise).
Connections	A measure of the firm's total connections. Calculate as follows. First, from Preqin, identify the managers of a given firm. Second, count the number of funds that each employee has previously been a part of. Sum all these appearances. Third, from Execucomp, identify if the fund's mangers have been, or are, members of publicly listed boards. Sum these appearances. Fourth, sum the appearances in Execucomp and in Preqin. This is the connections index.
Board Rep Required	A dummy that equals 1 if Preqin reports the firm requires board representation.
Prefers Controlling Shares	A dummy that equals 1 if Preqin reports that the firm prefers a controlling shareholding in the portfolio company.
Solo Investor	A dummy that equals 1 if Preqin reports that the firm prefers to be a sole investor in the portfolio company.
Market Return	The return earned on the market over the year before the fund initiated fund raising. The market return is the return on the Center for Research in Security Prices equally weighted index.
Crowded PE Market	The number of funds of a particular type that exist in a given year divided by the total number of PE funds. The ''types'' defined in Preqin are balanced, buyout, coinvestment, subsidiary, distressed, early stage, seed, start-up, expansion, fund-of-funds, infrastructure, late stage, mezzanine, resources, real estate, secondaries, ''special situation,'' venture, and venture debt.
Num Inds	The number of industries in which the PE fund invests.
ln(Num Inds)	The natural log of the number of industries in which the fund invests.
Num Geos	The number of geographic regions in which the PE fund will invest.
ln(Num Geos)	The natural log of the number of geographic regions in which the PE fund will invest.
Stage Drift	An indicator that equals 1 if the fund indicates that it will invest in a particular ''stage'' (early, expansion, late, or other) of investment and it invests outside that stage.
Proxy Base Fee	The average base fee charged by funds in the subject fund's size range and buyout versus venture category. The buyout/venture category is an indicator that equals 1 if the fund invests in buyout or late-stage investments and equals 0 otherwise. There are seven size ranges: 0–50 m, 50–100 m, 100–250 m, 250–500 m, 500–1,000 m, 1,000–2,000 m, and >2,000 m.
Proxy Performance Fee	The average performance fee charged by funds in the subject fund's size range and buyout versus venture category.

(*Continued*)

Table I. (Continued)

Variable	Definition
State Dummies	These are indicators that equal 1 if the fund is based in California (CA), New York (NY), or Washington (WA)
Fund Sequence	The number of prior funds in the fund's sequence that have raised capital prior to the present fund.
Bubble Dummy	An indicator that equals 1 if the fund's vintage is from 1999 to 2000.

represent the fund's size and a measure of the "smallness" of the fund's investments. This induces a model of the form:

$$\text{Performance} = f(\text{Fund Size}, \text{Inverse Investment Size}, \text{Fund Size} \times \text{Inverse Investment Size}, \text{Controls}). \quad (20)$$

Here, "Performance" is the measure of fund performance (the IRR or exit multiple), "Fund Size" is the natural log of the fund's size, "Inverse Investment Size" is the inverse of the natural log of the average investment size, and "Controls" denotes the set of control variables. I use the inverse of the investment size in order to capture the impact of investing in "small" companies. Estimation is by ordinary least square (OLS). The models use robust standard errors and vintage (year of genesis) fixed effects.[5] I estimate the models for the full sample and for subsamples of buyout and venture funds.

I analyze whether large funds invest in large companies by using three key classes of model: (1) logit models where the dependent variables is an indicator that equals 1 if the fund's average investment size is in the bottom 25% or top 25% of the sample, (2) ordered logit model with a categorical dependent variable that is the size quartile of the fund's investments, and (3) an OLS model where the dependent variable is the natural log of the fund's average investment size. The generic form of the model is below.

$$\text{Investment Size Variable} = f(\text{Fund Size}, \text{Controls}). \quad (21)$$

The following sections detail the data source and further define the variables. Table I summarizes them.

[5] The results are robust to clustering technique, holding in models that cluster by fund region or by preferred investment type.

3.1.b Data source

The data are from Preqin, Thomson VentureXpert, and Execucomp. The performance data are from the Preqin "Performance Analyst" database. The Preqin "Fund Manager Profiles" database contains information on fund managers' prior PE positions. It also contains information on fund managers' preferences for board representation, shareholding, and syndication and the fund's claimed expertise.[6] Preqin's "Fund Terms" database contains anonymous data on fund fees. Execucomp contains members of the board of directors of publicly listed companies. This is useful for checking whether employees in the PE fund also serve on the board of a publicly listed company. Thomson VentureXpert contains data on the size of the companies in which the fund invests. The sample only contains funds that invest in the USA.

The total sample contains 1,222 fund PE funds. The sample only includes funds that raised capital after 1985 and excludes funds that are involved in distressed debt, infrastructure, or public–private partnerships.

The main analysis does not directly distinguish between "venture" and "buyout" funds. Instead, it distinguishes between "venture" and "buyout" funds by examining the "characteristics" of the fund, not a simplistic classification of a fund as "venture" or "buyout." The rationale is that there is no bright-line distinction between "buyout" funds and "venture funds." Importantly, large "buyout funds" can and do invest in small venture investments. Thus, the characteristics of the fund are the important distinguishing factors. These include the desire to syndicate and the use of connections. Nonetheless, I do examine whether the results hold for both buyout and VC investments. I code a fund as a "VC" fund if it Preqin statues that it makes venture or early-stage investments. I classify a fund as a buyout fund if Preqin explicitly states that it is a buyout fund or if Preqin classes it as making late-stage investments. These groups are mutually exclusive. There are 632 VC funds and 590 buyout funds.[7]

3.1.c Performance variables

The two performance variables are the fund's IRR and its liquidation multiple (following Phalippou and Gottschalg, 2009). These come from Preqin. I note that there are alternative measures of returns. These include the proportion of successful IPO exits (Cumming, Fleming, and Schwienbacher, 2009; Hege, Palomino, and Schwienbacher, 2009). However, these alternative measures should logically factor into the fund's final IRR and multiple.

[6] Preqin records claims of expertise in financing, particular industries, management, marketing, networking, operations, recruiting, strategy, and technical matters.

[7] The "buyout" and "VC" definitions are robust to restricting the classification to requiring that Preqin classify the fund as "venture" or "buyout" only.

3.1.d Size variables

The measure of the fund's size is the total amount of capital that the fund raises (Fund Size), as reported by Preqin. Regression models control for the natural log of the fund size (ln(Fund Size)). The measure of the fund's investment size is the average size of the firms in which the fund invests (Investment Size), as derived from Thomson VentureXpert. I also examine Fund Size, and Investment Size, quartiles.[8] The main models control for the inverse of the natural log of the investment size (1/ln(Investment Size)). This is because the goal is to examine the relation between large funds and small companies.

3.1.e Control variables

The control variables are factors that might explain the relationship between the fund's size and its returns.[9] The control variables come in several categories.

Type and size of investment. The model "Seed," which is a dummy variable that equals 1 if the fund self-reports a desire to invest in seed companies. Prior evidence documents kurtosis in the expected value of seed investments (Korteweg and Sorensen, 2009). Thus, while the preference to invest in seed companies might influence investment returns, the sign of the influence is unclear.

Claimed expertise. The models control for the fund's claimed expertise. Prior literature reports that funds can earn returns by either cherry picking strong companies or adding value to weak companies (Ber and Yafeh, 2004; de Bettignies and Brander, 2007; Ivanov and Xie, 2010). This applies especially to investments in small companies, which generate the most value if the manager adds "value" or "expertise" (Gomez-Mejia, Balkin, and Welbourne, 1990; Gans and Stern, 2003). Thus, if the fund claims expertise across more areas, then it should be more able to add value and thus should generate higher returns. Preqin reports claims of expertise in (1) types of industry, (2) management, (3) marketing, (4) networking, (5) operations, (6) recruiting, (7) strategic direction, and (8) technical aspects. The model generates a dummy variable for each of these and then sums them to obtain "Expertise," an index of the claims of expertise.

[8] The results using fund size and investment size quartiles yield similar results to models that use continuous variables and are omitted for brevity. Also, given that many portfolio companies are small, I measure investment size in thousands and fund size in millions.

[9] I note that data limitations make it impossible to control for all factors that might influence PE funds' returns. For example, I lack data on the funds' covenants (Gompers and Lerner, 1996), institutional investors (see Lerner, Schoar, and Wong, 2007), or bargaining power (see Cumming, 2008; Cumming and Johan, 2008).

Connections. The model controls for how "connected" the fund manager is. Bygrave (1988) and Hochberg, Ljungqvist, and Lu (2007) report that fund managers generate higher returns if they are more "connected," as proxied by being involved in more coinvestments with other firms. Connected funds are more likely to invest in small companies (Saxenian and Li, 2003). Connections appear important for executing large cross-border deals (Saxenian and Hsu, 2001), raising debt (Shane and Cable, 2002), certifying IPO quality (Megginson and Weiss, 1991), and timing IPOs (Wang, Wang, and Lu, 2002; Giot and Schweinbacher, 2007). Thus, connections should increase investment returns.

The proxy for connections derives from Preqin and Execucomp. Two sources of connections are sitting on the board of directors of listed companies and being associated with other PE funds. Preqin reports the employees who work at a fund. Execucomp reports the people who sit on a board of directors. For a given fund, the "Connections" variable is the sum of (1) the number of prior funds an employee has been in and (2) the number of boards on which an employee has sat.

Preferred board representation. VC-backed board members can monitor entrepreneurs (Barry *et al.*, 1990) and assist with strategy (MacMillan, Kulow, and Khoylian, 1988). Increased involvement in a portfolio company should increase its performance (Zahra and Pearce, 1989; Fried, Bruton, and Hisrich, 1998). Preqin reports whether a fund "requires" board representation. Thus, the variable "Board Rep Required" equals 1 if the fund requires board representation.

Preferred syndicate role. Involvement in investment syndicates can generate value by improving capital raising (following Lockett and Wright, 2001), sharing expertise (Bygrave, 1987), and improving investment screening (Lerner, 1994; Casamatta and Haritchabalet, 2007). Thus, the models include "Solo Investor," a dummy that equals 1 if the fund states a desire to be a sole investor in its companies.

Preferred shareholding. Firms that prefer to hold shares in the portfolio company should earn higher returns. First, small companies with greater research and development intensity require more monitoring (Gompers, 1995). Large stock holdings can facilitate monitoring (Edmans, 2009).

Second, entrepreneurial growth coupled with equity investment is one key source of returns for PE firms and venture capitalists (Wright *et al.*, 2000). Corroborating this is evidence that funds actively involve themselves in the IPO process and often maintain equity positions after the issue (Barry *et al.*, 1990). Thus, shareholdings should provide returns for PE funds. Thus, the models include "Prefers Controlling Shares," an indicator that equals 1 if Preqin reports a preference for holding a controlling shareholding.

PE and general market conditions. The conditions in the general market might influence returns, but the prediction is ambiguous. One possibility is that poor market conditions correlate with a "flight to quality" or a movement away from highly speculative investments (following Caballero and Krishnamurthy, 2007). This might depress fund returns. However, Diller and Kaserer (2009) find a negative correlation between market returns and fund returns. This implies that strong market returns encourage excess investment in PE funds. This excess investment induces overcrowding, which might reduce fund returns. Thus, the models include "Market Return," which is the return earned on the market over the year before the fund initiated fund raising.[10] Furthermore, to control for the possibility of overcrowding in a particular PE sector, the models include "Crowded PE Market," which is the number of funds of a particular type that exist in a given year divided by the total number of PE funds.[11]

Diversification variables. Diversification might influence returns. Arguably, diversification might reduce returns by reducing the fund's risk and allowing PE managers to shirk (following Amihud and Lev, 1981). Supporting this, Moeller and Schlingemann (2005) find that the market reacts negatively to takeovers that diversify across industry or geographic region.

PE funds, in contrast to other firms, might benefit from diversification for several reasons. First, PE funds typically invest in firms that are high risk. Some reduction in this risk might reduce managerial risk aversion and thus encourage value creation (Aron, 1988; Humphery-Jenner, 2011). Second, debt financing is important for PE funds (DeAngelo and DeAngelo, 1987; Colla, Ippolito, and Wagner, 2010; Demiroglu and James, 2010). Reducing the riskiness of cash flows might improve debt terms. Third, the returns on PE investments are positively skewed (Lossen, 2006), with a high variance (Diller and Kaserer, 2009). This suggests that diversification might be more beneficial for PE funds than for other firms.

The models control for diversification by using two variables. First, the models include "ln(Num Geos)," the natural log of the number of geographic regions in which the PE fund invests. Second, the models include "ln(Num Inds)," the natural log of the number of industries in which the PE fund invests.

[10] Cumming, Fleming, and Schwienbacher (2009) also control for returns earned during the period of investment. The results are robust to doing so. However, given that the (1) fund does not exit all investments at the same time and (2) the regressions are at a fund level, introducing investment period returns might induce inaccuracies.

[11] The "types" defined in Preqin are balanced, buyout, coinvestment, subsidiary, distressed, early stage, seed, start-up, expansion, fund-of-funds, infrastructure, late stage, mezzanine, resources, real estate, secondaries, "special situation," venture, and venture debt.

Investment stage drift. Cumming, Fleming, and Schwienbacher (2009) highlight the importance of "style (stage) drift" to PE fund returns. They focus on the business stage (i.e., start up, expansion, or late) of the fund's portfolio companies. They classify a fund as a drifting fund if it invests in a company whose stage is outside of the fund's stated focus. I take a similar approach. I define portfolio companies as being "early," "expansion," "late," or "other" stage and define the fund's stage focus similarly. A fund is a "drifting" fund if it is not a generalist fund and it makes an investment outside its stated stage focus. These data are from Thomson VentureXpert. The main point of difference from the approach in Cumming, Fleming, and Schwienbacher (2009) is that I do not restrict the sample to first-round investments or to specialist funds. Logically, this means that the present sample comprises more drifting funds.

Fees. High fees should reduce the fund's performance. Fees typically comprise (1) a fixed component charged on the funds under management and (2) a performance component (Korteweg and Sorensen, 2009; Phalippou and Gottschalg, 2009; Metrick and Yasuda, 2011). Phalippou and Gottschalg (2009) suggest that fixed management fees reduce returns more than performance fees do. Neither Thomson VentureXpert nor Preqin provide fee data for individual funds. However, Preqin's Fund Terms database provides anonymous fee data by fund type and fund size range. Thus, I compute the "proxy base" and "proxy performance" fee as the average base or performance fee for the fund's size range and type (either buyout or venture).[12] This has the side advantage of ameliorating fears of endogeneity between returns and fees.

PE fund state. The state in which the PE fund operates may influence returns. Prior literature suggests that VC can agglomerate in regional clusters and that this can influence returns (see, e.g., Folta, Cooper, and Baik, 2006; Gilbert, McDougall, and Audretsch, 2008). I control for this by including dummy variables that equal 1 if the fund is based in California (CA), Washington (WA), or New York (NY).[13]

Fund sequence. The fund's "sequence" might influence returns. Firms sometimes raise funds in a sequence. A fund can be the first fund in a sequence, a follow-on fund, or a fund that is not part of a sequence. Cumming, Fleming, and Schwienbacher (2009) show that later sequence funds tend to perform better,

[12] This is similar in approach to the method used to compute "proxy premiums" for takeover targets (see Officer, 2007; Humphery-Jenner and Powell, 2011).

[13] I also estimate models that include state dummies. The results vis-à-vis the fund size–investment size relation are stronger in these models.

as proxied by the number of successful IPO exits. Thus, I control for the number of prior funds raised prior to the present fund, as listed in Thomson VentureXpert.

Bubble dummy. The high-tech bubble period between 1999 and 2000 may be a period of skewed PE returns (following Cumming, Fleming, and Schwienbacher, 2006). Thus, the "Bubble Dummy" is an indicator that equals 1 if the fund's vintage is during the period of 1999–2000 (consistent with Armour and Cumming, 2006).

3.2 RESULTS

This section contains the results. There are four key analyses: (1) the relation between fund size and returns; (2) the joint relation between fund size, investment size, and returns; (3) whether the relation holds for buyout and venture funds; and

Table II. Number of funds by vintage

Year	All	Average fund size (USD 2008 m)	Average investment size (USD 2008 m)
1985	10	122.00	15.29
1986	11	175.29	51.72
1987	20	241.88	33.90
1988	12	203.33	17.88
1989	24	392.38	40.14
1990	17	174.79	17.01
1991	10	285.64	17.23
1992	21	246.50	14.27
1993	30	271.74	22.08
1994	44	310.59	30.26
1995	39	461.20	29.54
1996	44	430.20	21.31
1997	66	468.04	18.26
1998	82	593.63	22.93
1999	98	676.21	21.84
2000	136	847.37	15.67
2001	75	603.26	16.94
2002	61	493.63	16.14
2003	56	527.12	17.58
2004	69	554.66	15.44
2005	92	850.40	20.85
2006	112	1,065.89	20.16
2007	93	1,055.76	14.75
Total	1,222	11,051.52	511.21

(4) whether large funds optimally invest in large companies in general.

3.2.a Fund size and fund performance

Univariate analysis. Table II contains the number of funds by vintage, defined as the year in which the fund began raising capital. The number of funds increases over time, reflecting both improvements in data quality and growth in the PE sector. The number spikes around 1998–2000, likely reflecting the tech bubble. The number surges again in 2005 and 2006, likely reflecting the positive market conditions at the time. This confirms the desirability of including the "bubble" period indicator.

Table III contains univariate statistics for funds sorted by size sorted into subsamples of funds whose assets are in the top 25%, top 50%, bottom 75%, or bottom 50% of the sample. The key univariate finding is that larger funds have significantly lower IRRs and multiples (at 1% significance). Furthermore, large funds are significantly more likely to invest in large portfolio companies to claim high levels of expertise. Additionally, large PE funds invest in significantly more geographic regions and industries than do small funds. That is, large PE funds are more diversified. Conversely, large funds are significantly less likely to invest in a "crowded" PE type.[14] These results suggest that large funds earn lower returns, but it is necessary to control for fund characteristics when analyzing these returns.

Figure 1 contains the average fund IRR and exit multiple for fund size deciles. Panel (a) examines IRRs. Panel (b) examines multiples. The figures suggest that larger funds earn lower IRRs and have lower multiples. Nonetheless, the statistics in Table III reveal significant differences between the characteristics of large and small funds. The regression results control for these differences.

Table IV contains the correlation statistics. The correlations indicate that several fund-level factors might influence IRRs and multiples. Fund size is negatively correlated with returns, whereas investment size is positively correlated with returns. Furthermore, the correlation statistics show that several explanatory variables are correlated with one another. While this suggests that multicollinearity may be an issue, no regression variance inflation factor (VIF) statistic exceeds 2 and the results hold in principal components regressions that condense the explanatory variables into orthogonal factors.

Table V contains results for regressions that examine the relation between fund size and fund performance (as proxied by the IRR or exit multiple). The fund size measures are the natural log of the fund's size (ln(Fund Size)) and indicators that equal 1 if the fund's size is in the top 25% or 50% of the sample. Here, the coefficient on fund size is significant and negative in all models and for both performance measures.

[14] I note that this sample comprises more "drifting" funds than does the sample in Cumming, Fleming, and Schwienbacher (2009). This reflects the fact that their sample focused on first-round investments, whereas the present sample comprises all investment rounds.

Table III. Univariate statistics by fund size

This table contains univariate statistics. Column 1 contains all funds. Column 2 (Column 5) contains average values for funds whose size is in the top 25% (top 75%) of all funds. Conversely, Column 3 (Column 6) contains average values for funds whose size is in the top 50% (bottom 50%) of all firms. Columns 4 and 7 contain the differences between Columns 2 and 3 and Columns 5 and 6, respectively. ***, **, and * denote significance at 1%, 5%, and 10%, respectively, using a *t* test for means or a two-sample *t* test for difference in means.

	All (1)	Fund top 25% (2)	Fund bottom 75% (3)	Difference (4 = 2 − 3)	Fund top 50% (5)	Fund bottom 50% (6)	Difference (7 = 5 −6)
IRR	0.100***	0.043	0.119***	−0.075***	0.051***	0.147***	−0.096***
Multiple	1.680***	1.262	1.822***	−0.560***	1.282***	2.068***	−0.786***
Fund Size	625.377***	1,906.205***	202.813***	1,703.392***	1,156.021***	116.118***	1,039.903***
Investment Size	16.633***	36.189***	10.181***	26.008***	25.147***	8.461***	16.685***
Seed	0.071***	0.026***	0.085***	−0.060***	0.058***	0.083***	−0.025*
Expertise	3.694***	4.212***	3.523***	0.689***	4.009***	3.392***	0.617***
Connections	2.455***	3.826***	2.003***	1.824***	0.971***	1.960***	1.011***
Board Rep Required	0.387***	0.425***	0.374***	0.051*	0.430***	0.345***	0.085***
Prefers Controlling Shares	0.129***	0.218***	0.099***	0.118***	0.169***	0.089***	0.080***
Solo	0.179***	0.176***	0.179***	−0.003	0.184***	0.174***	0.010
Market Return	0.161***	0.153***	0.164***	−0.010	0.152***	0.170***	−0.017
Crowded PE Market	0.170***	0.159*	0.174***	−0.015*	0.159***	0.181***	−0.022***
Num Inds	12.394***	13.529***	12.020***	1.509***	13.207***	11.613***	1.594***
Num Goes	5.639***	7.832***	4.915***	2.916***	6.508***	4.805***	1.703***
Stage Drift	0.719***	0.539***	0.773***	−0.234***	0.625***	0.810***	−0.185****
Proxy Base fee	2.178***	1.951***	2.246***	−0.294***	2.117***	2.236***	−0.119***
Proxy Performance Fee	20.166***	20.923***	19.938***	0.984***	20.626***	19,722***	0.904***
NY	0.191***	0.355***	0.141***	0.213***	0.272***	0.113***	0.159***
CA	0.255***	0.206***	0.269***	−0.063**	0.233***	0.275***	−0.042*
WA	0.017***	0.000	0.022***	−0.022**	0.007**	0.027***	−0.021***
Fund Sequence	4.048***	5.851***	3.507***	2.344***	4.928***	3.199***	1.729***
Bubble Dummy	0.061***	0.078***	0.056***	0.022	0.070**	0.053***	0.017

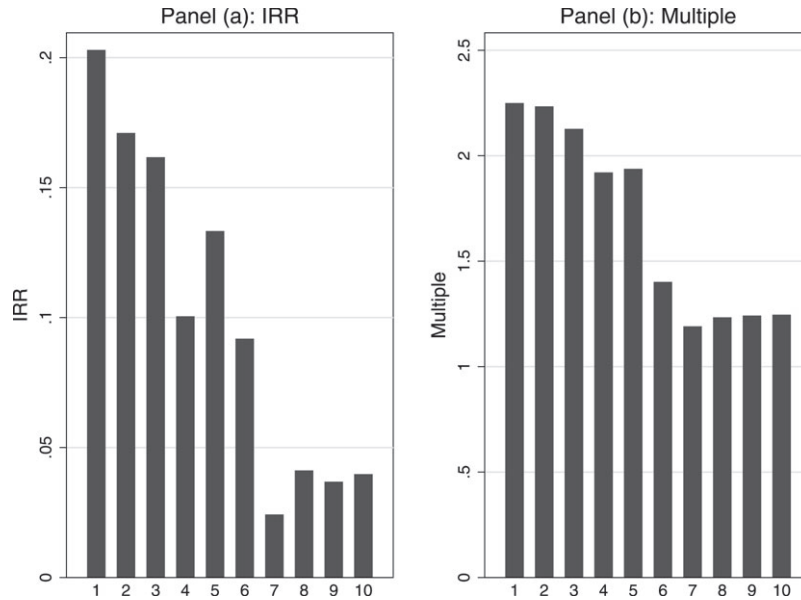


Figure 1. Fund IRR and exit multiple by fund size decile. This figure contains the average fund IRR and exit multiple for each decile of fund size. Group 1 represents the smallest fund size. Group 10 represents the largest fund size. Panel (a) examines the fund's IRR. Panel (b) examines the exit multiple.

Other notable results are as follows: First, the fund's expertise increases its returns. This supports the theory that funds add value to their companies on average (following Gomez-Mejia, Balkin and Welbourne, 1990; Gans and Stern, 2003). Second, diversification across industry and geographic region improves IRRs and multiples (consistent with Humphery-Jenner, 2010). This suggests that diversification might benefit PE funds either by improving financing terms or by ameliorating managerial risk aversion. Third, fees reduce performance (supporting Phalippou and Gottschalg, 2009). Fourth, the fund's state is important. For example, funds in California have higher returns, whereas funds from Washington have lower returns.[15]

These results are economically significant: the smallest 25% of funds in the sample earn IRRs of 14.7%, whereas the largest 25% earn IRRs of 4.57%. This highlights significant diseconomies of scale. Furthermore, a one standard deviation

[15] These results are robust to replacing the CA, WA, and NY dummies with dummies for all states that have PE funds (one of which is omitted to avoid perfect collinearity).

Table IV. Correlation statistics

This table contains pairwise correlation statistics. *p* Values are given in parentheses.

		A	B	C	D	E	F
A	ln(Fund Size)						
B	ln(Investment Size)	0.56 (0.00)					
C	Seed	−0.05 (0.06)	−0.09 (0.00)				
D	Expertise	0.23 (0.00)	0.27 (0.00)	0.04 (0.16)			
E	Connections	0.17 (0.00)	0.17 (0.00)	0.00 (0.90)	0.11 (0.00)		
F	Board Rep Required	0.11 (0.00)	0.16 ((0.00)	−0.03 (0.23)	0.24 (0.00)	−0.06 (0.03)	
G	Prefers Controlling Shares	0.18 (0.00)	0.18 (0.00)	−0.04 (0.13	0.18 (0.00)	0.12 (0.00)	0.24 (0.00)
H	Solo	0.04 (0.15)	−0.03 (0.37)	0.15 (0.00)	0.13 (0.00)	0.00 (0.88)	0.06 (0.03)
I	Market Return	0.01 (0.67)	−0.02 (0.58	0.01 (0.83)	−0.02 (0.47)	−0.02 (0.52)	0.01 (0.79)
J	Crowded PE Market	0.06 (0.03)	0.23 (0.00)	−0.13 (0.00)	0.12 (0.00)	0.04 (0.17)	0.12 (0.00)
K	ln(Num Inds)	0.13 (0.00)	0.12 (0.00)	0.06 (0.04)	0.25 (0.00)	0.08 (0.01)	0.12 (0.00)
L	ln(Num Geos)	0.20 (0.00)	0.14 (0.00)	0.03 (0.31)	0.15 (0.00)	0.07 (0.02)	0.00 (0.97)
M	Stage Drift	−0.24 (0.00)	−0.24 (0.00)	0.18 (0.00)	−0.05 (0.06)	−0.03 (0.36)	−0.11 (0.00)
N	Proxy Bae Fee	−0.38 (0.00)	−0.42 (0.00)	0.26 (0.00)	−0.08 (0.00)	−0.12 (0.00)	−0.15 (0.00)
O	Proxy Performance Fee	0.51 (0.00)	0.15 (0.00)	0.08 (0.01	0.11 (0.00)	0.08 (0.01)	−0.02 (0.59)
P	NY	0.25 (0.00)	0.31 (0.00)	−0.11 (0.00)	0.07 (0.01)	0.06 (0.02)	0.11 (0.00)
Q	CA	−0.05 (0.10)	−0.03 (0.27)	0.12 (0.00)	−0.02 (0.38)	−0.01 (0.69)	−0.14 (0.00)
R	WA	−0.12 (0.00)	−0.08 (0.00)	0.03 (0.34)	−0.05 (0.07)	−0.05 (0.10)	0.03 (0.33)
S	Fund Sequence	0.23 (0.00)	0.14 (0.00)	0.02 (0.55)	0.06 (0.04)	0.04 (0.14)	0.07 (0.02)
T	Bubble Dummy	0.03 (0.27)	−0.01 (0.82)	0.01 (0.79)	0.00 (0.91)	−0.02 (0.49)	−0.01 (0.71)

		G	H	I	J	K	L
I	Market Return	−0.02 (0.44)					
J	Crowded PE Market	0.00 (1.00)	−0.08 (0.00)				
K	ln(Num Inds)	0.12 (0.00)	−0.03 (0.30)	0.12 (0.00)			
L	ln(Num Geos)	0.03 (0.31)	−0.03 (0.29)	0.02 (0.50)	0.25 (0.00)		
M	Stage Drift	0.01 (0.86)	−0.01 (0.80)	−0.11 (0.00)	0.05 (0.09)	−0.03 (0.30)	
N	Proxy Base Fee	0.04 (0.14)	−0.03 (0.32)	−0.16 (0.00)	−0.02 (0.50)	−0.06 (0.05)	0.43 (0.00)
O	Proxy Performance Fee	0.05 (0.09)	−0.02 (0.54)	−0.07 (0.02)	0.09 (0.00)	0.12 (0.00)	0.04 (0.20)
P	NY	−0.06 (0.04)	0.01 (0.80)	0.09 (0.00)	0.00 (0.87)	0.03 (0.33)	−0.32 (0.00)
Q	CA	−0.01 (0.73)	0.00 (0.93)	−0.09 (0.00)	−0.08 (0.01)	−0.04 (0.12)	0.07 (0.01)
R	WA	0.02 (0.57)	0.01 (0.61)	−0.05 (0.07)	0.00 (0.95)	−0.03 (0.31)	0.07 (0.02)
S	Fund Sequence	0.07 (0.02)	−0.04 (0.21)	−0.03 (0.32)	0.10 (0.00)	0.27 (0.00)	−0.07 (0.01)
T	Bubble Dummy	0.01 (0.82)	−0.36 (0.00)	−0.06 (0.03)	0.02 (0.54)	−0.03 (0.26)	0.03 (0.28)

(*Continued*)

Table IV. (Continued)

		A	B	C	D	E	F
		M	N	O	P	Q	R
P	NY	0.02 (0.53)	1.00				
Q	CA	0.05 (0.06)	−0.28 (0.00)	1.00			
R	WA	−0.06 (0.03)	−0.06 (0.02)	−0.08 (0.01)	1.00		
S	Fund Sequence	0.06 (0.05)	0.04 (0.21)	−0.01 (0.79)	−0.01 (0.77)	1.00	
T	Bubble Dummy	0.07 (0.02)	−0.02 (0.49)	0.03 (0.28)	−0.01 (0.79)	0.02 (0.57)	1.00

increase in size reduces IRRs by 50% and multiples by 20%.[16] The issue is then whether investments in small companies can partially explain this result.

Fund size, investment size, and returns. The second key prediction is that large funds earn lower (higher) returns if they invest in small (large) companies.

Figure 2 fits a smoothed splinse to show the relationship between PE fund size, investment size, and IRRs. The figure shows that large funds earn lower returns than do small funds. The lowest returns accrue to large funds that invest in very small firms. Conversely, small funds earn higher returns on average. This appears to hold regardless of the investment size. However, it is important to note that few small funds make large investments; for example, only 1.16% of funds whose size is in the bottom 25% of the sample have an average investment size in the top 25% of the sample. These findings largely hold for both buyout and venture funds, with unreported graphs for venture and buyout funds having a similar shape. Nonetheless, it is important to control for other factors that might explain this relationship.

The regression models analyze the relation between fund size and returns, controlling for other factors that might influence returns.

Table VI contains the regression results. The key result is that the large funds earn lower returns when they invest in small companies; in Column 4, the interaction of "ln(Fund Size)" and "1/ln(Investment Size)" is negative and significant at 10% across both performance measures.[17]

Figure 3 supports the results. The graph plots the predicted IRR versus the fund's size, the inverse of the average investment size, and the interaction thereof. The results show a strong negative relationship between the fund size and the interaction

[16] I calculate these by multiplying the coefficient on "ln(Fund Size)" in Table V (−0.066) by the standard deviation of "ln(Fund Size)" (1.30) and dividing by the mean IRR (8.84%) or exit multiple (1.67).

[17] It is important to note that these results are unlikely to merely reflect a "risk premium" for investing in small companies. This is because large investments tend to perform better on average (at 1% significance in Table V). This implies that any relation between (1) large and small funds and (2) large and small investments is unlikely to merely reflect a size-based risk premium.

Table V. The relation between fund's size and its IRR

This table examines the relation between the PE fund's size and IRR that it earns. The dependent variable is the fund's IRR. The key size variable in Columns 1 is the natural log of the fund's size. The size variables in Columns 2–5 are dummies that equal 1 if the fund's size is in the top 25%, top 50%, lower 25%, or lower 50% of all funds, respectively. All models use robust standard errors clustered by fund vintage. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Size variable Dependent variable	ln(Fund Size) IRR	*I*(Size Top 25%) IRR	*I*(Size Top 50%) IRR	ln (Fund Size) Multiple	*I*(Size Top 25%) Multiple	*I*(Size Top 50%) Multiple
Size Variable	−0.066*** (0.000)	−0.083*** (0.000)	−0.094*** (0.000)	−0.538*** (0.000)	−0.566*** (0.000)	−0.887*** (0.000)
Seed	0.094** (0.013)	0.084** (0.028)	0.084** (0.027)	0.924** (0.012)	0.856** (0.021)	0.844** (0.021)
Expertise	0.012*** (0.002)	0.009** (0.018)	0.009** (0.012)	0.113*** (0.000)	0.093*** (0.004)	0.097*** (0.003)
Connections	0.002 (0.106)	0.002 (0.182)	0.002 (0.252)	0.017 (0.102)	0.013 (0.186)	0.012 (0.233)
Requires Board Rep	0.022 (0.163)	0.019 (0.224)	0.025 (0.113)	0.051 (0.643)	0.027 (0.810)	0.083 (0.452)
Prefers Controlling Shares	−0.012 (0.545)	−0.006 (0.754)	−0.006 (0.767)	−0.11 (0.371)	−0.067 (0.621)	−0.064 (0.632)
Solo Investor	0.012 (0.521)	0.008 (0.669)	0.007 (0.698)	0.131 (0.375)	0.099 (0.514)	0.097 (0.510)
Market Return	0.028 (0.445)	0.017 (0.649)	0.014 (0.706)	0.169 (0.514)	0.067 (0.802)	0.052 (0.844)
Crowded PE Market	0.288*** (0.000)	0.282*** (0.000)	0.266*** (0.000)	1.999*** (0.000)	1.993*** (0.000)	1.824*** (0.000)
ln(Num Inds)	0.047*** (0.000)	0.044*** (0.000)	0.049*** (0.000)	0.127 (0.197)	0.101 (0.312)	0.147 (0.141)
ln(Num Geos)	0.049*** (0.001)	0.048*** (0.001)	0.044*** (0.002)	0.461*** (0.001)	0.440*** (0.002)	0.430*** (0.001)
Stage Drift	0.023 (0.123)	0.025* (0.091)	0.016 (0.295)	0.107 (0.255)	0.124 (0.220)	0.038 (0.696)
Proxy Base Fee	−0.156*** (0.000)	−0.063* (0.053)	−0.038 (0.174)	−0.960*** (0.000)	−0.107 (0.620)	−0.064 (0.670)
Proxy Performance Fee	0.007 (0.251)	−0.026*** (0.001)	−0.023*** (0.000)	0.075 (0.236)	−0.216*** (0.000)	−0.139*** (0.000)
NY	0.037** (0.022)	0.023 (0.151)	0.028* (0.087)	0.157 (0.109)	0.035 (0.739)	0.094 (0.365)
CA	0.062*** (0.002)	0.057*** (0.005)	0.056*** (0.005)	0.437** (0.020)	0.382** (0.046)	0.386** (0.041)
WA	−0.152*** (0.000)	−0.126*** (0.003)	−0.135*** (0.002)	−0.903*** (0.000)	−0.690*** (0.000)	−0.774*** (0.000)
Fund Sequence	0.001 (0.377)	0 (0.859)	0 (0.993)	0.011 (0.206)	−0.001 (0.948)	0.002 (0.764)
Bubble Dummy	0.018 (0.489)	0.013 (0.638)	0.01 (0.718)	−0.167 (0.213)	−0.22 (0.106)	−0.233* (0.095)
Constant	0.299*** (0.002)	0.459*** (0.000)	0.359*** (0.001)	3.039*** (0.000)	4.505*** (0.000)	3.109*** (0.000)
Observations	1,222	1,222	1,222	1,192	1,192	1,192
R^2 (%)	13.50	10.30	11.50	12.40	8.80	11.10
F statistic	11.748*** (0.000)	8.394*** (0.000)	9.884*** (0.000)	7.864*** (0.000)	6.762*** (0.000)	7.993*** (0.000)

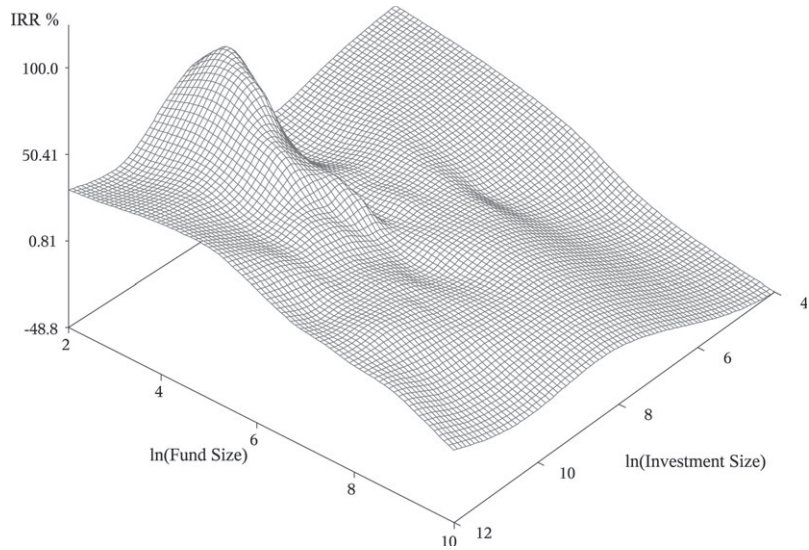


Figure 2. IRRs by fund size and investment size for all funds. This figure plots the relation between the fund's size (in USDm) and its average investment size (in USD'000). The data points are fitted values computed using a smoothed spline model.

of fund size and investment size. This supports the finding that large funds earn lower returns when they invest in small companies.

The overall finding is that large funds gain if they invest in large companies, but they lose if they invest in small companies. These results are economically significant. For the largest 25% of funds, investments in the largest 25% of companies earn average IRRs of 5.17%, whereas investments in the smallest 25% of companies earn IRRs of −2.98%. Supporting this, a one standard deviation increase in the size of "ln(Fund Size)/ln(Investment Size)" reduces IRRs by 52% and multiples by 19%.[18]

This implies that one explanation for large funds' poor performance is the suboptimal investment in small companies. The next issue is to examine whether these results hold for buyout and for venture funds.

Examining buyout versus VC funds. The two issues are (1) whether the relation between fund size and investment size differs between buyout and VC funds and (2) whether this influences returns.

[18] I calculate this by multiplying the coefficient on the interaction term in Table VI of Column 4 (−0.395) and Column 8 (−2.798) by the standard deviation of the interaction term (0.116) and dividing by the mean IRR (8.84%) or multiple (1.68). I note that this is an incomplete way of assessing economic significance because it does not explicitly account for the covariates; however, it provides an indication of the magnitude of the coefficient.

Table VI. Interaction regressions

This table uses continuous variables to examine investments by large funds in small companies. The dependent variable is the fund's IRR. The fund size variable is the natural log of the capital under management (in USDm). The small investment size variable is the inverse of the natural log of the fund's average investment size. All models use robust standard errors clustered by fund vintage. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Dependent variable	IRR	IRR	IRR	IRR	Multiple	Multiple	Multiple	Multiple
ln(Fund Size)	−0.066*** (0.000)		−0.078*** (0.000)	−0.040* (0.056)	−0.538*** (0.000)		−0.591*** (0.000)	−0.294** (0.047)
1/ln(Investment Size)		−1.830*** (0.000)	−3.081*** (0.000)	−1.559 (0.131)		−4.064 (0.126)	−13.480*** (0.000)	−1.486 (0.838)
ln(Fund Size) × 1/ln(Investment Size)				−0.395* (0.079)				−2.798* (0.063)
Seed	0.094** (0.013)	0.081** (0.037)	0.091** (0.015)	0.091** (0.015)	0.924** (0.012)	0.845** (0.024)	0.914** (0.013)	0.914** (0.013)
Expertise	0.012*** (0.002)	0.006* (0.097)	0.009** (0.014)	0.009** (0.017)	0.113*** (0.000)	0.083*** (0.009)	0.102*** (0.001)	0.102*** (0.001)
Connections	0.002 (0.106)	0.001 (0.346)	0.002 (0.178)	0.002 (0.216)	0.017 (0.102)	0.011 (0.283)	0.015 (0.139)	0.014 (0.168)
Requires Board Rep	0.022 (0.163)	0.018 (0.259)	0.018 (0.251)	0.017 (0.269)	0.051 (0.643)	0.029 (0.796)	0.033 (0.765)	0.03 (0.783)
Prefers Controlling Shares	−0.012 (0.545)	−0.001 (0.979)	−0.002 (0.905)	−0.004 (0.825)	−0.11 (0.371)	−0.06 (0.667)	−0.067 (0.589)	−0.091 (0.449)
Solo Investor	0.012 (0.521)	0.011 (0.558)	0.016 (0.362)	0.017 (0.334)	0.131 (0.375)	0.106 (0.486)	0.15 (0.310)	0.155 (0.292)
Market Return	0.028 (0.445)	0.014 (0.694)	0.029 (0.410)	0.03 (0.408)	0.169 (0.514)	0.048 (0.855)	0.172 (0.505)	0.179 (0.487)
Crowded PE Market	0.288*** (0.000)	0.240*** (0.000)	0.227*** (0.001)	0.217*** (0.001)	1.999*** (0.000)	1.884*** (0.000)	1.729*** (0.000)	1.689*** (0.000)
ln(Num Inds)	0.047*** (0.000)	0.044*** (0.000)	0.046*** (0.000)	0.047*** (0.000)	0.127 (0.197)	0.109 (0.275)	0.124 (0.209)	0.13 (0.187)
ln(Num Geos)	0.049*** (0.001)	0.040*** (0.006)	0.047*** (0.001)	0.046*** (0.001)	0.461*** (0.001)	0.397*** (0.003)	0.455*** (0.001)	0.449*** (0.001)
Stage Drift	0.023 (0.123)	0.02 (0.197)	0.019 (0.196)	0.019 (0.184)	0.107 (0.255)	0.096 (0.348)	0.09 (0.335)	0.101 (0.272)
Proxy Base Fee	−0.156*** (0.000)	0.045 (0.182)	−0.131*** (0.000)	−0.127*** (0.000)	−0.960*** (0.000)	0.479** (0.026)	−0.854*** (0.000)	−0.786*** (0.000)
Proxy Performance Fee	0.007 (0.251)	−0.049*** (0.000)	0.008 (0.191)	0.009 (0.112)	0.075 (0.236)	−0.346*** (0.000)	0.078 (0.212)	0.078 (0.201)
NY	0.037** (0.022)	0.006 (0.720)	0.019 (0.243)	0.017 (0.309)	0.157 (0.109)	−0.024 (0.817)	0.078 (0.411)	0.062 (0.519)
CA	0.062*** (0.002)	0.047** (0.021)	0.051*** (0.009)	0.052*** (0.008)	0.437** (0.020)	0.346* (0.069)	0.387** (0.038)	0.386** (0.039)
WA	−0.152*** (0.000)	−0.127*** (0.003)	−0.155*** (0.000)	−0.160*** (0.000)	−0.903*** (0.000)	−0.702*** (0.000)	−0.913*** (0.000)	−0.943*** (0.000)
Fund Sequence	0.001 (0.377)	−0.001 (0.435)	0.001 (0.507)	0.001 (0.463)	0.011 (0.206)	−0.004 (0.608)	0.01 (0.266)	0.01 (0.259)
Bubble Dummy	0.018 (0.489)	0.003 (0.896)	0.017 (0.501)	0.019 (0.475)	−0.167 (0.213)	−0.275** (0.042)	−0.172 (0.195)	−0.163 (0.220)
Constant	0.299*** (0.002)	0.912*** (0.000)	0.687*** (0.000)	0.506*** (0.000)	3.039*** (0.000)	6.355*** (0.000)	4.732*** (0.000)	3.307*** (0.003)
Observations	1,222	1,222	1,222	1,222	1,192	1,192	1,192	1,192
R^2	0.135	0.103	0.155	0.157	0.124	0.083	0.13	0.131
F statistic	11.748*** (0.000)	7.761*** (0.000)	12.126*** (0.000)	11.986*** (0.000)	7.864*** (0.000)	6.111*** (0.000)	7.448*** (0.000)	7.304*** (0.000)

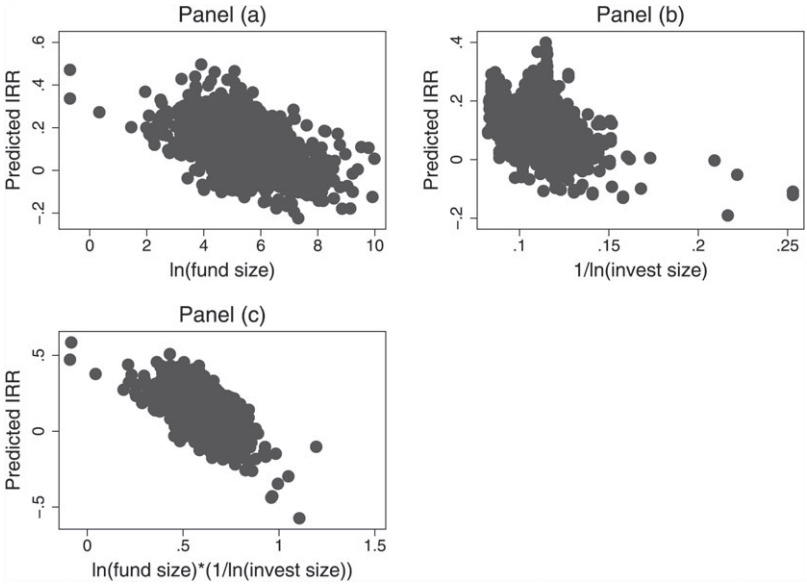


Figure 3. Fitted values plots. Panel (a) plots the predicted IRR from versus the natural log of the fund's size. Panel (b) plots the predicted IRR versus the inverse of the natural log of the average investment size. Panel (c) plots the predicted IRR versus the interaction of (1) the natural log of the fund's size with (2) the inverse of the natural log of the average investment size.

Table VIII contains univariate statistics. The statistics indicate that buyout funds are larger on average and make larger average investments, both significant at 1%. Figure 4 supports this; it suggests that buyout funds are larger and make larger investments. Furthermore, the scatter plot is similar in patter for buyout and VC funds, suggesting that the relationship between fund size and investment size is similar for both buyout and VC funds. Buyout funds have higher average IRRs and multiples; the average difference is insignificant, whereas the median difference is significant at 1%. This suggests some skewness in returns. Figure 5 contains kernel density plots for the IRRs. It confirms that IRRs are positively skewed for both buyout and VC funds, but they are more skewed for VC funds than for buyout funds. However, these results do not analyze the relation between returns, investment size, and fund size. Thus, multivariate results are necessary.

Table IX contains the multivariate results. The table suppresses control variables for brevity. It uses the same continuous variable specification as in Table VI. It analyzes subsamples of funds that are (1) buyout and late stage, (2) venture and early stage, (3) buyout only,[19] or (4) venture only. The key result is that the interaction term "lnFundSize × InvLnInvestSize" is negative and significant

[19] These models omit the "Seed" variable because it is a constant 0 for all observations.

in all models. Furthermore, supporting the previous results, IRRs tend to decrease with firm size. Figure 6 supports these results. It plots the fitted values from the regressions in Panels A and B of Table IX. The plot shows a negative relationship between IRRs and the interaction term "lnFundSize × InvLnInvestSize." That is, as funds get larger, they earn lower returns if they make small investments. This holds for both buyout and VC funds.

Overall, the results indicate that the distinction between "buyout" and "venture" funds does not bias the results.

Do large funds invest in large companies? An attendant issue to test the assumption that small funds prefer to invest in small companies.

Table VII contains the regression results. Columns 1 and 2 contain logit models where the dependent variables are indicators that equal 1 if the fund's average investment size is in the top 25% or bottom 25% of the sample, respectively. Column 3 contains an ordered logit model where the dependent variable contains the quartile in which fund's investment size falls. Column 4 is an OLS model with the dependent variable being the natural log of the fund's average investment size, "ln(Investment Size)."

The results in Columns 1 and 2 show that fund size significantly increases (decreases) the likelihood that the average investment size is in the top 25% (bottom 25%) of the sample. The results in Column 3 indicate that the likelihood of investing in a larger investment size quartile increases with fund size. Column 4 shows

Table VII. Univariate statistics for buyout and VC funds

This table contains univariate statistics for buyout and VC funds. Column 1 examines buyout funds. Column 2 examines VC funds. Column 3 examines the difference between Columns 1 and 2. *** denotes significance at 1% using a difference in means test for means or a rank sum test for medians.

	Statistic	Buyout (1)	VC (2)	Difference (3)
Fund size (USDm)	Mean	861.68	252.84	608.84***
	Median	407.50	158.00	249.50***
Investment size (USD'000)	Mean	255.16	69.25	185.91***
	Median	124.03	59.26	64.77***
IRR	Mean	0.09	0.08	0.01
	Median	0.08	0.01	0.08***
Multiple	Mean	1.65	1.54	0.10
	Median	1.30	1.03	0.27***

that the average investment size increases with the fund size. Here, the coefficient on "ln (Fund Size)" implies that a one standard deviation increase in "ln (Fund Size)" induces a 5% increase in the average investment size.

Table VIII. Investment preferences of large funds

This table examines the investment preferences of large funds. The dependent variables represent the fund's average investment size. The key independent variable is ''ln(Fund Size).'' The dependent variables in Columns 1 and 2 are indicators that equal 1 if the average investment size is in the top 25% or bottom 25% of the sample, respectively; here, estimation is by lobit. The dependent variable in Column 3 is an ordered categorical variable with four categories corresponding to the four quartils of investment size; here, estimation is by an ordered logit model. The dependent variable in Column 4 is the natural log of the fund's average investment size, ''ln(Investment Size)''; here, estimation is by OLS. All models use robust standard errors clustered by fund vintage. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Dependent variable Estimation technique	*I*(Invest Top 25%) Logit (1)	*I*(Invest Low 25%) Logit (2)	Investment quartiles Ordered logit (3)	ln(Investment Size) OLS (4)
ln(Fund Size)	0.728*** (0.000)	−0.593*** (0.000)	0.907*** (0.000)	0.339*** (0.000)
Seed	−0.398 (0.417)	0.237 (0.337)	−0.07 (0.673)	0.032 (0.520)
Expertise	0.064 (0.145)	−0.077*** (0.007)	0.03 (0.312)	0.062*** (0.000)
Connections	−0.037*** (0.005)	0.039** (0.010)	−0.037*** (0.001)	0.012*** (0.002)
Requires Board Rep	−0.197 (0.381)	0.106 (0.512)	−0.156 (0.125)	0.105*** (0.006)
Prefers Controlling Shares	0.639** (0.046)	−0.605** (0.032)	0.433* (0.072)	−0.085 (0.413)
Solo Investor	0.007 (0.965)	−0.201 (0.188)	−0.019 (0.880)	−0.124* (0.084)
Market Return	0.751 (0.103)	−0.346 (0.395)	0.383 (0.169)	−0.06 (0.656)
Crowded PE Market	2.983*** (0.004)	−0.003 (0.998)	1.111 (0.153)	1.482*** (0.000)
ln(Num Inds)	−0.135 (0.267)	0.377*** (0.004)	−0.210** (0.032)	0.008 (0.841)
ln(Num Geos)	−0.566*** (0.002)	0.182 (0.161)	−0.299*** (0.004)	0.048 (0.185)
Stage Drift	0.239 (0.293)	0.161 (0.483)	−0.111 (0.607)	−0.002 (0.980)
Proxy Base Fee	−1.649*** (0.005)	−0.013 (0.971)	−0.529 (0.174)	−0.708*** (0.000)
Proxy Performance Fee	−0.131 (0.306)	0.268*** (0.000)	−0.258*** (0.005)	−0.011 (0.735)
NY	0.446** (0.015)	−0.974*** (0.000)	0.768*** (0.000)	0.428*** (0.000)
CA	−0.317 (0.123)	−0.128 (0.412)	−0.012 (0.917)	0.218*** (0.000)
WA	−0.387 (0.685)	0.425 (0.120)	−0.141 (0.558)	0.068 (0.615)
Fund Sequence	0.069*** (0.000)	−0.092** (0.049)	0.075*** (0.000)	0.002 (0.712)
Bubble Dummy	0.307* (0.070)	−1.024*** (0.000)	0.476*** (0.000)	0.003 (0.946)
Constant	0.386 (0.889)	−4.088*** (0.000)		8.151*** (0.000)
Constant Cut 1			−3.271*** (0.001)	
Constant Cut 2			−1.829* (0.059)	
Constant Cut 3			−0.297 (0.756)	
Observations	1,222	1,222	1,084	1,222
R^2 (%)	26.20	13.20	14.30	43.40

The control variables yield some interesting results. First, funds that invest in large firms tend to prefer to hold a controlling interest. This is unsurprising given the significant capital investment involved in a large company. Second, funds are more likely to invest in large companies if there are many competing PE funds. This suggests that when there are many competing funds, it becomes more difficult to find high-quality small ventures. Third, funds that are later in the fund sequence are more likely to invest in large companies. This is unsurprising given that later sequence funds likely have access to more capital.



Figure 4. Fund size and inverse investment size. This figure plots the log fund size versus the inverse of the natural log of the average investment size for buyout versus VC funds.

The overall importance of these results is that they support the assumption that small funds tend to invest in small firms and large funds tend to invest in large firms. This supports the modeling procedure and the finding that small (large) funds should invest in small (large) companies.

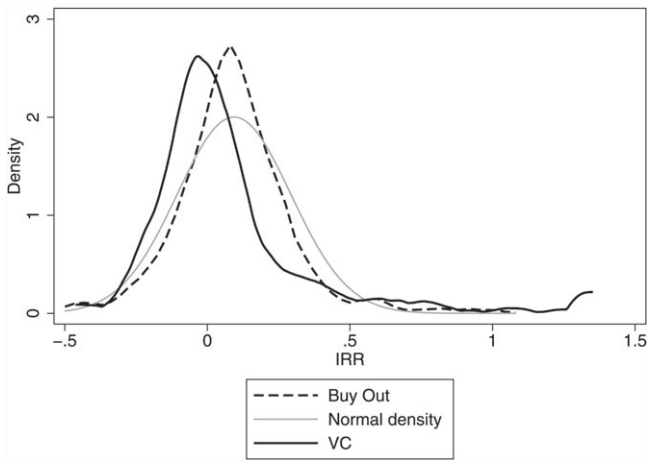


Figure 5. Fund size and inverse investment size. This figure contains kernel density plots for the IRRs of VC and buyout funds.

Table IX. IRRs, investment size, and fund size for buyout and VC funds

This table examines the relation between the PE fund's size and IRR that it earns. The dependent variable is the fund's IRR. The table examines IRRs for funds classified as (1) either buyout or late stage, (2) either venture or early stage, (3) buyout only, and (4) venture only. All models use robust standard errors clustered by fund vintage. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Panel A: buyout and late stage				
ln(Fund Size)	−0.048*** (0.000)		−0.059*** (0.000)	0.000 (0.998)
1/ln(Investment Size)		−2.297*** (0.000)	−2.817*** (0.000)	−0.386 (0.700)
ln(Fund Size) × 1/ln(Investment Size)				−0.650*** (0.008)
Constant	0.708 (0.243)	1.785*** (0.004)	1.016* (0.090)	0.613 (0.322)
Controls	Yes	Yes	Yes	Yes
Observations	590	590	590	590
R^2	0.114	0.111	0.158	0.169
Panel B: buyout only				
ln(Fund Size)	−0.055*** (0.000)		−0.064*** (0.000)	0.01 (0.674)
1/ln(Investment Size)		−2.595*** (0.000)	−2.987*** (0.000)	0.216 (0.825)
ln(Fund Size) × 1/ln(Investment Size)				−0.876*** (0.001)
	1.164 (0.108)	1.993** (0.011)	1.363* (0.050)	0.9 (0.195)
Controls	Yes	Yes	Yes	Yes
Observations	465	465	465	465
R^2	0.124	0.125	0.18	0.203
Panel C: venture and early stage				
ln(Fund Size)	−0.081*** (0.000)		−0.096*** (0.000)	−0.342** (0.022)
1/ln(Investment Size)		−2.498** (0.039)	−4.549*** (0.003)	−13.555** (0.032)
ln(Fund Size) × 1/ln(Investment Size)				−2.055* (0.087)
	−0.008 (0.941)	0.854*** (0.000)	0.588** (0.015)	1.482** (0.042)
Controls	Yes	Yes	Yes	Yes
Observations	632	632	632	632
R^2	0.176	0.147	0.191	0.196
Panel D: venture only				
ln(Fund Size)	−0.075*** (0.002)		−0.085*** (0.001)	−0.506*** (0.004)
1/ln(Investment Size)		−0.887 (0.548)	−2.732 (0.115)	−20.101*** (0.005)
ln(Fund Size) × 1/ln(Investment Size)				−3.580** (0.011)
	−0.049 (0.703)	0.408 (0.126)	0.338 (0.195)	2.211*** (0.006)
Controls	Yes	Yes	Yes	Yes
Observations	422	422	422	422
R^2	0.183	0.159	0.188	0.198

Robustness tests This section ensures that the results are robust. For brevity, the robustness tests are unreported. First, the results are robust to various forms of clustering. The results also hold in models that use dummies for, and/or cluster by, geographic preferences or industry preferences.

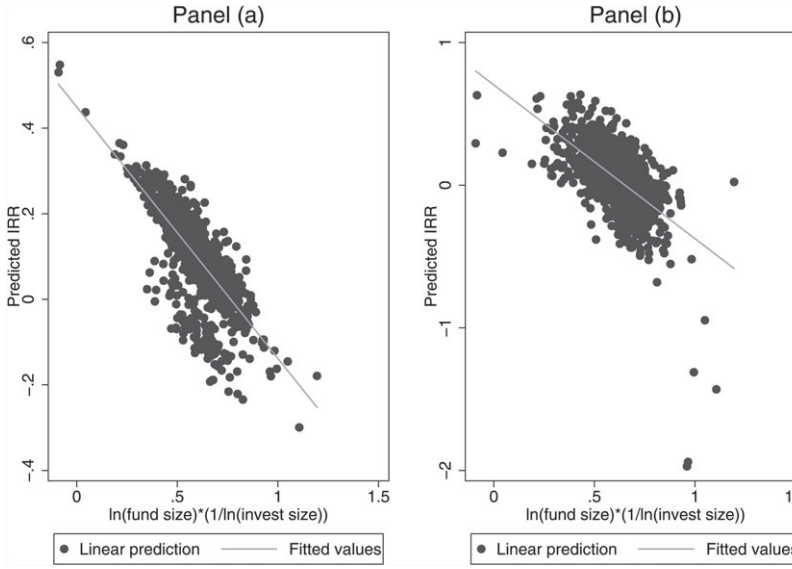


Figure 6. IRRs, investment size, and fund size. This figure plots the fund's IRR versus the interaction term ln(Fund Size) × 1/ln(Investment Size). The fitted values come from an estimation of the models in Panels A and B of Table IX. Panel (a) examines buyout funds and Panel (b) examines VC funds.

Second, the results are robust to multicollinearity. Table IV indicates that the explanatory variables might be correlated. However, the VIF of each variable does not exceed 2 in any regression and the results hold in principal components regressions that condense the nonsize variables into orthogonal components. The key relations between IRR and the size variables also hold in models that exclude control variables.

Third, the results are robust to the definition of size variable. The main models use the 25% and 50% cutoffs for low and high firms and investment size. The results hold for any cutoffs between these thresholds. Furthermore, they hold in models that define fund size as the total amount of funds that the firm raised before raising the current fund.

Fourth, the results are robust to outliers. The results hold in models that exclude observations whose Cook's D exceeds $4/n$, where n is the number of observations in the model. Furthermore, the models winsorize all continuous variables to ameliorate the impact of extreme observations.

Fifth, the results are robust to time period. The results hold in models that exclude funds established during the tech boom between 2000 and 2002. In fact, the results are stronger after excluding this time period. The results also hold in periods before and after the bubble period.

4. Conclusions

This paper examines the relation between PE fund size, investment size, and PE fund returns. It shows that investments in small companies are a key driver of the size effect in PE funds.

The theoretical model predicts that large funds should earn lower returns on average and should earn especially low returns when they invest in small companies. The intuition is that large funds' advantages are in raising capital and using connections. These advantages best suited to making large investments. In contrast, small PE funds' advantages are in nurturing young companies. This implies that large firms are better at investing in large companies and are worse at investing in small companies.

The empirical results show that large funds earn lower returns if they invest in small companies, whereas they earn higher returns if they invest in large companies. These results are economically significant. A one standard deviation increase in fund size reduces IRRs by 41%. A one standard deviation increase in the interaction of fund size and investment size reduces IRRs by 51%.

This provides a direct explanation for why large funds earn lower returns. This helps identify one avenue of value destruction by large PE funds. Further research could examine the interplay of government venture funding and market interventions on the fund size/investment size relation.[20]

Additionally, future work could examine further key avenues in which PE funds can create or destroy value and can examine the motivation for large funds to undertake suboptimal investments.

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[20] This follows prior research that shows that government intervention can influence the nature VC funds and the profitability of their investments (e.g., Cumming and Johan, 2007, 2009, 2010; Cumming and Dai, 2010a).

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