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Diversification in Private Equity Funds: On Knowledge Sharing, Risk Aversion, and Limited Attention

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Abstract

This paper examines diversification as a source of value creation and destruction in private equity (PE) funds. Previous literature has focused on the "diversification discount" in corporations. However, in PE funds, diversification might increase returns by ameliorating managerial risk aversion and facilitating knowledge sharing. I examine a sample of 1,505 PE funds and show that industry and geographic diversification can increase PE fund returns. This is likely due to knowledge sharing and learning, not merely risk reduction. Diversification can reduce returns if it spreads staff too thinly across industries or is motivated by risk aversion rather than performance bonuses.

I. Introduction

There are many risks and costs associated with diversification in corporations. Firms are often forced to employ additional agents in order to deal with new fields. Diversification can also increase corporate size and entrench managers, which can lead to shirking and empire building (Aron (1988), Amihud and Lev (1999)). Additionally, it may enable cross subsidization and overinvestment in poorly performing divisions (Berger and Ofek (1995)). However, diversification might help some corporations by reducing agency conflicts of managerial risk aversion and facilitating knowledge transfer between divisions. These benefits are especially important to private equity (PE) funds because they invest in high-risk companies and generate value by sharing knowledge and expertise.

Extant empirical literature focuses on corporations rather than PE funds and has found that diversification reduces firm value. Berger and Ofek (1995) and Denis, Denis, and Yost (2002) show that diversification enables firms to cross

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subsidize and overinvest in poorly performing units. Eckbo and Thorburn (2000) and Aw and Chatterjee (2004) show that the market reacts negatively to cross-border acquisitions. Moeller and Schlingemann (2005) find that the market reacts negatively to takeovers that diversify across region or industry and that this reflects a lower post-takeover operating performance.[1] Chakrabarti, Singh, and Mahmood (2007) show that the negative relation between diversification and performance is robust to country and level of economic development. Analogously, firms can generate value by refocusing and divesting noncore assets (Berger and Ofek (1999), Haynes, Thompson, and Wright (2002), and Matsusaka and Nanda (2002)). However, there are several reasons to believe that these results might not apply to PE funds.

PE funds are simultaneously investment vehicles and corporations. They invest in company portfolios but also have managers who actively engage in the corporate management and strategy of the portfolio company. Diversification might benefit both aspects. From a portfolio management perspective, PE funds invest in risky assets with high failure rates (Dimov and De Clercq (2006)), which can induce agency conflicts of managerial risk aversion. Diversification might ameliorate these conflicts. From a corporate perspective, syndication and connections between PE funds can create value (Hochberg, Ljungqvist, and Lu (2007)). Diversification can amplify these connections. It might also facilitate knowledge transfer between portfolio companies and expose managers to a wider range of skills (Lin and Lee (2011)). Furthermore, given that the regulatory environment can influence PE fund returns, international diversification might facilitate regulatory arbitrage. Seed or start-up companies especially should benefit due to their reliance on PE funds for managerial and technological expertise.

There is limited empirical evidence on the impact of diversification in the PE sector. Ljungqvist and Richardson (2003) examine diversification in 73 funds between 1981 and 1993. Their data set comprises funds in which their source (one limited partner (LP)) considered investing. They find no significant relation between internal rates of return (IRRs) and the number of industries in the funds' portfolios or the number or percentage invested in the dominant industry. Nonetheless, this might reflect self-selection on the part of the data source (the investor) to focus upon PE funds in which it wants to invest. Gompers, Kovner, and Lerner (2009) find that specialized funds tend to successfully exit more of their investments, although they do not examine the drivers or look at fund returns. Lossen (2006) examines 100 European funds and finds weak evidence that diversification across industries increases returns. However, the sample is limited to 100 PE funds in Europe, and the sign and significance of the result varies across model specifications. Knill (2009) finds a positive relation between diversification and growth (defined as the change in the fund's capital under management). But this definition of growth is not the same as returns, because growth encompasses the ability to raise capital rather than solely converting capital into value. Humphery-Jenner (2012) shows a positive relation between diversification and returns but does not test the driver of this relation.

[1] This event-study approach largely addresses the endogeneity concerns raised in Campa and Kedia (2002).

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The limited empirical evidence suggests that further examination of diversification in the PE industry is warranted. I examine whether industry and/or geographic diversification influences returns using a sample of 1,505 U.S. PE funds from 1980 to 2007. I document a positive relationship between diversification and returns. I explore whether this positive relationship is in some part due to knowledge sharing and learning between portfolio companies, or merely a consequence of endogeneity and risk reduction. I also examine whether diversification reduces funds' returns by spreading human resources too thinly, thereby limiting the attention individuals can pay to specific regions and industries, or by encouraging diversification purely motivated by managerial risk aversion with respect to performance bonuses.

The main contributions of this paper are to examine diversification in PE funds and to show that: i) diversification across industries increases PE funds' returns; ii) industrial diversification in prior funds raised by the present fund's management firm increases returns, implying that diversification may create skills and knowledge useful to the present fund; iii) diversification across regions increases IRRs in PE funds that make seed investments; iv) risk reduction (by increasing the number of portfolio companies) may increase PE funds' returns, but this does not drive the relation between diversification and returns; v) diversification across industries reduces returns if it spreads staff too thinly across industries or regions; and vi) diversification across industries reduces IRRs if the motivation is risk aversion rather than promoting performance bonus.[2] Endogeneity issues do not appear to drive the relationship between returns and diversification.

Of course, there are some additional potential explanations for the positive IRR-diversification relation. Diversification might reduce a fund's level of idiosyncratic risk exposure, which might enable it to invest in riskier companies, which might earn higher returns, on average. Additionally, diversified funds might be more selective when investing outside of their core areas, inducing a diversified fund to naturally select investments that earn higher IRRs. These explanations can function alongside the ones offered in this paper and pose an avenue for future research making use of detailed investment-level data.

The paper is structured as follows: Section II details the prior literature and hypotheses. Section III describes the sample, variables, and methodology. Section IV contains the results, and Section V concludes.

II. Literature Review and Hypothesis Development

The major areas of research are: i) whether diversification influences returns, and if so, ii) why diversification influences returns. The hypotheses are summarized in Table 1.

[2]Note that some caution is necessary when interpreting this result. I base this on results obtained from the average fund fees and carry payable by funds in the given fund's vintage, geographic focus, and type (i.e., venture capital (VC) or buyout).

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TABLE 1
Empirical Predictions

Table 1 summarizes the hypotheses. A complete description of the hypotheses is in Section II.

Hypothesis	Prediction	Empirical Test/Implication
Hypothesis 1	Diversification increases returns.	The diversification variables NUM_INDS and NUM_GEOS are positively related to returns.
Hypothesis 2	Diversification especially increases returns for seed funds.	The interactions I(SEED_FUND) × NUM_INDS and I(SEED_FUND) × NUM_GEOS are positively related to returns.
Hypothesis 3	Diversification in the last fund that was raised by the present fund's management firm should increase returns in the present fund.	The variables NUM_INDS(PRIOR_FUND) and NUM_GEOS(PRIOR_FUND) are positively related to returns.
Hypothesis 4	Diversification has no (or limited) impact on risk-adjusted returns.	The variables NUM_INDS and NUM_GEOS are not significantly related to returns after controlling for the fund's level of risk and do not influence returns after controlling for general portfolio diversification (as proxied by the number of portfolio companies).
Hypothesis 5	Diversification reduces returns if it spreads the staff too thinly across industries or regions.	The terms NUM_INDS/NUM_PEOPLE and NUM_GEOS/NUM_PEOPLE are negatively related to returns.
Hypothesis 6	Diversification reduces returns in funds that rely more on performance bonuses than on management fees (because diversification is merely to reduce risk here).	Returns are negatively related to the terms (CARRY/MANAGEMENT) × NUM_INDS and (CARRY/MANAGEMENT) × NUM_GEOS.
Hypothesis 7	There is a quadratic-type relationship between returns and joint industry-geographic diversification.	(INDUSTRIAL_DIVERSIFICATION × GEOGRAPHIC_DIVERSIFICATION) increases returns, whereas (INDUSTRIAL_DIVERSIFICATION × GEOGRAPHIC_DIVERSIFICATION)^2 decreases returns.
Hypothesis 8	The relation between diversification and returns merely reflects endogeneity.	Diversification does not influence returns in GMM regressions that instrument NUM_INDS or NUM_GEOS.
Hypothesis 9	Knowledge sharing/learning at least partially explains the relation between diversification and value creation.	Diversification increases returns on average; this especially holds for seed funds, is not due to mere risk reduction, and is not due to endogeneity/self-selection.

A. Diversification and Learning: On Seed Funds and Diversification in Prior Funds

Diversification may increase value for PE funds in general, and especially in seed-focused PE funds. A key explanation relates to knowledge sharing and learning.

1. Diversification in General and in Seed Funds

It is possible that diversification adds value to funds in several ways. The process of diversification likely compels PE managers to improve their skill set and industry connections. PE managers add value by providing managerial, financial, and technical expertise (McDougall, Robinson, and DeNisi (1992), Ivanov and Xie (2010)). In an innovation-intensive environment, managers can expand their knowledge base by engaging in diverse, but tangentially related, fields (Siegel, Siegel, and MacMillan (1988), Hurry, Miller, and Bowman (1992), and Lin and Lee (2011)). Additionally, Hochberg et al. (2007) highlight the financial

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importance of wide-ranging industry networks to PE funds. These networks rely on interactions between industries.

Diversification can facilitate knowledge spillovers, either from PE managers to (and from) portfolio companies or from portfolio companies to other portfolio companies. These mechanisms are important ways to create value (Hochberg et al. (2007)). Corporations seeking to diversify across similar knowledge-based industries find this method particularly useful (following Teece (1980), (1982), Hansen (2002), Tanriverdi and Venkatraman (2005), Miller (2006), and Schilling and Phelps (2007)). Furthermore, knowledge transfers foster innovation (Ahuja (2000), Tsai (2001)). Seed investments especially benefit, because they rely on knowledge sharing and managerial expertise to generate value.

These reasons lead me to theorize that diversification increases PE fund returns, especially if the fund invests in start-ups.

Hypothesis 1. PE fund returns increase with the number of industry segments and geographic regions in which the fund invests.

Hypothesis 2. PE funds that make "seed" or start-up investments benefit more from diversification than do other PE funds.

2. Returns and Prior-Fund Diversification

The learning hypothesis also implies that if i) a fund's management firm has raised prior funds, ii) there is some communication or personnel overlap between the funds, and iii) diversification induces learning and knowledge sharing, then the level of diversification in the previous fund should increase returns in the present fund. Diversification in prior funds raised by the same management firm should increase returns in the present fund. I focus on the level of diversification in the preceding fund.

Hypothesis 3. The level of diversification in a fund that was i) raised by the present fund's management firm, and ii) raised before the present fund should increase returns in the present fund.

B. Diversification and Risk Reduction

It is possible that risk reduction can explain the relationship between diversification and returns. First, diversification reduces a PE fund's exposure to firm-specific risk. It is possible that the mere reduction of risk creates value in PE funds by ameliorating agency conflicts of managerial risk aversion. Such agency conflicts are especially problematic in PE funds for two reasons. The first is that most of a manager's income is based on a performance bonus (called "carry") (Phalippou and Gottschalg (2009)). This is ordinarily payable if the IRR of the overall fund (see also individual investments) exceeds a particular threshold (called the "preferred return"), which might encourage managers to reduce the overall level of risk in order to increase the chances of meeting their benchmark. The second reason is that PE funds typically invest in risky portfolio companies. These have highly skewed returns with significant bankruptcy risk (Chiampou and Kallett (1989), Gompers and Lerner (1998), Cochrane (2005), and Korteweg

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and Sorensen (2010)). Therefore, PE managers might seek to reduce portfolio risk by diversifying.

The relationship between return and diversification, as such, might merely reflect a reduction in agency conflicts of managerial risk aversion rather than any latent benefit of diversification itself (i.e., through knowledge sharing). If, indeed, risk reduction drives the results, then diversification i) should not influence returns after controlling for the fund's portfolio size (on the grounds that the portfolio size represents the ability to reduce risk), and ii) should not influence returns after controlling for the fund's risk level (i.e., after adjusting IRRs for fund type, fund region, and fund vintage).[3]

Hypothesis 4. Diversification influences returns because it reduces a fund's riskiness. Thus, diversification should not influence returns after controlling for a fund's portfolio size (which is a proxy for the fund's reduction in investment-specific/idiosyncratic risk) and/or after controlling for a fund's level of risk (as proxied by the fund type, fund region, and fund vintage). Furthermore, returns should increase with the number of portfolio companies in which the fund invests.

C. Diversification and Limited Attention

The limited-attention hypothesis argues that diversification reduces returns if it requires staff to become spread too thinly. This is especially important in the PE sector, where funds are managed by relatively few staff (Metrick and Yasuda (2010)). Subsequently, larger PE funds can earn lower returns because the ratio of investments to staff increases. Thus, the PE staff devotes less time to each investment. Similar reasoning suggests that increasing diversification forces managers to monitor multiple industries and regions rather than focusing more deeply on one region or industry, perhaps to the detriment of each and thus overall returns.

Hypothesis 5. PE fund returns decrease as the ratio of industries (or geographies) to PE professionals rises.

D. Fees and Diversification

PE funds obtain funding from investors (limited partners) through contracting. A standard management contract stipulates the nature of the PE fund's compensation, which typically consists of both a management fee charged on capital under management and a performance bonus (carry) that is generally payable only if the fund's return exceeds a specific level (Metrick and Yasuda (2010), Kandel, Leshchinskii, and Yuklea (2011)).

The structure of these fees might influence a fund to diversify, and this might influence returns. A key problem is that the carry is payable only if the fund's overall return exceeds the threshold, which likely induces risk aversion with respect to exceeding the threshold. PE managers are encouraged to diversify the

[3]I operationalize this by including fund-vintage, fund-type, and fund-region dummy variables in the regressions. In unreported models, I also adjust for the average IRR by fund type, vintage, and region to reach qualitatively similar results.

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fund simply to reduce the risk of failing to reach their benchmark. Such risk-aversion-motivated diversification might reduce value (Aron (1988), Amihud and Lev (1999)).

Hypothesis 6. Returns to diversification decrease with the ratio of carry to management fee. That is, returns are negatively related to the interaction of carry or management fees and diversification.

E. Joint Industry and Geography Diversification

The interaction of industry and geographic diversification might influence PE fund returns. Hitt, Hoskisson, and Kim (1997) find that corporate returns increase (and then decrease) if firms jointly increase geographic and industrial diversification. This is largely based upon i) the creation of economies of scale and scope (Kogut (1984)), ii) the transfer of core business capabilities between industry and geographic units (Hamel (1991)), and iii) taking advantage of market discrepancies, such as wage differences (Kogut (1985)).

PE funds may, similarly, benefit from joint diversification; however, excess joint diversification might reduce returns. Jones and Hill (1988) and Hitt, Hoskisson, and Ireland (1994) suggest that increasing diversification can increase transaction costs. For PE funds, these involve fundraising and marketing costs, including management and logistics costs. Additionally, the joint diversification and subsequent reduction in any specialized regional or industrial knowledge will likely increase the information processing costs (as acknowledged in Jones and Hill (1988), Hitt et al. (1994), (1997)). This is especially important for PE funds due to their reliance on knowledge sharing.

Hypothesis 7. Diversification across both industry and geographic region initially increases returns, but significant joint diversification reduces returns.

F. Endogeneity and Self-Selection

The diversification literature has documented self-selection and endogeneity issues (e.g., Campa and Kedia (2002), Villalonga (2004)). Prior studies focus on whether the negative relation between firm value and diversification (the "diversification discount") is due to endogeneity. The situation in venture capital/private equity (VCPE) is different. Here, there are several possible sources of concern regarding endogeneity:

1. High-quality funds a) are more capable of managing the complexities of diversification, making them more likely to diversify, and b) earn higher returns due to their latent skill and quality.

2. Some funds might invest in riskier assets. Knowing this risk, they might set a higher hurdle rate for investments. They might also diversify in order to ameliorate risk, driving up IRRs. However, such a scenario does not imply that diversification directly increases returns.

3. Some funds might regard geographic or industrial diversification as onerous or difficult. These funds might set higher hurdle rates if they diversify. This might

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induce a positive relationship between IRRs and diversification, but it would only reflect the perceived difficulty of investing across multiple regions.

I address these concerns empirically in several ways. I use instrumental variables regressions (which addresses concern 1). In unreported robustness tests, I ensure that the results are robust across different subsamples of funds (i.e., buyout vs. venture), thereby ensuring that the results are valid regardless of a fund's riskiness (which addresses concern 2). The models that analyze prior-fund diversification also aim to address concern 3. These models focus on funds that have already diversified and likely acquired some skill operating in different environments. Therefore, they are less likely to demand a higher return when diversifying. Nonetheless, I test the hypothesis that endogeneity drives the results (against the null of no evidence in favor of diversification).

Hypothesis 8. Endogeneity drives the diversification/return relation.

G. Mosaic Learning/Knowledge-Sharing Hypothesis

The mosaic hypothesis builds on some of the earlier subhypotheses to examine whether any diversification benefit reflects learning and knowledge sharing. Diversification may create value through facilitating knowledge sharing and learning. Indirect support for this hypothesis arises if i) diversification creates value on average, ii) the funds that are most likely to benefit from knowledge sharing and learning benefit from diversification (i.e., seed funds) and there is no other obvious reason (i.e., endogeneity or mere risk reduction), and iii) diversification in prior funds increases returns in the present fund.

Hypothesis 9. Knowledge sharing/learning can help to explain a positive relation between returns and diversification.

III. Methods

I first outline the empirical framework, followed by a discussion of the sample and variables. Table 1 summarizes the empirical predictions and empirical testing strategy.

A. Method of Analysis

I use multivariate regressions to test the various hypotheses. The regression specification is in equation (1). I examine both industry and geographic diversification. I also examine models that replace NUM_INDS and NUM_GEOS with the level of diversification in the fund that was raised by the present fund's management firm and immediately prior to the present fund.

The main models use ordinary least squares (OLS) and include fund-vintage dummy variables, fund-type dummy variables, fund-region dummy variables, and cluster standard errors by fund vintage, family/management firm, and fund region. The use of dummy variables captures the possibility that other unobservable fund, region, and year factors might drive the results. These dummy variables also help to analyze Hypothesis 4 by risk adjusting the returns (for fund, region, and year

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effects). In unreported robustness tests, I also analyze Hypothesis 4 by replacing the IRR with the risk-adjusted IRR (ADJ_IRR). The clustered standard errors help to address the reported clustering in returns across funds run by the same management firm (see, e.g., Phalippou (2010)). I analyze Hypothesis 8 by using instrumental variables generalized method of moments (IVGMM) models. The IVGMM models use instruments for the variables NUM_INDS and NUM_GEOS. I discuss these models and the relevant instruments in more detail in the endogeneity/robustness section. The general regression model is

$$(1) \quad \text{RETURN} = \text{f(NUM_INDS, NUM_GEOS, INTERMEDIATING_TERM(S), CONTROLS)}.$$

Here, RETURN represents the funds' IRR (although in robustness tests I also analyze the fund's total value to paid-in capital and the fund's ADJ_IRR). CONTROLS represents the control variables. INTERMEDIATING_TERM(S) represents the terms used to test the various hypotheses.[4] The following sections detail the data source and variables.

B. Sample

The sample was gathered from Preqin, Thomson VentureXpert, and ExecuComp. The sample contains 1,505 funds that raised capital between 1980 and 2007.[5] In robustness tests, I restrict the sample to address concerns about returns from unrealized investments. Each observation represents a separate fund. There is only one observation per fund. The data are not panel data. Some PE corporations manage several funds.[6] Each fund is a discrete corporate entity with a distinct legal identity.

These data sets provide return, diversification, and control variable information that might influence returns. I obtain the returns data from Preqin. Diversification data and control variable data are gathered from both Preqin and Thomson VentureXpert (as outlined below). The sample excludes funds that lack return, diversification, or control variable data. I do not directly distinguish between "venture" and "private equity" funds. This is because there is no "bright-line" distinction between the types of funds. Instead, I use control variables to examine the characteristics of these funds. However, in unreported robustness tests, I ensure that the results hold for samples of buyout and nonbuyout funds. The results also hold when excluding potentially "unusual" years (e.g., the tech bubble years) and funds with a vintage after 2005 (which might not have finalized investing[7]).

The variables are in four categories: i) dependent (return) variables, ii) diversification variables, iii) intermediating variables that might influence the impact

[4]In summary, they are: (NUM_INDS × NUM_GEOS), (NUM_INDS × NUM_GEOS)^2, NUM_INDS/NUM_PEOPLE, NUM_GEOS/NUM_PEOPLE, NUM_INDS × CARRY/FLAT, NUM_GEOS × CARRY/FLAT, NUM_PORT_COS, and I(SEED_FUND).

[5]The study excludes observations from before 1980 due to the argued unreliability of Thomson VentureXpert before 1980. The results hold in a larger sample that includes funds raised before 1980.

[6]For example, the firm Welsh, Carson, Anderson & Stowe has nine separate funds in the sample.

[7]This helps to address the possibility that results are potentially spurious as older funds invest more and liquidate more; thus, they earn both higher IRRs and diversify more.

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of diversification, and iv) control variables that might influence returns. All of these variables might point to or explain a relationship between returns and diversification. Table 2 summarizes the variables and their sources.

TABLE 2
Variable Definitions

Table 2 contains the variable definitions. [a]The fund size groups are 0m–50m, 50m–100m, 100m–250m, 250m–500m, 500m–1,000m, 1,000m–2,000m, 2,000m or greater. They are based on capital under management.

Variable	Definition
IRR	The fund's internal rate of return, as reported by Preqin.
MULTIPLE	The fund's exit multiple, as reported by Preqin.
NUM_INDS	The number of industry-segments in which the fund lists. This is the sum of the number of different industries in which the fund exists (as reported by Preqin).
NUM_GEOS	The number of geographic regions in which the fund will invest. This is the sum of all the geographic regions that Preqin lists for a company.
NUM_PEOPLE	The number of professionals in the fund from Preqin's Fund Managers database.
NUM_PORT_COS	The number of portfolio companies in the fund as sourced from Thomson VentureXpert.
ln(FUND_SIZE)	The natural log of the capitalization of the fund, as reported in Preqin.
ln(INVESTMENT_SIZE)	The natural log of the average size of the fund's investments, as reported by Thomson VentureXpert.
I(SEED_FUND)	An indicator that equals 1 if Preqin reports that the fund invests in seed or start-up companies.
EXPERTISE	The sum of the fields of expertise that the fund claims to possess. Preqin reports the fields in which a fund professes to have expertise. The fund can claim expertise in i) particular industries, ii) technology, iii) management, iv) operations, v) marketing, vi) human resources, vii) recruiting, viii) networking, or ix) strategy. The variable EXPERTISE is the sum of the fields in which the fund claims expertise. Thus, EXPERTISE is bound between 0 and 7.
CONNECTIONS	The number of board positions or other PE-fund positions that a fund's employees have had. To create the variable CONNECTIONS: First, obtain from Preqin the list of key employees in a PE fund. Second, match these employees (by first name and last name) to employees i) Preqin lists as having served on another fund, or ii) ExecuComp lists as having served on the board of directors of a listed company. Third, set the CONNECTIONS as the sum of these matches.
I(SELF-INVESTS)	An indicator that equals 1 if Preqin states that the fund is a "limited partner" in itself; that is, that the fund must invest its own money to finance the fund.
I(REP_REQUIRED)	An indicator that equals 1 if Preqin states that the fund requires board representation in its portfolio companies.
I(PREFER_CONTROLLING_SHARES)	An indicator that equals 1 if Preqin states that the fund requires a controlling shareholding in its portfolio companies.
AVE_MGT_FEE	The average management fee charged by PE funds of the fund's vintage, geographic focus, size,[a] and type (buyout or nonbuyout). The data are from Preqin.
AVE_CARRY	The average carry rate charged by PE funds of the fund's vintage, geographic focus, size,[a] and type (buyout or nonbuyout).
NUM_ROUNDS	The average number of investment rounds in which the fund participates. The data are from Thomson VentureXpert.
CARRY/FLAT	The carry (defined above) divided by the management fee (defined above).
I(SOLO_INVESTOR)	An indicator that equals 1 if Preqin reports that the fund prefers to be a solo investor in its portfolio companies.
I(STRONG_EQUITY_MARKET)	An indicator that equals 1 if the return on the Center for Research in Security Prices (CRSP) equal-weighted index in the fund's vintage-year exceeds that in the prior year.
VCPE_SECTOR_ACTIVITY	The number of funds of the given fund's type that exist in the fund's vintage year scaled by the total number of VCPE funds in that vintage year.

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C. Dependent Variable: IRR

The dependent variables measure a fund's performance. First, I focus on the fund's IRR.[8] The IRR figures are net returns, because i) Preqin provides net returns but not gross returns or the specific timing of cash flows. Inferring gross returns in this manner leads to potentially inaccurate assumptions about a fund's life and cash flows; and ii) net returns are more relevant because they are the returns that the investor receives from the fund. The returns represent those for the latest year that the fund existed. Thus, if the fund is liquidated, then the IRR is based on all realized cash flows to date less the fees and carry. However, if the fund has not been liquidated, the IRR is based on all realized cash flows and the estimated value of unrealized assets. The estimated value is based on Preqin's internal estimates and data that Preqin obtains from the investors (LPs) and/or the fund. This is similar to the cash flow IRR in Kaplan and Schoar (2005).

Second, in unreported robustness tests, I examine a model similar to the "total-value-to-paid-in-capital" (TVPI) measure in Kaplan and Schoar (2005). This measure divides the fund's value (or the value of cash derived from the fund) by the amount paid in capital. I obtain this from Preqin (Preqin calls the TVPI the MULTIPLE). It is defined as "the ratio between the total value that the LP has derived from its interest in the partnership (i.e., distributed cash and securities plus the value of the LP's remaining interest in the partnership) and its total cash investment in the partnership, expressed as a multiple" (2010 Preqin).

Third, in unreported robustness tests, I analyze the fund's ADJ_IRR. I do this by subtracting the average return of all funds earned of the given fund's type, vintage and geographic focus. This benchmark return maximally reduces idiosyncratic risk; thus, it provides a method for testing whether diversification influences risk-adjusted returns.

D. Hypothesized Variables: Industry and Geographic Diversification

The diversification variables are NUM_INDS and NUM_GEOS, which are the number of industry sectors[9] and the number of geographic regions,[10] respectively, in which the fund invests.[11] The data are from Preqin. I also examine

[8]Note that there are many measures of "fund success" (see Kaplan and Schoar (2005)). Thus, I ensure that the results of the test I use are robust by corroborating with another success measure: exit multiple (the final value of the fund divided by the amount of capital raised). I suppress these results for brevity.

[9]Preqin indicates if the fund invests in companies in the following 34 fields: Business services, communications, computer services, consumer products, consumer services, media, education, engineering, environmental services, financial services, gaming, healthcare, security, manufacturing, clean technology, energy (general), energy (renewable), food, hardware, software, retail, utilities, biotechnology, medical devices, medical instruments, medical technology, entertainment, chemicals, aerospace, insurance, Internet focused, marketing, leisure, and environmental services.

[10]A geographic region is a country (such as Australia) with two key exceptions: i) north, east, south, west, and central United States count as separate regions, and ii) countries in the Pacific Rim count as one region.

[11]The results in Figures 1 and 2 show a monotonic relationship between IRRs and both industry diversification and geographic diversification. This suggests against including nonlinear industry diversification or geographic diversification terms. While some studies show a curvilinear relationship between diversification and performance (Hoskisson, Hitt, and Hill (1991), Palich, Cardinal, and

diversification in prior funds raised by the given fund's management firm. A management firm can raise many funds. If some overlap in personnel between funds and diversification does facilitate learning, then diversification in the prior fund should increase returns in the present fund. Thus, I examine models that replace NUM_INDS and NUM_GEOS with the number of industries and/or regions invested in by the fund i) raised immediately prior to the present fund, and ii) raised by the present fund's management firm. These models drop observations for which there was no "prior fund." This reduces the sample size to 753 observations.

E. Hypothesized Intermediating and Moderator Variables

Seed Funds. The variable I(SEED_FUND) is an indicator that equals 1 if the fund invests in seed or start-up companies and prefers seed investments. A seed fund can invest in nonseed investments; however, a "Nonseed Fund" does not invest in seed investments.[12] Prior literature shows that start-up investments have a high failure rate (Roure and Maidique (1986), Zacharakis and Meyer (2000), and Dimov and De Clercq (2006)). Thus, the prediction is that smaller investments experience lower returns.

Number of People. The variable NUM_PEOPLE is the number of investment professionals in the fund. I obtain this from Preqin's Fund Managers database. The professionals are people who manage investments (and do not include general and administrative staff). I use this to test Hypothesis 5 by analyzing the interaction terms NUM_GEOS/NUM_PEOPLE and NUM_ INDS/NUM_PEOPLE.

Carry/Flat. To test Hypothesis 6, I examine the variable CARRY/FLAT, which is the ratio of the performance fees to the flat management fees. The "carry" is the performance fee that is payable if the fund meets a certain benchmark return.[13] The management fee is typically around 1.5% to 2.5% of the funds under management. There are no publicly available data on the fees charged by investors (LPs) to individual funds. However, there is little variation in fees when the funds are sorted into size groups[14] and fund types (Metrick and Yasuda (2010), Kandel et al. (2011)). Thus, I use the average carry and average flat fee for funds of a given fund's vintage, type (buyout or nonbuyout), region of geographic focus, and size.

Number of Portfolio Companies. The regressions control for the number of portfolio companies (NUM_PORT_COS). I predict that increasing the number of portfolio companies should increase returns because it is likely to reduce the fund's exposure to idiosyncratic risk; thus, the fund's return should increase. This

Miller (2000), and Qian, Khoury, Peng, and Qian (2010)), these studies focus on pure corporate diversification as opposed to diversification in PE funds.

[12]Preqin only reports whether a fund makes seed investments. It does not report the dollar value of the investments deemed to be seed investments. Thus, SEED is a dummy variable rather than a continuous variable.

[13]Interviews with VCPE professionals and data from Preqin indicate that a typical benchmark is 8%.

[14]The fund size groups are 0m–50m, 50m–100m, 100m–250m, 250m–500m, 500m–1,000m, 1,000m–2,000m, and 2,000m or greater. They are based on capital under management.

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addresses the possibility that risk reduction drives the relation between returns and industry/geographic diversification.

F. Control Variables

I control for various factors that might influence VCPE funds' returns, such as fund size (Humphery-Jenner (2012)),[15] investment size, number of investment rounds (Guler (2007)), the amount of expertise that the fund claims to have, the fund's connections (Hochberg et al. (2007), Demiroglu and James (2010)), the fund's reliance on its own funding, whether the fund makes investments by itself (as opposed to as a syndicate, see Bygrave (1987)), whether the fund requires representation on portfolio companies' boards or prefers a controlling shareholding, the average management fee and carry rate for the fund's type and size group, and whether the fund operates in a "hot" market, which could enable, or force, funds to invest in companies with diminishing returns to investment (Gompers and Lerner (2000), Diller and Kaserer (2009)). Table 2 has a full description of calculations.

IV. Results

I begin by presenting a sample description. Then, I present multivariate regression results.

A. Sample Description

Table 3 contains the sample statistics and Table 4 contains the pairwise correlations. Column 1 of Table 3 examines all PE funds in the sample. Columns 2–5 of Table 3 partition the sample into geographic diversification quartiles, where geographic diversification is the number of countries in which the fund invests. Columns 6–9 of Table 3 partition the sample into quartiles by the level of industrial diversification, where industrial diversification is the number of industries in which the fund invests. Panel A contains means and Panel B contains medians (I omit dummy variables).

The key univariate result is that IRRs and multiples increase with industry and geographic diversification.[16] In both cases, funds whose industry or geographic diversification is in the top quartile of the sample have higher IRRs and multiples. Industrial diversification and geographic diversification appear to increase together; that is, funds that diversify across industries are more likely to diversify across countries. Furthermore, diversified firms appear to establish more connections, emphasizing the importance of connections to operating across geographic and industry environments. A final interesting point is that diversified

[15]This is similar to the presence of diseconomies of scale in general industrial corporations (see, e.g., Moeller, Schlingemann, and Stulz (2004), (2005), Humphery-Jenner and Powell (2011)).

[16]Note that the "ADJ_IRR" is not 0 on average. The reason is that the adjustment is for all funds that have IRR information. My sample imposes more data limitations and thus is a subsample of the full set of funds.

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TABLE 3

Univariate Statistics

Table 3 contains the univariate statistics for the sample of 1,505 PE funds. Panel A contains sample means and Panel B contains sample medians (here, I omit statistics for indicator variables). Column 1 contains statistics for all the funds. Columns 2–5 focus on geographic diversification. Geographic diversification is the number of countries in which the fund invests. Columns 2–5 contain statistics for funds whose geographic diversification is in the 1st–4th quartiles, respectively. Columns 6–9 focus on industrial diversification. Industrial diversification is the number of industries in which the fund invests.

		Geographies				Industries			
		Quartile							
Variable	All Funds	1	2	3	4	1	2	3	4
Panel A. Means									
IRR (%)	8.912	6.502	8.259	10.778	12.895	4.481	6.965	10.951	13.958
ADJ_IRR (%)	3.204	0.991	3.150	5.026	6.500	−1.159	2.233	5.062	7.311
MULTIPLE	1.590	1.489	1.578	1.641	1.768	1.409	1.539	1.669	1.769
NUM_INDS	12.378	10.337	12.764	13.706	15.381	4.542	9.480	14.529	22.589
NUM_GEOS	5.638	2.747	4.000	5.478	12.460	4.688	4.331	6.343	7.381
ln(FUND_SIZE) ($m)	5.516	5.294	5.439	5.506	6.014	5.170	5.528	5.586	5.843
ln(INVESTMENT_SIZE) ($000)	9.047	8.889	9.170	8.926	9.385	8.812	9.044	9.066	9.316
I(SEED_FUND)	0.071	0.065	0.037	0.075	0.099	0.046	0.088	0.072	0.081
EXPERTISE	3.690	3.398	3.974	3.776	4.074	2.898	3.621	3.793	4.619
CONNECTIONS	2.450	2.340	1.377	3.263	2.668	1.729	2.189	2.685	3.336
I(SELF-INVESTS)	0.085	0.016	0.079	0.059	0.247	0.039	0.085	0.147	0.063
I(REP_REQUIRED)	0.386	0.387	0.340	0.435	0.373	0.344	0.376	0.361	0.480
I(PREFERS_CONTROLLING_SHARES)	0.128	0.124	0.110	0.110	0.159	0.082	0.128	0.110	0.210
I(SOLO_INVESTOR)	0.179	0.169	0.099	0.286	0.167	0.094	0.157	0.245	0.225
NUM_ROUNDS	34.938	30.777	30.037	48.281	36.633	26.348	28.142	36.196	51.649
NUM_PORT_COS	15.609	14.404	12.275	19.422	17.172	11.276	12.649	17.838	21.432
NUM_PEOPLE	9.065	6.967	7.778	9.956	13.444	6.366	7.668	10.005	12.770
AVE_FLAT	2.219	2.214	2.186	2.238	2.232	2.256	2.231	2.212	2.166
AVE_CARRY	20.500	20.176	20.401	20.323	21.345	20.413	20.530	20.414	20.683
CARRY/FLAT	9.445	9.240	9.532	9.234	9.970	9.229	9.393	9.409	9.820
NUM_INDS/NUM_PEOPLE	1.787	1.839	2.115	1.806	1.489	1.036	1.609	1.970	2.682
NUM_GEOS/NUM_PEOPLE	0.791	0.584	0.676	0.851	1.237	0.985	0.702	0.755	0.698
VCPE_SECTOR_ACTIVITY	0.168	0.165	0.171	0.177	0.167	0.142	0.153	0.189	0.191
I(STRONG_EQUITY_MARKET)	0.482	0.475	0.524	0.486	0.470	0.459	0.490	0.484	0.497
Panel B. Medians									
IRR (%)	6.000	4.800	7.400	5.800	8.000	4.300	4.800	6.300	8.300
ADJ_IRR (%)	0.400	−0.300	0.500	2.100	1.050	−0.900	0.000	1.100	1.950
MULTIPLE	1.200	1.160	1.290	1.180	1.290	1.140	1.170	1.210	1.330
NUM_INDS	11.000	10.000	11.000	13.000	17.000	5.000	9.000	15.000	24.000
NUM_GEOS	4.000	3.000	4.000	5.000	11.000	3.000	3.000	4.000	5.500
ln(FUND_SIZE) ($m)	5.521	5.391	5.521	5.541	6.118	5.165	5.598	5.521	5.770
ln(INVESTMENT_SIZE) ($000)	8.875	8.781	9.005	8.830	9.281	8.643	8.865	8.923	9.103
EXPERTISE	4.000	4.000	4.000	4.000	4.000	3.000	3.000	4.000	5.000
NUM_ROUNDS	15.000	15.000	9.000	31.000	10.000	13.000	10.000	23.000	14.000
NUM_PORT_COS	9.000	9.000	7.000	16.000	8.000	8.000	8.000	13.000	10.000
NUM_PEOPLE	8.000	6.000	7.000	9.000	12.000	6.000	7.000	10.000	11.000
AVE_FLAT	2.307	2.307	2.307	2.307	2.307	2.307	2.307	2.307	2.142
AVE_CARRY	20.000	19.889	20.000	20.000	20.400	19.889	20.000	20.000	20.000
CARRY/FLAT	8.622	8.622	8.823	8.622	8.622	8.622	8.823	8.622	9.337
NUM_INDS/NUM_PEOPLE	1.333	1.464	1.714	1.250	1.063	0.750	1.333	1.500	2.167
NUM_GEOS/NUM_PEOPLE	0.571	0.429	0.571	0.625	0.875	0.750	0.500	0.500	0.550
VCPE_SECTOR_ACTIVITY	0.158	0.179	0.204	0.204	0.118	0.105	0.118	0.205	0.216

funds are more likely to invest in "seed" investments. This is likely because seed investments are risky; funds diversify in order to manage risk.

B. Do Diversified Funds Earn Higher Returns?

The results support the hypothesis that diversification across industry increases returns. The main regression results are in Table 5. Column 1 includes both NUM_INDS and NUM_GEOS but does not interact them. Only NUM_INDS

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TABLE 4

Correlation Statistics

Table 4 contains pairwise correlation statistics. Square brackets contain *p*-values.

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
IRR	A																			
NUM_INDS	B	0.13 [0.00]																		
NUM_GEOS	C	0.05 [0.05]	0.28 [0.00]																	
NUM_ROUNDS	D	0.09 [0.00]	0.22 [0.00]	0.02 [0.49]																
NUM_PORT_COS	E	0.11 [0.00]	0.24 [0.00]	0.03 [0.20]	0.92 [0.00]															
NUM_PEOPLE	F	0.15 [0.00]	0.46 [0.00]	0.51 [0.00]	0.16 [0.00]	0.19 [0.00]														
ln(FUND_SIZE)	G	–0.16 [0.00]	0.16 [0.00]	0.27 [0.00]	–0.02 [0.52]	0.01 [0.68]	0.40 [0.00]													
ln(INVESTMENT_SIZE)	H	0.09 [0.00]	0.15 [0.00]	0.19 [0.00]	–0.04 [0.11]	–0.04 [0.11]	0.42 [0.00]	0.55 [0.00]												
I(SEED_FUND)	I	0.09 [0.00]	0.05 [0.05]	–0.01 [0.77]	0.19 [0.00]	0.17 [0.00]	0.05 [0.07]	–0.07 [0.01]	–0.09 [0.00]											
EXPERTISE	J	0.11 [0.00]	0.29 [0.00]	0.13 [0.00]	0.09 [0.00]	0.09 [0.00]	0.36 [0.00]	0.20 [0.00]	0.26 [0.00]	0.07 [0.01]										
CONNECTIONS	K	0.06 [0.02]	0.09 [0.00]	0.02 [0.34]	0.03 [0.26]	0.04 [0.13]	0.24 [0.00]	0.14 [0.00]	0.16 [0.00]	–0.01 [0.70]	0.09 [0.00]									
I(SELF-INVESTS)	L	–0.07 [0.00]	0.05 [0.06]	0.39 [0.00]	–0.06 [0.01]	–0.05 [0.04]	0.04 [0.10]	0.11 [0.00]	–0.02 [0.48]	–0.07 [0.00]	–0.16 [0.00]	–0.05 [0.05]								
I(REP_REQUIRED)	M	0.06 [0.03]	0.12 [0.00]	0.01 [0.73]	–0.06 [0.01]	–0.04 [0.13]	0.14 [0.00]	0.08 [0.00]	0.14 [0.00]	–0.01 [0.83]	0.29 [0.00]	–0.08 [0.00]	–0.19 [0.00]							
I(PREFERS_CONTROLLING_SHARES)	N	0.02 [0.42]	0.14 [0.00]	0.11 [0.00]	–0.10 [0.00]	–0.10 [0.00]	0.24 [0.00]	0.16 [0.00]	0.19 [0.00]	–0.04 [0.13]	0.20 [0.00]	0.06 [0.01]	–0.04 [0.08]	0.24 [0.00]						
AVE_FLAT	O	–0.03 [0.33]	–0.09 [0.00]	0.03 [0.26]	0.19 [0.00]	0.17 [0.00]	–0.12 [0.00]	–0.24 [0.00]	–0.26 [0.00]	0.17 [0.00]	–0.10 [0.00]	–0.05 [0.03]	0.05 [0.05]	–0.14 [0.00]	–0.17 [0.00]					
AVE_CARRY	P	–0.09 [0.00]	0.04 [0.16]	0.32 [0.00]	0.11 [0.00]	0.12 [0.00]	0.22 [0.00]	0.56 [0.00]	0.25 [0.00]	–0.01 [0.57]	0.05 [0.04]	0.05 [0.05]	0.13 [0.00]	–0.06 [0.02]	0.03 [0.33]	0.16 [0.00]				
I(SOLO_INVESTOR)	Q	0.04 [0.14]	0.13 [0.00]	0.04 [0.11]	0.03 [0.30]	0.04 [0.11]	0.14 [0.00]	0.03 [0.28]	–0.02 [0.35]	0.17 [0.00]	0.14 [0.00]	0.00 [0.96]	–0.03 [0.21]	0.09 [0.00]	0.11 [0.00]	0.02 [0.35]	–0.01 [0.58]			
VCPE_SECTOR_ACTIVITY	R	0.12 [0.00]	0.15 [0.00]	–0.08 [0.00]	0.11 [0.00]	0.12 [0.00]	0.06 [0.02]	–0.09 [0.00]	0.11 [0.00]	–0.04 [0.11]	0.13 [0.00]	–0.02 [0.39]	–0.10 [0.00]	0.16 [0.00]	0.12 [0.00]	–0.20 [0.00]	–0.23 [0.00]	0.04 [0.09]		
I(STRONG_EQUITY_MARKET)	S	–0.02 [0.52]	0.02 [0.52]	0.01 [0.73]	–0.02 [0.54]	–0.01 [0.58]	–0.02 [0.50]	–0.01 [0.73]	0.00 [0.85]	–0.02 [0.37]	0.04 [0.15]	–0.02 [0.34]	–0.03 [0.33]	0.01 [0.74]	–0.02 [0.45]	0.01 [0.79]	0.01 [0.70]	0.01 [0.70]	0.05 [0.05]	

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is positive and significant (at 1% significance), suggesting that diversification across industries increases returns.

Column 2 of Table 5 examines joint industry and region diversification. Both NUM_INDS and NUM_GEOS are positive and significant. However, the interaction term NUM_ INDS × NUM_GEOS is negative and significant. Together,

TABLE 5

Baseline Regression Results

Table 5 contains the baseline regression results. The dependent variable is the fund's IRR. The models include fund-vintage dummies, fund-type dummies, and fund-region dummies, and cluster standard errors by fund vintage, family/management firm, and fund region. Square brackets contain *p*-values. Table 2 defines the variables. ** and * indicate significance at the 1% and 5% levels, respectively.

	Dependent Variable: IRR			
	1	2	3	4
NUM_INDS	0.334**	0.529**	0.145	0.220
	[0.002]	[0.000]	[0.386]	[0.543]
NUM_GEOS	0.078	0.688*	0.103	1.961*
	[0.666]	[0.032]	[0.760]	[0.012]
$(NUM_INDS)^2$				0.003
				[0.794]
$(NUM_GEOS)^2$				−0.081*
				[0.011]
NUM_INDS × NUM_GEOS		−0.038*	0.060	−0.008
		[0.015]	[0.079]	[0.853]
$(NUM_INDS \times NUM_GEOS)^2$			−0.001**	0.000
			[0.001]	[0.842]
NUM_ROUNDS	−0.060	−0.058	−0.056	−0.065*
	[0.066]	[0.075]	[0.085]	[0.048]
NUM_PORT_COS	0.212*	0.209*	0.199*	0.227*
	[0.020]	[0.023]	[0.028]	[0.014]
NUM_PEOPLE	0.345*	0.413**	0.400**	0.387**
	[0.015]	[0.004]	[0.005]	[0.007]
ln(FUND_SIZE)	−3.262**	−3.429**	−3.544**	−3.640**
	[0.000]	[0.000]	[0.000]	[0.000]
ln(INVESTMENT_SIZE)	2.007**	2.060**	2.263**	2.228**
	[0.005]	[0.004]	[0.001]	[0.002]
I(SEED_FUND)	10.121**	9.994**	9.313**	9.338**
	[0.004]	[0.004]	[0.007]	[0.007]
EXPERTISE	0.677*	0.640*	0.621*	0.644*
	[0.030]	[0.041]	[0.047]	[0.038]
CONNECTIONS	0.148	0.136	0.131	0.122
	[0.132]	[0.167]	[0.186]	[0.219]
I(SELF-INVESTS)	−3.017	−3.706	−4.371	−3.616
	[0.210]	[0.129]	[0.079]	[0.147]
I(REP_REQUIRED)	0.723	0.324	0.867	0.729
	[0.606]	[0.819]	[0.531]	[0.599]
I(PREFER_CONTROLLING_SHARES)	−2.036	−1.493	−1.349	−1.148
	[0.234]	[0.384]	[0.432]	[0.504]
AVE_MGT_FEE	−3.626*	−3.831*	−3.510*	−3.723*
	[0.039]	[0.028]	[0.041]	[0.035]
AVE_CARRY	0.444	0.426	0.355	0.442
	[0.172]	[0.193]	[0.277]	[0.181]
I(SOLO_INVESTOR)	0.630	0.783	1.421	1.223
	[0.686]	[0.616]	[0.364]	[0.435]
VCPE_SECTOR_ACTIVITY	−29.008**	−28.098**	−27.869**	−28.935**
	[0.003]	[0.003]	[0.004]	[0.002]
I(STRONG_EQUITY_MARKET)	−9.781	9.436	10.491	11.052
	[0.436]	[0.455]	[0.392]	[0.367]
No. of obs.	1,505	1,505	1,505	1,505
R^2	31.30%	31.60%	32.00%	32.30%

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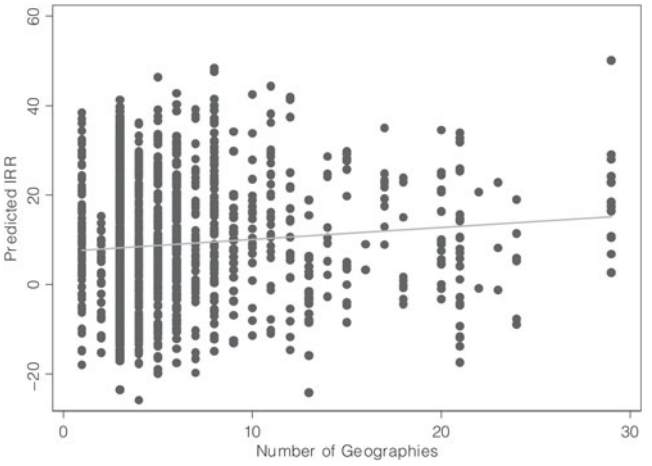
these results imply that diversification across a reasonable number of industries and regions improves IRRs; however, excess joint diversification across both industries and regions reduces returns.

Columns 3 and 4 of Table 5 examine the quadratic interaction (NUM_INDS × NUM_GEOS)^2. The main result in column 3 is that the quadratic term is negative and statistically significant (although it is economically small in magnitude). Furthermore, the statistical significance appears to be due to a small number of high-diversification funds, as illustrated in Figure 1. For example, the interaction term (NUM_INDS × NUM_GEOS)^2 is insignificant in a sample that excludes funds in the top 95% of geographic diversification, or it merely excludes the 13 "very high diversification" funds that have the greatest level of geographic diversification. Column 4 also controls for the individual quadratic terms (NUM_INDS)^2 and (NUM_GEOS)^2; only (NUM_GEOS)^2 is statistically significant (and negative), suggesting that "excessive" diversification might cause funds to spread themselves too thinly. It is worthy of note that in columns 3 and 4 the term NUM_INDS is not statistically significant; however, this likely reflects the inclusion of additional interaction terms and the pursuant collinear concerns.

FIGURE 1

Fitted IRRs by Geographic Diversification

Figure 1 plots "predicted IRRs" by geographic diversification. The "predicted IRRs" are the fitted values from an estimation of equation (1) that only includes NUM_GEOS and the controls. The vertical axis is the fund's percentage IRR. The horizontal axis is the number of geographic regions in which the fund invests.



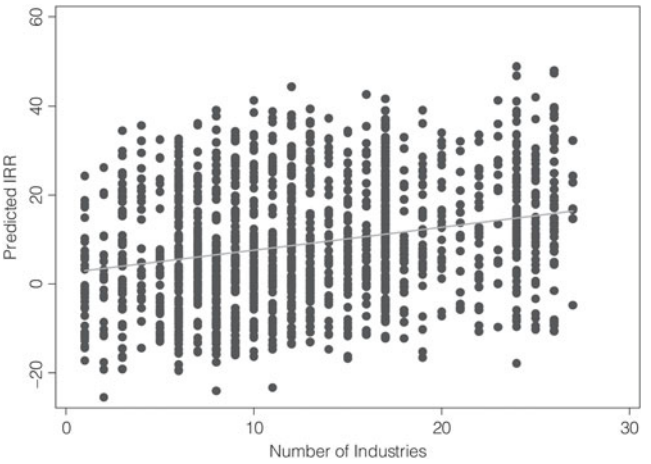
Figures 1 and 2 illustrate and support the results. They depict the fitted values from an estimation of equation (1) when there are no intermediating variables. That is, the figures show the relation between i) IRRs and NUM_GEOS (Fig. 1), and ii) IRRs and NUM_INDS (Fig 2). They illustrate the positive relationship between returns and both industry diversification and geographic diversification. In particular, Figure 2 suggests a monotonic relationship between industrial diversification and IRRs, in contrast to certain prior studies that document a nonlinear relationship between IRRs and diversification (Hoskisson et al. (1991), Palich et al. (2000), and Qian et al. (2010)). This discrepancy is likely due to the fact that

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FIGURE 2

Fitted IRRs by Industrial Diversification

Figure 2 plots "predicted IRRs" by industrial diversification. The "predicted IRRs" are the fitted values from an estimation of equation (1) that only includes NUM_INDS and the controls. The vertical axis is the fund's percentage IRR. The horizontal axis is the number of industries in which the fund invests.



these studies focus on corporate diversification rather than PE fund diversification. Figure 1 suggests that IRRs generally increase with geographic diversification; however, there is some evidence of outliers, which I examine in more detail in robustness tests (the results are largely robust to omitting the "high geographic diversification" funds from the sample).

Large funds, as proxied by ln(FUND_SIZE), earn significantly lower returns (at 1% significance in all models). This suggests diseconomies of scale in PE. Private equity funds that invest in large companies earn higher returns (the coefficient on ln(INVESTMENT_SIZE) is positive and significant at 1% in all models). This may reflect skewness in the returns on small PE investments.

The coefficient on NUM_PORT_COS is positive and significant at 5% significance in all of columns 1–4 of Table 5. This implies that returns increase with the number of companies in a fund's portfolio. A possible explanation is that increasing the number of portfolio companies decreases the fund's exposure to company-specific (idiosyncratic) risk. This might improve the fund's risk/return relationship and ameliorate agency conflicts of managerial risk aversion. Reducing idiosyncratic risk might also enable the fund to increase its exposure to systemic risk, thereby increasing overall returns while keeping total risk constant. An additional explanation is that investing across more companies gives the fund managers more experience and skills. The increased skill and experience enable managers to derive more value from each portfolio company.

Returns decrease with the number of financing rounds (NUM_ROUNDS), although this result is weakly significant (at 10% significance). Guler (2007) suggests that institutional/political pressures may induce suboptimal investments in subsequent investment rounds. The negative coefficient on NUM_ROUNDS

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provides some support for this hypothesis, indicating that returns decrease if the fund undertakes many investment rounds.

The coefficient on VCPE_SECTOR_ACTIVITY is negative and significant. This quadrates with the "money-chasing deals" hypothesis that excess VCPE activity creates overcrowding and forces funds to invest in companies that have diminishing returns to investment (see Diller and Kaserer (2009)).

The overall finding is that diversification increases returns. The issue, then, is whether diversification especially benefits funds that invest in start-ups.

C. Does Diversification Especially Assist PE Funds That Make Seed Investments?

The results largely support the seed-fund hypothesis (Hypothesis 2). The regression results are in columns 1–3 of Table 6. In columns 1 and 2, I separately examine the interaction terms I(SEED_FUND) × NUM_INDS and I(SEED_FUND) × NUM_GEOS; they are positive and significant at 10% and 1%, respectively. In column 3, I include both interaction terms, and only I(SEED_FUND) × NUM_GEOS is positive and significant (at 5% significance). Interestingly, NUM_INDS is positive and significant (at 5% or 1%) in columns 1–3. Overall, these results imply that geographic diversification is more important for funds that invest in seed companies (and geographic diversification is more important than industrial diversification). A possible explanation is that geographic scope can facilitate knowledge sharing, which can drive innovation and increase returns.[17]

D. Returns and Prior-Fund Diversification

Columns 4–6 of Table 6 indicate that diversification in previous funds increases IRRs, although this mainly applies to prior industrial diversification. The key result is that the coefficient of NUM_INDS(PRIOR_FUND) is positive and significant at 1% significance whether examined individually (column 4) or with NUM_GEOS(PRIOR_FUND) (column 6). There is limited evidence that prior geographic diversification improves IRRs; the coefficient on NUM_GEOS(PRIOR_FUND) is only weakly significant when analyzed individually (at 10% significance in column 5) and is insignificant in column 6. Overall, the results suggest that industry-based diversification in prior funds improves IRRs in subsequent funds. This supports the hypothesis that diversification in prior funds generates useful skills that can benefit subsequent funds; diversification might convey benefits of knowledge sharing and learning.

E. Diversification and Limited Attention

There is support for the limited-attention hypothesis as columns 1–3 of Table 7 show. The coefficient on the term NUM_INDS/NUM_PEOPLE is negative

[17] This is analogous to the use of geographic diversification within multinationals to drive innovation enterprises (see, e.g., Almeida, Song, and Grant (2002), Almeida and Phene (2004), Phene and Almeida (2008), Jenkins and Tallman (2010), and Tallman and Chacar (2011a), (2011b)).

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TABLE 6

Diversification, Seed Funds, and Prior Diversification

Table 6 contains regressions that focus on seed funds and diversification in prior funds. The dependent variable is the fund's IRR. The models are OLS models that include fund-vintage dummies, fund-type dummies, fund-region dummies, and cluster standard errors by fund vintage, family/management firm, and region. Table 2 contains the variable definitions. Square brackets contain *p*-values. ** and * indicate significance at the 1% and 5% levels, respectively.

	Dependent Variable: IRR					
	1	2	3	4	5	6
NUM_INDS	0.234*	0.306**	0.255*			
	[0.019]	[0.004]	[0.011]			
NUM_GEOS	0.064	−0.079	−0.061			
	[0.725]	[0.658]	[0.729]			
I(SEED_FUND) × NUM_INDS	1.070		0.588			
	[0.056]		[0.325]			
I(SEED_FUND) × NUM_GEOS		3.092**	2.594*			
		[0.004]	[0.028]			
NUM_INDS(PRIOR_FUND)				0.442**		0.410**
				[0.004]		[0.009]
NUM_GEOS(PRIOR_FUND)					0.330	0.223
					[0.062]	[0.211]
NUM_ROUNDS	−0.064*	−0.053	−0.056	−0.069	−0.070	−0.069
	[0.049]	[0.102]	[0.081]	[0.091]	[0.094]	[0.095]
NUM_PORT_COS	0.216*	0.196*	0.201*	0.223	0.263*	0.225
	[0.015]	[0.028]	[0.022]	[0.070]	[0.035]	[0.067]
NUM_PEOPLE	0.368**	0.383**	0.390**	0.246	0.306	0.179
	[0.009]	[0.007]	[0.006]	[0.135]	[0.063]	[0.297]
ln(FUND_SIZE)	−3.348**	−3.502**	−3.510**	−3.182*	−3.452*	−3.213*
	[0.000]	[0.000]	[0.000]	[0.027]	[0.019]	[0.026]
ln(INVESTMENT_SIZE)	2.020**	2.135**	2.122**	0.641	0.558	0.601
	[0.004]	[0.002]	[0.003]	[0.525]	[0.588]	[0.553]
I(SEED_FUND)	−4.281	−6.093	−11.400	11.912*	11.986*	11.805*
	[0.525]	[0.246]	[0.099]	[0.017]	[0.017]	[0.018]
EXPERTISE	0.740*	0.655*	0.693*	0.791	0.892	0.785
	[0.017]	[0.036]	[0.026]	[0.096]	[0.059]	[0.098]
CONNECTIONS	0.153	0.140	0.144	0.134	0.158	0.154
	[0.116]	[0.154]	[0.140]	[0.402]	[0.319]	[0.339]
I(SELF-INVESTS)	−2.727	−2.218	−2.187	−4.809	−6.214*	−5.863*
	[0.259]	[0.355]	[0.362]	[0.058]	[0.026]	[0.032]
I(REP_REQUIRED)	1.062	1.295	1.389	−1.753	−1.989	−1.758
	[0.448]	[0.355]	[0.321]	[0.367]	[0.308]	[0.365]
I(PREFER_CONTROLLING_SHARES)	−2.401	−1.980	−2.190	−5.220*	−5.217	−5.030
	[0.154]	[0.243]	[0.191]	[0.048]	[0.050]	[0.057]
AVE_MGT_FEE	−3.939*	−4.129*	−4.220*	−2.437	−2.432	−2.404
	[0.026]	[0.019]	[0.017]	[0.218]	[0.223]	[0.226]
AVE_CARRY	0.466	0.486	0.491	0.511	0.441	0.449
	[0.152]	[0.131]	[0.127]	[0.206]	[0.294]	[0.279]
I(SOLO_INVESTOR)	0.756	0.159	0.304	0.518	1.027	0.698
	[0.623]	[0.917]	[0.841]	[0.796]	[0.615]	[0.731]
VCPE_SECTOR_ACTIVITY	−27.849**	−29.187**	−28.522**	−29.364*	−23.234	−28.916*
	[0.004]	[0.002]	[0.003]	[0.032]	[0.090]	[0.034]
I(STRONG_EQUITY_MARKET)	8.808	−13.864	−12.630	−17.833**	−18.745**	−18.828**
	[0.476]	[0.309]	[0.344]	[0.008]	[0.009]	[0.005]
No. of obs.	1,505	1,505	1,505	753	753	753
R^2	31.90%	32.30%	32.40%	35.70%	35.10%	35.90%

and significant in all models (1% significance in column 1, 5% significance in column 3). Furthermore, NUM_GEOS/NUM_PEOPLE is negative and weakly significant (10% significance) when analyzed alone (but not after controlling for NUM_INDS/NUM_PEOPLE). This reflects the collinear nature of the

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TABLE 7

Diversification, Limited Attention, and Fees

Table 7 contains regressions that focus on the fees and the number of people in the fund. The dependent variable is the fund's IRR. The models are OLS models that include fund-vintage dummies, fund-type dummies, fund-region dummies, and cluster standard errors by fund vintage, family/management firm, and region. Table 2 contains the variable definitions. Square brackets contain *p*-values. ** and * indicate significance at the 1% and 5% levels, respectively.

	Dependent Variable: IRR					
	1	2	3	4	5	6
NUM_INDS	0.539** [0.000]	0.338** [0.002]	0.521** [0.001]	0.939** [0.003]	0.333** [0.002]	0.856** [0.009]
NUM_GEOS	0.106 [0.551]	0.289 [0.192]	0.156 [0.515]	0.087 [0.634]	0.648 [0.125]	0.517 [0.219]
NUM_INDS/NUM_PEOPLE	−1.239** [0.008]		−1.123* [0.048]			
NUM_GEOS/NUM_PEOPLE		−1.799 [0.058]	−0.445 [0.709]			
CARRY/FLAT				5.948 [0.358]	5.233 [0.412]	6.400 [0.320]
CARRY/FLAT × NUM_INDS				−0.064* [0.027]		−0.055 [0.062]
CARRY/FLAT × NUM_GEOS					−0.058 [0.085]	−0.043 [0.197]
NUM_ROUNDS	−0.062 [0.060]	−0.059 [0.071]	−0.061 [0.062]	−0.056 [0.097]	−0.059 [0.080]	−0.057 [0.092]
NUM_PORT_COS	0.215* [0.018]	0.208* [0.023]	0.214* [0.019]	0.206* [0.025]	0.212* [0.021]	0.209* [0.023]
NUM_PEOPLE	0.090 [0.598]	0.183 [0.265]	0.074 [0.675]	0.344* [0.017]	0.339* [0.019]	0.344* [0.017]
ln(FUND_SIZE)	−3.366** [0.000]	−3.226** [0.000]	−3.347** [0.000]	−3.139** [0.000]	−3.235** [0.000]	−3.232** [0.000]
ln(INVESTMENT_SIZE)	2.165** [0.002]	2.012** [0.005]	2.152** [0.002]	1.983** [0.005]	1.884** [0.007]	1.920** [0.006]
I(SEED_FUND)	9.848** [0.005]	9.968** [0.005]	9.836** [0.005]	9.879** [0.005]	10.109** [0.004]	9.898** [0.005]
EXPERTISE	0.618* [0.049]	0.619* [0.048]	0.609 [0.053]	0.696* [0.026]	0.688* [0.027]	0.695* [0.026]
CONNECTIONS	0.147 [0.134]	0.150 [0.126]	0.148 [0.132]	0.152 [0.117]	0.149 [0.128]	0.152 [0.118]
I(SELF-INVESTS)	−3.093 [0.199]	−3.199 [0.185]	−3.131 [0.195]	−3.338 [0.168]	−2.910 [0.225]	−3.183 [0.187]
I(REP_REQUIRED)	0.857 [0.541]	0.692 [0.621]	0.837 [0.552]	0.673 [0.632]	0.800 [0.568]	0.729 [0.604]
I(PREFER_CONTROLLING_SHARES)	−1.799 [0.290]	−2.012 [0.239]	−1.815 [0.286]	−2.039 [0.231]	−2.095 [0.220]	−2.077 [0.222]
AVE_MGT_FEE	−3.653* [0.037]	−3.713* [0.035]	−3.672* [0.036]	22.958 [0.494]	20.169 [0.546]	23.252 [0.489]
AVE_CARRY	0.410 [0.206]	0.410 [0.212]	0.405 [0.213]	−3.054 [0.494]	−2.654 [0.550]	−3.048 [0.495]
I(SOLO_INVESTOR)	0.494 [0.750]	0.557 [0.720]	0.488 [0.753]	0.729 [0.642]	0.707 [0.652]	0.738 [0.638]
VCPE_SECTOR_ACTIVITY	−29.030** [0.003]	−28.355** [0.003]	−28.866** [0.003]	−29.724** [0.002]	−29.659** [0.002]	−29.729** [0.002]
I(STRONG_EQUITY_MARKET)	9.059 [0.463]	−9.925 [0.420]	9.058 [0.463]	9.818 [0.433]	−10.017 [0.428]	9.879 [0.428]
No. of obs.	1,505	1,505	1,505	1,505	1,505	1,505
R^2	31.60%	31.40%	31.60%	31.50%	31.40%	31.50%

denominator. Funds that spread staff thinly across industries tend to do so across geographies as well. Overall, the results indicate that while both forms of diversification can reduce IRRs by spreading staff too thinly, industrial diversification is more harmful.

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F. Diversification and Fees

The regression results given in columns 3–6 of Table 7 provide support for the hypothesis that high levels of carry can create risk aversion, which motivates managers to diversify and reduce risk, thereby reducing returns. The coefficient on CARRY/FLAT × NUM_INDS is negative and significant at 5% in column 3, and it is weakly significant at 10% in column 6. The coefficient on CARRY/FLAT × NUM_GEOS is only weakly significant (at 10%) in column 5 and it is insignificant in column 6. Overall, the results suggest that performance-based compensation can reduce returns by encouraging value-destroying diversification across industries (likely designed to reduce the risk of failing to earn a performance bonus).

G. Endogeneity and Other Robustness Tests

Endogeneity Issues. Endogeneity does not appear to drive the relation between diversification and IRRs. The generalized method of moments (GMM) results are found in Table 8. The four instruments are: i) the number of funds that the management firm had previously raised, ii) an indicator that the management firm is a member of a venture capital organization, and indicators that the management firm prefers to invest across, iii) a diverse range of industries, and iv) a diverse range of regions.[18] The firm's preference for diversification (as opposed to the fund's preference) could clearly influence fund operations through management pressure, but it need not influence IRRs. The number of prior funds raised may influence the level of diversification by providing managers with the skills necessary to diversify. Prior experience may influence IRRs (following Gompers et al. (2009)), but the results are robust when this instrument is omitted. There is no reason to believe that being a member of a venture capital association must influence returns.

The key findings in the GMM results (Table 8) are that NUM_INDS and NUM_GEOS remain positive and significant in both models (5% significance in each case). While there is no perfect way to ensure that the instruments are valid, some confidence comes from the results being qualitatively similar when individual instruments are omitted. Additionally, the Hansen *J*-statistic suggests that the null of no overidentification cannot be rejected, and the Kleibergen-Paap statistics suggest that null of underidentification can be rejected.

Consistency across Buyout, Nonbuyout, and Venture Funds. The results are consistent across buyout funds, nonbuyout funds, and venture/early-stage funds (which are a subset of the nonbuyout funds). Here, I classify a fund as a "buyout fund" if Preqin lists its focus as being in buyouts. I classify a fund as a "venture" or "early-stage" fund if Preqin lists its fund type as "Venture," "Early Stage," or "Seed." The sample comprises 589 buyout funds and 916 nonbuyout funds. Note that there is only one buyout fund classified as a "seed" fund. Subsequently, I only run the seed interactions for nonbuyout funds. The industry-based diversification

[18] I deem a fund to prefer diverse industries/regions if Thomson VentureXpert states that the fund has no preference concerning regions/industries or diverse regions/industries. All instruments are from Thomson VentureXpert.

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TABLE 8

Instrumental Variables GMM Results

Table 8 contains instrumental variables (IV) GMM-based regression results. The dependent variable is the fund's IRR. Square brackets contain *p*-values. The models include fund-vintage dummy variables and cluster standard errors by vintage and by the fund's family (i.e., overarching management firm). All models include fund-vintage dummies and fund-type dummies, and cluster standard errors by the fund's vintage, family and region. The instrumented variables are NUM_INDS and NUM_GEOS. The four instruments are: the number of funds that the management firm had previously raised, an indicator that the management firm is a member of a venture capital association, and indicators that the management firm prefers to invest across a diverse range of industries or regions. ** and * indicate significance at the 1% and 5% levels, respectively.

	Dependent Variable: IRR	
	1	2
NUM_INDS	1.671*	
	[0.033]	
NUM_GEOS		2.310*
		[0.038]
NUM_ROUNDS	−0.068*	−0.050
	[0.038]	[0.140]
NUM_PORT_COS	0.136	0.230*
	[0.174]	[0.013]
NUM_PEOPLE	−0.241	−0.261
	[0.557]	[0.656]
ln(FUND_SIZE)	−2.783**	−3.458**
	[0.001]	[0.000]
ln(INVESTMENT_SIZE)	2.143**	2.029**
	[0.003]	[0.008]
I(SEED_FUND)	9.088**	10.061**
	[0.005]	[0.002]
EXPERTISE	0.170	0.583
	[0.702]	[0.098]
CONNECTIONS	0.121	0.237*
	[0.256]	[0.034]
I(SELF-INVESTS)	−4.299	−12.617
	[0.075]	[0.083]
I(REP_REQUIRED)	0.754	0.844
	[0.594]	[0.542]
I(PREFER_CONTROLLING_SHARES)	−2.660	−3.183
	[0.123]	[0.085]
AVE_MGT_FEE	−4.473*	−2.940
	[0.016]	[0.153]
AVE_CARRY	0.452	−0.125
	[0.166]	[0.817]
I(SOLO_INVESTOR)	−1.045	1.645
	[0.514]	[0.355]
VCPE_SECTOR_ACTIVITY	−39.558**	−29.577**
	[0.001]	[0.004]
I(STRONG_EQUITY_MARKET)	−1.997	−4.183
	[0.448]	[0.103]
No. of obs.	1,505	1,505
Hansen *J* overidentification statistic	3.598	4.947
	[0.308]	[0.175]
Kleibergen-Paap LM underidentification statistic	17.830	25.840
	[0.001]	[0.000]
Kleibergen-Paap Wald underidentification statistic	18.940	29.150
	[0.001]	[0.000]
R^2	21.70%	21.50%

increases IRRs for buyout funds (significant at 1% or 5%), though a tabulation is suppressed for brevity. The result is less statistically significant for nonbuyout funds and venture/early-stage funds. Most interaction terms have similar signs and significances to those in the main regressions.

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Other Performance Measures. Kaplan and Schoar (2005) utilize several measures of fund performance. The IRR measure (in the main models) is similar to the IRR based on reported cash flows in Kaplan and Schoar. Kaplan and Schoar also suggest using a "total-value-to-paid-in-capital" (TVPI) measure, which is a fund's value divided by the amount of money paid into it (what Preqin calls a fund's "multiple"). In (unreported) models that replace IRRs with TVPIs, the coefficients on the NUM_INDS and NUM_GEOS variables (and interactions thereof) are broadly consistent with those in the main models. In unreported tests I also replace the "IRR" with an "ADJ_IRR," which adjusts the fund's IRR for the average IRR of all funds of the subject fund's vintage, geographic region, and type.

Collinearity. The results are robust to diversification variable collinearity concerns. While no variance inflation factor statistic exceeds 5, there is a significant correlation between the number of investment rounds and the number of portfolio companies. Nonetheless, the results are unaffected when removing either or both of these variables, as well as insignificant variables.

Time Period. The results are robust to clustering and time period. First, the results hold when using fund-vintage dummy variables and when clustering by vintage, overall managing firm, fund region, or fund type (as indicated in the reported models). Second, the results also hold when excluding funds with a vintage after 2005 (which might not have finished investing). Third, the results are robust to including dummy variables for the date of the firm's last investment (rather than for the date in which the fund raised its capital).

Unrealized Returns. The results are robust against concerns that certain funds had not entirely concluded investment/disinvestment. In such circumstances, IRRs would not reflect the fund's total returns across all assets. However, there is no reason to believe these systematic biases exist for or against diversified funds. Nonetheless, the main results restrict the sample to funds whose vintage is before 2005. I also ensure that the results hold when I further restrict the sample to funds raised before 2002, allowing them 10 years to exit investments. This reduces the sample to 965 funds. Furthermore, the results are robust to restricting the sample to comprise only funds that last reported cash flows or IRRs before 2010 (i.e., funds for which Preqin's last updating date was 2009 or earlier); these funds are the ones most likely to have been liquidated by the end of the sample period. For brevity, I suppress these results.

Geographic Outliers. Figure 1 suggests that very high diversification funds might drive the relationship between IRRs and geographic diversification. I examine this by i) removing the funds whose NUM_GEOS is in the top 5% of the sample, and ii) removing the 13 most diversified funds. If I exclude these 13 "most diversified" funds, then results to industrial diversification are qualitatively unchanged. The results to geographic diversification, however, are weaker. Geographic diversification still increases IRRs (and this is still statistically significant); however, the interaction terms are generally less significant.

V. Conclusion

This paper analyzes the benefits and drawbacks of diversification in PE funds. Extant corporate finance literature has focused on diversification as an avenue of

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value destruction. However, diversification might improve returns for corporations that make risky investments, lack agency conflicts, and benefit from knowledge spillovers. PE funds are examples of such corporations.

The results suggest that diversification increases PE funds' IRRs, perhaps because it facilitates knowledge sharing. The key results are: i) industry-based diversification increases IRRs on average, although there is less support for geography-based diversification outside of seed funds; ii) there is only limited evidence of a quadratic relationship between diversification and returns;[19] iii) regional diversification, especially, increases IRRs for seed funds, which are the funds most likely to benefit from knowledge sharing; iv) industry-based diversification in prior funds raised by a fund's management firm increases IRRs in subsequent funds, which implies learning from prior funds' diversification-based experiences; v) diversification across industries can reduce IRRs if it spreads staff over too many industries or regions (i.e., lowers the staff-to-industry or staff-to-region ratios); and vi) industry-based diversification coupled with a high carry/flat ratio reduces returns, suggesting diversification motivated by risk aversion over fees might reduce returns. Endogeneity and mere risk reduction do not appear to drive the relation between returns and diversification.

It is worth identifying some possible alternative reasons for positive diversification-IRR relationship. First, diversification reduces a fund's exposure to firm-specific risk. This allows the fund to invest in riskier companies (for a given level of portfolio risk). These investments should yield higher expected returns in equilibrium. Second, a diversified fund might be pickier when investing outside its core areas. Thus, it might forego low-risk-low-IRR projects in regions/industries about which it has relatively little knowledge (and thus convey more fund-specific risk for the fund). Then, one would observe a positive IRR-diversification relation, but this would not be because diversification is desirable per se. Future studies involving fine company-level data could focus on disentangling these hypotheses.

These findings contribute to the literature by highlighting the impact of diversification on PE fund performance. I also emphasize the need to consider a fund's characteristics when analyzing whether diversification is likely to increase or decrease IRRs.

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[19]The coefficient on $(NUM_GEOS)^2$ is negative and significant at 5% in column 4 of Table 5; however, this is mainly due to a small number of highly geographically diversified funds.

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