Value Created by Private Equity: Evidence from Two-Sided Matching in Leveraged Buyouts

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Abstract

The market for private equity sponsored leveraged buyouts (LBOs) can be characterized as matching between private equity firms and target companies. This paper develops a structural model based on a two-sided matching model to solve an endogeneity problem caused by mutual selection by private equity firms and target companies. The model identifies and estimates two sources of the value created in LBOs: debt and monitoring. Overall, the monitoring by private equity firms creates greater economic value than debt. When the LBOs are sponsored by older private equity firms, debt destroys value. However, these private equity firms are better monitors, which compensates their loss on debt. Private equity investments in poorly performing companies or small companies are more profitable. This study also finds that the main reason why private equity firms form consortia in LBOs is to bring better debt financing to club deals. There is no strong evidence supporting the view that these deals impede bidding competitions.

Keywords: private equity, leveraged buyouts, structural model, two-sided matching model

JEL Classification: G20, G23

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1 Introduction

Private equity firms, more specifically buyout funds, acquire companies or divisions of companies using large amounts of debt – the so called leveraged buyouts (LBOs). Many factors contribute to value creation in LBOs. According to previous research, debt (Kaplan [17], Ivashina and Kovner [14]) and monitoring (Smith [31], Kaplan [18], DeGeorge and Zeckhauser [6], Holthausen and Larcker [13]) are two possible sources of value. Debt creates value directly through tax benefits, and indirectly through mitigated agency problems (DeAngelo, DeAngelo, and Rice [5]). Monitoring includes all direct influence of private equity firms on target companies, such as suggesting new strategies and recruiting seasoned executives. Despite the importance of private equity as an asset class in the economy, little is known about the economic magnitude of the value created through debt and the value created through monitoring. This is because these two types of value are entangled together empirically.[1]

This paper develops an econometric model of the LBO market to identify and estimate the value created through debt and the value created through monitoring. The paper further analyzes how the values vary with the characteristics of private equity firms and target companies. It also provides main motivations for the practice of club deals[2] studied by Officer, Ozbas, and Sensoy [27].

There are two challenges in the estimation. First, the value that can be created by the specific match between private equity firms and target companies is known only to the bidding firms. This information cannot be systematically observed in the data. Moreover, different bidders may have different valuations of the same target company. In the framework of classical linear regressions, the dependent variable is *missing*. Second, the mutual selection by private equity firms and target companies causes an endogeneity problem. Private equity firms search for investment opportunities and compete against each other to acquire the most attractive target companies; meanwhile boards of directors of the target companies select the winning bids for the best interest of shareholders. The deal outcomes – which private equity firm acquires which target company – are endogenously decided by the choices of both sides.

To solve these two problems, this paper introduces a structural model based on a two-

[1] Debt interest payments extract undistributed cash out of the target company and keep the management from investing in negative NPV projects for private benefits (Lehn and Poulsen [22]). In the meantime, private equity investors can achieve the same goal by closely monitoring the company's investment decisions.

[2] A club deal is the deal in which the acquirer is a private equity consortium.

sided matching model, which describes the mutual selection by private equity firms and target companies.[3] In the matching model, a match between private equity firms and target companies is a potential LBO deal that creates value, and the value is measured by the expected total return on the target company's equity (abbreviated as *the total return*). The total return is the private equity firm's valuation of the target company's equity divided by its pre-buyout price. Since the total returns cannot be observed, they are calculated by a latent equity return function, a function of the characteristics of private equity firms and target companies.

One of the goals of this study is to estimate the parameters in the latent equity return function. The value created through debt and the value created through monitoring are calculated by these parameters. The estimation is based on the stability of match outcomes in the LBO market. In a realized LBO deal, the observed deal premium is the return on equity for the existing shareholders of the target company; the excess of the total return over the deal premium is the return for the private equity firm on each dollar value the firm pays the shareholders. Since the latent equity return function calculates the total return for each feasible match between private equity firms and target companies, the function together with the deal premium data tell us how private equity firms and target companies share the total returns. For the match outcomes to be stable, neither the private equity firms nor the target companies would have incentive to deviate from their current match, and this incentive compatibility is supported by an appropriate sharing mechanism of the total returns. The estimation of the structural model boils down to searching for the parameter values of the function that lead to this sharing mechanism.

I estimate the model using data on LBOs of public companies sponsored by private equity during the period from 1986 to 2007. The estimation first isolates the two components of debt and monitoring from macroeconomics factors and industry specific factors, which unfortunately cannot be identified by the model. Then using the estimated latent equity return function, I calculate the two types of values in the total return. Out of the expected total returns on the target companies' equity before deal announcements, the value created through debt is 3.1%,

[3]Strictly speaking, existing shareholders of the target companies, represented by boards of directors, choose selection mechanisms, e.g. ascending-bid or sealed-bid auctions (Cramton and Schwartz [4]), and take the highest bid under Delaware law (the predominant corporate law in the US). The advantage of estimating a matching game is that economists do not have to model matching procedures in matching games (Myerson [26]); therefore, the estimation does not require any information related to the auctions in terms of format. But the matching model in this paper implicitly includes this winning rule: target companies form preference on private equity firms based on the highest bids the latter can offer – the potential deal premia.

which is statistically not different from zero; and the value created through monitoring is 7.8%, which is statistically positive and significant.

I further investigate how the values vary with the characteristics of private equity firms or target companies, and over time. In LBOs sponsored by older private equity firms, debt destroys value. For private equity firms, more debt leads to higher private equity investment returns, but too much debt destroys value and reduces the total return of the potential match, which in turn reduces the probability of winning the bidding competitions. Older private equity firms can pursue the excess borrowing strategy because they create more value through monitoring, which compensates the loss of value on debt.

In general, the value created by the match is higher if the private equity firms invest in poorly performing companies or small companies. Private equity investments in the late 1990s are less profitable than those in other periods. This may be because the private equity industry in the late 1990s became better organized and more efficient than in the 1980s. The time effect is no longer significant after the year 2001.

This paper also analyzes the motivation for club deals using the structural model. In the existing literature, there are many explanations for the phenomenon of private equity consortia, such as: to obtain better debt financing, to share risks, and to alleviate bidding competitions. In order to find out the main reason for this practice, the paper constructs a measure called the Coalition Contribution Index (CCI). The index of a private equity firm measures its popularity among the investing firms that decide to submit joint bids. A firm that better fits the motivation for joint bidding has a higher index regardless of what the motivation is. So, if the dominant motivation is related to debt financing, we will find connections between the debt and the index. Otherwise, there is no such relation.

The estimation identifies such a relation, suggesting that private equity firms form consortia to bring better debt financing to club deals. In addition to this finding, the estimated latent equity return function allows us to examine the difference in sharing of the total returns between the private equity firms and the target companies in club deals and in single firm deals. I find no strong evidence supporting the view that private equity firms have an advantage in sharing total returns against target company existing shareholders in club deals.

The contribution of this paper is both in the empirical findings and in the structural approach. First, this is the first paper to directly estimate the value created by private equity at

deal level. The paper estimates that the value created through debt is statistically zero, which rules out the possibility that private equity *fund* returns are the result of wealth reallocation from bondholders to private equity investors. Second, the structural approach in this paper can be generalized to broader research topics in empirical corporate finance, such as recruitment of corporate managers and corporate financial decisions in a competitive environment.

2 Related Literature

Guo, Hotchkiss, and Song [11], Acharya, Hahn, and Kehoe [1] study value creation in LBOs. One of their key approaches is to form peer industry groups and use their financial data as benchmarks. Intuitively speaking, if private equity investors are actively involved in management of post-buyout companies, their abilities and experience may affect the magnitude of the value that could be created. In contribution to existing literature, the matching model in my paper considers this heterogeneity of investors.

Sørensen [32] also applies structural modeling and uses a two-sided matching model. In studying venture capital industry, Sørensen [32] finds that companies backed by more experienced venture capitalists (VCs) are more likely to go public. This is due to sorting effect and direct influence by VCs. Sørensen [32] identifies and estimates these two effects. My paper studies a different research question, and focuses on total values created by specific matches in LBO markets and their cross-sectional variation.

There is a growing literature studying private equity returns at the fund level, such as, Jones and Rhodes-Kropf [16], Ljungqvist and Richardson [23], Kaplan and Schoar [19], Phalippou and Gottschalg [28], Jegadeesh, Kraeussl, and Pollet [15]. Many factors contribute to the value created in LBOs that leads to private equity fund returns. These sources of value includes macroeconomic factors, debt, and direct influence of private equity investors on target companies, i.e., monitoring.

Gompers and Lerner [9] and [10] find that macroeconomic factors affect the capital flows into private equity, and they also affect the valuation of individual deals. Kaplan [17] studies the tax benefits of debt in LBOs. In the study of company post-buyout performance, Smith [31], Kaplan [18], DeGeorge and Zeckhauser [6], Holthausen and Larcker [13], Guo, Hotchkiss, and Song [11] find evidence that the monitoring by private equity firms improves the operating

performance of companies.

Ljungqvist, Richardson, and Wolfenzon [24] have analyzed the investment behaviors of buy-out funds in LBO markets. They examine what factors affect a private equity fund's investment decisions. They find different investment behaviors by established funds and younger funds. Related to their research, I study how the value created in LBOs vary with the characteristics of the private equity firms.

3 The Structural Model

Papers in other areas of research have successfully applied the structural modeling approach (Berry, Levinsohn, and Pakes [2]). In the study of LBO markets, traditional linear regression models cannot solve the endogeneity problem mentioned in section 1. One solution to the endogeneity problem is instrumental variable (IV) method. A widely used instrument is the distance between investors and companies. But it may not be a valid instrument in the study of LBOs. For instance, a target company may register in a U.S. State with lower corporate tax rates, have headquarters in the Midwest, and have multiple manufacturing facilities outside North America. The distance can hardly be a good measure of the cost of monitoring the company.

The matching in the LBO market is many-to-many. A private equity firm is a collection of funds, and each fund invests in a portfolio of companies. The seller of a company may choose one private equity firm as the buyer, or a consortium of private equity firms. Due to this many-to-many feature in the selection process, the choice models, such as multinomial Probit model, are difficult to implement. First, the maximum number of companies that a private equity firm can invest in is unobservable. Second, anecdotal evidence suggests that the formation of teams in submitting joint bids follows a pattern similar to social networks, and the number of possible team formations grows exponentially with the total number of firms. The structural model in this paper can easily solve these problems.

4 The Model

4.1 Model Setup

Consider a market for leveraged buyouts, in which there are a finite set of public companies U (the "targets"), indexed by $i \in U$, and a finite set of private equity firms D (the "acquirers"), indexed by $a \in D$. The index i also identifies the leveraged buyout deal of target company i. In this market, private equity firms are searching for profitable deals and they can acquire more than one companies. In the mean time, companies will be sold to a private equity firm or a consortium of firms that offers the highest bid. This creates a market of many-to-many matching.[4]

Several exogenous objects characterize this matching market. The space of matches is $U \times D$. Let $\mu = \langle a, i \rangle$ be a match between private equity firm a and company i. For a match to be feasible the private equity firm's inception year must be before the transaction year. And for each feasible match there is a total value calculated by the latent equity return function $r_{\langle a,i \rangle}$. An assignment A is a finite collection of matches, which is a subset of all matches in $U \times D$. Given each assignment $A = \{\mu_1, \mu_2, \ldots\}$, let $T = \{t_{\mu_1}, t_{\mu_2}, \ldots\}$ be the set of transfers for all matches in A. Each $t_\mu \in \mathbb{R}^+$ represents a deal premium that a private equity firm pays to a target company, and t_μ specifies how the firm and the target company share the total value r_μ. For example, in KKR's buyout of Nabisco, Nabisco pre-announcement stock price is p_0; KKR believes its equity worth p_2 after due diligence; and the deal is closed at price p_1. So $t_\mu = p_1/p_0$ and $r_\mu = p_2/p_0$.[5]

I give an example to illustrate this setting. Three private equity firms appear in the history of Ohio Mattress Company (under the name Sealy Corporation after 1990). They are Gibbons Green Van Amerongen, Bain Capital, and Kohlberg Kravis Robert & Company in 1989, 1997, and 2004 buyout deals, respectively. In any given year, say 1992, all three matches are feasible because all three firms were founded well before 1992. Each match creates a total value measured by the total return $r_{\langle a,i \rangle}$ which is a function of the characteristics of the firm and the company and is unobservable to econometricians. Feasible matches have the potential to be developed into real transactions. In the completed transaction between Gibbons Green and Ohio Mattress Company, $r_{\langle a,i \rangle}$ is the expected total return that Gibbons Green can create

[4] I will follow most of the notations in Fox [7].
[5] I use log returns in later empirical estimation.

on each dollar value that it pays for the equity of Ohio Mattress Company, and $t_{\langle a,i\rangle}$ is the actual deal premium paid by Gibbons Green in the transaction,[6] which is astounding 94.29 percent. For a deal to be attractive, the individual rationality condition is $1 \leq t_{\langle a,i\rangle} \leq r_{\langle a,i\rangle}$.[7]

Let $Q : U \cup D \to \mathbb{N}^+$ be the set of quotas, where $q_a^d \in Q$ is the quota of a private equity firm a and $q_i^u \in Q$ is the quota of a target company i. The quota q_a^d represents the maximum number of companies a private equity firm can acquire, and the quota q_i^u represents the maximum number of private equity firms possible in forming a consortium. Let X be the collection of all outcome relevant exogenous characteristics for the transaction, the acquiring firm, and the target company. The matching market can be represented by a combination of (D, U, Q, X, A, T).

Let M_i be the maximum debt (including senior and subordinate debt) to EBITDA multiple of the transaction in which the target is the company i. Let Y_i be the transaction period dummy, I_i be the target company industry dummy, R_i be the target company's EBITDA to total assets ratio, V_i be the target company's market value of equity before the deal. Also define E_a as the private equity firm's age at the time of the transaction, and S_a as the firm's cumulative committed capital under management. The payoff relevant exogenous elements are a collection of vectors $X = \{x_i^u = (M_i, Y_i, I_i, R_i, V_i)', i \in U; x_a^d = (E_a, S_a)', a \in D\}$.

For any given pair $\langle a, i\rangle$ in a match outcome (A, T), it is the combination of the private equity firm's productivity and the target company's assets (tangible, intangible, human capital, etc.) that contributes to the total returns. So the latent equity return function is affected by both the target companies and the private equity firms' characteristics. The model in this paper can identify the linear effects from target companies and the cross interaction effects by target companies and private equity firms. This is sufficient for the study because private equity firms as stand alone entity cannot create any value. The latent equity return function for a one-to-one matched transaction is defined as the following.

[6] The return r is a relative measure adjusted by a relevant discount factor. The model cannot explain what this discount factor is.

[7] The markup $r_{\langle a,i\rangle}/t_{\langle a,i\rangle}$ depends on allocations of bargaining power between private equity firms and target companies, or intensity of bidding competitions.

Definition 1. *The latent equity return function of a transaction* $\langle a, i\rangle$ *for* $i \in U$ *and* $a \in D$ *is*

$$\begin{aligned} r_{\langle a,i\rangle} = \quad & \exp\Big[\big(\alpha_1 M_i + \alpha_2 M_i^2 + \alpha_3 I_i + \alpha_4 Y_i + \alpha_5 R_i + \alpha_6 V_i\big) \\ & + \big(\beta_0^1 M_i + \beta_1^1 R_i + \beta_2^1 V_i\big) \cdot E_a + \big(\beta_0^2 M_i + \beta_1^2 R_i + \beta_2^2 V_i\big) \cdot S_a + \varepsilon_{\langle a,i\rangle}\Big]. \end{aligned} \tag{1}$$

The error term $\varepsilon_{\langle a,i\rangle}$ contains two main components: measurement errors and deviation of the latent equity return function from its "correct" form. The age E_a and the size S_a are proxies for the private equity firm's experience and ability, respectively. Measurement errors occur when partners in young private equity firms have previous buyout experience. In addition to these measurement errors, there is a residual, which is a collection of higher order terms of the exogenous variables in X. Fortunately, the residual does not affect the estimation for marginal effects and cross-interaction effects of those variables. I do not specify probability distributions for $\varepsilon_{\langle a,i\rangle}$, since the estimation is semi-parametric.

The LBOs studied in this paper are in general many-to-many matching. Recently, it is more common for firms to form consortia and submit joint bids. A target company may be acquired by more than one private equity firms; a private equity firm can acquire many companies. This is a typical many-to-many matching market, which is different from marriage matching, where one-to-one restriction is legally binding. I generalize the latent equity return function from a one-to-one matching market to a many-to-many matching market. Let C^d denote a coalition of private equity firms (a coalition may have only one firm). When target company i is acquired by private equity firms C^d, it generates a collection of total returns $r_{\langle a,i\rangle}$, where $a \in C^d$. Each $r_{\langle a,i\rangle}$ is calculated by the latent equity return function given as the following.

Definition 2. *The latent equity return function of a transaction* $r_{\langle a,i\rangle}$*, in which target company* i *is acquired by private equity firm* a*, where firm* a *is in a coalition* C^d*, is*

$$\begin{aligned} r_{\langle a,i\rangle} = \quad & \exp\Bigg[\big(\alpha_1 M_i + \alpha_2 M_i^2 + \alpha_3 I_i + \alpha_4 Y_i + \alpha_5 R_i + \alpha_6 V_i\big) \\ & + \big(\beta_0^1 M_i + \beta_1^1 R_i + \beta_2^1 V_i\big) \cdot E_a + \big(\beta_0^2 M_i + \beta_1^2 R_i + \beta_2^2 V_i\big) \cdot S_a \\ & + \lambda_{-a}\left(\big(\beta_0^1 M_i + \beta_1^1 R_i + \beta_2^1 V_i\big) \cdot \sum_{a' \in C^d, a' \neq a} E_{a'} + \big(\beta_0^2 M_i + \beta_1^2 R_i + \beta_2^2 V_i\big) \cdot \sum_{a' \in C^d, a' \neq a} S_{a'}\right) \\ & + \varepsilon_{\langle a,i\rangle}\Bigg]. \end{aligned} \tag{2}$$

The coefficient λ_{-a} cannot be identified, so β^1s and β^2s remain the same for firm a's bidding partners $a' \in C^d$.

The summation of age E_a and capital under management S_a of private equity firms in one coalition measures their joint experience and ability. An alternative measure is the maximum values in each category among the members of a coalition. But this alternative can be easily rejected by the data, since otherwise, all private equity firms should team together with the most experienced and the largest firms, such as Bain Capital or KKR, which is not the case: elite firms tend to join those with comparable experience and size.

This functional form is log additively separable in the characteristics of private equity firms, E_a and S_a. It has an advantage in estimation because the cross-interaction effects will not be affected by whether it is a single firm deal or a club deal.

The estimation is semi-parametric. I will estimate the parameters in the latent equity return function, but specification of the probability distributions of the error terms is unnecessary (please see Fox [7]).

For the estimation purpose, I assume that, in the latent equity return function, the maximum debt to EBITDA multiple associated with a deal is unchanged regardless which private equity firm wins the bid. This assumption can be justified by the rationale that a company's cash flow must be strong enough to service post-buyout debt repayment and interest payment requirements, and the amount of debt a company can sustain in a leveraged buyout is restricted by the company's financial conditions. The benefit or cost of extra debt that is taken in a deal is then related to the winning private equity firm's characteristics.[8]

4.2 Private Equity Consortium Analysis

Recently, private equity firms often form consortia in corporate takeovers (Boone and Mulherin [3]). This type of deals are called *club deals*. A major criticism of private equity consortia is that joint bids in club deals tend to be less aggressive, which is against boards of directors' initial purpose of choosing auctions – to create highest possible bids for shareholders. This topic is important not only in academia, but also in policy, public interests, and courts. In this

[8]This point can also be explained by the practice of stapled finance, which is common in M&A markets after the year 2001. Stapled finance is a loan commitment arranged by the seller for whoever wins the bidding contest (Povel and Singh [29]), and the winning firm has an option but not obligation to choose this loan commitment. The size of the loan can be an indicator for the actual size of debt financing.

paper, I apply the same empirical technique to identify private equity firms' main motivation to form private equity consortia. I will leave systematic analysis to future research.

In the existing literature, there are some explanations for the practice of joint bidding. A group of private equity firms join together can obtain more debt financing with better terms; and they may also reduce the fierceness of bidding competitions. A third explanation is risk sharing: private equity firms form a consortium in one buyout transaction due to restrictions in their investment agreements with Limited Partners, which mandate the upper bound of the proportion of a certain fund that can be invested in one deal. As believed by the Limited Partners, joint investments can limit risk exposure of the injected equity by each consortium member. From an individual firm point of view, the main difference between these competing explanations is whether an extra consortium participant is an active investor or a passive free rider. So when a target company is matched with many private equity firms, this is equivalent to saying, whether adding one more firm to the acquiring team would significantly affect the performance of other investment partners.

I introduce a concept of Coalition Contribution Index (CCI) to measure popularity of a private equity firm in a consortium independent of its motivations, and then examine how CCI is interacting with the characteristics of the target companies in the latent equity return function. A private equity firm's Coalition Contribution Index measures the willingness of other private equity firms in accepting this firm as their investment partner. The CCI of a private equity firm is defined as the total number of its investment partners normalized by the total number of deals participated by that firm. The formation of coalitions is organization of the buyer side in LBO markets. And the Index indicates the popularity of a private equity firm in the process of this formation among its peers.

Direct study of formation of coalitions is cumbersome. It is technically infeasible to examine all possible coalitions empirically because of its large quantity of possible combinations, and we can only observe a limited number of realized coalitions. The Coalition Contribution Index is an alternative approach to study coalitions. The Index is assigned to each private equity firm, which is intrinsic to that particular firm. This index measures a firm's characteristics when it is interacting with other firms in a coalition, and it remains fixed when this firm is moved from one coalition to another. The Coalition Contribution Index enters the latent equity return function as interacting terms with the characteristics of the target companies.

Definition 3. *The latent equity return function of a transaction $\langle a, i\rangle$, in which target company i is acquired by private equity firms a, is*

$$\begin{aligned} r_{\langle a,i\rangle} = \quad & \exp\Big[\big(\alpha_1 M_i + \alpha_2 M_i^2 + \alpha_3 I_i + \alpha_4 Y_i + \alpha_5 R_i + \alpha_6 V_i\big) \\ & + \big(\beta_0^1 M_i + \beta_1^1 R_i + \beta_2^1 V_i\big) \cdot E_a + \big(\beta_0^2 M_i + \beta_1^2 R_i + \beta_2^2 V_i\big) \cdot S_a \\ & + \big(\beta_0^3 M_i + \beta_1^3 R_i + \beta_2^3 V_i\big) \cdot CCI_a + \varepsilon_\mu\Big]. \end{aligned} \tag{3}$$

The functional form for many-to-many matching is defined similar to (2). The empirical examination of the reason for consortia is to look at how the Index is interacting with the companies' characteristics. If a firm that joins a consortium can bring better debt financing and other expertise, it will have statistically significant connections with the maximum debt to EBITDA multiple, and this relation is positive. Otherwise, the Contribution Index will not have any such connection.

The Coalition Contribution Index is constructed in the same method as the concept of *degree* in graph theory. The graph theory has been applied in the study of social networks, and the study of networks of venture capital firms (Hochberg, Ljungqvist, and Lu [12]). The Contribution Index measures the weight of a private equity firm in coalitions. Similar to the social network measure, this concept can be easily illustrated in the same way by both matrix and graph representations, which are standard in the study of multilateral relations. Table 4 and Figure 2 are illustrations of an example, in which there are 6 transactions and 7 prominent private equity firms.

In the matrix representation, a symmetric matrix indicates the ties between private equity firms (Table 4). Two firms have a connection if they have been in at least one transaction together. In the setting of this paper, the matrix is undirected, that is, we do not distinguish lead investors from others. The diagonal elements are replaced with total number of deals in which the corresponding firms are involved. So the Coalition Contribution Index is computed as the sum of a column or a row's non-diagonal elements divided by the diagonal elements. In the graph representation of a square symmetric matrix, a node represents a private equity firm, and lines leading outward from that node represent its connections with other firms. The number of connections is defined as *degree* of that node. After normalizing by the number of that firm's overall transactions, we obtain its Coalition Contribution Index.

4.3 Equilibrium Concept

In matching games, agents compete against each other trying to match with attractive partners. For an outcome to be in equilibrium, the agents should not have incentive to deviate from their matched partners. The most widely used equilibrium concept is pairwise stable equilibrium. Research by Roth [30] suggests that natural experiments in UK medical intern markets have proved robustness of pairwise stable matchings. The estimation in this paper relies on the pairwise stability in LBO outcomes. In this section, I describe matching decision rules, agent preferences, and incentive constraints.

I follow the standard marriage matching decision rules with the one-to-one restriction relaxed. In the LBO matching markets, I assume, private equity firms search for potential target companies; owners of the companies that agree to sell organize formal auctions or solicit bids ("beauty contests"); the private equity firms submit bids; boards of directors of the companies select the winning bids. This is consistent with empirical observations that private equity firms submit bids and post-buyout plans through bidding contests and deals have to be approved by the target companies' board of directors and shareholders.

I do not explicitly model preferences of private equity firms or target companies, but their preferences depend on how they share total values created by matches. As described in section 4.1, t_μ specifies how they share the total return in the form of t_μ and r_μ/t_μ, which are log additive. In a realized transactions μ, t_μ is the actual return for existing shareholders of the target company, and they often do not know the true value of r_μ. In its preference, a target company ranks private equity firms based on the magnitudes of t_μs the latter can offer. A private equity firm's payoff is positively related to the markup r_μ/t_μ, and negatively related to the amount of equity it uses to finance the deal. Private equity firms also rank target companies in their preferences. Allocations of bargaining power or intensity of competitions decide the location of t_μ on the interval of $[1, r_\mu]$.

In pairwise stable equilibrium, there is a set of incentive compatibility and individual rationality conditions: for any two pairs of matches in the match outcome with two target companies and two private equity firms, both the private equity firm and the target company are willing to participate in their deal (the "IR" constraint), and neither target company has incentive to switch to the other company's acquirer (the "IC" constraint). These conditions are summarized by a collection of inequalities.

Definition 4. *A feasible outcome* (A, T) *is a pairwise stable equilibrium of this matching game if:*

1. *For all* $\langle a, i\rangle \in A$, $\langle b, j\rangle \in A$, $\langle b, i\rangle \notin A$, *and* $\langle a, j\rangle \notin A$,

$$t_{\langle a,i\rangle} \geq r_{\langle b,i\rangle}/(r_{\langle b,j\rangle}/t_{\langle b,j\rangle}). \tag{4}$$

2. *For all* $\langle a, i\rangle \in A$,

$$t_{\langle a,i\rangle} \geq 1, \tag{5}$$

and

$$r_{\langle a,i\rangle} \geq t_{\langle a,i\rangle}. \tag{6}$$

Part 1 of the definition states the incentive compatible constraint: company i would not deviate from its current buyer firm a to firm b even if firm b is indifferent of switching. In the inequality (4), $r_{\langle b,j\rangle}/t_{\langle b,j\rangle}$ is the actual markup that firm b can receive in the realized transaction $\langle b, j\rangle$; keep the value of firm b's current return unchanged and suppose firm b and company i are matched together, $r_{\langle b,i\rangle}/(r_{\langle b,j\rangle}/t_{\langle b,j\rangle})$ is the maximum return that firm b can pay to company i if b acquires i without hurting its current markup; if this value is less than company i's current return $t_{\langle a,i\rangle}$, i would not walk away from its current transaction and choose firm b instead of firm a. Note that the same inequality must hold for company j's incentive simultaneously.

To explain part 1 in the language of marriage matching games, in an outcome of a marriage matching market, for any two couples $\langle 1, 1\rangle$ and $\langle 2, 2\rangle$, where man 1 matches with woman 1 and man 2 matches with woman 2, and suppose women select men. These two couples are pairwise stable if the following condition is true, woman 1 would not marry man 2 instead of man 1 even if man 2 weakly prefers woman 1 to his current match woman 2; the same condition holds for woman 2.

A caveat is that the LBO matching markets are not efficient. It may happen that private equity firms and target companies which can create highest total values cannot be matched together. This is because fund sizes of a private equity firm are fixed and the number of deals it can participate in is limited. This limitation corresponds to the quota q_a^d assigned to each private equity firm in the model.

Some may wonder if pairwise stability is a realistic equilibrium concept in LBO markets, since quite often in a very short period, there are a group of private equity investors searching for investment opportunities in one industry and a group of companies searching for buyers in the mean time. Group stability is a straightforward equilibrium concept for these markets, since group stability requires stability among a group of private equity firms and a group of companies. The following proposition shows that it is sufficient to look at pairwise stable assignment outcomes.

Proposition 1. *In the matching game described above, an assignment outcome* (A, T) *is group stable if and only if it is pairwise stable.*

Next section introduces a feasible estimation procedure based only on deal match outcomes.

4.4 Related Inequalities

This paper uses a modified maximum score estimator originally studied by Fox [7]. This method makes empirical estimation of a matching model computationally feasible. In contrast, a direct approach requires checking the inequalities given in section 4.3 to predict possible matches and calculating likelihood of match assignments, then maximizing this likelihood with respect to parameters. The computation burden of the second approach is prohibitively heavy.

The maximum score estimator relies only on deal outcomes to estimate model parameters. The estimator searches for parameter values to maximize stability of observed LBO outcomes. In this paper, the model can estimate the actual scale of each parameter and there is no parameter normalization . This is because the deal premium t_μs are observable, which specify how target companies and private equity firms share the total return r_μs. By including deal premium data, the maximum score estimator scales parameter values and thus scales the latent equity return function in searching for solutions. In this way, the paper can estimate the actual magnitude of the value created through debt and the value created through monitoring.

The proposition states that the pairwise stable equilibrium exists and is unique under the assumptions: private equity firms submit bids; target companies select the winning bids; and each private equity firm has a quota on the total number of companies it can acquire.

Proposition 2. *The pairwise stable equilibrium of the matching game given above exists and is unique.*

The existence of the matching equilibrium is vital for the estimation, while the uniqueness is less important, since the estimator only checks the incentive compatibility condition, which is a necessary condition and must be satisfied by any pairwise stable equilibrium.

The essence of the maximum score estimator in this paper is the following. Section 4.1 introduces the latent equity return function, which calculates the expected total return that can be created by each feasible match between a target company and a private equity firm. The firm's inception year must be before the transaction year for a match to be feasible. Then I select two match outcomes, $\langle a, i\rangle$ and $\langle b, j\rangle$, that are realized transactions, and both $\langle b, i\rangle$ and $\langle a, j\rangle$ are feasible but are not match outcomes. The set of match outcomes is a subset of all feasible matches. Whether these two transactions, $\langle a, i\rangle$ and $\langle b, j\rangle$, are pairwise stable is decided by the values of trial parameters in the latent equity return function. The estimation by this maximum score estimator is the set of parameter values that lead to the highest number of pairwise stable pairs for a given range of latent equity return values.

By Definition 4, the maximum score objective function is given by

$$\mathcal{Q} = \sum_{\langle a,i\rangle,\langle b,j\rangle \in A} \mathbf{1}\Big[\ \mathcal{I}\big(a, i; b, j\big)\ \Big], \tag{7}$$

where the group of inequalities $\mathcal{I}(a, i; b, j)$ are

$$\log(t_{\langle a,i\rangle}) \geq \log(r_{\langle b,i\rangle}) - \Big(\log(r_{\langle b,j\rangle}) - \log(t_{\langle b,j\rangle})\Big); \tag{8a}$$

$$\log(t_{\langle b,j\rangle}) \geq \log(r_{\langle a,j\rangle}) - \Big(\log(r_{\langle a,i\rangle}) - \log(t_{\langle a,i\rangle})\Big). \tag{8b}$$

This pair of inequalities is the work horse of the estimation, and I can estimate the parameters in the latent equity return function using the observed outcomes of the LBO markets. The indicator functions $\mathbf{1}[\cdot]$ are equal to 1 when the condition $\mathcal{I}$ is true and 0 otherwise. The estimator searches for parameter values that maximize the objective function. The estimation procedure will be outlined in the next section. This estimator does not impose the individual rationality constraints either for the target companies or for the private equity firms, because the transfer t_μ is a very noisy measure, and it is redundant to incorporate this part of error into the score function.

The general latent return function r_μ of a transaction $\mu = \langle a, i \rangle$ can be written as

$$r_\mu = \exp\Big[\, f_i(X_i) + f_a(X_a) + f_{a,i}(X_i \cdot X_a) + \varepsilon_\mu \,\Big], \tag{9}$$

where X_i and X_a are characteristic vectors for the target company i and the private equity firm a. Function f_i and f_a are functions solely of the characteristics of company i and firm a, respectively, while function $f_{a,i}$ is a function of cross products of characteristics X_i and X_a. Now, re-write equation (8b) as

$$\log(t_{\langle b,j \rangle}) - \log(t_{\langle a,i \rangle}) \geq \log(r_{\langle a,j \rangle}) - \log(r_{\langle a,i \rangle}). \tag{10}$$

The general latent return function r_μ is log additive separable in functions f_i, f_a, and $f_{a,i}$, and we can see that all terms in function f_a that are related to firm a are canceled out in equation (10). By the Theorems in Fox [7], the latent equity return function given by Definition 1 and 2 can be identified.

In comparison, Fox [7] introduces a concept of local production function. In the leveraged buyout context of this paper, the local return function for deal outcomes, $\langle a, i \rangle$ and $\langle b, j \rangle$, is defined as

$$f_{a,i;b,j} = \log(r_{\langle a,i \rangle}) + \log(r_{\langle b,j \rangle}). \tag{11}$$

And the corresponding maximum score objective function is given by

$$\mathcal{Q} = \sum_{\langle a,i \rangle, \langle b,j \rangle \in A} \mathbf{1}\Big[\, f_{a,i;b,j} > f_{b,i;a,j} \,\Big]. \tag{12}$$

The indicator functions $\mathbf{1}[\cdot]$ are equal to 1 when the inequality in brackets is true and 0 otherwise. The estimates of the parameters are those which maximize the objective function. This estimator can only identify the parameters in the function $f_{a,i}$, the cross interaction terms.

Note that if we sum inequality (8a) and inequality (8b), we get the inequality in equation (12). The return functions and the transfers, which satisfy conditions (8a) and (8b), must satisfy the inequality in equation (12). So the condition specified by local return function is only a necessary condition, while $\mathcal{I}(a, i; b, j)$ is both sufficient and necessary in terms of incentive compatibility.

4.5 Estimation

The estimation is a two-step procedure combining linear regressions and maximization of the score objective function.

The main step of the estimation is to search for parameter values that maximize the score objective function. The paper uses Differential Evolution (DE) method, an algorithm developed by Storn and Price [34]. DE is a stochastic direct search method that is designed to search for global maxima of objective functions; and it can handle objective functions with jumps. The objective function in the maximum score estimator is a step function, which is piecewise constant and piecewise continuous. If a global optimum exists, it will occur in a closed and bounded subspace of the parameter space. And at least one optimum will be at a jump of the objective function. Since the existence of global optimum is known (there are 1320, 3538, and 9082 feasible pairs of matches in the three merger waves respectively, the summation of which is the upper bound for the optimum), DE is a proper algorithm for the estimation in this paper.

Because the score objective function is a step function, there is a continuum of global optima in a very large space (there are 23 or 26 parameters), and it is difficult to decide which set of parameter values is relevant. Regarding this, the paper adopts a simple two-step estimation strategy. In the first step, I suppose target companies and acquiring firms split the total return by a fixed fraction λ, $0 < \lambda < 1$. Since deal premium is observable, this gives a set of total returns. λ's are chosen sporadically between 0 and 1 to avoid bias. Using OLS regression, we have the initial values of the parameters for the estimation. These initial values are further perturbed by noises with normal distributions to form an augmented set of initial values for the estimation. In the second step, the estimation runs a controlled DE algorithm. Controlled DE algorithm is in the sense that the average value of the latent equity return function is kept within a pre-determined range, for example, ten times the average deal premium, which corresponds to the situation that the existing shareholders of the target companies obtain 10% of the total return.

The computation is lengthy due to the estimation nature of structural models. I use subsampling to compute confidence intervals. 75% deals are randomly drawn from the full samples for one computation procedure, so that these random draws can spread through three LBO waves. Over $1,000$ such calculations are computed for confidence intervals. A small number of

estimations that cause the latent equity return function well exceed the pre-determined range are discarded.

5 Data Description

5.1 Description of Sample

The data of LBO transactions come from the SDC Platinum database owned by Thomson Financial. This database is used in several previous studies of LBOs, e.g., Guo, Hotchkiss, and Song [11], and Officer, Ozbas, and Sensoy [27]. I focus on the LBOs sponsored by private equity firms.

First, I extract all completed transactions with announcement date between May 1986 and February 2007 in which the deal value is greater than $100 million, and the buyer owns more than 50% of the target's shares outstanding after the transaction. Among these transactions, the targets are identified by SDC as publicly traded companies, and the deals are characterized as "financial sponsors" with "leveraged buyout" acquisition technique. I also restrict the sample to those target companies with available financial data and reported acquisition premium. The initial screening leaves a sample of 297 possible LBOs. Each deal is examined manually to ensure it satisfies the above search criterions.

Then, by reading the comprehensive leveraged buyout reports of these deals, I identify the transactions sponsored by private equity firms or with participation of these firms. A financial buyer is treated as a private equity firm when it is: i) described as private equity firm, leveraged buyout firm, or venture capital in the business description of the acquirer or synopsis of the transaction; ii) reported in the May 2007 issue of Private Equity International (PEI) magazine; iii) claimed to be specialized in leveraged buyouts in its online profile. The sample includes divisions of the investment banks JP Morgan, Merrill Lynch, Morgan Stanley, and First Boston Credit Suisse, that provide equity financing in buyouts. In some cases, a founding partner leaves an established buyout firm and starts a new firm in the same business. For example, although Mr. Kohlberg is involved in the transactions sponsored by Kohlberg Kravis Roberts & Company (KKR) before his resignation in 1987, Kohlberg & Company and KKR are treated as two different private equity firms. I do not use the LBO and "going private" flags provided by SDC, since Officer, Ozbas, and Sensoy [27] reports missing data of

the deals sponsored by private equity firms.

Data on loan terms come from Loan Pricing Corporation's DealScan database. Borrowers' names, loan spread and maximum debt to EBITDA multiple are observable in this database. Both loan spreads and debt to EBITDA multiples are widely used deal measures in academic research and in practice. In general, private equity firms sponsor loans with the target companies as the borrowers. To match the deals from SDC and the loans from DealScan, I first search target company names in DealScan, and then identify debt financing in LBO transactions by restricting deal purpose as LBO and limiting the time frames.

Finally, the deals in the sample are divided into three waves according to the year in which they are announced: wave from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007. This partition of transactions is corresponding to the merger and buyout waves in the 1980s and the one from late 1990s to recent credit crunch (spanning across the bust of tech bubble in 2001). The three waves of deals will be estimated together but as three separate matching markets so that we can examine if there exists difference in value creation between these periods.

5.2 Description of Variables

From the sample, I form a deal matching matrix with the private equity firms and the target companies as rows and columns. Each entry in this matrix is a dummy variable which is 1 if the private equity firm and the target company corresponding to that entry are involved in a buyout transaction, and 0 otherwise. This is equivalent to saying that the dummy is 1 if they are in a match and 0 if they are not matched. Then, the sum of each row is the number of transactions completed by the private equity firm corresponding to that row; and the sum of each column is the number of financial buyers in one transaction, which is a club deal if the sum is greater than 1.

The observed firm characteristics are the inception year, and the cumulative committed capital raised. Age of a firm at the time of its transaction is a reasonable measure for its experience (please see Gompers [8], and Hochberg, Ljungqvist, and Lu [12]). The cumulative committed capital raised is the measure of a firm's ability. Private equity firms are organized as collections of funds. When the partners of a firm (the General Partners, the GPs) are seeking capital commitment from investors (the Limited Partners, the LPs), the target fund size is an indicator of their intrinsic abilities. This is because under-commitment is detrimental to a

firm's reputation and over-commitment will cause investors' concerns of suboptimal investing behaviors of the fund managers. The combination of the two measures, cumulative committed capital and age, can distinguish long time prominent private equity firms from those who are less active but have been in the LBO industry for a significantly long time, such as KKR versus Kelso & Company.

The observed exogenous characteristics for the target companies are the deal announcement date, industry, market value, and financial conditions before the transactions. The companies are divided into industries according to the Fama-French 12-industry portfolio categories. The target's performance is measured by the ratio of EBITDA to total assets for the fiscal year prior to the deal announcement. This is the measure of a company's fundamental characteristics. When the EBITDA data is missing for a target company, it is filled by the data from its major competitors in the same industry adjusted by total assets.

Characteristics of the buyout debt financing are loan spreads and debt to EBITDA multiples. Both measures are key terms in practice and in academic research (e.g., Ivashina and Kovner [14]). This paper will focus on the maximum debt to EBITDA multiple as the main description for the debt financing. Due to computation burden, the structural model in this paper is not able to analyze debt financing in more details. As pointed out by Kaplan and Stein [20], it is equally crucial to consider buyout loans contractual features – seniority, maturity, and the division between public and private lenders. I hope that advanced computation technology and econometric methods in the near future will allow us to address this research question.

6 Results

6.1 The Latent Equity Return Function

Section 4.5 describes the procedure of the estimation in details. The latent equity return function in the form of equation (2) is estimated with the industry and merger wave dummy variables included. In the latent equity return generated by the matching between a private equity firm and a target company, the financing benefit in LBO deals is estimated at 3.1%, and the management benefit by the investing firms is estimated at 7.8%. The null hypothesis that these two benefits are statistically equal is rejected at 1% level. Table 5 reports the estimation

results. The empirical model in this paper is different from the classical regression model, and the interpretation is also different.

Not surprisingly, the coefficient of the maximum debt to EBITDA multiple is positive (0.0210) and statistically significant. The debt does affect the latent returns positively and significantly. The coefficient of the cross interaction term between the multiple and the age of the private equity firm is positive at 0.0002 and statistically significant at 10% level. This coefficient is the second order cross derivative of the latent equity return function with respect to the multiple and the firm age. It indicates that, at the average age level of private equity firms, the amount of debt borrowed by the private equity firms is increasing in firm's age. Older firms are established – their ability to screen for better deals and their ability to manage post-buyout companies are known to lenders. Banks provide bridge loans in hope to generate profits in post-buyout refinancing (e.g., issuance of high yield bonds, also known as junk bonds). Institutional investors, such as pension funds, are major high yield bond buyers. Established private equity firms benefit from their relationship with these lenders and this relationship is built upon the firms' solid investment track records.

The model can identify linear effects of target companies' characteristics on total returns of LBO transactions. Both coefficients of the term EBITDA on total assets (ROA) and the term log market value in the latent equity return function are negative and significant. The private equity investments in poorly performing companies or small companies are more profitable than those investments in good companies or large companies. Intuitively speaking, there is larger margin for operational improvement in poorly performing companies. This is also an indirect evidence of the important role that private equity firms are playing in LBO deals. As to the size effect of target companies, there is more asymmetric information problem associated with small public traded companies. Private equity investors as private investors do not have to reveal strategic information to the public, so they can invest in information opaque small companies and explore this advantages.

The investment period matters in the total return of a LBO deal. The estimation includes the time dummy variables for the LBO waves in the late 1990s and after the year 2001. If we compare the two latent equity return functions, one that does not contain the Coalition Contribution Index (CCI) with the one that does, *ceteris paribus*, a transaction in the late 1990s is less profitable than the one in the 1980s. This is true in both estimations. A transaction in the

first few years after 2001 may also generate less total return, but this is no longer true when the CCI is included in the estimation. This is consistent with what we have observed in the history of the LBO sector of the private equity industry. In the late 1990s, an increasing number of private equity investors are competing for a limited number of investment opportunities, which drives down the average expected total returns. After the year 2001, less competent private equity investors have left the market and the industry is better organized. In the estimated latent equity return function with the CCI, the deals in the LBO wave after 2001 no longer have significant negative time effect.

In the estimation reported by Table 6, I examine which characteristics of target companies are more important in the private equity firms' deal choices for given levels of their age and size. I run "horse race" on the cross interaction terms between companies' return on assets, market value and firms' age, size. The data samples of return on assets and market value are converted into percentiles so that they are in the same unit for comparison. The latent equity return function is first estimated with the converted companies' characteristics. The coefficients for the cross interaction terms between companies' return on assets, market value and firms' age are available. Then I take difference of the absolute values of these two coefficients. The term with larger value wins the "horse race". For the significance of the difference, I randomly draw 75% deals from the full sample, and calculate the difference for each random draw. This gives the empirical distribution of the difference, and I can examine the significance from this distribution. It is the same procedure for the cross interaction terms between companies' return on assets, market value and firms' size.

If I hold firm size fixed, the market value (size) of the target companies is a factor more important than the companies' financial conditions (return on assets) in the firms' decision to pursue the deal. This is because when the competition among private equity firms became fierce in the late 1980s and late 1990s, some private equity firms were focusing more on larger companies to avoid direct bidding competitions against younger and smaller firms. And large amount of commitment from institutional investors as Limited Partners also lead to bigger buyout funds and made large deals possible. In summary, size of the target companies is the first criterion that a private equity firm uses to screen for investment opportunities.

Given a firm's age, the estimation shows that target companies' financial conditions (return on assets) is more important than its size, but this relation is not significant. This is caused

by the heterogeneity in the background of private equity firms. Some relatively younger firms are in fact founded by veterans from prestigious investment banks, who can raise large buyout funds and target bigger companies. But for some firms, although they have been in the private equity industry for a long period, they only restrict their focus in middle market on mid-size companies.

6.2 Contributions by "Congenial" Firms

In this section, I analyze whether the Coalition Contribution Index (CCI) is an important factor in the latent equity return function, and how it relates to the characteristics of the target companies. The Index enters the latent equity return function as cross interaction terms with debt financing, the maximum debt to EBITDA multiple, and the target company's characteristics, such as, return on total assets and market value. The estimation indicates a significant connection between high CCI and high debt to EBITDA multiple. This suggests, the main motivation for joint bidding practice is that private equity partners can bring better debt financing to club deals. Table 7 reports the estimation results.

In the estimated latent equity return function that includes CCI, the coefficient of the cross interaction term between the debt to EBITDA multiple and the Index is positive significant. This indicates that more "congenial" or popular firms tend to be associated with higher leverage in their buyout deals. Note that the estimation is over all buyout transactions, including both club deals and single firm deals. The estimated coefficient says that the firms with high CCI raise more debt financing in their transactions. During the due diligence process of each deal, the bidders project the target company's future cash flow and estimate the maximum debt that the post-buyout company can sustain. If a private equity firm bidder can raise cheaper debt financing, this will give that firm an advantage in the bidding competition for the target company. And the finding that these firms are well accepted by other private equity firms in club deals suggest that firms join together in order to obtain better debt financing.

It is true that sometimes private equity firms submit joint bids because of other concerns, but they may not be the dominant reasons. If the only purpose of club deals is to alleviate the severeness of bidding competitions, the CCI is a very conservative measure. The CCI is a special descriptive measure for private equity firms' unobservable characteristics, which to some extent indicates how well a firm is accepted by other private equity firms in club deals.

The Index is constructed as the total number of other private equity firms which have been investment partners with this firm divided by the total number of deals this firm has been involved. If private equity firms intend to reduce competitions by joint bidding, the ability and the experience of partner firms are less important factors in formation of teams. In this situation, firms are more concerned with whether bidding partners are comfortable co-investors. Then social networks form among these firms, and bidders tend to join a smaller set of firms with closer social ties. However, we still find significant connection between CCI and debt financing.

The coefficient for the cross interaction term between target companies' return on assets and the CCI is also positive and significant. Intuitively, for the post-buyout company to enjoy tax benefit of debt, there has to be reasonable cash flow under tax shield. And strong cash flow can help the company to service more debt. This is an indirect evidence for the conjecture that the Index indicates a firm's ability to raise debt financing.

Several private equity firms team together may be able to acquire mammoth companies. And because the investment agreements between Limited Partners and General Partners usually mandate the maximum portion of a fund that can be invested in one company, fund managers of private equity firms can invest in bigger companies in club deals than by themselves. An interesting finding by the estimation of the latent equity return function is that the investment consortium makes the deal possible, but it is not a value creator. The coefficient for the cross interaction term between the market value of the target companies and the CCI is insignificant although positive.

6.3 Club Deals versus Single Firm Deals

The empirically estimated latent equity return function allow us to examine the difference between the performance of private equity firms in club deals and their performance in single firm deals. The paper restricts its focus on private equity firms that have participated in at least one leveraged buyout consortium. The goal of the analysis in this section is to answer the question, conditioned on the knowledge that a private equity firm has been involved in club deals, on average, what is the performance difference of that firm between club deals and single firm deals. There are firms in the sample which are never involved in club deals. These firms self-select to acquire target companies by themselves for many reasons, such as, their

emphasis on management autonomy, i.e., some firms that need dominant control to implement a particular investment strategy do not want to share controls with other firms. Including these firms in the comparison will cause bias.

One difficulty of the comparison is that the model in this paper cannot identify linear effects from private equity firms in the latent equity return function, and the empirical estimated function is only a partial form of the "true" function. But, if we assume that the true equity return function is in the form of equation (9), then de-mean within the collection of all transactions by a specific firm can eliminate that firm's linear effect. De-mean normalizes all firms' expected total returns to one, which is equivalent to keeping all firms at the same starting point before a race. All deals finished by these firms are divided into two groups, club deals and single firm deals.

If private equity firms form consortium in order to alleviate bidding competitions, we should observe no significant difference in the latent returns calculated by the latent equity return function between club deals and single firm deals; while in the meantime, private equity firms can retain larger portions of the total value created in club deals. Opposite to this view, if private equity firms can bring better financing to a bidding consortium and share investment risks among themselves, we should observe no significant advantage held by private equity firms in sharing total returns with the target companies' existing shareholders, and more importantly, these firms may generate relatively higher expected total returns in club deals.

The paper uses a two-sample Kolmogorov-Smirnov test for the performance comparison analysis. Because the estimation of the latent equity return function is semiparametric – the probability distributions of the error terms are not specified, standard Chi-square test for comparative purposes is less favorable, which requires grouping observations into intervals but small number of intervals can change test statistics dramatically. K-S test is an alternative distribution free test of goodness of fit. As described in the model of this paper, the latent equity return function calculates the total expected equity return on any feasible match between a target company and a private equity firm, and this return plus some random shock, which is unknown to outsiders, gives the firm's *ex ante* belief of the prospect of the deal. Since each firm's average expected returns on all its deals is normalized to one, an intuitive method of comparison is to examine whether the returns for club deals and those for single firm deals are being drawn from the same probability distribution. This is related to comparison of value

distributions from two separate sample sets. K-S test does not require the number of the observations in the two sample sets to be equal.

Denote the empirical cumulative probability distribution functions for the latent returns in club deals and in single firm deals as $F_c(\cdot)$ and $F_s(\cdot)$ respectively. The two-sample K-S test statistic is

$$D_{n,n'} = \sup_x \left|F_{c,n}(x) - F_{s,n'}(x)\right|,$$

where n and n' are their sample sizes. The Kolmogorov distribution is defined as the distribution of the random variable

$$K = \sup_{t\in[0,1]} \left|B(t)\right|,$$

where $B(t)$ is the Brownian bridge. The null hypothesis is that the two data samples come from the same probability distribution. The alternative hypothesis can be either the two data samples come from two different probability distributions, or one data sample comes from a distribution which stochastically dominates (or is stochastically dominated by) the second distribution. Depending on the alternative hypothesis, the test can be either two-tail or one-tail. Denote K_α as the critical values of the Kolmogorov distribution. The null hypothesis is rejected at level α if

$$\sqrt{\frac{nn'}{n+n'}} D_{n,n'} > K_\alpha.$$

(please see Massey [25] and Stephens [33].)

The paper finds that private equity firms generate higher latent returns in club deals statistically and have no significant advantage in sharing total returns. I have performed K-S test on both overall total returns and the private equity firms' share of returns, with the two data sample sets as club deal returns and single firm deal returns. Graphically, the empirical cumulative distribution function of the returns from club deals lies below that of the returns from single firm deals. Figure 4 and Figure 5 report the test results.

In the analysis of total values of latent equity return function, the null hypothesis of equal distribution is rejected at 1% significance level with p-value being 0.00. Although there are only small variations of the returns in both club deals and single firm deals, returns in club deals strongly dominate the returns in single firm deals, in the sense of first order stochastic dominance, which is illustrated in Figure 4 that the empirical cumulative distribution function

of the returns in club deals lies below that of the returns in single firm deals. From the consortium analysis, we know that higher Coalition Contribution Index is associated with higher maximum debt to EBITDA multiple, and debt financing contributes insignificant economic value to leveraged buyout transactions. Combining this result with the finding in this section, we have seen strong evidence supporting that private equity firms do generate higher returns in club deals from a social welfare maximizer point of view.

To examine whether private equity firms have advantage in sharing total returns with target companies' existing shareholders in club deals, we subtract deal premia from the latent returns and perform K-S test on the firms' portion of the investment returns. The null hypothesis cannot be rejected at 5% significance level and the p-value is 0.0576. This result contributes greatly to our understanding of private equity firms' investment strategies. Many believe that private equity firms form consortia in order to facilitate collusion in the auctions of target companies. This is not surprising since joint bidding reduces the number of bidders. But this view fails to consider the situation that a handful of strong and serious bidders can generate higher total returns and higher deal premia than a pool of weak and less serious bidders.

7 Final Remarks

This paper develops a structural model based on a two-sided matching model to study LBOs sponsored by private equity, and it identifies and estimates the value created through debt and the value created through monitoring. I find that monitoring by private equity firms creates greater value than debt in private equity sponsored LBOs. My study also finds that private equity firms form consortia in LBOs in order to bring better debt financing to club deals. There is, however, no strong evidence supporting the view that these deals impede bidding competitions.

Separating the value created through debt and the value created through monitoring is important for understanding private equity sponsored LBOs. If the value created through debt is positive, any investor, who can acquire a company using large amounts of debt, is able to benefit from high leverage. Different from debt, the value created through monitoring is the value created by the activities of private equity investors. This value is specific to the joint relation between private equity firms and target companies, the matching relation.

The model in this paper solves an endogeneity problem caused by mutual selection by private equity firms and target companies in LBO markets. This structural approach in empirical corporate finance is of independent interest. In situations where researchers cannot observed economic agents' choice sets and decision making, or cannot identify directions of causality, it is difficult to apply traditional linear regression models. Structural models combine theoretical models with empirical estimation to address these problems. It may help further our understanding of the behaviors of investors and corporate managers.

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Table 1: Summary Statistics: Private Equity Firms

The sample consists of 101 private equity firms founded between 1968 and 2004 ("inception year"). A financial buyer is classified as a private equity firm when it is: i) described as private equity firm, leveraged buyout firm, or venture capital in its business description or in deal synopsis; ii) reported in the May 2007 issue of Private Equity International (PEI) magazine; iii) claimed to be specialized in leveraged buyouts in its profile. The cumulative capital under management is the aggregate size of funds raised by a private equity firm for the purpose of conducting leveraged buyout deals.

		Cumulative Capital under Management (bil)			
Inception Year	Obs.	Min.	Max.	Mean	Median
1968	2	12.0	12.0	12.0	12.0
1969	2	1.8	3.0	2.4	2.4
1971	1	30.0	30.0	30.0	30.0
1972	1	1.4	1.4	1.4	1.4
1974	1	20.0	20.0	20.0	20.0
1975	1	2.5	2.5	2.5	2.5
1976	1	46.7	46.7	46.7	46.7
1978	4	1.0	11.0	5.9	5.8
1980	2	4.9	8.0	6.5	6.5
1981	1	2.0	2.0	2.0	2.0
1982	2	1.0	3.0	2.0	2.0
1983	4	2.5	12.5	5.5	3.5
1984	6	0.1	75.0	18.3	8.8
1985	4	6.0	51.0	23.9	19.3
1986	4	0.4	38.0	20.6	22.0
1987	3	2.8	85.5	30.7	3.7
1988	5	0.5	3.7	2.3	3.0
1989	6	0.6	22.0	8.3	6.5
1990	3	2.0	37.0	13.8	2.5
1991	3	2.0	3.3	2.7	2.8
1992	7	0.8	46.7	13.0	3.0
1993	2	2.0	7.5	4.8	4.8
1994	3	0.6	14.3	5.3	1.0
1995	9	0.5	24.0	5.2	2.0
1996	3	1.2	5.0	2.6	1.6
1997	3	0.5	2.0	1.3	1.5
1998	6	1.5	29.5	7.1	2.9
1999	4	0.2	14.0	4.0	0.9
2000	4	1.5	9.0	5.4	5.5
2001	1	8.0	8.0	8.0	8.0
2004	2	1.9	4.0	2.9	2.9
Total	101	0.1	85.5	9.6	3.2

Table 2: Summary Statistics: Target Companies

The sample consists of 208 completed leveraged buyout transactions sponsored by private equity firms from May 1986 to February 2007. Deals are identified by the target companies. Deal years are broken down into three waves according to the macro merger waves, from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007. The data of maximum debt come from Loan Pricing Corporation's DealScan database, which includes credit lines, revolvers, and senior bank loans. The maximum debt to EBITDA multiples are trimmed to non-negative values. Return on assets is the ratio of EBITDA over total fixed assets. Size of the target companies is the market value of all equity outstanding 4 weeks before the deal announcement date.

		Maximum Debt to EBITDA Ratio			
Deal Year	Obs.	Min.	Max.	Mean	Median
1986-1991	52	-18.26	47.31	8.10	6.82
1992-2001	72	0.55	23.95	5.47	4.84
2002-2007	84	-311.27	34.89	7.39	6.82
1986-2007	208	-311.27	47.31	6.90	5.86

		Return on Total Assets			
Deal Year	Obs.	Min.	Max.	Mean	Median
1986-1991	52	-0.047	0.357	0.162	0.160
1992-2001	72	0.059	0.330	0.171	0.158
2002-2007	84	-0.022	0.295	0.135	0.126
1986-2007	208	-0.047	0.357	0.154	0.152

		Market Value 4 Weeks before Ann. (mil)			
Deal Year	Obs.	Min.	Max.	Mean	Median
1986-1991	52	31.8	13,593.3	903.6	300.3
1992-2001	72	67.8	4,605.3	402.0	216.6
2002-2007	84	46.9	18,206.2	2,582.0	830.8
1986-2007	208	31.8	18,206.2	1,407.8	383.7

Table 3: Deal Matching Matrix

Table 3 is a sub-matrix of the deal matching matrix, which illustrates the organization of the matching markets and their outcomes. The first row lists all target companies in the order of deal announcement dates, from May 1986 to February 2007. The first column lists all private equity firms which are first arranged by the years of inception, from the oldest to the newest, then ranked by size of the cumulative capital under management in descending order. Other entries of the matrix are either 0 or 1. If a private equity fund is the actual acquirer of a target company, the entry corresponding to that fund's parent firm and the target company is 1, and 0 otherwise. The sum of each row assigned to a private equity firm is the total number of deals in which the firm is involved. The sum of each column assigned to a target company is the number of private equity firm buyers. The sum is greater than one if it is a club deal. The matching matrix format is designed for sub-sampling, i.e., the sub-matrix for all deals which are completed by the private equity firms that are ever involved in club deals, is the collection of rows that have non-zero entries in the columns with greater than one summation.

	...	Safeway	Multicare	Panamsat	AMC	SunGard	Freescale	...
...								
Carlyle Group		0	0	1	0	0	0	
Bain Capital		0	0	0	0	1	0	
Blackstone		0	0	0	0	0	1	
KKR		1	0	1	0	0	0	
TPG		0	1	0	0	0	0	
Apollo Mgt.		0	0	0	1	0	0	
Permira		0	0	0	0	0	1	
...								

Table 4: Consortium Formation Matrix

This symmetric matrix represents the formation of the private equity consortium in the example of Table 3. The diagonal elements are the number of deals each firm has completed. Given a private equity firm, the sum of non-diagonal elements corresponding to that row or column represents the number of firms who have connections with the given firm. The connections are undirected, so the matrix is symmetric, which means the model does not distinguish which firm is the lead investor in a club deal. The Coalition Contribution Index (CCI) is computed as the number of connections normalized by the total number of deals conducted by that firm, that is, the sum of all non-diagonal entries of a row or a column divided by the value of the diagonal element in that row or column. For example, in this matching matrix, KKR is involved in 2 transactions with one of them a club deal, so its index is 0.5; while Bain Capital has conducted only one single firm deal, so its index is 0.

	⋯	Carlyle	Bain Capital	Blackstone	KKR	TPG	Apollo	Permira	⋯
⋯									
Carlyle Group		1	0	0	1	0	0	0	
Bain Capital		0	1	0	0	0	0	0	
Blackstone		0	0	1	0	0	0	1	
KKR		1	0	0	2	0	0	0	
TPG		0	0	0	0	1	0	0	
Apollo Mgt.		0	0	0	0	0	1	0	
Permira		0	0	1	0	0	0	1	
⋯									

Table 5: Latent Equity Return Function

The sample consists of 101 private equity firms, 208 leveraged buyout transactions of target companies with deal value $100 million or above during the period between May 1986 and February 2007. The data also include the matching outcomes between the private equity firms and the target companies. Given a feasible match between a private equity firm and a target company, the latent equity return function is a function of the characteristics of both the private equity firm and the target company, which calculates the maximum expected equity return the deal can possibly generate if the firm actually acquires the company. Private equity firms' characteristics are firm's age at the time of transaction and cumulative capital under management, which is the aggregate dollar value of leveraged buyout funds raised by the firm. Target companies' characteristics are return on total assets and market value. The maximum debt to EBITDA multiple is assumed to remain the same regardless which firm is the final winner of the bids. The model can identify linear terms of the company's characteristics and cross interactions between the firm and the company's characteristics in the latent equity return function. Target companies are categorized by Fama-French 12 industry portfolios according to their four digit SIC code at the time of transactions. All leveraged buyout deals are grouped into three markets, from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007 following the three merger waves. The function is estimated by a modified maximum score estimator. The initial parameter values in the latent equity return function are obtained by OLS regressions with re-scaled deal premia as the dependent variable, under the assumption that the private equity firms and the target company existing shareholders share the deal surplus at a fixed ratio. The initial values are then perturbed by error terms with normal probability distributions. For a pair of match outcomes between private equity firms and target companies, if the latent equity return function with the trial parameter values allow this pair of matches satisfying pairwise stability, the estimator scores 1 on this pair; otherwise, it scores 0. A controlled Differential Evolution algorithm is run to search for parameter values that increase the value of the score objective function. The estimation of the parameters are the values that maximize the score objective function within a pre-specified range. Finding a global optimum is unnecessary. We use subsampling and computing two-tail confidence intervals to calculate significance levels of the parameters. In the report, ***, **, and * denote significance at 1%, 5%, and 10% level, respectively.

Table 5 of Latent Equity Return Function

		95% Confidence Interval	
	Coeff.	Lower Bound	Upper Bound
MULTIPLE	0.0210**	0.0127	0.0528
MULTIPLE ^{2}	7.38E-05**	2.15E-05	3.15E-04
INDUSTRY_1	0.8372**	0.2864	1.3053
INDUSTRY_2	0.7367*	-0.0431	1.1858
INDUSTRY_3	0.8962***	0.4003	1.2234
INDUSTRY_5	0.7006*	-0.0902	0.9130
INDUSTRY_6	0.8209**	0.3327	1.0886
INDUSTRY_7	0.9726***	0.5294	2.1573
INDUSTRY_8	0.8991*	-0.3425	1.2984
INDUSTRY_9	0.8169**	0.5972	1.1120
INDUSTRY_10	0.8063**	0.4425	1.0878
INDUSTRY_11	0.7680***	0.4612	0.8725
INDUSTRY_12	0.7872**	0.3563	0.9351
WAVE_2	-0.2127*	-0.4671	0.0265
WAVE_3	-0.2862*	-0.5169	0.3549
ROA	-0.1653*	-0.6812	0.0008
ln MARKET_VALUE	-0.0196***	-0.1654	-0.0089
MULTIPLE $*$ ln AGE	0.0002*	-0.0002	0.0006
ROA $*$ ln AGE	0.0344*	-0.0131	0.0573
ln MARKET_VALUE $*$ ln AGE	-0.0007**	-0.0015	-0.0001
MULTIPLE $*$ ln SIZE	-0.0019**	-0.0119	-0.0008
ROA $*$ ln SIZE	-0.0388	-0.0671	0.0809
ln MARKET_VALUE $*$ ln SIZE	0.0019***	0.0016	0.0251

Table 6: Relative Importance

The sample consists of 101 private equity firms, 208 leveraged buyout transactions of target companies with deal value $100 million or above during the period between May 1986 and February 2007. The data also include the matching outcomes between the private equity firms and the target companies. Given a feasible match between a private equity firm and a target company, the latent equity return function is a function of the characteristics of both the private equity firm and the target company, which calculates the maximum expected equity return the deal can possibly generate if the firm actually acquires the company. Private equity firms' characteristics are firm's age at the time of transaction and cumulative capital under management, which is the aggregate dollar value of leveraged buyout funds raised by the firm. Target companies' characteristics are return on total assets and market value. The maximum debt to EBITDA multiple is assumed to remain the same regardless which firm is the final winner of the bids. Target companies are categorized by Fama-French 12 industry portfolios according to their four digit SIC code at the time of transactions. All leveraged buyout deals are grouped into three markets, from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007 following the three merger waves. The function is estimated by a modified maximum score estimator. The initial parameter values in the latent equity return function are obtained by OLS regressions with re-scaled deal premia as the dependent variable. The initial values are then perturbed by error terms with normal probability distributions. For a pair of match outcomes between private equity firms and target companies, if the latent equity return function with the trial parameter values allow this pair of matches satisfying pairwise stability, the estimator scores 1 on this pair; otherwise, it scores 0. A controlled Differential Evolution algorithm is run to search for parameter values that increase the value of the score objective function. The estimation of the parameters are the values that maximize the score objective function within a pre-specified range. To examine the relative importance of target companies' characteristics in the decisions of forming matches, we run "horse race" on the cross interactions between firm and company characteristics. Companies' return on total assets and market value are re-scaled into percentiles, such that they are in the same unit. To determine which factor is more important in match formation given firm age at the time of transaction, absolute values of the coefficients of the term ROA·ln(AGE) are subtracted by absolute values of the coefficients of the term ln(MV)·ln(AGE). If the result is positive, then ROA wins the "horse race"; otherwise, the factor of market values wins. Similarly, we can examine which factor is more important in match formation given firm size. We use subsampling and computing two-tail confidence intervals to calculate significance levels of the differences between coefficients. In the report, ***, **, and * denote significance at 1%, 5%, and 10% level, respectively.

Table 6 of Relative Importance

	Coeff.	95% Confidence Interval	
		Lower Bound	Upper Bound
MULTIPLE	0.0203*	-0.0034	0.0315
MULTIPLE ^{2}	9.64E-05**	3.14E-05	4.84E-04
INDUSTRY_1	0.8094**	0.4061	1.3586
INDUSTRY_2	0.4681**	0.3680	2.1081
INDUSTRY_3	0.8650***	0.6004	1.3786
INDUSTRY_5	0.6012*	-0.0719	0.9976
INDUSTRY_6	0.8042***	0.6398	1.0065
INDUSTRY_7	0.9183**	0.3647	1.2204
INDUSTRY_8	0.9129*	-1.8227	1.7818
INDUSTRY_9	0.7842***	0.6601	1.1420
INDUSTRY_10	0.7970**	0.3901	1.1611
INDUSTRY_11	0.6765***	0.4178	0.9574
INDUSTRY_12	0.8440***	0.5605	0.9305
WAVE_2	-0.1539*	-0.3075	0.0069
WAVE_3	-0.3294*	-0.5688	0.1658
ROA	-0.0405*	-0.1307	0.0051
ln MARKET_VALUE	-0.2161***	-1.5822	-0.1572
MULTIPLE $*$ ln AGE	0.0004*	-0.0006	0.0008
ROA $*$ ln AGE	0.0083*	-0.0013	0.0449
ln MARKET_VALUE $*$ ln AGE	-0.0073*	-0.0148	0.0019
MULTIPLE $*$ ln SIZE	-0.0021***	-0.0037	-0.0014
ROA $*$ ln SIZE	-0.0067	-0.0100	0.0033
ln MARKET_VALUE $*$ ln SIZE	0.0215***	0.0186	0.1532
	Diff(Coeff.)		
HORSE RACE on ln AGE	0.0006	-0.0115	0.0341
HORSE RACE on ln SIZE	-0.0375***	-0.1510	-0.0109

Table 7: Private Equity Consortium Analysis

The sample consists of 101 private equity firms, 208 leveraged buyout transactions of target companies with deal value $100 million or above during the period between May 1986 and February 2007. The data also include the matching outcomes between the private equity firms and the target companies. Given a feasible match between a private equity firm and a target company, the latent equity return function is a function of the characteristics of both the private equity firm and the target company, which calculates the maximum expected equity return the deal can possibly generate if the firm actually acquires the company. Private equity firms' characteristics are firm's age at the time of transaction and cumulative capital under management, which is the aggregate dollar value of leveraged buyout funds raised by the firm. Firms' characteristics also include the Coalition Contribution Index (CCI), which measures a firm's weight or importance in formation of bidding coalitions. A firm's CCI is computed as the total number of firms that have connections with the given firm normalized by the total number of deals that firm is involved in. Target companies' characteristics are return on total assets and market value. The maximum debt to EBITDA multiple is assumed to remain the same regardless which firm is the final winner of the bids. Target companies are categorized by Fama-French 12 industry portfolios according to their four digit SIC code at the time of transactions. All leveraged buyout deals are grouped into three markets, from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007 following the three merger waves. The function is estimated by a modified maximum score estimator. The initial parameter values in the latent equity return function are obtained by OLS regressions with re-scaled deal premia as the dependent variable. The initial values are then perturbed by error terms with normal probability distributions. For a pair of match outcomes between private equity firms and target companies, if the latent equity return function with the trial parameter values allow this pair of matches satisfying pairwise stability, the estimator scores 1 on this pair; otherwise, it scores 0. A controlled Differential Evolution algorithm is run to search for parameter values that increase the value of the score objective function. The estimation of the parameters are the values that maximize the score objective function within a pre-specified range. Finding a global optimum is unnecessary. We use subsampling and computing two-tail confidence intervals to calculate significance levels of the parameters. In the report, ***, **, and * denote significance at 1%, 5%, and 10% level, respectively.

Table 7 of Private Equity Consortium Analysis

		95% Confidence Interval	
	Coeff.	Lower Bound	Upper Bound
MULTIPLE	0.0277	-0.0302	0.0338
MULTIPLE ^{2}	6.61E-05	-2.19E-04	3.20E-04
INDUSTRY_1	0.8438**	0.3219	1.2248
INDUSTRY_2	0.8956**	0.1090	2.6855
INDUSTRY_3	0.7715**	0.1150	1.0424
INDUSTRY_5	0.8060*	-0.0085	3.5647
INDUSTRY_6	0.7603***	0.6728	1.2889
INDUSTRY_7	0.9574**	0.2759	1.4759
INDUSTRY_8	0.8860**	0.3564	2.3435
INDUSTRY_9	0.8086***	0.5958	1.0162
INDUSTRY_10	0.7800***	0.2191	1.2170
INDUSTRY_11	0.6440**	0.2760	1.5692
INDUSTRY_12	0.9011***	0.5028	1.0185
WAVE_2	-0.1968**	-0.3892	-0.0202
WAVE_3	0.3609	-1.1504	0.2218
ROA	0.0573	-0.2626	0.2824
ln MARKET_VALUE	-0.0615***	-0.2432	-0.0250
MULTIPLE $*$ ln AGE	0.0002*	-0.0000	0.0002
ROA $*$ ln AGE	0.0340	-0.1151	0.1203
ln MARKET_VALUE $*$ ln AGE	-0.0008*	-0.0013	0.0042
MULTIPLE $*$ ln SIZE	-0.0036*	-0.0067	0.0007
ROA $*$ ln SIZE	-0.0448**	-0.1407	-0.0021
ln MARKET_VALUE $*$ ln SIZE	0.0089	-0.0180	0.0262
MULTIPLE $*$ CCI	0.0060**	0.0054	0.0491
ROA $*$ CCI	0.0871*	-0.1146	0.1588
ln MARKET_VALUE $*$ CCI	0.0060	-0.0241	0.8018

Table 8: Firm Size Effect on Performance

The sample consists of 101 private equity firms, 208 leveraged buyout transactions of target companies with deal value $100 million or above during the period between May 1986 and February 2007. The data also include the matching outcomes between the private equity firms and the target companies. To examine the performance difference between big firms and small firms, the full sample of private equity firms are divided into two groups with equal number according to their cumulative capital under management. Two latent equity return functions are estimated separately for the two groups. For any feasible match between a private equity firm and a target company, the latent equity return function is a function of the characteristics of both the private equity firm and the target company, which calculates the maximum expected equity return the deal can possibly generate if the firm actually acquires the company. Private equity firms' characteristics are firm's age at the time of transaction and cumulative capital under management, which is the aggregate dollar value of leveraged buyout funds raised by the firm. Target companies' characteristics are return on total assets and market value. The maximum debt to EBITDA multiple is assumed to remain the same regardless which firm is the final winner of the bids. The model can identify linear terms of the company's characteristics and cross interactions between the firm and the company's characteristics in the latent equity return function. Target companies are categorized by Fama-French 12 industry portfolios according to their four digit SIC code at the time of transactions. All leveraged buyout deals are grouped into three markets, from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007 following the three merger waves. Industry and market dummy variables are included in the estimation but not reported. The functions are estimated by the modified maximum score estimator. The initial parameter values in both estimations are the estimated values for the full sample latent function. For a pair of match outcomes between private equity firms and target companies, if the latent equity return function with the trial parameter values allow this pair of matches satisfying pairwise stability, the estimator scores 1 on this pair; otherwise, it scores 0. In order to estimate the function for a particular firm size group, in the pair of matches under examination of pairwise stability, there must be at least one private equity firm from that size group, big or small. Then the controlled Differential Evolution algorithm is run to search for parameter values that increase the value of the score objective functions. The estimation of the parameters are the values that maximize the score objective function within a pre-specified range. Finding a global optimum is unnecessary. We use subsampling and computing two-tail confidence intervals to calculate significance levels of the results. In the report, ***, **, and * denote significance at 1%, 5%, and 10% level, respectively.

Table 8 of Firm Size Effect on Performance

Big Firms	Coeff.	95% Confidence Interval	
		Lower Bound	Upper Bound
MULTIPLE	0.0210**	0.0127	0.0528
MULTIPLE ^{2}	7.38E-05**	2.15E-05	3.15E-04
ROA	-0.1653*	-0.6812	0.0008
ln MARKET_VALUE	-0.0196***	-0.1654	-0.0089
MULTIPLE $*$ ln AGE	0.0002*	-0.0002	0.0006
ROA $*$ ln AGE	0.0344*	-0.0131	0.0573
ln MARKET_VALUE $*$ ln AGE	-0.0007**	-0.0015	-0.0001
MULTIPLE $*$ ln SIZE	-0.0019**	-0.0119	-0.0008
ROA $*$ ln SIZE	-0.0388	-0.0671	0.0809
ln MARKET_VALUE $*$ ln SIZE	0.0019***	0.0016	0.0251

Small Firms	Coeff.	95% Confidence Interval	
		Lower Bound	Upper Bound
MULTIPLE	0.0166**	0.0127	0.0528
MULTIPLE ^{2}	1.31E-04**	2.15E-05	3.15E-04
ROA	-0.1708*	-0.6812	0.0008
ln MARKET_VALUE	-0.0212***	-0.1654	-0.0089
MULTIPLE $*$ ln AGE	-0.0002*	-0.0002	0.0006
ROA $*$ ln AGE	0.0463*	-0.0131	0.0573
ln MARKET_VALUE $*$ ln AGE	-0.0011**	-0.0015	-0.0001
MULTIPLE $*$ ln SIZE	-0.0161**	-0.0119	-0.0008
ROA $*$ ln SIZE	-0.0505	-0.0671	0.0809
ln MARKET_VALUE $*$ ln SIZE	0.0007***	0.0016	0.0251

Table 9: Firm Age Effect on Performance

The sample consists of 101 private equity firms, 208 leveraged buyout transactions of target companies with deal value $100 million or above during the period between May 1986 and February 2007. The data also include the matching outcomes between the private equity firms and the target companies. Since private equity firms may be involved in multiple deals, to examine the performance difference when firms are young and when firms are more experienced, the observed firm company pairs rather than firms alone are separated into two age groups with equal number, the old and the young. Two latent equity return functions are estimated separately for the two groups. For any feasible match between a private equity firm and a target company, the latent equity return function is a function of the characteristics of both the private equity firm and the target company, which calculates the maximum expected equity return the deal can possibly generate if the firm actually acquires the company. Private equity firms' characteristics are firm's age at the time of transaction and cumulative capital under management, which is the aggregate dollar value of leveraged buyout funds raised by the firm. Target companies' characteristics are return on total assets and market value. The maximum debt to EBITDA multiple is assumed to remain the same regardless which firm is the final winner of the bids. The model can identify linear terms of the company's characteristics and cross interactions between the firm and the company's characteristics in the latent equity return function. Target companies are categorized by Fama-French 12 industry portfolios according to their four digit SIC code at the time of transactions. All leveraged buyout deals are grouped into three markets, from 1986 to 1991, from 1992 to 2001, and from 2002 to 2007 following the three merger waves. Industry and market dummy variables are included in the estimation but not reported. The function is estimated by the modified maximum score estimator. The initial parameter values in both estimations are the estimated values for the full sample latent function. For a pair of match outcomes between private equity firms and target companies, if the latent equity return function with the trial parameter values allow this pair of matches satisfying pairwise stability, the estimator scores 1 on this pair; otherwise, it scores 0. In order to estimate the function for a particular firm age group, in the pair of matches under examination of pairwise stability, there must be at least one private equity firm from that age group, old or young. Then the controlled Differential Evolution algorithm is run to search for parameter values that increase the value of the score objective functions. The estimation of the parameters are the values that maximize the score objective function within a pre-specified range. Finding a global optimum is unnecessary. We use subsampling and computing two-tail confidence intervals to calculate significance levels of the results. In the report, ***, **, and * denote significance at 1%, 5%, and 10% level, respectively.

Table 9 of Firm Age Effect on Performance

Old Firms	Coeff.	95% Confidence Interval	
		Lower Bound	Upper Bound
MULTIPLE	0.0533**	0.0127	0.0528
MULTIPLE ^{2}	1.19E-04**	2.15E-05	3.15E-04
ROA	-0.4634*	-0.6812	0.0008
ln MARKET_VALUE	-0.0098***	-0.1654	-0.0089
MULTIPLE $*$ ln AGE	0.0011*	-0.0002	0.0006
ROA $*$ ln AGE	0.0838*	-0.0131	0.0573
ln MARKET_VALUE $*$ ln AGE	-0.0004**	-0.0015	-0.0001
MULTIPLE $*$ ln SIZE	-0.0087**	-0.0119	-0.0008
ROA $*$ ln SIZE	0.0041	-0.0671	0.0809
ln MARKET_VALUE $*$ ln SIZE	0.0062***	0.0016	0.0251

Young Firms	Coeff.	95% Confidence Interval	
		Lower Bound	Upper Bound
MULTIPLE	0.0210**	0.0127	0.0528
MULTIPLE ^{2}	7.38E-05**	2.15E-05	3.15E-04
ROA	-0.1653*	-0.6812	0.0008
ln MARKET_VALUE	-0.0196***	-0.1654	-0.0089
MULTIPLE $*$ ln AGE	0.0002*	-0.0002	0.0006
ROA $*$ ln AGE	0.0344*	-0.0131	0.0573
ln MARKET_VALUE $*$ ln AGE	-0.0007**	-0.0015	-0.0001
MULTIPLE $*$ ln SIZE	-0.0019**	-0.0119	-0.0008
ROA $*$ ln SIZE	-0.0388	-0.0671	0.0809
ln MARKET_VALUE $*$ ln SIZE	0.0019***	0.0016	0.0251

Table 10: Value Creation Analysis

In the latent equity return function, I group all terms that contain the maximum debt to EBITDA multiple M_i into the category of "debt"; group all terms related to the characteristics of private equity firms E_a and S_a (but not M_i) into the category of "monitoring". Using the estimated parameters for the full sample and the subsamples under different firm characteristics, i.e., age and size, and using average values of the variables in those terms, I calculate the estimated value created through debt and the estimated value created through monitoring.

$$\begin{aligned} \log\ r_{\langle a,i\rangle} = \ & \left(\alpha_1 M_i + \alpha_2 M_i^2 + \alpha_3 I_i + \alpha_4 Y_i + \alpha_5 R_i + \alpha_6 V_i\right) \\ & + \left(\beta_0^1 M_i + \beta_1^1 R_i + \beta_2^1 V_i\right) \cdot E_a + \left(\beta_0^2 M_i + \beta_1^2 R_i + \beta_2^2 V_i\right) \cdot S_a + \varepsilon_{\langle a,i\rangle} \end{aligned} \tag{13}$$

This calculation is based on two key assumptions: (i) private equity firms that have no experience and no ability do not create value; (ii) private equity firms as stand alone entities do not create value.

	Within Total Value Created by an Average Match	
	Debt	Monitoring
Full Sample	3.1%	7.8%
Large PE Firms	2.2%	8.3%
Small PE Firms	-50.7%	-2.4%
Older PE Firms	-14.0%	56.2%
Younger PE Firms	3.0%	7.7%

Figure 1: Firm Age Distribution

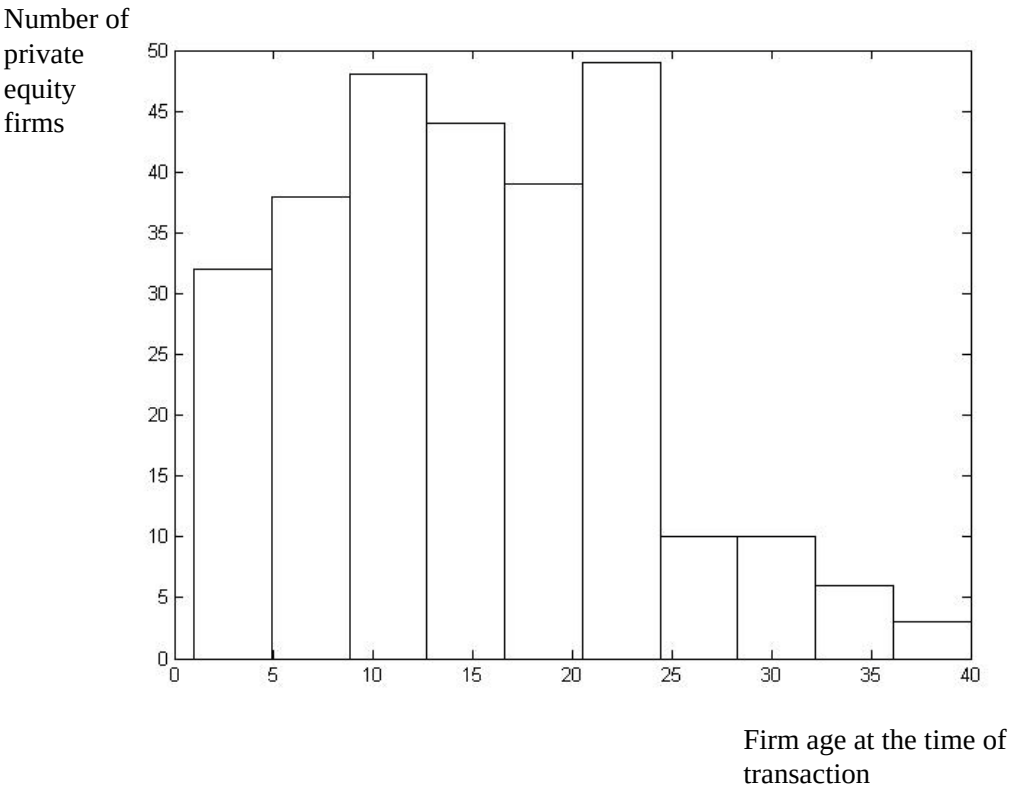

Figure 1 illustrates the age distribution of private equity firms at the time of transactions. Since a firm may be active in more than one deal, some private equity firms are counted multiple times; while several firms may also join together to acquire a target company in a club deal, so some deals are also counted multiple times. There are 279 deal-age observations overall. These observations are grouped into 10 4-year intervals, and the figure shows the number of firms in each interval.

Figure 2: Consortium Formation Graph

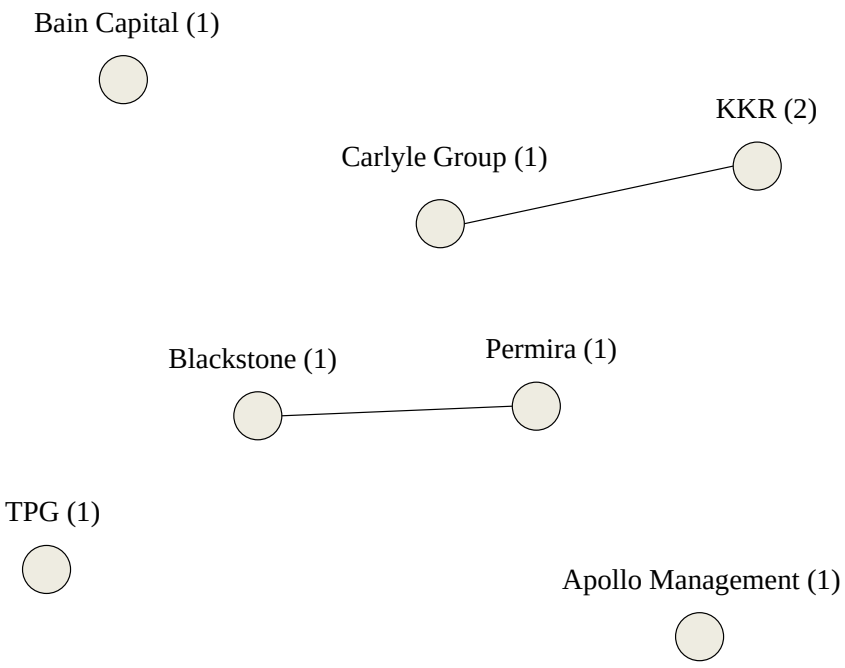

Figure 2 is the graph equivalent of the Table 4 on formation of private equity consortia in leveraged buyout deals. It is an illustrative selection of 6 deals conducted by 7 prominent private equity firms. Nodes on the graph represent private equity firms, and lines connecting the nodes indicate those firms that are partners in deals. The graph is undirected since lines do not show which firm is the lead investor. The number in the parenthesis is the number of deals that private equity firm has participated in this subsample. The number of lines leading out of a node is defined as the *degree* of the corresponding private equity firm in this graph. The degree of a private equity firm measures the extent how much other private equity firms are willing to accept this particular firm as a bidding partner. The Coalition Contribution Index (CCI) of a private equity firm is the degree normalized by the total number of deals that firm is involved in.

Figure 3: Differential Evolution Algorithm

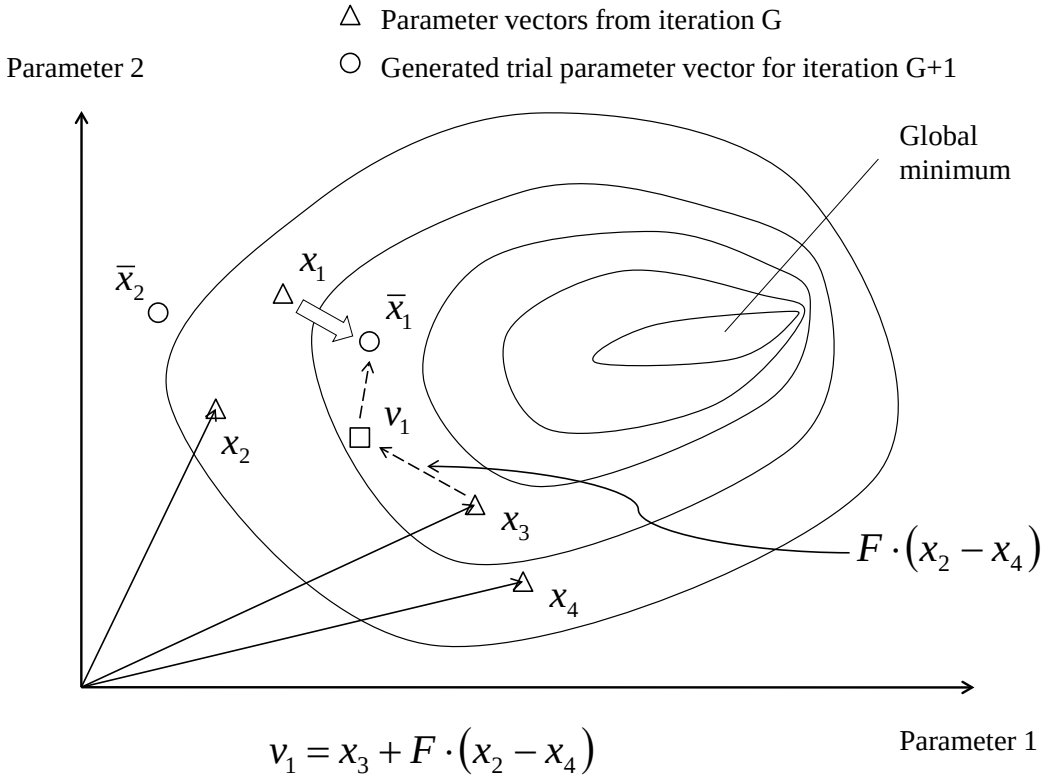

Figure 3 is a graph illustration of the Differential Evolution algorithm introduced by Storn and Price [34]. DE algorithm is a stochastic direct search method for global optimum. Suppose we are searching a global minimum of a cost function, and we start from N initial trial parameter vectors. Given N, $N \geq 4$, parameter vectors of dimension D in iteration G, the N new vectors in iteration $G+1$ are generated as the following. For vector x_1, randomly select 3 vectors other than x_1 in the same iteration G, e.g., x_2, x_3, and x_4. Generate vector v_1 as $x_3 + F \cdot (x_2 - x_4)$, where F is a random number strictly between 0 and 2. A trial vector $\bar{x}_1$ is generated by random selecting entries from x_1 and v_1. At least one entry from v_1 must be selected. If $\bar{x}_1$ yields a smaller cost function value than x_1, $\bar{x}_1$ replaces x_1 as a new parameter vector in iteration $G+1$; otherwise, x_1 is retained. x_2, ..., x_N are treated with the same procedure from iteration G to iteration $G+1$. In this example, $\bar{x}_1$ replaces x_1 while x_2 is retained in the iteration $G+1$.

Figure 4: Single Firm Deal versus Club Deal: Raw Returns

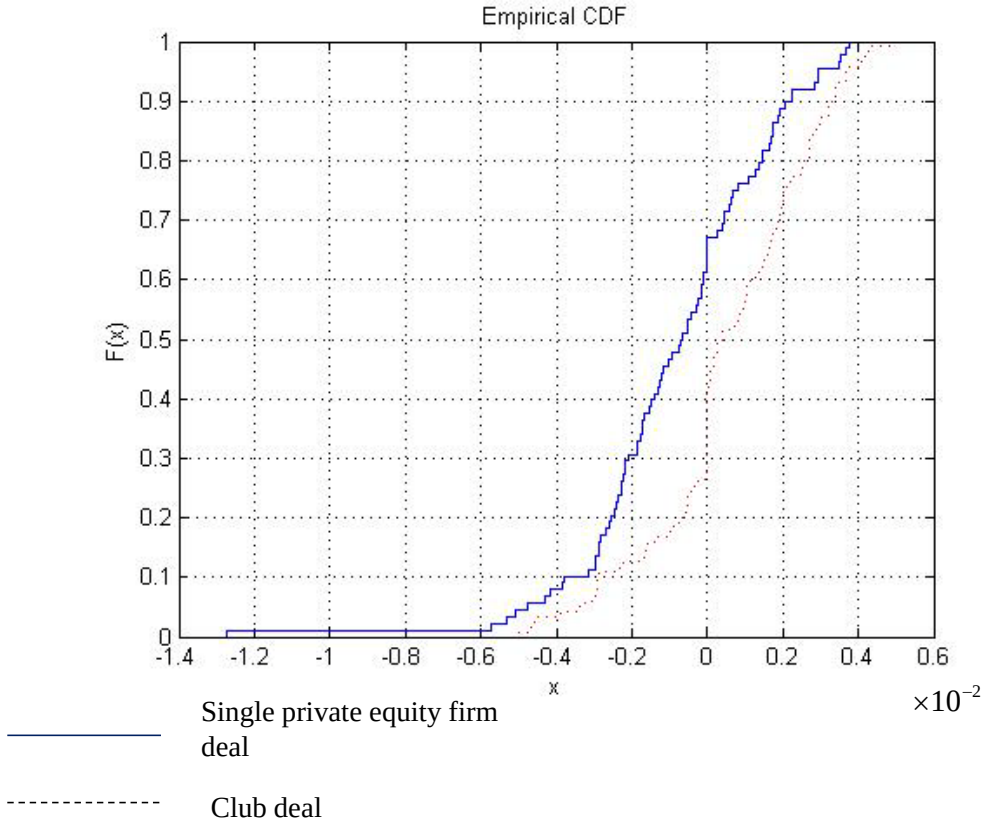

Figure 4 draws two empirical cumulative distribution functions of the values of the latent equity return functions grouped by whether the transactions are club deals or single firm deals. The private equity firms which have joined at least one consortium are first selected from the full sample. Then the deals conducted by those firms are selected, which include single firm deals but the acquiring firms are involved in club deals of other target companies. The values of the corresponding latent equity return functions are de-meaned at firm level to eliminate firm linear effect, since the model cannot identify this effect. A Kolmogorov-Smirnov test is performed to examine whether these two groups of values are coming from a same probability distribution, which is the null hypothesis. The alternative hypothesis is that the returns by club deals are first order stochastic dominating the returns by single firm deals, or equivalently speaking, the distribution function of club deal latent equity return values is smaller in general. The test is an one-tail K-S test. The null hypothesis is rejected at 1% level with p-value equal to 0.00 and the test statistics is 0.3531.

Figure 5: Single Firm Deal versus Club Deal: Firm Surplus

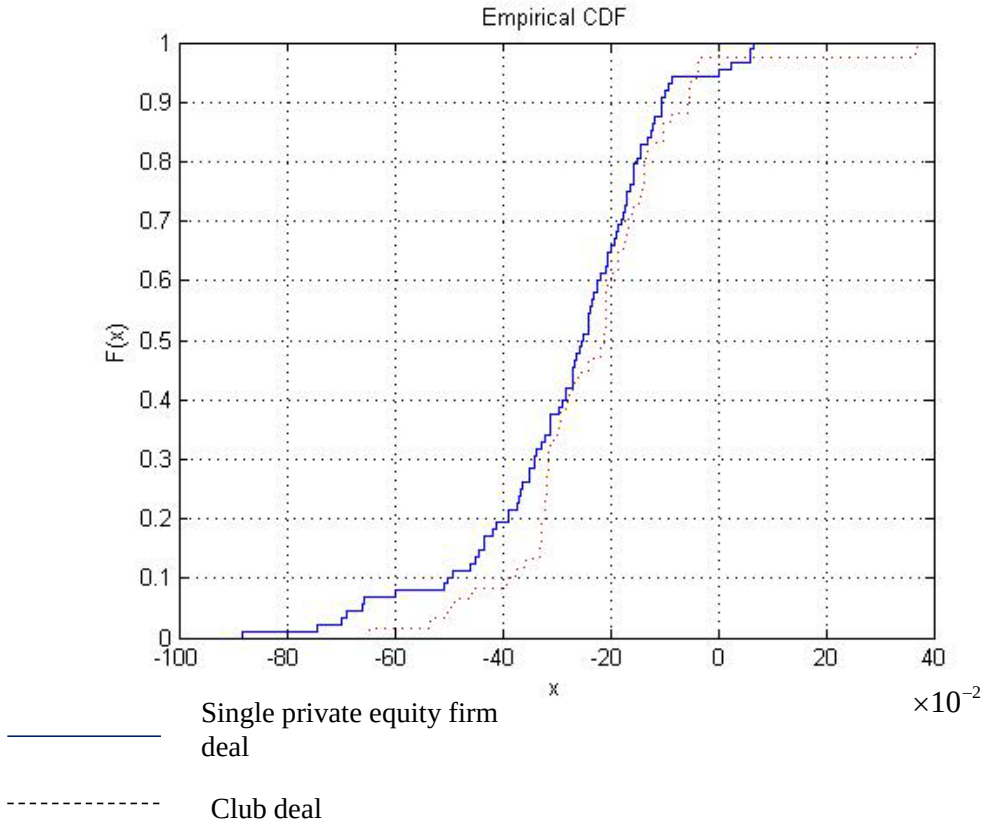

Figure 5 draws two empirical cumulative distribution functions of the private equity firms' portion of the deal surplus grouped by whether the transactions are club deals or single firm deals. The private equity firm's portion of the deal surplus is the actual expected return a firm can create from a deal after paying the target company's existing shareholders. The private equity firms which have joined at least one consortium are first selected from the full sample. Then the deals conducted by those firms are selected, which include single firm deals but the acquiring firms are involved in club deals of other target companies. The values of the corresponding latent equity return functions are first de-meaned at firm level to eliminate firm linear effect, then subtracted by log one plus deal premia. A Kolmogorov-Smirnov test is performed to examine whether these two groups of values are coming from a same probability distribution, which is the null hypothesis. The alternative hypothesis is that the returns by club deals are first order stochastic dominating the returns by single firm deals, or equivalently speaking, the distribution function of firm actual returns from club deals is smaller in general. The test is an one-tail K-S test. The null hypothesis cannot be rejected at 5% level. The p-value is 0.0576 and the test statistics is 0.1837. The null hypothesis cannot be rejected either in a two-tail K-S test when the alternative hypothesis is that the two empirical distribution functions are coming from two different probability distributions.