VC Index Calculation White Paper

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This document describes the calculation of the Sand Hill Index of Venture Capital (the "Index"). The Index is intended to measure the monthly value of a value-weighted portfolio of venture capital (VC)-funded companies. This approach is different from indexes that report averages of returns to investments in venture capital funds themselves. The fund returns approach suffers from biases resulting from the difficulty of obtaining results from all venture capital funds. There is no general public reporting of fund results, and the results most difficult to obtain typically are the worst results. Omission of the worst results from the averages leads to an index that is biased upwards.

Unlike indices built from fund returns (the components of which may invest in a mixture of buyouts, other types of alternative assets and public equities as well as venture capital deals), our approach starts with the Dow Jones VentureSource ("DJVS") database of individual companies and measures the change in value (before fees and carry) for them. This index is an index of venture-funded company value. The companies included in the Index are a subset of the companies in the DJVS database. We include only venture-backed companies headquartered in the United States. Unlike funds, the individual companies can be easily classified by industry, stage and other groupings, allowing us to do cross-sectional analysis and compile specialized indices.

Inclusion in the DJVS database is in part qualified by the DJVS criteria:

> "VentureSource tracks privately-held and innovative companies that receive cash-for-equity financing directly from an institutional venture capital limited partnership or LLC or from another private equity entity making an equity investment structured like a venture capital round."

Venture-funded firms are privately owned, are not registered (with the SEC), and do not have shares traded in any public market. Nonetheless there are events that give rise to market prices for them (i.e., a value based on an arms-length transaction) from time to time. Venture-backed firms receive their funding intermittently over the course of several years in distinct funding "rounds," at which time a proportion of the firm's ownership is transferred to the investing VC funds in exchange for cash. The proportion of the firm's equity transferred in exchange for the cash investment is based on a negotiated "pre-money" value. A market value for the firm is thereby established at the time of each financing round.

Similarly, a value is established at the time a company goes public, is acquired, or shuts down (goes out of business). These points when firm value is revealed through a market transaction (financing rounds and exit events) provide opportunities to observe firm value, and we refer to them collectively as "valuation events."

[1] Both with Sand Hill Econometrics.

We use these observed values along with other firm characteristics to construct a monthly value-weighted index in the following steps:

1. Estimate values for valuation events where values are not revealed
2. Interpolate firm value for months between valuation events
3. Estimate the value of non-exited firms between the time of their last round and the index end
4. Construct a value-weighted, continuously-invested index of value for all venture-funded companies alive (from first round of funding to exit) as of each month in the index.

These steps are described below. In addition, Appendix A provides a more detailed discussion of the index construction with some examples of the estimation methods applied to a specific venture-funded company.

Estimating Value for Non-value-revealing Events

Sources of Data

The VentureSource division of Dow Jones collects detailed information on the funding and exit events of venture-backed firms throughout the United States and provides our main source of firm-level data, including known values. In addition we merge in supplementary data sources as described in Appendix B. In addition, we use the Dow Jones U.S. Total Stock Market Index (TSM) for historical public market stock values.

Estimation of Missing Firm Values

At the time of an IPO, the value of the company going public is always known or "revealed." Value is assumed to be zero at the time of a shutdown or failure. However, for many funding rounds and acquisitions the company value at the time of the event is not reported, shared, or revealed. For these events with missing values, we estimate firm value.

When companies raise money in private funding rounds, they nearly always indicate how much money they are raising, how much they have raised so far in their history, what industry they are in, their business stage, their location, and many other details. Only sometimes do they share the value implied by the terms of the funding. To estimate value for the companies not revealing, we use the information available about firms that have revealed values to estimate the non-revealed value. We use the following variables as predictors of value:

Firm and Round Characteristic Variables

- Amount raised at the valuation event (raised)
- Amount raised in the previous history of the company ("Raised-to-Date" or RTD)
- Firm industry: InfoTech, health, retail, other (categorical variable)
- Company business stage: startup, development, beta, clinical trials, shipping, profitable (categorical variable) indicators
- Company funding stage: seed, early, late, mezzanine (categorical variable)
- Whether company had a bridge round immediately prior to the event (categorical variable)

- Whether company has ever revealed value prior to this event (categorical variable)
- Value at most recent valuation event, if available
- Time elapsed since last valuation event

Selection Bias Correction Variables, Using "Uncensored" Data Collected by Sand Hill

- whether the source of the value is a Sand Hill uncensored source,[2]
- interaction of censored indicator and amount raised in this round
- interaction of censored indicator and total amount raisedprior to this round

Macroeconomic Variables

- Level of the Dow Jones TSM (Total Stock Market Index)
- Categorical variables indicating time (indicator variable for each quarter

We selected the variables on the basis of availability and usefulness. Yes, there are other factors that would be useful (income, revenues, number of employees, etc.) but these are not regularly disclosed. Our research has made us confident that the variables we do use are systematically related (in a forecasting sense) to company value.

We use this historical data to perform a non-linear least squares (NLLS) regression, specifically using a log model which allows us to construct an estimated value for non-revealed values. We exclude from the regression any revealed values that are more than four standard deviations from the mean value for any five-year period (the data extend from 1990 forward through today). A more detailed description of the regression estimates and the process used to identify and exclude outliers from the regression is presented in AppendixA and Appendix B, respectively.

We are confident that companies that reveal value at the time of a fund-raising are more valuable, other things equal, than others. We address the value-revelation bias by including data on value which Sand Hill has, but is not generally public, and indicating that these data are from uncensored sources. Thus, our approach to selection bias is not a correction of the types developed by McFadden and Heckman, but a direct comparison of censored with uncensored historical data**.**

Estimation of Firm Value for Acquisitions when Value is Not Revealed

To estimate missing acquisition values we perform a nonlinear least squares regression similar to the one used to estimate non-revealed round values. Additional fields we use for estimating acquisition value are 1) whether the acquirer was a public company or not, 2) time elapsed from first round to the acquisition, 3) time elapsed from the most recent round to the acquisition, and 4) the number of employees at acquisition, and whether this number is known or not.

[2] A company value is considered "uncensored" if the value is neither provided to DJVS nor generally made public, but would be available to an investor in the funded company.

For estimating missing acquisition values, we once again exclude outliers. We drop acquisitions for $400 million or more (based on our analysis of the historical data, we are confident that there are no acquisitions for $400 million or more for which value was not revealed). The resulting coefficients are used to calculate estimated values for acquisitions with missing values.

For both the estimated round values and for acquisitions, we address the bias that results from converting from log values to level (dollar) values by estimating a "scaling factor" (SF_{acq}) using the value-weighted average difference between the actual revealed value V_{acq} and the fitted acquisition value $\hat{V}_{acq}$.

There is a further and more important bias correction: Our research indicates that firms for which the acquisition value is missing are on average worth much less than those for which a value is readily available. Our experience is that the harder a value is to find, the lower it is. To account for this phenomenon, we further adjust downward the values calculated from applying the regression coefficients to each company's individual data (money raised, time elapsed, etc.) We calibrate this adjustment factor λ (a number between zero and one) and multiply the estimated value by this adjustment factor to get the final estimated value: $(\hat{V}_{acq} * \lambda)$. For a detailed discussion of how this adjustment factor is calculated see Appendix C.

Re-calculating Estimated Values for Non-value-revealing Events

The Index is updated on a quarterly basis, incorporating all of the new data that becomes available each quarter. In theory each estimated value for non-revealed funding rounds and acquisitions could also be re-calculated with each quarterly update, using all of the additional information in the analyses described above. To provide greater historical stability for the index, however, we only re-calculate estimated values under the following circumstances:

- If the date of the event is within three years of the current update quarter (e.g., the update for 2014-Q1 would re-calculate all estimated values for those events that occurred in 2011-Q1 or later).[3]
- If any of the data items used to estimate the values has changed, regardless of how old the event is (e.g., if research indicated that the amount raised in the funding round was revised in the current quarterly data update from $20M to $25M, but the valuation remained unrevealed, we would re-estimate the value using the regression results from the current quarter's update).

In this manner the estimated values for the early part of the index are "frozen" and not revised unless some additional information becomes available that would warrant its re-calculation. Note that if a previously non-revealed value becomes revealed, which is often the case when a company goes public and reveals details of its funding history in documents filed with the SEC, the revealed value is always used no matter how old the event may be. In this way, a revealed value is always

[3] A review of archived snapshots of the DJVS data indicated that a three-year window is sufficient to ensure that 90 to 95% of the values that will eventually become revealed have entered the data and are stable (i.e., not subject to revision).

used regardless of when the information becomes available. The initial point at which estimated values were "frozen" occurred with the Index update for the 2011-Q2 data.

Monthly Interpolation Between Valuation Events

We generate a monthly pre- and post-money value for each firm in the sample between its first and last known valuation events. In months containing a valuation event, we have pre- and post-money values (i.e., either revealed or estimated). Between those months, we interpolate to estimate monthly firm values using changes in the stock market.

Interpolation when the firm has a value greater than zero at both events

The interpolation method used depends on whether both the post-money value at the most recent prior value (time t) and the pre-money value at the subsequent event (time T) are strictly positive. If they are, meaning neither event represents a firm failure and neither has a zero or negative estimated value (a result of estimation error), we calculate the discount factor used between the event at time t and the event at time T according to

$$\gamma = \frac{\log\left(\frac{v_T / M_T}{V_t / M_t}\right)}{T - t}$$

This formulation assumes a market beta of 1. To add a market beta (β) other than 1 and facilitate the use of a commonly-understood β, let us first re-write the equations above to use returns rather than levels.

Let

$$R^v_{t,s} = v_s / V_t$$

Now we rewrite the above formula for γ as

$$\gamma = \frac{\log\left(\frac{R^v_{t,T}}{R^M_{t,T}}\right)}{T - t}$$

and

$$R^v_{t,s} = R^M_{t,s} e^{\gamma(s-t)}$$

Combining these two:

$$R^v_{t,s} = R^M_{t,s} \cdot \left(\frac{R^v_{t,T}}{R^M_{t,T}}\right)^{\left(\frac{s-t}{T-t}\right)}$$

So the beta version (not in the sense of an early version of a product, but instead using the sense of "beta" as a coefficient in the Capital Asset Pricing Model (CAPM)) of this would be as follows:

$$R^v_{t,s} = \left(\beta\left(R^M_{t,s} - 1\right) + 1\right) \left[\frac{R^v_{t,T}}{\left(\beta\left(R^M_{t,T} - 1\right) + 1\right)}\right]^{\left(\frac{s-t}{T-t}\right)}$$

Choose β such that the correlation of revisions with M is zero. This must be done jointly with the calibration of extrapolation parameters in order to estimate the extrapolation and interpolation parameters in a manner consistent with each other.

Interpolation when one or both events have zero value

When the value at time T is equal to zero (which is the case for shutdowns, the outcome for roughly half of venture companies) we use an arithmetic method to interpolate value between the last funding event and the shutdown:

$$R^v_{t,s} = \left(\beta\left(R^M_{t,s} - 1\right) + 1\right) \left[\frac{T - s}{T - t}\right]$$

For both types of interpolation, we choose β such that the correlation of revisions with the public market M is zero. This must be done jointly with the calibration of extrapolation parameters so that we estimate the extrapolation and interpolation parameters in a manner consistent with each other. Our current calibration results in a value of 1.37 for β.

Extrapolation for Unexited Companies

For unexited companies after their last known funding round, we estimate monthly value starting from the value at the company's last valuation event through the end of the index. The estimation of these monthly values includes three components: a constant term, a market return multiplied times a coefficient, and a "decay parameter" multiplied times the number of months since the last funding round for the company. Specifically, the monthly returns after the final funding round for an unexited company are estimated using the following formula:

$$R^v_s = \alpha + \beta * R^M_s + \gamma * \left(s - t\right)$$

where

R^v_s is the monthly return for the company for month t

α is the constant term (derivation explained below)

β is the coefficient for the market return (derivation explained below)

R^M_s represents the monthly return for the stock market index

γ is the decay coefficient (derivation explained below)

(s-t) is the number of months between the month for which the return is being calculated *(s)* and the month of the company's final funding round *(t)*.

The extrapolation parameters α, β and γ are derived from the historical data using a calibration technique that minimizes the sum of the squared differences between the monthly level of the full VC index as currently estimated using all available data and the level as it would have been estimated using only the data available at a historical point in time. Specifically, the index is estimated at quarterly intervals, with a one-quarter lag between the time when data become available and the first publication of the index (e.g., for Q1 2009, we assume that the January, February and March monthly index levels are first published in June of 2009, so that all of the funding and exit data for April, May and June are also available in estimating the index through March 2009). We also currently assume that data enters the DJVS database as it occurs - that is, there is no delay between the time a funding round or exit occurs and the time at which it becomes available for estimating the index.

Using those assumptions, we initialize the parameters at a reasonable starting value and estimate the monthly index levels as they would have been estimated for each quarter from 1998 through 2007. This represents a 10-year period, which would include 40 quarterly updates of the index. We also calculate the "ultimate" index levels for the same period using all available data through today. We then calculate the squared difference between the ultimate index level and each initial monthly index level from 1998-2007. We then adjust the values for α, β and γ and run the exercise again, until we find the values that minimize the sum of the squared monthly differences. We plan to re-calibrate these parameters on an annual basis, using a 10-year rolling window with a full 2-year delay or lag between the end of the window and the "current" year (i.e., in 2011 the window will move from 1998-07 to 1999-08).

Aggregation

To calculate the value-weighted index, for each month s the pre- and post-money value of included firms is summed over all included firms (denoted by i) by

$$Pre_s = \sum_{i=1}^{N} v_{s,i}$$

and

$$Post_s = \sum_{i=1}^{N} v_{s,i}$$

where v represents the pre-money value and V represents the post-money value.

The index return is calculated as

$$Ret_s = \frac{Pre_s}{Post_{s-1}}$$

The index level *(I)* is set to 100 in January 1992. Thereafter

$$I_s = I_{s-1} Ret_s$$

Note that a firm is only included in the calculation of Ret_s if it exists in $Post_{s-1}$ and also in Pre_s, otherwise new firms and firms that leave the sample would change the computed returns of the index. Note also that all pre- and post-money values above represent the value of the entire company, including both venture-funded and non-venture-funded portions.

Appendix A:
Detailed Discussion of Index Construction

This appendix provides additional detail for the calculation of the Sand Hill Index (the "Index"). Specifically, it discusses the choice of estimation techniques for constructing the index and alternatives that were considered and why we believe the selected technique is superior.

As noted in the White Paper, the Index is built not from the fund-level return data used to construct other published venture capital indices, but rather from company-level pricing data, which we believe is necessary to create an unbiased, timely, monthly index of value that is analogous to traded-market indices such as the Dow Jones U.S. Total Stock Market Index. Building an index from company-level data faces two major challenges.

First, events that produce market values do not occur continuously for private companies as they do for traded stocks. Instead they occur episodically, when a company raises new money, goes public, is acquired, or goes out of business. The Index only includes venture-funded companies that remain independent and private, so when companies go public, are acquired, or go out of business they exit the index at the time, with the "exit event" providing the terminal value for that company's valuation stream. The episodic nature of pricing events requires that we estimate intermediate monthly values, both between pricing events (interpolated values) and for the months following the last funding round for those companies that have not yet exited (extrapolated values).

Second, the reporting of value by companies that complete funding rounds is voluntary. Often companies report that they completed a fund-raising but do not report the value at which shares were sold. The companies that do report values are not a random sample of all companies; rather, they are a biased sample--successful companies are more likely to share values, and funded companies that eventually go public are more likely to reveal their full funding history (albeit after the fact) as part of their initial public offering documents. Thus, it is important to account for and correct this bias when estimating non-revealed company values at funding rounds.

Finally, companies exit the index in one of three ways: IPO, acquisition, or shutdown. For those companies that go public, the terminal value can be obtained from public documents, and for those that shut down, the terminal value is zero. For acquisitions, value of the company is not always reported. Sometimes an announcement indicates the value, or other sources become available. Higher values are more likely to be revealed, as they tend to generate more press coverage and general interest. Many acquisition values remain missing and must be estimated.

Where company values must be estimated, the following properties are desirable for estimates:

- unbiased (i.e., they will not consistently overestimate or underestimate the true value);
- minimum variance (estimate should minimize some measure of the difference between the estimated values and the true values); and
- realistic (for example, no negative values and no extreme changes from one month to the next)

The remaining sections below are divided as follows to provide additional information on the approach used for each type of estimate:

- company values at the time of a funding round,
- company values for acquisitions,
- monthly company values between valuation events, and
- monthly values for non-exited companies from the date of each company's last funding round through the end of the index (extrapolated values).

Estimating missing company values at the time of a funding round

- As described in the White Paper, missing values for funding rounds are estimated using non-linear least squares (NLLS) on those companies with revealed values to estimate valuations for those funding rounds that are not revealed. The variables used in the regression are described in more detail in the white paper.

Using the estimated coefficients obtained using the revealed values in the historical data set, we then calculate estimated pre-money values $\hat{V}_{pre}$ for all funding rounds in which this value is not revealed. This estimate, however, is biased because it represents an exponentiated value from the log model used to estimate the coefficients. To correct for this bias we estimate a "scaling factor" *(SF)* using the value-weighted average difference between the actual revealed pre-money value V_{pre} and the estimated pre-money value $\hat{V}_{pre}$ as follows:

$$SF = avg\left(V_{pre}\right) / avg\left(\hat{V}_{pre}\right)$$

The final estimated pre-money value is then estimated as $(\hat{V}_{pre} * SF)$. After all missing pre-money values (V_{pre}) have been estimated, post-money values are set to $V_{post} = (V_{pre} + Raised)$, the pre-money value plus the amount raised in this round.

This estimation technique is superior for the following reasons:

- As explained above, applying the scaling factor $avg\left(V_{pre}\right) / avg\left(\hat{V}_{pre}\right)$ corrects for the bias inherent when using the exponentiated value from the log model, providing an unbiased estimation of the true value V_{pre}.

- By taking the exponential of the right-hand variable, we ensure that the resulting estimated value $\hat{V}_{pre}$ is always positive.

- We estimate the pre-money value rather than the post-money value to eliminate the possibility of estimating a post-money value that is less than the amount raised in the round, which would result in a negaive pre-money value. Using the approach above, we are assured of estimating positive values for both pre-money and post-money values for the firm at the time of the funding round.

- We estimate values for companies rather than returns because some company event streams will not provide a revealed value for any funding rounds (indeed, most companies that have recently entered the index will have only one funding round thus far, and many of those funding rounds will not have a revealed value). If we were to estimate returns rather than values, we would still need some additional technique to estimate the initial value for many companies; this approach eliminates the need for such an additional step.

Estimating non-revealed company valuations for acquisitions

Acquisition values are also often missing and must therefore be estimated. Acquisition values are different from values at funding rounds - no additional funds are raised. In addition, the reporting bias observed in funding rounds appears to be quite different from the reporting bias observed in acquisitions. For funding rounds, there are many motives for concealing value. For acquisitions, the main reason for concealment appears to be simply to avoid revealing less profitable outcomes. Thus we use a different strategy for estimates for acquisitions with missing values.

To estimate missing acquisition values we perform a nonlinear least squares regression similar to the one used to estimate non-revealed round values, though the form of the regression differs, using those explanatory variables shown to have the most explanatory power for estimating acquisition values. We also apply a scaling factor to address the bias resulting from converting from log values to level (dollar) values, estimated using the historical data on acquired companies. Finally, we adjust for the observed bias correlated with the difficulty of finding acquisition values as described above. This approach provides the same advantages as our approach to estimating non-revealed funding round values—we estimate only positive values for which any observed bias has been corrected.

Alternative Techniques for Estimating Firm Value

The standard techniques often used to value companies (especially publicly-traded companies) cannot be applied here, as we seldom have information about company sales, revenues, income, cash flows, and so on. Alternatives to the regression approach we use could include the following:

Discounted Cash Flow Method

Estimating value by discounted cash flow requires an understanding of the size of the appropriate market for the company being analyzed, some estimation of the market share through time, and the net present value of the discounted cash flow. Such detailed information is simply not available for the companies included in the index.

"Relative Value" or "Guideline" Method

This approach involves identifying a set of comparable publicly-traded companies to the one being analyzed and using the standard financial price multiples (e.g., price-to-earnings or price-to-book value) for the firm being analyzed to estimate a value. Such an approach is inappropriate here because (1) most of the companies whose values are estimated would not correspond to publicly-traded companies given their development state or low level of profitability, and (2) the earnings or book value information is unavailable or not comparable (e.g., the purpose of securing a VC investment is to complete the research and development

necessary to produce the good or service, so that most early-stage VC-funded companies would not yet have any earnings).

Estimating monthly company values between two funding rounds or between a funding round and an exit event (interpolated values)

The interpolation of values between two valuation events (i.e., between funding rounds or between the final funding round and company exit) is necessary because the Index is published as a monthly series. When the two company values are both positive, the interpolated values are estimated as follows:

$$R^{v}_{t,s} = \left(\beta\left(R^{M}_{t,s} - 1\right) + 1\right) \left[\frac{R^{v}_{t,T}}{\left(\beta\left(R^{M}_{t,T} - 1\right) + 1\right)}\right]^{\left(\frac{s-t}{T-t}\right)}$$

When the second value is zero (i.e., a shutdown) the formula is as follows:

$$R^{v}_{t,s} = \left(\beta\left(R^{M}_{t,s} - 1\right) + 1\right) \left[\frac{T-s}{T-t}\right]$$

Where

R = a monthly return,

s = the current month,

t = the month of the most recent valuation event,

T = the month of the following event (the next event after month s),

M = the DJ TSM Index

β = the beta value that expresses the relationship between venture-backed companies and M

v_i = the pre-money value for the firm.

Estimating the values between two known values is, on its face, a fairly straightforward proposition. One alternative to the approach used would be to carry the company forward at its last known value until the subsequent valuation event occurs; however, valuation events are often years apart, and this would often result in a large change in value in a single month and would not be a realistic reflection of the true valuation history for the company. Another alternative would be to construct a straight-line movement from the first valuation to the second. This approach fails to take account of normal irregular movements in value and would also introduce correlation between the return in the month of value update and returns in previous months. Essentially, all of the value change would be incorporated into a single month, and the return for that month would be related to stock market returns for that month as well as to returns for the stock market back to the company's previous valuation data. This flaw is strongly present in reported returns compiled from fund partnership reports.

Estimating monthly values for each non-exited company from the time of its last funding round through the end of the index (extrapolated values)

For each non-exited company included in the index, we need to estimate monthly values from the time of its last funding round through the end of the index period, using only information that is currently available. To better understand the issues related to extrapolating values, consider the evolution of an individual company's value stream over time. A company will enter the index when it has its first funding round. After that initial round, its value must be estimated via extrapolation until it has a follow-on round or exits, at which point the intervening monthly values will be estimated using the interpolation technique rather than the extrapolation technique. To provide liquidity for the VC investors, each funded company must eventually exit the index via IPO, acquisition, or shutdown. Thus, our goal with the extrapolation algorithm is to provide an unbiased, minimum-error estimate of the monthly company value that will eventually be revealed at the next pricing event.

As explained above, we estimate these values by calculating each monthly return related to stock market returns and applying a decay for time elapsed since the most recent round of funding.

This approach results in an unbiased estimate of company value that will result in the total index most closely resembling the "ultimate" value that the index will have in the future, when additional pricing events occur for the extant companies in the index, and extrapolated values are replaced with interpolated values.

Including a public market component when interpolating or extrapolating firm values

The reason we use stock market data when interpolating monthly firm values between valuation events and when extrapolating monthly firm values after the last known funding event is that we are confident that venture capital values and stock market values are highly correlated, and stock market data are available much more quickly than venture data are. Analysis of investors' returns on venture portfolios indicates that for the period prior to 2001, the beta for venture capital was roughly two (2.0) and the correlation of quarterly venture returns with stock market returns was about 0.8. For the period after 2001, the beta is one (1.0) and the correlation is still roughly 0.8. [4] As such, including a market component to the movement between funding events and for estimating monthly values for non-exited companies after their most recent funding event provides a more realistic estimate of the company's value.

Comparing the Sand Hill Index to Other Indexes

Among the alternatives for tracking venture capital activity are the VentureWire indices of the flows

[4] See Susan E. Woodward, "Measuring Risk for Venture Capital and Private Equity Portfolios", Sand Hill Econometrics Working Paper, 2009, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1458050, and Hall, Robert E. and Susan E. Woodward, "Benchmarking the Returns to Venture", Working Paper, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=474181. Both of these works show the high correlation between venture returns and stock market returns.

of funding into venture capital and various compilations of fund returns by organizations such as Cambridge Associates, Thomson, and others.

The VentureWire figures do not really measure the value of venture-funded companies, but only the flows of money to them. Funding and value are correlated, but they are not the same. Our goal is to provide an index of value.

The returns published by Cambridge Associates (published on their web site) and Thomson (not public) are averages of returns on limited partnership funds. Our understanding is that the data come from customers who come to them for evaluations of fund performance. Our understanding is also that they simply add the fund returns for each quarter and divide by the number of funds, so the returns are not value-weighted. We believe that these returns are biased upwards for the natural reason that customers do not need or want evaluations of the worst-performing funds. When funds perform poorly, they generally do not succeed in raising another fund, and data on them evaporates; thus, it is not possible to reconstruct it from any regularly-gathered sources. Even though venture-funded companies are more numerous than venture capital funds, it is more feasible to construct complete funding and outcome histories from company data than from fund data.

We believe that nearly every venture-funded company becomes part of the VentureSource database upon raising its first round of venture capital. Once in the database, VS follows it through any additional funding rounds until it goes public, is acquired, or shuts down. Because the companies are systematically captured at first round, following them to their outcome is feasible. With complete data on all venture-funded companies, we can achieve an index of venture capital value that is value-weighted and continuously invested which can be used to track returns to all venture capital through time, and which can also be used to measure the risk of venture capital and the correlation of its returns with stock market returns. The compilations of fund returns, because they are missing the worst outcomes, produce return series that are biased upwards and not value-weighted.

Sample of Venture-Funded Company Valuation Stream

To better illustrate the process by which the valuation stream for a single venture-funded, consider the following example. First, the company's funding history available from DJVS is as follows:

Company ID	ICB Code	ICB Industry	Close Date	Event Type	Business Status	Pre-Money ($MM)	Raised ($MM)	Post-Money ($MM)
XXXXXX	9578	Technology	04/08/05	Early	Startup	6.00	6.00	12.00
XXXXXX	9578	Technology	08/01/06	Early	Product in Beta Test		15.00	
XXXXXX	9578	Technology	05/02/08	Early	Generating Revenue	55.00	12.00	67.00

This company is a technology firm that raised 33 million dollars over three funding rounds, the first in 2005 and the most recent in 2008. Value is revealed for two of those rounds. At this point the company has not had a liquidity event (i.e., it has not gone public, been acquired, or gone out of business), so it remains in the Index. The first step in constructing the full valuation stream for this company involves estimating a value for the funding round(s) where value is not revealed--here, only the second round value needs to be estimated. This is accomplished by applying the coefficients generated from the nonlinear least squares regression described above to estimate the non-revealed pre-money value, and the post-money value is calculated by adding the amount raised in the round

to the pre-money value as follows (the estimated values here are shown in **blue**):

Company ID	ICB Code	ICB Industry	Close Date	Event Type	Business Status	Pre-Money ($MM)	Raised ($MM)	Post-Money ($MM)
XXXXXX	9578	Technology	04/08/05	Early	Startup	6.00	6.00	12.00
XXXXXX	9578	Technology	08/01/06	Early	Product in Beta Test	**35.64**	15.00	**50.64**
XXXXXX	9578	Technology	05/02/08	Early	Generating Revenue	55.00	12.00	67.00

The second step in constructing the valuation stream is to estimate a monthly value for each month between funding rounds. These interpolated values are estimated using the following formula:

$$R_{t,s}^{v} = \left(\beta\left(R_{t,s}^{M} - 1\right) + 1\right) \left[\frac{R_{t,T}^{v}}{\left(\beta\left(R_{t,T}^{M} - 1\right) + 1\right)}\right]^{\left(\frac{s-t}{T-t}\right)}$$

The table below shows the interpolated values for all of the months between the funding rounds for this company, with the interpolated estimates given in **green**. To illustrate how the calculation works, assuming a value of 1.37 for β, the interpolation formula would be as follows for May 2005:

$$R_{t,s}^{v} = \left(1.37\left(\left[5331.11/4806.01\right] - 1\right) + 1\right) \bullet \left[\frac{\left[35.64/12.00\right]}{\left(1.37\left(5710.35/4806.01 - 1\right) + 1\right)}\right]^{\left(\frac{1}{16}\right)} = 1.2131$$

Multiplying 1.2131 by the previous value of 12.00 results in the value of 14.56, as shown in the table below for the Pre-Money value in May 2005 (2005-05).

yyyy-mm	Month (s-t)	ICB Industry Index	Returns from Last Round	Pre-Money ($MM)	Raised ($MM)	Post-Money ($MM)
2005-04	-	4,806.01		6.00	6.00	12.00
2005-05	1	5,331.11	1.2131	**14.56**	-	**14.56**
2005-06	2	5,268.24	1.2601	**15.12**	-	**15.12**
2005-07	3	5,644.67	1.4556	**17.47**	-	**17.47**
2005-08	4	5,559.27	1.5058	**18.07**	-	**18.07**
2005-09	5	5,641.09	1.6193	**19.43**	-	**19.43**
2005-10	6	5,383.03	1.6071	**19.29**	-	**19.29**
2005-11	7	5,806.13	1.8714	**22.46**	-	**22.46**
2005-12	8	5,697.68	1.9271	**23.13**	-	**23.13**
2006-01	9	6,010.51	2.1780	**26.14**	-	**26.14**
2006-02	10	6,015.23	2.3005	**27.61**	-	**27.61**
2006-03	11	6,144.49	2.4939	**29.93**	-	**29.93**
2006-04	12	6,152.82	2.6360	**31.63**	-	**31.63**
2006-05	13	5,651.54	2.4942	**29.93**	-	**29.93**
2006-06	14	5,472.77	2.5237	**30.28**	-	**30.28**
2006-07	15	5,206.20	2.4929	**29.91**	-	**29.91**
2006-08	-	5,710.35		**35.64**	15.00	**50.64**
2006-09	1	5,885.95	1.0355	**52.43**	-	**52.43**
2006-10	2	5,987.32	1.0529	**53.32**	-	**53.32**
2006-11	3	6,266.60	1.1120	**56.31**	-	**56.31**
2006-12	4	6,163.79	1.0809	**54.73**	-	**54.73**
2007-01	5	6,216.48	1.0862	**55.00**	-	**55.00**
2007-02	6	6,139.36	1.0615	**53.75**	-	**53.75**
2007-03	7	6,125.83	1.0516	**53.25**	-	**53.25**
2007-04	8	6,450.77	1.1190	**56.66**	-	**56.66**
2007-05	9	6,709.82	1.1706	**59.28**	-	**59.28**
2007-06	10	6,858.06	1.1965	**60.59**	-	**60.59**
2007-07	11	6,887.36	1.1955	**60.53**	-	**60.53**
2007-08	12	7,125.98	1.2409	**62.83**	-	**62.83**
2007-09	13	7,367.70	1.2864	**65.14**	-	**65.14**
2007-10	14	7,631.22	1.3360	**67.65**	-	**67.65**
2007-11	15	6,999.36	1.1898	**60.25**	-	**60.25**
2007-12	16	7,009.93	1.1845	**59.98**	-	**59.98**
2008-01	17	5,958.28	0.9506	**48.13**	-	**48.13**
2008-02	18	5,847.00	0.9207	**46.62**	-	**46.62**
2008-03	19	5,867.22	0.9192	**46.54**	-	**46.54**
2008-04	20	6,290.53	1.0027	**50.77**	-	**50.77**
2008-05	-	6,718.61		55.00	12.00	67.00

The final step in completing the full valuation history for this company is to estimate monthly values from the time of its last round through the end of the index. For this example, assume the index ends in December 2009. As explained above, the formula used to estimate extrapolated values is as follows:

$$R_s^v = \alpha + \beta * R_s^M + \gamma * (s - t)$$

The table below shows the extrapolated values for a sample company, using values for α, β *and* γ of -0.000013, 1.59, and -0.00048 respectively.

Applying this return times the previous value: 67.00*(-0.1669+1)=55.82. . The table below shows the values using the extrapolation formula in **red**.

yyyy-mm	Month (s-t)	ICB Industry Index	Returns from Last Round	Pre-Money ($MM)	Raised ($MM)	Post-Money ($MM)
2008-05	-	6,718.61		55.00	12.00	67.00
2008-06	1	6,015.34	-0.1427	**55.82**	-	**55.82**
2008-07	2	5,962.85	-0.0126	**54.99**	-	**54.99**
2008-08	3	6,144.83	0.0405	**57.58**	-	**57.58**
2008-09	4	5,103.32	-0.2319	**41.95**	-	**41.95**
2008-10	5	4,226.97	-0.2353	**30.39**	-	**30.39**
2008-11	6	3,679.48	-0.1782	**24.05**	-	**24.05**
2008-12	7	3,759.83	0.0273	**24.80**	-	**24.80**
2009-01	8	3,632.54	-0.0488	**23.37**	-	**23.37**
2009-02	9	3,445.60	-0.0731	**21.36**	-	**21.36**
2009-03	10	3,956.38	0.1982	**26.29**	-	**26.29**
2009-04	11	4,528.14	0.1928	**32.19**	-	**32.19**
2009-05	12	4,627.40	0.0257	**33.12**	-	**33.12**
2009-06	13	4,842.32	0.0587	**35.36**	-	**35.36**
2009-07	14	5,432.44	0.1610	**41.98**	-	**41.98**
2009-08	15	5,555.73	0.0258	**43.19**	-	**43.19**
2009-09	16	5,844.62	0.0653	**46.43**	-	**46.43**
2009-10	17	5,619.71	-0.0581	**43.21**	-	**43.21**
2009-11	18	5,881.46	0.0572	**46.03**	-	**46.03**
2009-12	19	6,307.10	0.0920	**50.91**	-	**50.91**

Appendix B:
Data Processing Prior to Estimation of Index

The data as received from DJVS must first be processed before it can be used to generate the VC index. The following steps summarize the main processing activities:

1. We do not include every firm in the DJVS data in the index. Excluded companies are those which we believe are not best described as venture-backed companies. Typically they are very large and only a small proportion of their funding comes from venture sources. We remove these firms entirely from the data and they are not included in any part of the index calculation.

2. Any records that are missing a CloseDate value are removed (all events must have a date to be included in the index estimation).

3. The DJVS data include event types that are not appropriate for the purposes of generating the VC index, such as PIPEs, buyout rounds, etc. These events are removed.

4. Additional historical IPO information as researched by Sand Hill Econometrics is integrated into the data set. Specifically, the final value for a company in the index that exits via an IPO must be equal to the total number of shares outstanding prior to the IPO times the IPO offering price. This information has not historically been captured by DJVS; rather, the DJVS data captures the fully diluted value of the company including any additional shares issued in the IPO.

5. Additional "uncensored" valuations as captured by Sand Hill Econometrics are integrated into the DJVS data. The Sand Hill Database of venture-backed companies included information that came from uncensored sources - specifically, quarterly or annual reports provided by the VC fund general partners to the limited partners (investors). These data include both rounds and exits, and represent information that is sometimes neither revealed publicly nor provided to DJVS. Historical research has shown that values that are publicly shared are on average higher than values not shared - that is, the general partners and companies themselves are less likely to disseminate information on funding rounds or exits when those events reveal a low company value. An essential part of the index calculation includes correcting for this reporting bias, so the uncensored data available from the Sand Hill database is integrated into the DJVS data and marked as uncensored if the DJVS data did not have a revealed value for the event.

6. The "recap" and "restart" companies are processed. Both of these designations imply that the prior venture investors are wiped out and new investors "start over" with the company. Prior to October 2009, a "RECAP" in the DJVS data indicated that the company was taken over by buyout investors, and a "RESTART" indicated that the new investors were VC investors. As of October 2009, however, these designations were reversed ("RECAP indicates new VC investors, RESTART indicates buyout investors). Thus, for companies with a RECAP we create a shutdown record equal to the recap date, then assign a new companyID for the events starting with the RECAP round to treat those rounds (and,

potentially, exits) as belonging to a new company. For companies with a "RESTART" round, we simply create a shutdown record equal to the date of the RESTART and ignore the events after that point.

7. If a company has more than one round that occurs within the same month, the raised amounts are combined and the maximum postval value is used to create a single financing round for the company for that month.

Treatment of Outliers

There are a few VC-backed companies which are orders of magnitude more valuable than the majority of the sample. Although we consider these outlier firms to be valid venture-funded firms and include them in the index calculation, we do not believe they are helpful in inferring value for the companies that do not reveal value, simply because values so large would not be feasible to conceal. Their inclusion would have a misleading influence on the estimated values for companies not revealing value. We therefore exclude from the estimating regression any financing round that has a revealed value more than four standard deviations from the mean for any 10-year rolling period.

Appendix C:
Calibration of Acquisition Missing Value Adjustment Factor

We model the relationship between the value of an acquired firm as an exponentially decreasing function of the amount of difficulty involved in obtaining that value. We use four datasets to model the difficulty level: Source A (an M&A database), DJVS data, Source B (another M&A dataset to which Sand Hill has access), and the merged DJVS+Sand Hill database. We let x, the amount of difficulty involved in obtaining acquisition value, be proxied by the percentage of acquisition values each dataset contains.

We model the average revealed value of an acquired firm with difficulty x as

$$A_r(x) = \frac{1}{x}\int_0^x V_0 \cdot e^{-\alpha s}\,ds = \frac{V_0\left(1 - e^{-\alpha x}\right)}{\alpha x}$$

.

We calibrate α over the following data, letting the mean revealed value $(M_{r,i})$ be our estimate of $A_r(x_i)$.

Source *(i)*	**Percentage Found *(x)***	**Mean Revealed Value $(M_{r,i})$**
Source A	16%	$181 million
DJVS	41%	$143 million
Source B	50%	$120 million
DJVS+SH	56%	$94 million

The choice of α determines the value of the parameter $V_{0,i}$ for each dataset, i, by

$$V_{0,i} = \frac{\alpha x_i M_{r,i}}{1 - e^{-\alpha x_i}}$$

In principle, $V_{0,i}$ should be the same for all observations, so we vary α to minimize the coefficient of variation of $V_{0,i}$ over these four observations. That is, we minimize its standard deviation divided by its mean. This computation yields a value of α=3.7.

We can calculate the value of unreported acquisitions corresponding to difficulty x_i (that is, the value of acquisitions too difficult to get if we are expending only up to effort x_i) using the integration equation for $A(\cdot)$ for firms between difficulty x and 1. Since this estimates the average value of non-revealed firms, we denote it by $A_u(x)$.

$$A_u(x) = \frac{1}{1-x}\int_x^1 V_0 \cdot e^{-\alpha s}\,ds = \frac{V_0\left(e^{-\alpha} - e^{-\alpha x}\right)}{\alpha x - \alpha}$$

For the DJVS dataset this value is $24.78 million. Since the average value of reported acquisitions is $143 million, the average unreported acquisition is worth *24.78/143=0.1733* as much as the average reported acquisition.

To calculate the adjustment factor we calculate the mean value of the reported firms *(M_r)* and the estimated mean value of non-revealed acquisition values using the regression equation described in the acquisition section before applying any adjustment. Then

$$\lambda = \frac{0.1733 \cdot M_r}{A_u}$$

Where M_r and A_u refer to the calculated values corresponding to DJVS. Filling in for the above equation results in a value of about 0.20 for λ.

The adjustment factor depends on the target ratio of mean non-revealed to mean revealed acquisition values. This, in turn, depends on the dataset we are examining. The index going forward will use only DJVS data, whereas the data we use to calculate the historical index uses DJVS+SH data. This implies that, going forward, we may need to re-calculate the value of λ periodically, just as we need to re-calibrate other parameters used to estimate non-revealed company values.