Initial Public Offerings: An Asset Allocation Perspective*

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ABSTRACT

We examine whether investors can improve their investment opportunity sets by adding an IPO portfolio to a set of benchmark portfolios sorted by firm size and book-to-market ratio. Using U.S. IPOs from 1980-2002, we find that adding a value-weighted IPO portfolio does lead to a statistically and economically significant enlargement of the investment opportunity set for investors relative to investing solely in a set of benchmark portfolios. Furthermore, IPOs associated with prestigious lead underwriters are the main source of this augmentation of the mean-variance investment opportunity set. The improvement for diversification may be explained by extending the incomplete spanning argument in Mauer and Senbet (1992). Finally, our study implies that issuing IPO exchange traded funds or similar products could provide diversification gains to investors.

JEL Classification: G00; G11; G30

Keywords: Initial Public Offerings; Investment Opportunity Set; Mean-Variance Spanning Test

1. Introduction

Initial public offerings (IPOs) have received a lot of attention from both academic researchers and practitioners, with the attention focusing on underpricing, hot issue markets, and long-run performance (see, for example, Ritter and Welch (2002) for a recent review). Non-redundant financial assets can help improve the completeness of financial markets and risk sharing among investors (see Huang and Litzenberger (1988) and Ingersoll (1987)). Thus, whether adding IPO stocks as a new asset class to the financial markets can significantly expand the minimum-variance frontier relative to already publicly traded stocks and gain substantial diversification benefits for investors or fund managers is an important and intriguing question. Our study suggests an asset allocation perspective to explore the IPO market.

The view of asset allocation is consistent with the fact that there are investment vehicles focusing on investing in IPOs. Renaissance Capital recently created a mutual fund that invests solely in IPOs, "IPO plus Aftermarket Fund" (Nasdaq symbol: IPOSX). The objective of this mutual fund is capital appreciation by investing in IPO firms, both at the offering and in the aftermarket.[1] In July 2005, Van Kampen Investments launches the first IPO unit investment trust, based on a value-weighted, rule-based IPO index, IPOX-30 index (Nasdaq symbol: VKTIDX).[2] This unit investment trust seeks to provide capital appreciation and a systematic way to track the aftermarket performance of the 30 largest IPOs ranked quarterly in the most recent 1000 trading days. More generally, mutual fund managers may decide whether to include some IPO stocks, like the Internet search engine companies Yahoo and Google, in their portfolios if the Sharpe ratio of their funds can be

[1] Another mutual fund heavily invested in the IPO market was H&Q IPO & Emerging Company Fund, starting in October 1999. This mutual fund has become JP Morgan Mid Cap Growth Fund since March 2001 due to the merge of JP Morgan and Chase H&Q.
[2] An IPO boutique, IPOX Schuster LLC, compiles and maintains the value-weighted IPOX-30 index to capture the activity of the 30 largest IPOs in the latest 1000 trading days.

increased after addition of those new assets.[3]

We apply portfolio selection analysis to explore the asset allocation perspective of IPOs. The portfolio selection analysis, dating back to Markowitz (1952), has been a standard treatment in the investment and finance textbooks. Yet, the literature has not addressed the following issues in IPO research. First, does an IPO portfolio significantly enlarge the investment opportunity set relative to currently traded stocks? To answer this question, we employ mean-variance spanning tests to examine whether adding an IPO portfolio can significantly enlarge the investment opportunity set for investors relative to a set of benchmark portfolios sorted by firm size and book-to-market ratio.

Second, to what extent is an IPO portfolio able to enlarge the mean-variance frontier? The mean-variance spanning tests only examine whether the minimum-variance frontier expansion is statistically significant. The Sharpe ratio is the "reward to variability" ratio and measures the slope of the line from the risk-free rate to any portfolio in the mean-standard deviation plane (see Sharpe (1994)). Bekaert and Urias (1996) suggest that one can assess the economic significance of the shift in the minimum-variance frontier by evaluating the change in the Sharpe ratio. A positive change in the Sharpe ratio for the tangency portfolio on the minimum-variance frontier implies that the new tangency portfolio provides an extra return for a unit increase in standard deviation. We measure both the change and percentage change in the Sharpe ratio to quantitatively assess the economic significance of adding an IPO portfolio to a set of benchmark portfolios to gain diversification benefits. In addition to the Sharpe ratio, we also measure the diversification benefits by considering the risk (standard deviation) deduction due to the shift in the global minimum-variance (GMV) portfolio when adding an IPO portfolio to benchmark portfolios.

Finally, what types of IPOs offer large diversification improvements? We examine

[3] Yahoo was founded in 1994 and went public on April 12, 1996. The company was added to the S&P 500 index in December 1999. Google was incorporated in California in 1998 and went public on August 19, 2004.

several IPO characteristics that have been studied in the IPO literature and complement these studies by providing an asset allocation perspective. IPOs in the 1980s backed by venture capitalists experienced less short-run underpricing, which Barry, Muscarella, Peavy, and Vetsuypens (1990) and Megginson and Weiss (1991) attribute to better monitoring and quality certification. Brav and Gompers (1997) find that long-run underperformance is limited to small nonventure backed IPOs. A strand of the literature also examines the relationship between underwriter reputation and underpricing and between reputation and long-run returns (see, for example, Logue (1973), Beatty and Ritter (1986), Booth and Smith (1986), Carter and Manaster (1990), Beatty and Welch (1996), Carter, Dark, and Singh (1998), and Logue, Rogalski, Seward, and Foster-Johnson (2002)). However, the empirical results are mixed due to different sample periods and methodologies. Another usual taxonomy of IPOs is based on industries to proxy for technology type (see Mauer and Senbet (1992), Benveniste, Ljungqvist, Wilhelm, and Yu (2003) for IPO initial returns; Ritter (1991) and Brav (2000) for the long-run performance of IPOs). To examine the relationship between IPO characteristics and the expansion of the investment opportunity set, we divide IPOs into different groups based on venture backing, underwriter reputation, and industry classification.

The above issues are intriguing in their own right to academics and also have pragmatic implications to both the issuance of IPO exchange traded funds (ETFs) or similar investment vehicles and mutual fund managers for IPO security selection and portfolio management. Our main findings can be summarized as follows. First, we compare the statistical and economic significance of the shifts in the mean-variance frontier for an investor who adds an IPO portfolio to a set of benchmark portfolios relative to an investor who invests only in a set of benchmark portfolios. To put the IPO market into perspective, the average monthly ratio of the IPO market value from the previous three years to the market value of non-IPO firms is only around 4%. However, we find that investing in a value-weighted IPO portfolio reliably improves the investment opportunity set, while investing in an equally weighted IPO portfolio does not. This implies that large IPOs are more likely to be associated with enlarging the investment opportunity set. In terms of the percentage change in the Sharpe ratio, adding a value-weighted IPO portfolio to a set of benchmark portfolios increases the Sharpe ratio of the tangency portfolio by 5.5%. On the other hand, consistent with the mean-variance spanning test results, adding an equally weighted IPO portfolio to a set of benchmark portfolios increases the Sharpe ratio of the tangency portfolio by only 2.50%.

Second, we divide IPOs into different groups based on whether they are venture capital backed, or whether they are associated with prestigious underwriters. Alternatively, the IPO sample is also sorted into nine different industries based on the classification of Ritter (1991), Spiess and Affleck-Graves (1995), and Brav (2000). Using different types of IPO portfolios, we examine which of them help investors improve their investment opportunity set. IPOs backed by venture capitalists, IPOs with prestigious underwriters, and IPOs in the business services, computer, and health care industries allow investors to expand their investment opportunity set under both equally weighted and value-weighted schemes. The highest increase for the Sharpe ratio of the tangency portfolio after adding these IPO portfolios is 13.39% from the equally weighted one-year business services IPO portfolio.

Finally, we consider the sub-period 1980-1998 to avoid the impact of the Internet bubble period as a robustness check for our results. We find that the test statistics are more significant for the sub-period 1980-1998, but the main results do not change. We also use three IPO indexes, compiled by IPOX Schuster LLC, as IPO portfolios to test the mean-variance spanning hypothesis. We find that adding these value-weighted IPO indexes significantly expand the mean-variance frontier formed by the 25 size/book-to-market benchmark portfolios. Furthermore, to avoid possible extreme portfolio weights, it is more practicable to restrict the optimal weight of each portfolio to be between –1 and 1. The results based on restricted portfolio weights are also consistent with our main results.

There is one possible explanation for the findings that some IPO portfolios provide significant diversification benefits in terms of the expansion of the mean-variance frontier, which is based on the argument of incomplete spanning by stocks traded in the secondary market. Mauer and Senbet (1992) present a theory that IPO underpricing is a function of incomplete spanning of the IPO by secondary market assets and the degree of investor access to the IPO market, which reflects a primary risk premium. Extending the incomplete spanning argument could explain the result that adding an IPO portfolio with specific characteristics can significantly expand the mean-variance frontier because some specific IPO portfolios are not highly correlated with secondary market assets and thus provide diversification benefits.

Our empirical findings also imply that investors would be interested in investing in IPOs beyond the underpricing consideration and help explain the existence of investment vehicles specializing in IPO investment. Furthermore, our empirical results point out the likelihood of the issuance of IPO exchange traded funds because they can provide potential diversification gains relative to currently traded ETFs based on market capitalization and value/growth style.

The remainder of this paper is organized as follows. Section 2 provides the methods used to evaluate the mean-variance spanning. Section 3 describes the data and provides details of the procedures used for selecting the benchmark portfolios. Section 4 presents the empirical results. Section 5 concludes the paper.

2. Testing for and Measuring IPO Diversification Benefits

2.1 Mean-Variance Spanning Tests

Huberman and Kandel (1987) first introduce a mean-variance spanning test. The method tests whether adding a set of new assets can improve the investment opportunity set relative to a set of basis assets (i.e., expand the mean-variance frontier). This test has been used in a variety of research topics in finance. Errunza, Hogan, and Hung (1999) use mean-variance spanning tests to examine whether the gains from international diversification can be reached without trading abroad. DeRoon, Nijman, and Werker (2001) use regression-based tests for mean-variance spanning with short-sales constrains and transaction costs to test whether U.S. investors could extend their efficient set by investing in emerging markets when allowing for the friction costs. They find that after major emerging market liberalization there is strong evidence of diversification benefits when market frictions are excluded. However, this benefit disappears when investors face short-sales constraints or small transaction costs.

Mean-variance spanning tests enable us to analyze the effect on the mean-variance frontier of adding new assets to a set of benchmark assets. For example, if the mean-variance frontier of the set of benchmark portfolios and that of the benchmark portfolios plus an IPO portfolio coincides, then there is spanning. In this case, investors do not benefit from adding an IPO portfolio to their current portfolios. Whether an observed shift is statistically significant can be tested using regression-based mean-variance spanning tests. We briefly describe the main statistical tests that we use to examine whether adding an IPO portfolio could significantly improve the investment opportunity set relative to a set of benchmark assets. For convenience, we follow the notations and treatment in Kan and Zhou (2001). The details of the test statistics for mean-variance spanning tests are shown in Appendix A.[4]

We denote by K the set of benchmark portfolios (non-IPO portfolios that an investor may hold) with return R_{1t} and by N the set of test assets (one calendar-time IPO portfolio) with return R_{2t}. We estimate the following model using ordinary least squares as

[4] Our treatment for the mean-variance spanning tests is brief. For details we refer the readers to the comprehensive surveys by DeRoon and Nijman (2001) and Kan and Zhou (2001). In addition, Kan and Zhou (2001) examine the finite sample properties and compare the statistical power for two types of mean-variance spanning tests, namely, the regression-based approach and stochastic discount factor based (SDF-based) approach.

$$R_{2t} = \alpha + \beta R_{1t} + \xi_t,\ t=1,2,\ldots\ldots T,\ \text{(in matrix notation)} \tag{1}$$

Following Huberman and Kandel (1987), the null spanning hypothesis is

$$\text{H}_0:\ \alpha = 0_N,\ \ \delta = 1_N - \beta 1_K = 0_N, \tag{2}$$

where 0_N is defined as a zero vector with N elements. We calculate the Wald test statistic for the null hypothesis. If we fail to reject the null hypothesis, the benchmark assets then span the mean-variance frontier of the benchmark assets plus an IPO portfolio. In other words, failing to reject the null hypothesis implies that investors are not able to enlarge their investment opportunity set by adding an IPO portfolio. On the other hand, if the null hypothesis is rejected, adding an IPO portfolio does improve the investment opportunity set. The likelihood ratio and Lagrange multiplier tests are also used to test for mean-variance spanning since the Wald test is not the uniformly most powerful test.

In general, the test for mean-variance spanning can be divided into two parts: (1) the spanning of the global minimum-variance portfolio and (2) the spanning of the tangency portfolio. Therefore, we can rewrite all three asymptotic test statistics based on this geometric feature. For example, the Wald test can be rewritten as

$$W = T\left(\frac{(\hat{\sigma}_{R_1})^2}{(\hat{\sigma}_R)^2} - 1\right) + T\left(\frac{1+\hat{\theta}_R(R_1^{GMV})^2}{1+\hat{\theta}_{R_1}(R_1^{GMV})^2} - 1\right), \tag{3}$$

where $(\hat{\sigma}_{R_1})^2$ and $(\hat{\sigma}_R)^2$ are the global minimum-variance of the benchmark assets and benchmark assets plus an IPO portfolio, respectively. $\hat{\theta}_{R_1}(R_1^{GMV})$ is the slope of the asymptote of the mean-variance frontier for the benchmark assets, and $\hat{\theta}_R(R_1^{GMV})$ is the slope of the tangency line of the mean-variance frontier for the benchmark portfolios plus an IPO portfolio. The first term measures the change of the GMV portfolios due to the addition of an IPO portfolio. The second term measures whether there is an improvement of the squared tangency slope due to adding an IPO portfolio to the set of benchmark portfolios.

Kan and Zhou (2001) report that the asymptotic tests have very good power in testing assets that can reduce the variance of the GMV portfolio, but have little power against test assets that can only improve the tangency portfolio. They therefore suggest a step-down procedure that requires us to first test $\alpha=0_N$ and then to test $\delta=0_N$ conditional on $\alpha=0_N$. If the rejection is due to the first test, we know that it is because the two tangency portfolios are very different. If the rejection is due to the second test, it is because the two GMV portfolios are very different. Figure 1 depicts the geometric interpretation of the step-down test using the equally weighted three-year IPO portfolio of the computer industry. The tests described so far assume that the returns are normally distributed and the error term in Equation (1) is homoskedastic. We also use a GMM Wald test to adjust for return non-normality and heteroskedasticity.

2.2 Measuring Diversification Gains of Adding IPO Investment

Based on the step-down test of Kan and Zhou (2001), we could attribute the test significance for the expansion of the minimum-variance frontier to the shift of the tangency portfolio and/or the shift of the global minimum-variance portfolio. The next question is to assess the extent or economic significance of diversification gains when one adds an IPO portfolio to benchmark portfolios. To correspond to the step-down test, we will apply two measures, namely the Sharpe ratio and the risk deduction of the GMV portfolio, to assess IPO diversification benefits.

Modern portfolio theory suggests that the Sharpe ratio is a natural choice to measure the shift in the tangency portfolio. The Sharpe ratio measures the slope of the line from the risk-free rate to any portfolio in the mean-standard deviation plane. Bekaert and Urias (1996) suggest that one can assess the economic significance of the shift in the minimum-variance frontier by evaluating the change in the Sharpe ratio. Petrella (2005) also uses the Sharpe ratio to measure the diversification benefits of investing in European small cap stocks. A positive change in the Sharpe ratio after adding an IPO portfolio implies that the new tangency portfolio provides an extra return for a unit increase in standard deviation. We measure both the change and percentage change in the Sharpe ratio to assess the economic significance of adding an IPO portfolio to a set of benchmark portfolios to gain diversification benefits.

Another measure of diversification benefits is to consider the risk deduction due to the shift in the GMV portfolio when adding an IPO portfolio to benchmark portfolios. The measure is defined as the difference in standard deviation between the GMV portfolio computed from the benchmark portfolios and the GMV portfolio computed from the benchmark plus IPO portfolios. As Petrella (2005) points out, the risk deduction measure assumes that investors are only concerned with minimizing risk and do not care about returns. Though this assumption is pretty strong, the risk deduction measure is independent of the expected return estimation and it is more difficult to estimate an expected return than a variance or standard deviation (see Merton (1980) and Jorion (1985)).

3. Data Description

Our sample of IPO firms is collected from Thomson Financial Securities Data (SDC) U.S. Common Stock Initial Public Offerings database, and it is composed of 6,961 IPOs from 1977 to 2002. Sample IPO firms meet the following criteria. (1) IPOs involve common stocks only. Consistent with previous IPO research, unit offers, real estate investment trusts (REITs), closed-end funds, American Depositary Receipts (ADRs), and reverse leveraged buyouts are excluded. (2) IPO firms have return data in the Center for Research in Security Prices (CRSP) database. (3) The offer price is greater than or equal to \$5. Figure 2 presents the distribution of the number of IPOs and the aggregate amount of gross proceeds.

The IPO portfolio used as a test asset in our mean-variance spanning tests is described as follows. For a given month, we form the one-year IPO portfolio by including all IPOs that went public during the prior 12 months. Similarly, we form the three-year IPO portfolio by including all IPOs that went public during the prior 36 months.[5] To avoid the impact of underpricing, we do not include the return from the first trading month when the firm just goes public. Figure 3 shows the relative market value of the three-year IPO portfolio to non-IPO firms. The average monthly ratio is 3.88% from 1980-2002, and the average for the period 1980-1998 is slightly less at 3.60%. We also find that the trend in this market value ratio is more consistent with the Nasdaq composite index trend rather than that for the S&P 500 index.

We further divide the IPO sample into venture capital backed IPOs and non-venture capital backed IPOs based on SDC's classification. We also partition our sample into IPOs associated with prestigious lead underwriters and IPOs without highly ranked lead underwriters based on whether the Carter and Manaster rank of the lead underwriter is greater than or equal to 8 (see Carter and Manaster (1990)). The updated underwriter reputation rank is collected from Carter, Dark, and Singh (1998) and Loughran and Ritter (2004).[6] The underwriter rank ranges from zero to nine based on the hierarchy of tombstone announcements. Finally, we sort IPOs into nine groups based on the industry classification provided by Ritter (1991), Spiess and Affleck-Graves (1995), and Brav (2000) (see Appendix B for detail). Panel A of Table 1 presents the returns and standard deviations of our different IPO portfolios. We find that the equally weighted venture backed IPO portfolios have higher mean returns and are riskier than the non-venture backed counterparts. However, the value-weighted venture backed IPO portfolios have lower mean returns but are riskier than their non-venture backed counterparts. We further notice that in general IPOs with prestigious lead underwriters perform much better and have higher risk than those with non-prestigious lead underwriters.

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[5] This is the reason why we start collecting data from 1977 to have our IPO portfolios start in 1980.

[6] The underwriter reputation rank is available at http://bear.cba.ufl.edu/ritter/rank.htm.

For the benchmark portfolios, we use five size and five book-to-market portfolios to form the 25 size and book-to-market portfolios of NYSE, AMEX, and Nasdaq stocks as described in Fama and French (1992, 1993). Another motivation to use these benchmark portfolios is that quite a few exchange traded funds (ETFs) are based on market capitalization and value/growth classification. For instance, iShares Morningstar Index Fund Series, iShares Russell Index Fund Series, and iShares S&P Index Fund Series are usually based on market capitalization and value/growth category.[7]

To be included in the benchmark portfolios, a firm must have had stock prices in CRSP for December of year *t-1* and June of year *t* and COMPUSTAT book common equity for year *t-1*. Moreover, the firms must have been on COMPUSTAT for two years prior to year *t* to avoid backfill bias. To avoid the contamination problem in benchmark portfolios pointed out by Loughran and Ritter (2000), we do not include the firms that have appeared in our IPO portfolios.

Following Fama and French (1992), we define BE as the COMPUSTAT book value of stockholders' equity, plus balance-sheet deferred taxes and investment credit (if available), minus the book value of preferred stock. Depending on availability, we use the redemption, liquidation or par value (in this order) to estimate the value of preferred stock. We also define ME as the market price of the stock times the number of shares outstanding. At the end of June each year from 1980-2002, the size (ME) and book-to-market (BE/ME) quintiles are created using only the NYSE stocks. Panel B of Table 1 presents the summary statistics of 25 size/book-to-market portfolios excluding firms that had IPOs in the past 12 months. Panel C of Table 1 presents the summary statistics of 25 size/book-to-market portfolios excluding firms that had IPOs in the past 36 months.

4. Mean-Variance Frontier Expansion from Adding IPO Investment

4.1 Full Sample Results

[7] More details about these ETFs can be found at http://www.ishares.com/fund_info/equity.jhtml.

We test whether adding an IPO portfolio to a set of benchmark assets based on 25 size and book-to-market portfolios enlarges the investment opportunity set for mean-variance investors. Table 2 presents empirical results from the mean-variance spanning test.[8] Based on the regression-based spanning tests, we reject the null hypothesis that the benchmark portfolios can span the value-weighted one-year and three-year IPO portfolios at the 5% significance level. However, we are unable to reject the null hypothesis for the equally weighted one-year and three-year IPO portfolios. In other words, adding a value-weighted IPO portfolio improves the investment opportunity set but adding an equally weighted IPO portfolio does not. We also use the Kan and Zhou (2001) step-down Wald test as a robustness check. For the value-weighted one-year IPO portfolio, W_1 is more significant than W_2, which means that the expansion of the mean-variance frontier mostly comes from the change in the tangency portfolio. For the value-weighted three-year IPO portfolio, W_1 is less significant than W_2, thus implying that the expansion mostly comes from the change in the global minimum-variance (GMV) portfolio. The results are similar when we use the GMM Wald (W_a) test and the GMM step-down Wald test (W_{a1} and W_{a2}).

The significant results for the cases of value-weight IPO portfolios, compared to equally weighted cases, can be verified from the correlations between an IPO portfolio and benchmark portfolios. The lower the correlations between an IPO portfolio and each of the 25 size/book-to-market portfolios, the more the investment opportunity set can be improved by adding an IPO portfolio. Table 3 shows the correlation coefficients for an IPO portfolio and each of the 25 size/book-to-market portfolios, excluding firms that had IPOs in the previous 12 and 36 months. Note that the correlation coefficients between the value-weighted 1-year IPO portfolio and each of the 25 size/book-to-market portfolios (Panel B of Table 3) are less than most of the correlation coefficients between the equally

[8] We also calculate the statistics for F, LR, LM, W_a, W_{a1}, and W_{a2} tests. In order to limit the size of the tables, we only report statistics from W, W_1, and W_2 tests and the other results are qualitatively the same.

weighted 1-year IPO portfolio and each of the 25 portfolios (Panel A of Table 3). The finding supports the statistical results in Table 2. On the other hand, the evidence for the cases of 3-year IPO portfolios is not clear.

The previous mean-variance spanning tests only examine whether the expansion of the minimum-variance frontier is statistically significant. As Bekaert and Urias (1996) suggest, we can assess the economic significance of the shift in the minimum-variance frontier by evaluating the change in the Sharpe ratio. The Sharpe ratio, also known as the "reward to variability" ratio, measures the slope of the line from the risk-free rate to any portfolio in the mean-standard deviation plane (see Sharpe (1994)). A positive change in the Sharpe ratio for the tangency portfolio implies that the new tangency portfolio provides an extra return for each percentage point increase in standard deviation. Intuitively, the absolute values of both the change and percentage change in the Sharpe ratio are inversely related to the p-values associated with the first step-down test (W_1). That is, if the first step-down test fails to reject the mean-variance spanning hypothesis, then we will find a small percentage change in the Sharpe ratio. Tobin (1958) introduces the well-known separation property and argues that portfolio choice can be separated into two steps: (1) the determination of the optimal tangency portfolio; (2) the construction of the mix between the risk-free asset and the optimal tangency portfolio, dependent on investors' preferences. Therefore, investors are more likely concerned with the change in the tangency portfolio than the global minimum-variance portfolio.

Earlier we show that when adding either an equally weighted one-year or three-year IPO portfolio, neither of them significantly expands the minimum-variance frontier based on the step-down test. In Table 2, the percentage change in the Sharpe ratio for the tangency portfolio is 2.43% when adding the equally weighted one-year IPO portfolio and 2.65%

when adding the equally weighted three-year IPO portfolio.[9] The risk deduction rate for the GMV portfolio is 0.00% and -0.28%, respectively. By contrast, adding a value-weighted one-year IPO portfolio significantly expands the minimum-variance frontier mostly due to a shift in the tangency portfolio. The percentage change in the Sharpe ratio for the tangency portfolio is 6.69%, much greater than 2.43% when adding an equally weighted one-year IPO portfolio. Furthermore, for one-year and three-year value-weighted IPO portfolios, we find a larger risk deduction on GMV portfolios with a rate of -0.29% and -0.57% as compared with the one-year and three-year equally weighted IPO portfolios.

When we look further at the change in the Sharpe ratio for the tangency portfolio, adding a value-weighted one-year IPO portfolio provides an extra return of 3.3% ((0.526-0.493)*100%) for a unit increase in standard deviation. However, adding an equally weighted one-year IPO portfolio only provides an extra return of 1.2% ((0.505-0.493)*100%) for a unit increase in standard deviation. The findings are consistent with the argument that the absolute change and the absolute percentage change in the Sharpe ratio are inversely related to the p-values associated with the first step-down test.

Figure 4 shows that the expansion of the mean-variance frontier when adding the three-year value-weighted IPO portfolio is more apparent than adding the three-year equally weighted IPO portfolio. In summary, our empirical results suggest that investing in a value-weighted IPO portfolio can significantly improve a mean-variance investor's investment opportunity set. In other words, investing in large IPOs within one year after the offer significantly gains the diversification benefit. Also, the sources of the improvement for the mean-variance frontier are different between the one-year value-weighted IPO portfolio and three-year value-weighted IPO portfolio.

4.2 Results Based on Various IPO Characteristics

[9] The complete results regarding the Sharpe ratios, and risk/return for tangency and GMV portfolios in Section 4 are available upon request.

4.2.1 Venture Capital Backed IPOs versus Non-Venture Capital Backed IPOs

Panel A of Table 4 presents the mean-variance spanning test results using venture capital backed and non-venture capital backed IPO portfolios separately. We reject the null hypothesis using the Wald test in both the equally weighted and value-weighted IPO portfolios regardless of the time horizon.[10] Using the step-down test, we find that the shift in the mean-variance frontier from adding either a value-weighted or an equally weighted venture backed IPO portfolio to the benchmark portfolios is due mainly to the change in the global minimum-variance portfolio rather than the change in the tangency portfolio. The percentage change in the standard deviation of the GMV portfolio is -1.13% for the three-year equally weighted case and -1.98% for the three-year value-weighted case, which further confirms the above results. One exception is that adding an equally weighted three-year venture backed IPO portfolio increases the Sharpe ratio for the tangency portfolio by 5.09%. The top graph in Figure 5 shows that the expansion of the mean-variance frontier from adding the value-weighted three-year venture backed IPO portfolio is due to the change in the global minimum-variance portfolio.

In the mean-variance spanning test results using a non-venture backed IPO portfolio, the Wald test rejects the null hypothesis in both the value-weighted one-year and three-year non-venture backed IPO portfolios. However, we cannot reject the null hypothesis for the equally weighted portfolios. Using the step-down test, we find that the shift in the mean-variance frontier when adding the value-weighted one-year or three-year non-venture backed IPO portfolio to the benchmark portfolios is largely due to the shift in the tangency portfolio. The percentage change in the Sharpe ratio for the tangency portfolio is around 10% when adding the value-weighted one-year IPO portfolio and around 5% when adding the value-weighted three-year IPO portfolio. The bottom graph of Figure 5 illustrates the

[10] In Table 4, we report only the results for 3-year IPO portfolios for brevity. The results for 1-year IPO portfolios are available from the authors upon request.

result for the value-weighted three-year non-venture backed IPO portfolio. Therefore, investing in large non-venture backed IPOs especially within one year after the offering significantly improves investors' ability to diversify.

In general, our findings show that adding an IPO portfolio backed by venture capital can significantly improve the investment opportunity set for mean-variance investors, regardless of the different time horizons and portfolio weighting schemes. In contrast, a non-venture capital backed IPO portfolio can only improve the investment opportunity set under the value-weighting scheme.

4.2.2 IPO Portfolios Based on Lead Underwriter Reputation

Panel B of Table 4 shows the results of mean-variance spanning tests using portfolios composed of IPOs with prestigious lead underwriters and IPOs with non-prestigious lead underwriters. For IPOs associated with prestigious lead underwriters, the null hypothesis is rejected by the Wald test in both value-weighted and equally weighted IPO portfolios for one year and three years. Using the step-down test, the shift in the mean-variance frontier by adding either a value-weighted or an equally weighted one-year IPO portfolio to the benchmark portfolios is mainly due to the change in the tangency portfolio. The percentage change in the Sharpe ratio for the tangency portfolio is 7.10% when adding the equally weighted one-year IPO portfolio and 8.11% when adding the value-weighted one-year IPO portfolio. On the other hand, the shift in the mean-variance frontier by adding either a value-weighted or an equally weighted three-year IPO portfolio to the benchmark portfolios is due mainly to the change in the global minimum-variance portfolio, although the change in the tangency portfolio is also statistically significant. The percentage change in the Sharpe ratio for the tangency portfolio is 4.89% when adding the equally weighted three-year IPO portfolio and 5.30% when adding the value-weighted three-year IPO portfolio. In addition, the percentage change in the standard deviation of the GMV portfolio when adding equally and value-weighted IPO portfolios are both -0.57%. Thus, investing in

IPOs associated with prestigious lead underwriters especially within one year after the offering significantly enhances the benefit of additional diversification. The top graph in Figure 6 shows that the value-weighted three-year IPO portfolio with prestigious lead underwriters is expanded due to the change in both the tangency and global minimum-variance portfolios.

For mean-variance spanning tests using IPOs with non-prestigious lead underwriters, the Wald test does not reject the null hypothesis for both value-weighted and equally weighted IPO portfolios regardless of the time horizon. In other words, investors cannot improve their investment opportunity set or gain significant diversification benefits by investing in IPOs with non-prestigious underwriters in addition to the 25 size/book-to-market portfolios. The bottom graph in Figure 6 shows that after adding the value-weighted three-year IPO portfolio, the mean-variance frontier is almost identical to the original minimum-variance frontier.

In a nutshell, we find that underwriter reputation has a large impact on the diversification benefits for including IPO stocks in one's portfolio. Investors who add an IPO portfolio associated with prestigious lead underwriters can significantly improve their investment opportunity set. However, adding an IPO portfolio without prestigious lead underwriters does not expand the minimum-variance frontier. Note that there is a strong positive correlation between the size of the offering and underwriter reputation. In particular, all large IPOs use prestigious lead underwriters.

4.2.3 IPO Portfolios Sorted by Industries

We also divide our IPO sample into nine industry portfolios based on Ritter (1991), Spiess and Affleck-Graves (1995), and Brav (2000). We find that adding business services, computer, and health care industry IPO portfolios can reject the mean-variance spanning hypothesis using a Wald test in both the value-weighted and equally weighted portfolios regardless of the time horizon.[11] We report these findings in Panel C of Table 4. We find that the sources for the mean-variance frontier expansion are different based on the step-down Wald test. The frontier expansion after adding IPOs in either the business services industry or the computer industry is due to the shift in both the tangency and global minimum-variance (GMV) portfolios. The only exception is the case adding a value-weighted three-year IPO portfolio in the business services industry.

For the business services industry, there is a 13.39% increase in the Sharpe ratio for the tangency portfolio when adding the equally weighted one-year IPO portfolio and a 9.13% increase when adding the value-weighted one-year IPO portfolio. We also find that the GMV portfolio risk deduction rates are -0.85% and -1.42% when adding equally and value-weighted three-year IPO portfolios. This implies that investment in IPOs in the business services industry after the offering could significantly gain diversification benefits. For the computer industry, the percentage change in the Sharpe ratio for the tangency portfolio is 6.09% when adding the equally weighted one-year IPO portfolio and 8.55% when adding the equally weighted three-year IPO portfolio. Furthermore, the GMV portfolio risk is reduced by 0.85% and 1.13% respectively when adding three-year equally weighted and value-weighted IPO portfolios. Therefore, investing in IPOs in the computer industry within three years after the offering significantly improves the diversification benefits. For IPOs in the health care industry, the frontier expansion is due mainly to the change in the global minimum-variance portfolio rather than the tangency portfolio. This finding is further confirmed by the risk deduction rate of GMV portfolios, ranging from -0.57% to -1.42%, after adding IPOs to the 25 size/book-to-market portfolios.

4.3 Robustness Check

4.3.1 The Internet Bubble

[11] To conserve space, we only discuss the results obtained for these three industries and the results for the remaining industry classification are available upon request.

In Table 5, we conduct mean-variance spanning tests for the period 1980-1998, which drops the period after the Internet Bubble as a robustness check. We find that most of the results are qualitatively similar to the results from the full sample period 1980-2002. From 1980 to 1998, adding the equally weighted IPO portfolios for both one and three years significantly expands the minimum-variance frontier formed by 25 size/book-to-market benchmark portfolios. Some subgroups of IPO portfolios that are originally insignificant in the sample period 1980-2002 are significant when we examine the period 1980-1998, which avoid the Internet Bubble impact. Overall, the main results do not change, therefore, the Internet Bubble period has only a minor influence on our results.

4.3.2 IPOX Indexes

An IPO boutique, IPOX Schuster LLC, compiles three value-weighted IPO indexes to capture the U.S. IPO activity. The IPOX Composite index is a dynamically reconstituted index in which new IPO stocks are selected at their seventh trading day and retained up to 1000 trading days after going public. The other two indices, IPOX-100 and IPOX-30, capture the activities of the top-100 and top-30 IPOs ranked by market capitalization in the IPOX Composite index. The number of member stocks is fixed at 100 and 30 but the index membership is reconstituted quarterly based on market capitalization.[12] Using these IPO indices as a new asset class for the periods 1980-1998 and 1980-2002, we conduct mean-variance spanning tests to examine whether these index portfolios could expand the minimum variance frontier. Table 5 reports that these value-weighted IPO indexes significantly expand the minimum variance frontier generated by 25 size/book-to-market benchmark portfolios. Thus, these results are consistent with the results obtained from our value-weighted IPO portfolios.

4.3.3 Portfolio Weight Constraints

[12] http://www.ipoxschuster.com/ provides more details and historical performance of these three IPO indexes. We thank Josef Schuster, the founder of IPOX Schuster LLC, for providing us with data on these three IPO indexes.

The previous mean-variance spanning tests examine whether the minimum-variance frontier expansion is statistically significant when no portfolio weight constraint is used. To avoid possible extreme portfolio weights, it would be more reasonable to restrict the optimal weight of each portfolio (IPO and the 25 benchmark portfolios) to be between -1 and 1, which is termed "the unit weight constraint."[13] Table 6 reports the optimal IPO portfolio weight and its corresponding Sharpe ratio for the full sample IPO portfolio and other five IPO portfolios that could significantly improve an investor's opportunity set. We show the empirical results for the case without a portfolio weight constraint and for the case with the unit weight constraint.

We find that the optimal weight for IPO portfolios is positive in all cases with or without restrictions. Therefore, the results imply that the portfolio weight constraint is not a main concern for our empirical finding. The optimal IPO portfolio weights and the corresponding Sharpe ratios decrease due to the introduction of the unit weight constraint. In summary, our empirical findings are robust even using a more reasonable portfolio weight constraint between –1 and 1.

4.4 Discussion

After discussing our empirical results, we offer an incomplete spanning explanation to explain that the mean-variance frontier formed by benchmark portfolios can be expanded by adding an IPO portfolio. Mauer and Senbet (1992) investigate the role of the secondary market to explain IPO underpricing based on the incomplete spanning argument. In their framework, at the offering stage, IPOs are priced in the primary market populated by firms that may have short operating history and relatively few comparable firms in the secondary market. The secondary market helps establish the after-market clearing prices for IPOs. Mauer and Senbet (1992) argue that IPO underpricing is a function of incomplete spanning

[13] This constraint can also correspond to the case that investors only trade ETFs and an IPO ETF exists in the financial market.

of the IPO by secondary market assets and the degree of investor access to the IPO market. Extending the incomplete spanning argument beyond IPO underpricing, it may be used to explain the rejection for the mean-variance spanning hypothesis, that is, adding an incomplete spanning IPO portfolio can expand the mean-variance frontier formed by benchmark portfolios. The intuition is that an incomplete spanning IPO portfolio is not highly correlated with the secondary market assets and thus provides diversification benefits. For example, prestigious lead underwriters are more likely to bring new successful technology firms to the market. These IPO firms are less likely to have perfect secondary market substitutes, making them more likely provide diversification benefits. Similarly, venture capitalists are also more likely to identify successful technology firms that are hard to value by secondary market assets. Thus, these successful technology IPO firms are more likely to offer diversification benefits.

Next, we point out implications for the empirical results that an IPO portfolio can help enlarge the investment opportunity set relative to an investment in a set of benchmark portfolios sorted by firm size and book-to-market ratio. One straightforward implication is that if one issues exchange traded funds (ETFs) using IPOs as a new asset class, these IPO ETFs could potentially add diversification benefits to currently traded ETFs based on the size and book-to-market classification. For example, in current ETF markets, iShares Morningstar Index Fund Series, iShares Russell Index Fund Series, and iShares S&P Index Fund Series are based on market capitalization and value/growth style. Another implication is that there should be demand for current investment vehicles specializing in IPO investment such as IPO mutual funds and unit trusts because investors can easily access to primary market portfolios and gain diversification benefits.

5. Conclusion

This paper investigates the IPO market from the perspective of asset allocation for the period 1980-2002. We employ the mean-variance spanning tests to examine whether adding

IPOs provides significant diversification benefits when added to a set of commonly used benchmark portfolios sorted by firm size and book-to-market ratio. To our knowledge, our study is the first to use the idea of mean-variance spanning in the IPO context.

The empirical results of this paper are summarized as follows. First, investors who invest in a value-weighted IPO portfolio are able to enlarge their investment opportunity set relative to an investment in a set of benchmark portfolios sorted by firm size and book-to-market ratio. In contrast, investing in an equally weighted IPO portfolio does not improve the investment opportunity set. Because institutional investors and mutual fund managers care more about value-weighted portfolios than equally weighted portfolios, the results show that investing in large IPOs expands the investment opportunity set and improves asset allocation.

Second, value-weighted and equally weighted venture backed IPO portfolios and IPO portfolios with prestigious lead underwriters significantly improve an investor's investment opportunity set. These results are significant for both one-year and three-year holding period. Third, based on the sort by industry, we find that investors can improve their investment opportunity set by holding IPO portfolios in the business services, computer, or health care industry. These three subgroups exhibited consistent results in both one-year and three-year portfolios regardless of the weighting scheme. Fourth, the Internet Bubble has only a minor influence on our results. Although for some groups of IPO portfolios the Wald statistics from 1980-1998 are larger than the statistics of the same groups from 1980-2002, the main conclusions do not change qualitatively. Another robustness check is adding IPO indexes compiled by IPOX Schuster LLC, which also significantly expands the minimum variance frontier formed by 25 size/book-to-market benchmark portfolios. Our empirical findings are robust even when using a more reasonable portfolio weight constraint between -1 and 1.

Our empirical findings are intriguing due to the fact that although the average monthly ratio of market value of IPOs from the prior 3 years to the market value of non-IPO firms is only around 4%, the diversification benefits are economically and statistically significant based on the mean-variance spanning tests and the percentage change in the Sharpe ratios. Furthermore, because investors can expand their investment opportunity set by adding an IPO portfolio to a set of portfolios sorted by firm size and book-to-market ratio, IPOs with certain characteristics, such as the involvement of venture capital and association with prestigious lead underwriters, are worth investing in. Since numerous exchange traded funds come to the market based on market capitalization and value/growth category, our empirical results imply that the issuance of IPO exchange traded funds can provide potential diversification gains relative to currently traded ETFs based on market capitalization and value/growth style. Our study also provides evidence that there should be demand for investment vehicles specializing in IPO investment such as IPO mutual funds and unit trusts.

Appendix A: Mean-Variance Spanning Tests

1. Asymptotic Mean-Variance Spanning Tests

As in Section 2.1, we denote by K the set of benchmark portfolios (non-IPO portfolios that an investor may hold) with return, R_{1t} and by N the set of test assets (one calendar-time IPO portfolio) with return, R_{2t}. Let the return on N+K assets as $R_t = \left[R_{1t}^{'} \quad R_{2t}^{'}\right]^{'}$, and the expected return on N+K assets as $\mu = E[R_t] \equiv \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}$. The variance-covariance matrix of N+K assets is $V = Var[R_t] \equiv \begin{bmatrix} V_{11} & V_{12} \\ V_{21} & V_{22} \end{bmatrix}$, where V is non-singular. We estimate the following model using ordinary least squares as

$$R_{2t} = \alpha + \beta R_{1t} + \xi_t,\ t=1,2,\ldots\ldots T \qquad (R=XB+E \text{ in matrix notation}), \tag{1A}$$

with the estimators of B and Σ are $\hat{B} \equiv [\hat{\alpha} \ \ \hat{\beta}] = (X^{'}X)^{-1}(X^{'}R)$ and $\hat{\Sigma} = \frac{1}{T}(R - X\hat{B})^{'}(R - X\hat{B})$.

Under the normality assumption, we have

$$\xi_t \sim N(0, \Sigma),\ \ vec(\hat{B}^{'}) \sim N(vec(B^{'}), (X^{'}X)^{-1} \otimes \Sigma). \tag{2A}$$

Following Huberman and Kandel (1987), the null hypothesis of “spanning” is

$$\text{H}_0\text{:}\ \ \alpha = 0_N,\ \ \delta = 1_N - \beta 1_K = 0_N. \tag{3A}$$

We can write this null hypothesis as $\Theta = \left[\alpha \ \ \delta\right]^{'} = O_{2\times N} = AB - C$, where $A = \begin{bmatrix} 1 & 0_K^{'} \\ 0 & -1_K^{'} \end{bmatrix}$ and $C = \begin{bmatrix} 0_N^{'} \\ -1_N^{'} \end{bmatrix}$. The distribution of the null hypothesis is $vec(\hat{\Theta}^{'}) \sim N(vec(\Theta^{'}), A(X^{'}X)^{-1}A^{'} \otimes \Sigma)$. By defining $\hat{G} = TA(X^{'}X)^{-1}A^{'} = \begin{bmatrix} 1 + \hat{\mu}_1^{'}\hat{V}_{11}^{-1}\hat{\mu}_1 & \hat{\mu}_1^{'}\hat{V}_{11}^{-1}1_K \\ \hat{\mu}_1^{'}\hat{V}_{11}^{-1}1_K & 1_K^{'}\hat{V}_{11}^{-1}1_K \end{bmatrix}$ and $\hat{H} = \hat{\Theta}\hat{\Sigma}^{-1}\hat{\Theta}^{'} = \begin{bmatrix} \hat{\alpha}^{'}\hat{\Sigma}^{-1}\hat{\alpha} & \hat{\alpha}^{'}\hat{\Sigma}^{-1}\hat{\delta} \\ \hat{\alpha}^{'}\hat{\Sigma}^{-1}\hat{\delta} & \hat{\delta}^{'}\hat{\Sigma}^{-1}\hat{\delta} \end{bmatrix}$,

we then denote by λ_1 and by λ_2 the two eigenvalues of the matrix, $\hat{H}\hat{G}^{-1}$. The distributions of the asymptotic Wald, likelihood ratio, and Lagrange multiplier test statistics for the null hypothesis are

$$W = T(\lambda_1 + \lambda_2) \overset{A}{\sim} \chi^2_{2N} . \tag{4A}$$

$$LR = T\sum_{i=1}^{2} \ln(1+\lambda_i) \overset{A}{\sim} \chi^2_{2N} , \tag{5A}$$

$$LM = T\sum_{i=1}^{2} \frac{\lambda_i}{1+\lambda_i} \overset{A}{\sim} \chi^2_{2N} . \tag{6A}$$

2. Finite Sample Mean-Variance Spanning Tests

The exact finite sample distribution of the likelihood ratio test under the null, as Huberman and Kandel (1987) and Jobson and Korkie (1989) also show, is

$$\left(\frac{1}{U^{\frac{1}{2}}} - 1\right)\left(\frac{T-K-N}{N}\right) \sim F_{2N,2(T-K-N)} \quad \text{for } N \geq 2, \tag{7A}$$

$$\left(\frac{1}{U} - 1\right)\left(\frac{T-K-1}{2}\right) \sim F_{2,(T-K-1)} \quad \text{for } N = 1, \tag{8A}$$

where $U = \left|\hat{G}\right| / \left|\hat{H} + \hat{G}\right|$.

3. Step-Down Asymptotic Wald Test Statistics

Based on Kan and Zhou (2001), the step-down procedure first tests $\alpha = 0_N$ and then tests $\delta = 0_N$ conditional on $\alpha = 0_N$. The first test ($\alpha = 0_N$) is straightforward. We simply ignore the null hypothesis of $\delta = 0_N$ in Equation (3A) and apply the same asymptotic Wald test procedure. Note that $\hat{H}\hat{G}^{-1}$ then degenerates to a scalar and its eigenvalue, denoted as λ_3, is actually itself. The second test ($\delta = 0_N$ conditional on $\alpha = 0_N$) is a test of $\delta = 0_N$ on estimating Equation (1A) without an intercept. We follow the same asymptotic Wald test procedure detailed above. The matrix $\hat{H}\hat{G}^{-1}$ in the second test is also a scalar. Thus, its eigenvalue, denoted as λ_4, is itself. The step-down asymptotic Wald tests can be written as

$$W_1 = T(\lambda_3) \overset{A}{\sim} \chi^2_{N} , \tag{9A}$$

$$W_2 = T(\lambda_4) \overset{A}{\sim} \chi^2_{N} . \tag{10A}$$

Based on Kan and Zhou (2001), Equations (9A) and (10A) can also be rewritten using the similar notation of the finite sample step-down F tests as (see Kan and Zhou (2001) for details)

$$W_1 = T\left(\frac{\hat{a} - \hat{a}_1}{1 + \hat{a}_1}\right), \tag{11A}$$

$$W_2 = T\left(\frac{1+\hat{a}_1}{1+\hat{a}} \times \frac{\hat{c}+\hat{d}}{\hat{c}_1 + \hat{d}_1} - 1\right), \tag{12A}$$

where $\hat{a}_1 = \hat{\mu}_1^{'}\hat{V}_{11}^{-1}\hat{\mu}_1$, $\hat{b}_1 = \hat{\mu}_1^{'}\hat{V}_{11}^{-1}1_K$, $\hat{c}_1 = 1_k^{'}\hat{V}_{11}^{-1}1_K$ and $\hat{d}_1 = \hat{a}_1\hat{c}_1 - \hat{b}_1^{\,2}$. Here $\hat{a}$, $\hat{b}$, $\hat{c}$ and $\hat{d}$ are the analogues of $\hat{a}_1$, $\hat{b}_1$, $\hat{c}_1$ and $\hat{d}_1$, based on benchmark assets plus an IPO portfolio.

4. Mean-Variance Spanning Tests under Non-Normality and Heteroskedasticity

The GMM Wald test is

$$W_a = T \times vec(\hat{\Theta}^{'})^{'}[(A_T \otimes I_N)S_T(A_T^{'} \otimes I_N)]^{-1} vec(\hat{\Theta}^{'}) \overset{A}{\sim} \chi^2_{2N}, \tag{13A}$$

where the moment condition is

$$E[g_t] = E(X \otimes E) = 0^{'}_{N(1+K)}, \tag{14A}$$

$$S_T = E[g_t^{'} g_t], \tag{15A}$$

$$A_T = \begin{bmatrix} 1+\hat{a}_1 & -\hat{\mu}_1^{'}\hat{V}_{11}^{-1} \\ \hat{b}_1 & -1_K^{'}\hat{V}_{11}^{-1} \end{bmatrix}. \tag{16A}$$

Following Kan and Zhou (2001), we also conduct step-down GMM Wald tests to disentangle the two sources of the spanning test. The test for α=0_N (denote as W_{a1}) is straightforward. We simply ignore the null hypothesis of δ=0_N in Equation (3A) and use Equation (13A). However, we need to change A_T to $A_T = \left[1+\hat{a}_1 \quad -\hat{\mu}_1^{'}\hat{V}_{11}^{-1}\right]$ due to the change in the null hypothesis. Testing δ=0_N conditional on α=0_N (denote as W_{a2}) is actually a test of $\delta=0_N$ using Equation (1A) without an intercept. We can also use Equation (13A) by changing A_T to $A_T=\left[-1_K'(\hat{V}_{11}+\mu_1\mu_1')^{-1}\right]$. Furthermore, new S_T is different from S_T of the joint test in Equation (15A) since X for the second step-down test has no intercept term (i.e., a vector of ones). Finally, we note that both step-down GMM Wald test statistics are distributed as chi-square with N degrees of freedom.

The details on how the change in matrix A_T is made are shown as follows. Based on Kan and Zhou (2001), A_T is the consistent estimate for $AE[XX']^{-1}$. For the first step-down test (testing $\alpha = 0_N$), A has to be changed as $\left[1 \ \ 0_K\right]$. Therefore,

$$A_T = AE[XX']^{-1} = \left[1+\hat{a}_1 \quad -\hat{\mu}_1'\hat{V}_{11}^{-1}\right]. \tag{17A}$$

For the second step-down test (testing $\delta=0_N$ conditional on $\alpha=0_N$), A has to be changed to $\left[-1_K'\right]$. Thus,

$$A_T = AE[XX']^{-1} = \left[-1_K'(\hat{V}_{11}+\mu_1\mu_1')^{-1}\right], \tag{18A}$$

where new X is different from X in Equation (17A), since there is no intercept term in the regression equation estimated.

Appendix B: SIC Codes for Industry Classification

The classification of industries is based on Ritter (1991), Spiess and Affleck-Graves (1995), and Brav (2000).

Industry	SIC Codes
Banking (Financial Institutions)	602-603, 612, 620-628, 671.
Biotechnology (Drug and Genetic Engineering)	283.
Business services (Business Services; Communications)	480-489, 731-736, 738-739, 871-874.
Computers (Computer Hardware; Computer Software)	357, 737.
Equipment (Electronic Equipment; Optical, Medical and Scientific Equipment)	366, 367, 369, 381-384.
Health Care (Health Care and HMOs; Insurance)	631-641, 800-809.
Metal (Metal and Metal Products)	331-349, 351-356, 358-359.
Retailers and Wholesalers (Retailers; Wholesalers; Restaurant chains)	501-519, 520-573, 581, 591-599.
Others	—

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Figure 1

Geometry of the Step-Down Mean-Variance Spanning Tests

The figure illustrates the economic meaning of the step-down tests by plotting the mean-variance frontier of 25 size/book-to-market benchmark portfolios (the inner solid frontier) and the benchmark plus IPO portfolios (the outer dashed frontier) in the mean-standard deviation space. The IPO portfolio is the three-year equally weighted (EW) computer industry IPO portfolio from July 1980 to December 2002 (270 months).

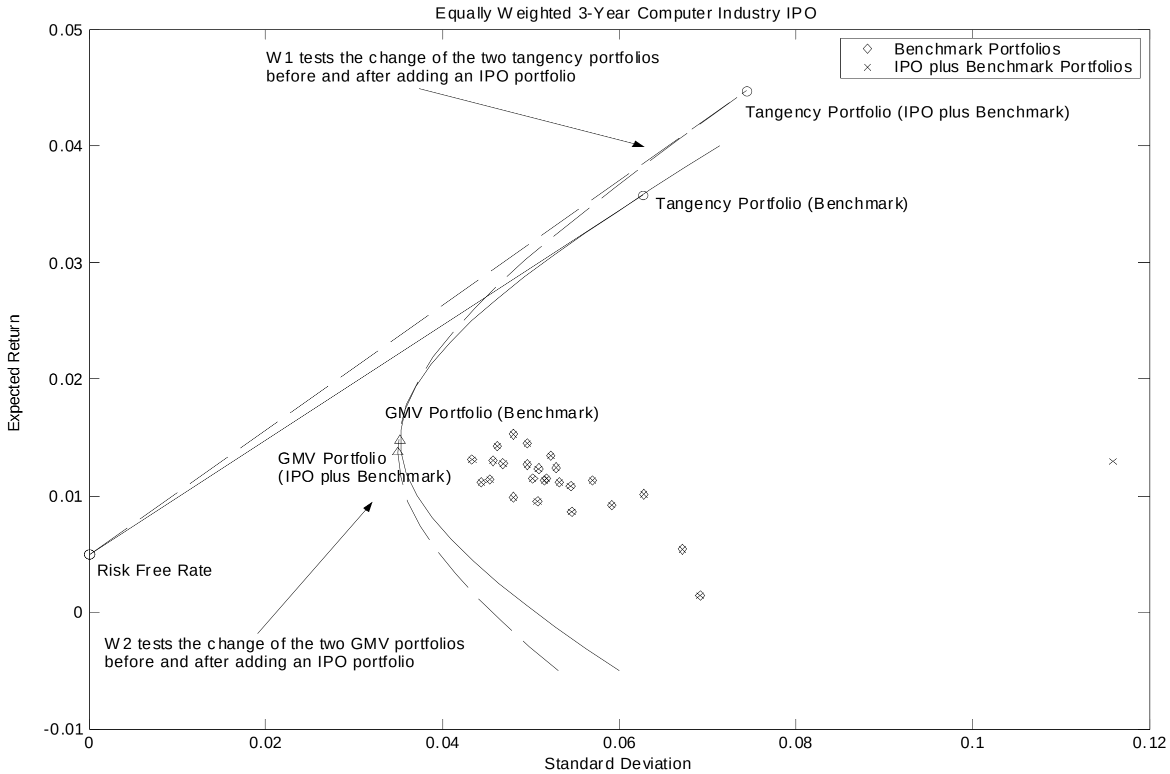


Figure 2
Distribution of Initial Public Offerings by Year, 1977-2002

Our sample of initial public offerings is collected from Thomson Financial Security Data and includes 6,961 initial public offerings from 1977-2002 meeting the following criteria: (1) the offerings involve common stocks only, so unit offers, REITs, closed-end funds, and ADRs are excluded; (2) IPO firms have return data in CRSP; (3) the offer price is greater than or equal to $5.

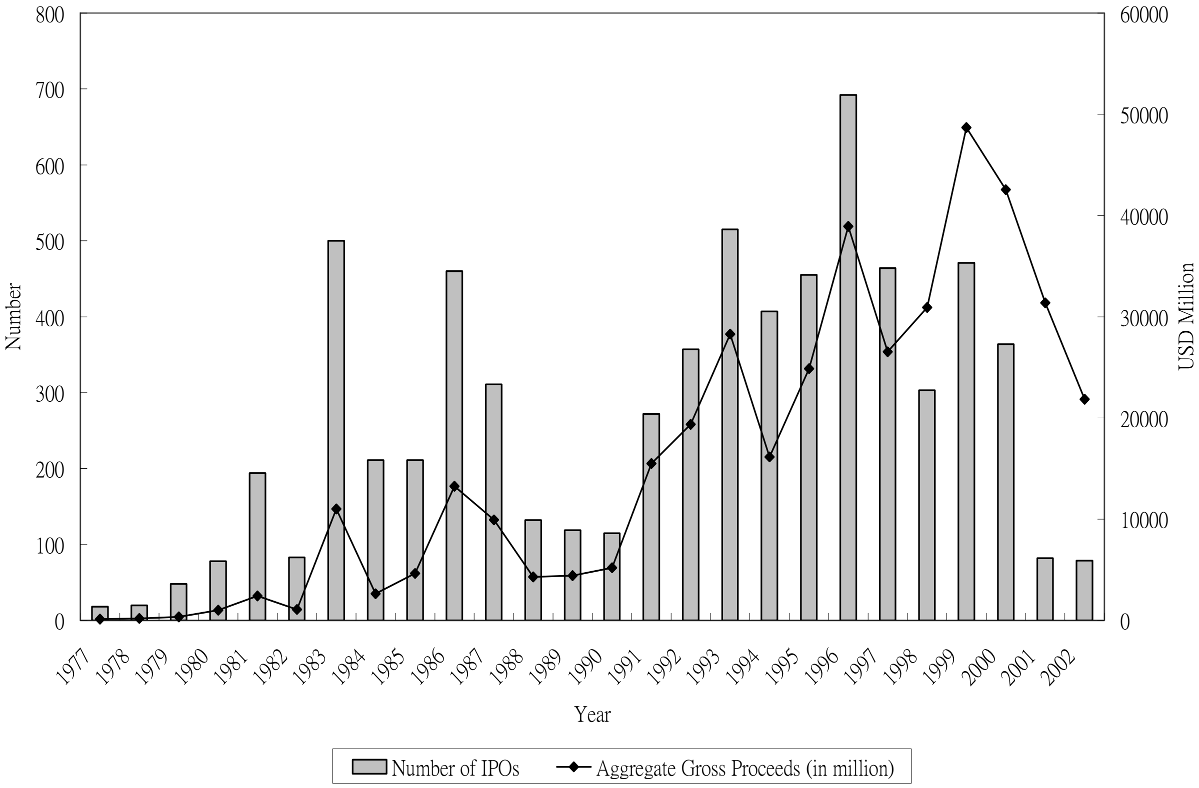


Figure 3
Market Indices and the Ratio of IPO/Non-IPO Firm Market Value

Market indices are the S&P 500 index and Nasdaq composite index. The IPO portfolio is a three-year IPO portfolio that includes all IPOs within the last 36 months. The ratio is the total market value of the three-year IPO portfolio divided by the total market value of the non-IPO firms in CRSP within the last 36 months. The market value is defined as the market price of the stock times the number of shares outstanding.

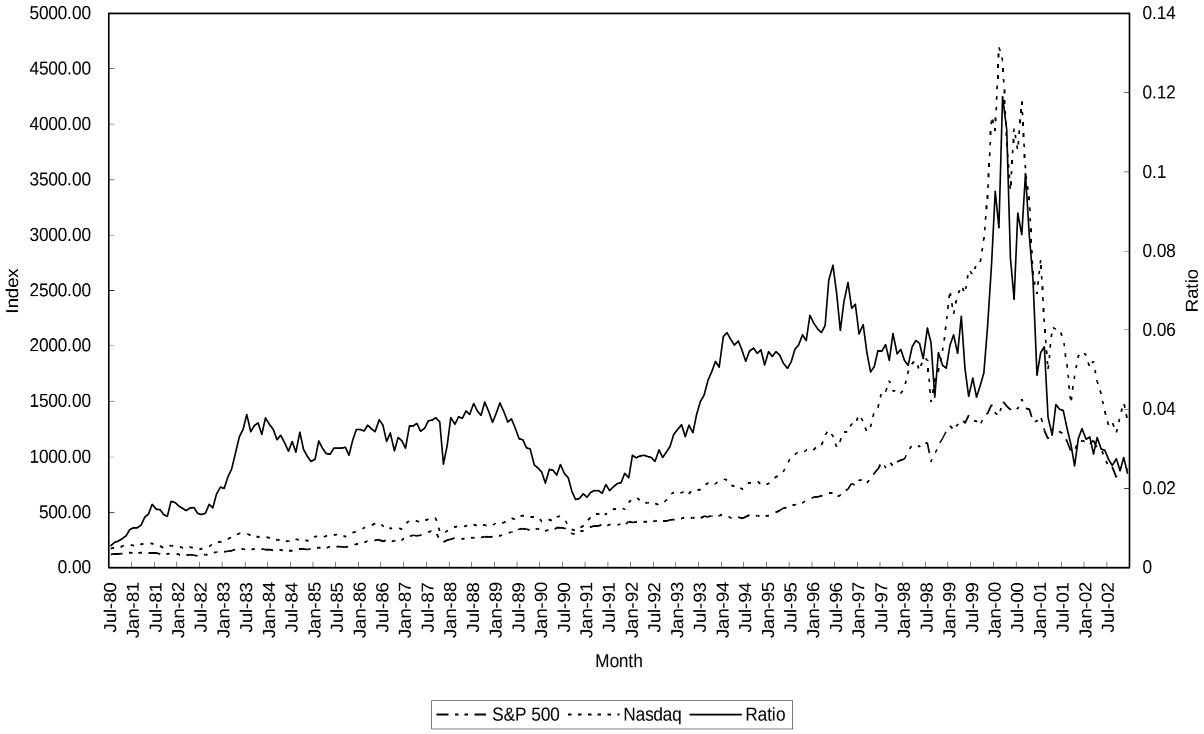
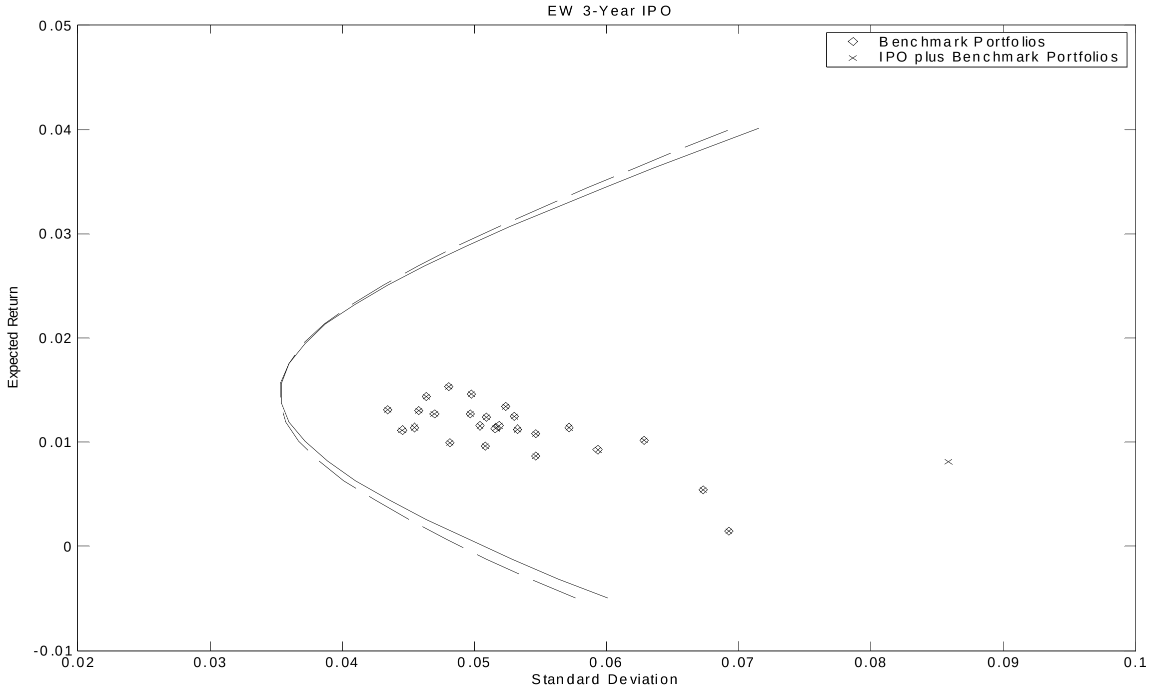


Figure 4

Mean-Variance Frontiers of Benchmark Assets and Benchmark Assets plus IPOs

The figure plots the mean-variance frontier of 25 size/book-to-market benchmark portfolios (the inner solid frontier) and the benchmark plus IPO portfolios (the outer dashed frontier) in the mean-variance space. IPO portfolios are the three-year equally weighted (EW) and value-weighted (VW) IPO portfolios from July 1980 to December 2002 (270 months).



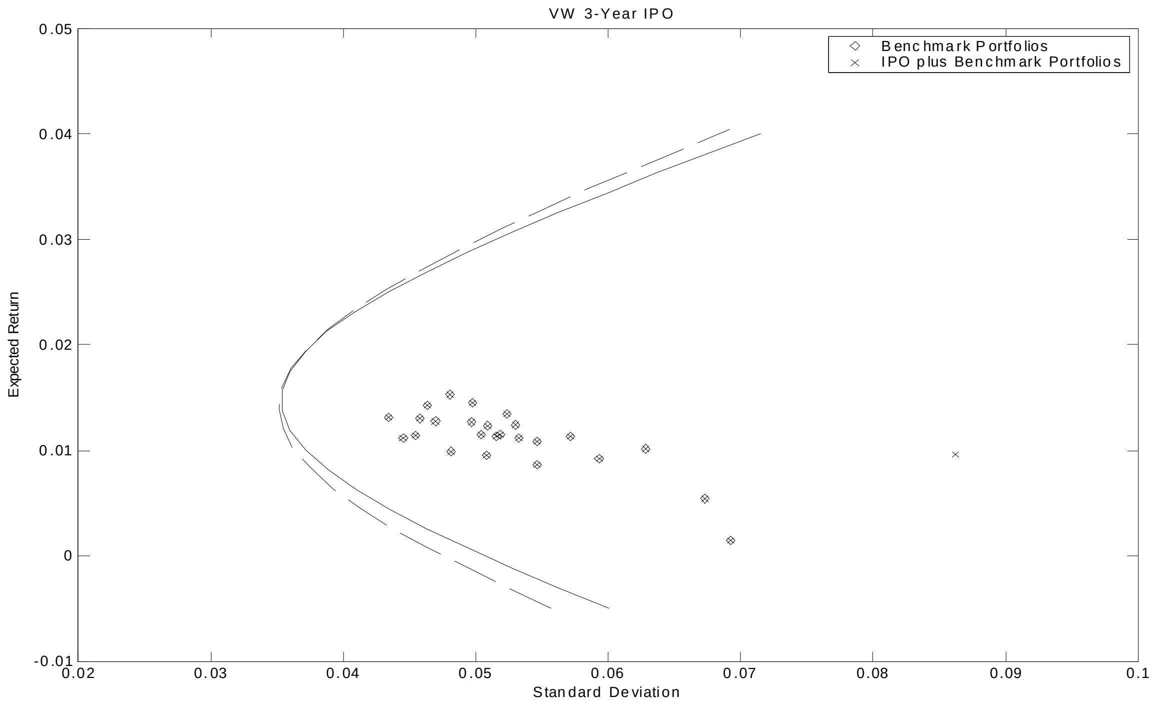
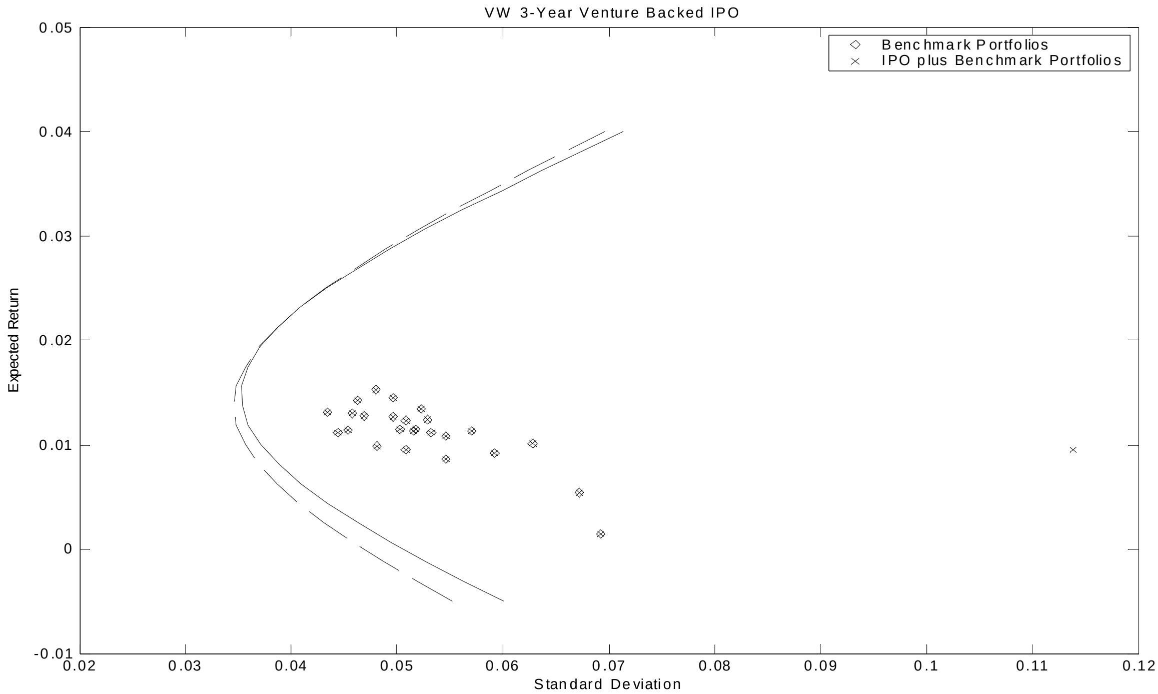


Figure 5
Mean-Variance Frontiers of Benchmark Assets and Benchmark Assets plus Venture Backed IPOs or Non-Venture Backed IPOs

The figure plots the mean-variance frontier of 25 size/book-to-market benchmark portfolios (the inner solid frontier) and the benchmark plus IPO portfolios (the outer dashed frontier) in the mean-variance space. IPO portfolios are the three-year value-weighted (VW) venture backed and non-venture backed IPO portfolios from July 1980 to December 2002 (270 months).



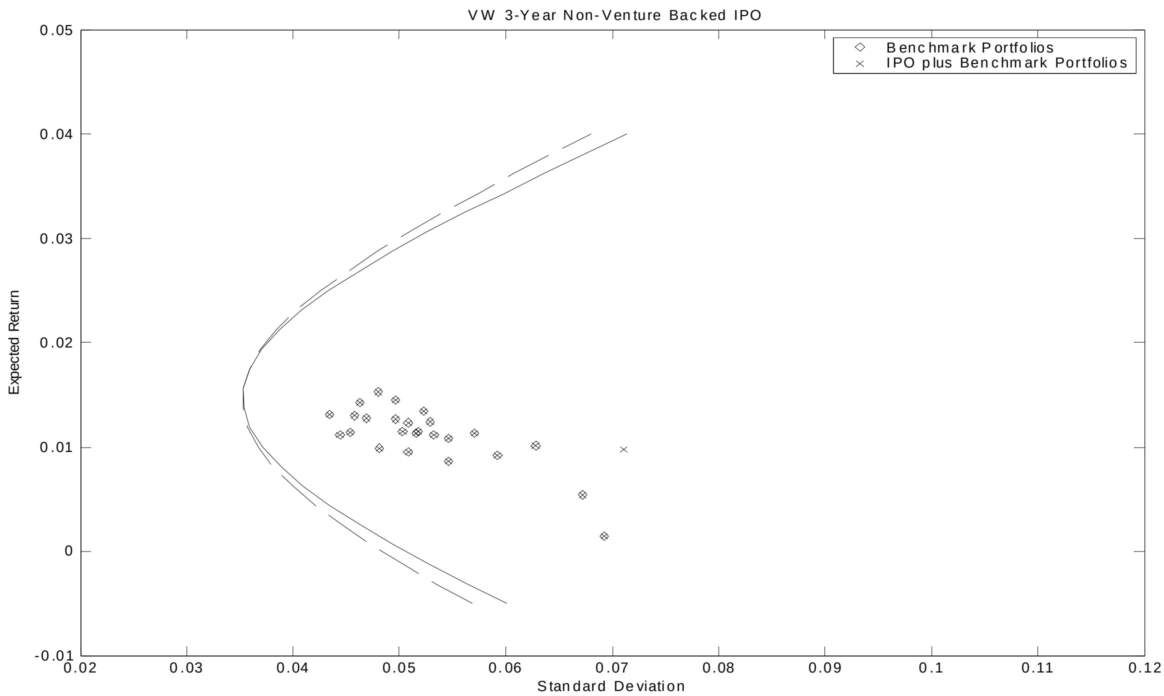
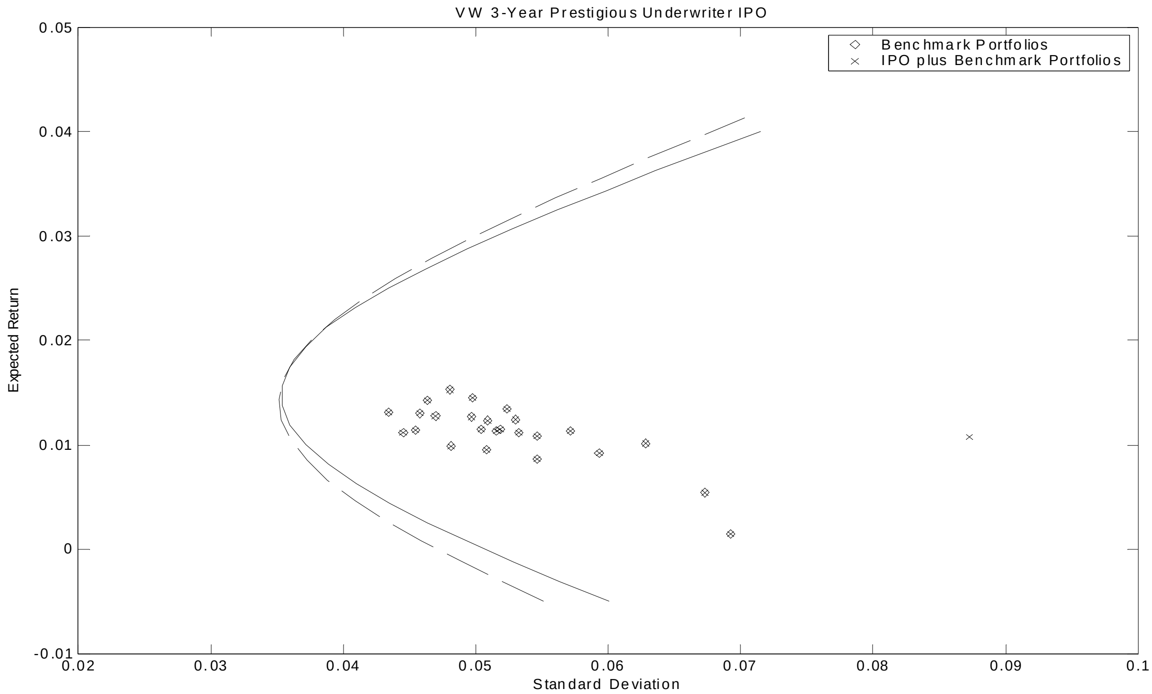


Figure 6
Mean-Variance Frontiers of Benchmark Assets and Benchmark Assets plus IPOs with Prestigious Lead Underwriters or Non-Prestigious Lead Underwriters

The figure plots the mean-variance frontier of 25 size/book-to-market benchmark portfolios (the inner solid frontier) and the benchmark plus IPO portfolios (the outer dashed frontier) in the mean-variance space. IPO portfolios are three-year value-weighted (VW) IPO portfolios with either prestigious lead underwriters or non-prestigious lead underwriters from July 1980 to December 2002 (270 months).



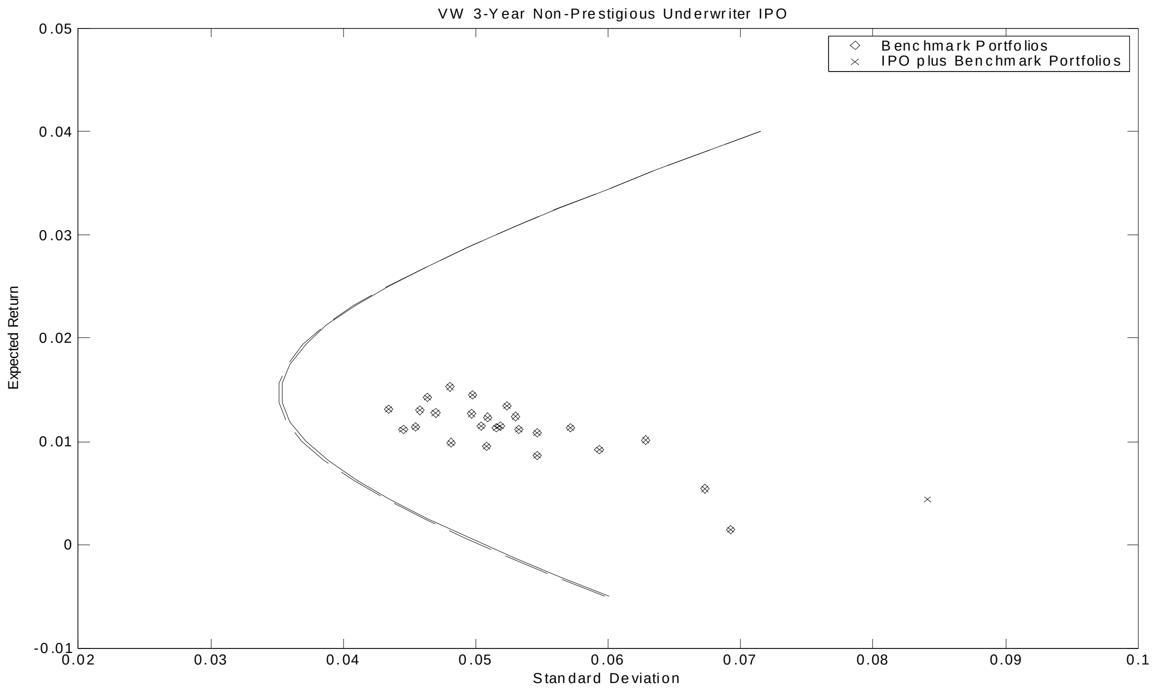


Table 1

Monthly returns and standard deviations of IPO Portfolios and Benchmark Portfolios,

Panel A presents descriptive statistics of different IPO portfolios: equally weighted and value-weighted IPO portfolios from July 1980 to December 2002 (270 months). Calendar-time portfolios are formed for each month of our sample period by including firms that went public during the prior 12 and 36 months. Panel B presents the mean monthly percentage returns and monthly percentage standard deviations (in parenthesis) of the 25 size/book-to-market portfolios excluding firms that have gone public in the past 12 months. Panel C presents the mean monthly percentage returns and monthly standard deviations (in parenthesis) of the 25 size/book-to-market portfolios excluding firms that have gone public in the past 36 months.

Panel A

	Equally weighted				Value-weighted			
	one-year		three-year		one-year		three-year	
	Mean (%)	St. Dev. (%)	Mean (%)	St. Dev. (%)	Mean (%)	St. Dev. (%)	Mean (%)	St. Dev. (%)
All IPOs	**0.91**	**8.87**	**0.81**	**8.58**	**1.34**	**9.14**	**0.96**	**8.62**
Venture backed	1.15	10.70	1.03	10.48	1.27	12.12	0.96	11.39
Non-Venture backed	0.82	7.89	0.73	7.56	1.45	7.71	0.98	7.11
With prestigious underwriters	1.36	9.22	1.06	8.96	1.50	9.18	1.07	8.72
With non-prestigious underwriters	0.17	8.72	0.61	7.95	0.33	10.27	0.43	8.41
IPOs by Industry								
Bank Industry	1.21	6.50	1.46	5.92	1.73	10.99	1.63	9.98
Biotechnology Industry	1.55	11.69	1.71	10.97	1.14	12.35	1.11	10.59
Business Service Industry	2.18	11.90	1.14	9.86	2.07	11.74	0.91	9.58
Computer Industry	1.45	12.39	1.29	11.60	1.70	13.75	1.42	12.79
Equipment Industry	1.02	11.41	1.11	10.64	0.71	11.59	1.26	11.15
Health Care Industry	2.20	11.98	1.71	8.95	2.41	11.68	1.84	9.24
Metal Industry	0.57	10.35	0.97	8.18	0.66	10.93	0.57	8.48
Retailer and Wholesaler Industry	0.38	9.12	0.45	8.12	1.72	11.48	1.09	9.09
Other Industry	0.29	7.36	0.42	6.82	1.22	7.92	0.86	6.40

Panel B

		Size									
		Smallest		2		3		4		Largest	
Book-to-Market	Lowest	0.15	(7.07)	0.59	(6.94)	0.96	(6.58)	0.87	(6.07)	1.16	(5.24)
	2	0.87	(5.62)	1.13	(5.79)	1.06	(5.51)	1.12	(5.35)	1.13	(5.16)
	3	0.98	(4.94)	0.92	(5.14)	1.23	(5.12)	1.14	(5.04)	1.26	(4.96)
	4	1.08	(4.52)	1.40	(4.67)	1.26	(4.71)	1.30	(4.57)	1.32	(4.32)
	Highest	1.16	(4.58)	1.20	(5.34)	1.43	(4.97)	1.50	(4.82)	1.33	(5.21)

Panel C

		Size									
		Smallest		2		3		4		Largest	
Book-to-Market	Lowest	0.14	(6.92)	0.54	(6.73)	1.01	(6.29)	0.92	(5.92)	1.15	(5.18)
	2	0.86	(5.46)	1.13	(5.71)	1.08	(5.46)	1.12	(5.32)	1.13	(5.16)
	3	0.99	(4.81)	0.95	(5.08)	1.23	(5.09)	1.15	(5.03)	1.27	(4.96)
	4	1.11	(4.45)	1.43	(4.63)	1.27	(4.70)	1.30	(4.58)	1.31	(4.34)
	Highest	1.14	(4.54)	1.24	(5.30)	1.45	(4.97)	1.53	(4.80)	1.34	(5.23)

Table 2
Mean-Variance Spanning Tests of IPOs using
25 Decontaminated Size/Book-to-Market Portfolios as Benchmarks

The period for the mean-variance spanning test is from July 1980 to December 2002 (270 months). The IPO portfolios are the equally and value-weighted portfolios of IPOs that have gone public during the prior 12 months and 36 months for each month. Excluding firms in the IPO portfolios, the benchmark portfolios are 25 size/book-to-market portfolios constructed by all firms (with a CRSP share code of 10 or 11) trading on the NYSE, AMEX, or Nasdaq. The table also reports the mean returns and standard deviations of the tangency and global minimum-variance (GMV) portfolios before and after adding IPO portfolios. W represents the asymptotic Wald test. W_1 and W_2 are the step-down Wald tests. P-values are in parentheses. * denotes the 5% significance level and ** denotes the 1% significance level. The mean monthly risk-free rate (1-month T-bill rate), 0.5%, is used in computing the tangency portfolio weights and the Sharpe ratios.

	Equally Weighted					Value-Weighted				
		Step-Down Tests					Step-Down Tests			
	W	W_1		W_2		W	W_1		W_2	
One-Year		before	after	before	after		before	after	before	after
Tangency Portfolio										
Mean Return (%)		3.52	3.73				3.52	4.09		
Standard Deviation (%)		6.13	6.39				6.13	6.81		
Sharpe Ratio		0.493	0.505				0.493	0.526		
% Change in Sharp Ratio		2.43					6.69			
GMV Portfolio										
Mean Return (%)				1.48	1.47				1.48	1.44
Standard Deviation (%)				3.50	3.50				3.50	3.49
Test Statistics	4.001	2.363		1.724		10.421	6.335		3.992	
P Value	(0.135)	(0.133)		(0.189)		(0.006)**	(0.012)*		(0.046)*	
Three-Year		before	after	before	after		before	after	before	After
Tangency Portfolio										
Mean Return (%)		3.58	3.83				3.58	4.04		
Standard Deviation (%)		6.27	6.61				6.27	6.92		
Sharpe Ratio		0.491	0.504				0.491	0.512		
% Change in Sharp Ratio		2.65					4.28			
GMV Portfolio										
Mean Return (%)				1.47	1.44				1.47	1.41
Standard Deviation (%)				3.53	3.52				3.53	3.51
Test Statistics	5.110	2.048		3.039		9.992	3.345		6.566	
P Value	(0.078)	(0.152)		(0.081)		(0.007)**	(0.067)		(0.010)*	

Table 3
Correlation Coefficients for an IPO Portfolio and Each of the 25 Size/book-to-Market Portfolios

Panel A presents the correlation coefficients for the equally weighted 1-year IPO portfolio and each of the 25 size/book-to-market portfolios. Panel B presents the correlation coefficients for the value-weighted 1-year IPO portfolio and each of the 25 size/book-to-market portfolios. Panel C presents the correlation coefficients for the equally weighted 3-year IPO portfolio and each of the 25 size/book-to-market portfolios. Panel D presents the correlation coefficients for the value-weighted 3-year IPO portfolio and each of the 25 size/book-to-market portfolios.

Panel A: Correlation Coefficients for EW 1-Year IPO Portfolio and 25 Size/Book-to-Market Portfolios

		Size				
		Smallest	2	3	4	Largest
Book-to-Market	Lowest	0.84	0.81	0.80	0.75	0.65
	2	0.76	0.75	0.68	0.65	0.57
	3	0.71	0.64	0.58	0.58	0.50
	4	0.70	0.66	0.61	0.53	0.45
	Highest	0.70	0.56	0.60	0.54	0.35

Panel B: Correlation Coefficients for VW 1-Year IPO Portfolio and 25 Size/Book-to-Market Portfolios

		Size				
		Smallest	2	3	4	Largest
Book-to-Market	Lowest	0.80	0.78	0.78	0.76	0.67
	2	0.72	0.72	0.66	0.64	0.56
	3	0.67	0.62	0.58	0.58	0.50
	4	0.65	0.61	0.61	0.52	0.47
	Highest	0.63	0.52	0.55	0.50	0.32

Panel C: Correlation Coefficients for EW 3-Year IPO Portfolio and 25 Size/Book-to-Market Portfolios

		Size				
		Smallest	2	3	4	Largest
Book-to-Market	Lowest	0.86	0.81	0.78	0.75	0.64
	2	0.76	0.75	0.67	0.68	0.58
	3	0.71	0.64	0.59	0.59	0.52
	4	0.71	0.66	0.62	0.55	0.47
	Highest	0.70	0.58	0.63	0.54	0.38

Panel D: Correlation Coefficients for VW 3-Year IPO Portfolio and 25 Size/Book-to-Market Portfolios

		Size				
		Smallest	2	3	4	Largest
Book-to-Market	Lowest	0.85	0.82	0.81	0.80	0.71
	2	0.75	0.74	0.68	0.69	0.61
	3	0.69	0.66	0.60	0.60	0.56
	4	0.68	0.65	0.63	0.55	0.52
	Highest	0.65	0.57	0.59	0.51	0.36

Table 4

Mean-Variance Spanning Tests Based on Various IPO Characteristics

The period for the mean-variance spanning tests is from July 1980 to December 2002 (270 months). The test portfolios are the equally and value-weighted portfolios of IPOs with various characteristics. In each month, the IPOs in the test portfolios went public during the prior 36 months. Excluding firms in the IPO portfolios, the benchmark portfolios are 25 size/book-to-market portfolios constructed by all firms (with a CRSP share code of 10 or 11) trading on the NYSE, AMEX, or Nasdaq. W represents the Wald test. W_1 and W_2 are the step-down Wald tests. P-values are in parentheses. * denotes the 5% significance level and ** denotes the 1% significance level. The mean monthly risk-free rate (1-month T-bill rate), 0.5%, is used in computing the tangency portfolio weights and the Sharpe ratios.

Panel A: Venture Capital Backed and Non-Venture Capital Backed IPOs

	Equally Weighted			Value-Weighted		
		Step-Down Tests			Step-Down Tests	
	W	W_1	W_2	*W*	W_1	W_2
Venture Backed IPOs						
Test Statistics	14.018	3.929	9.944	15.696	1.215	14.415
P Value	(0.001)**	(0.048)*	(0.002)**	(0.000)**	(0.270)	(0.000)**
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.516			0.502	
% Change in Sharpe Ratio		5.09			2.24	
Non-Venture Backed IPOs						
Test Statistics	1.189	0.849	0.339	6.669	4.388	2.244
P Value	(0.552)	(0.357)	(0.560)	(0.036)*	(0.036)*	(0.134)
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.496			0.515	
% Change in Sharpe Ratio		1.02			4.89	

Panel B: IPOs Associated with Prestigious and Non-Prestigious Lead Underwriters

	Equally Weighted			Value-Weighted		
		Step-Down Tests			Step-Down Tests	
	W	W_1	W_2	*W*	W_1	W_2
IPOs with Prestigious Underwriters						
Test Statistics	11.146	3.967	7.075	11.366	4.347	6.908
P Value	(0.004)**	(0.046)*	(0.008)**	(0.003)**	(0.037)*	(0.009)**
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.515			0.517	
% Change in Sharpe Ratio		4.89			5.30	
IPOs with Non-Prestigious Underwriters						
Test Statistics	0.427	0.394	0.033	3.489	0.135	3.353
P Value	(0.821)	(0.530)	(0.856)	(0.175)	(0.714)	(0.067)
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.493			0.491	
% Change in Sharpe Ratio		0.41			0.00	

Panel C: Business Services, Computer, and Health Care Industry IPOs

	Equally Weighted			Value-Weighted		
		Step-Down Tests			Step-Down Tests	
	W	W_1	W_2	*W*	W_1	W_2
Business Services Industry IPOs						
Test Statistics	13.492	4.958	8.381	9.014	0.044	8.968
P Value	(0.001)**	(0.026)*	(0.004)**	(0.011)*	(0.834)	(0.003)**
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.521			0.493	
% Change in Sharpe Ratio		6.11			0.41	
Computer Industry IPOs						
Test Statistics	16.837	7.320	9.266	15.716	4.355	11.180
P Value	(0.000)**	(0.007)**	(0.002)**	(0.000)**	(0.037)*	(0.001)**
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.533			0.519	
% Change in Sharpe Ratio		8.55			5.70	
Health Care Industry IPOs						
Test Statistics	8.305	1.362	6.908	9.058	0.290	8.759
P Value	(0.016)*	(0.243)	(0.009)**	(0.011)*	(0.591)	(0.003)**
Sharpe Ratio before Adding IPOs		0.491			0.491	
Sharpe Ratio after Adding IPOs		0.501			0.495	
% Change in Sharpe Ratio		2.04			0.81	

Table 5
Summary of Results and Robustness Check

The periods of the mean-variance spanning test are from July 1980 to December 2002 (270 months) and from July 1980 to December 1998 (222 months). We use the period 198007-199812 to conduct the robustness check to avoid the impact of the internet bubble. One-year and three-year portfolios are formed by IPOs that have gone public during the prior 12 months and 36 months. IPOX indexes are value-weighted IPO indexes compiled by IPOX Schuster LLC. The mark X represents that the Wald test is significant at the 5% level, and N/A stands for "not applicable".

	1980-2002				1980-1998			
	One-Year		Three-Year		One-Year		Three-Year	
	EW	VW	EW	VW	EW	VW	EW	VW
All IPOs		**X**		**X**	**X**	**X**	**X**	**X**
Venture Backed	X	X	X	X	X	X	X	X
Non-Venture Backed		X		X	X	X		X
Prestigious Lead Underwriters	X	X	X	X	X	X	X	X
Non-prestigious Lead Underwriters						X		X
IPOs by Industries								
Banking		X		X		X	X	X
Biotechnology			X				X	X
Business services	X	X	X	X	X	X	X	X
Computer	X	X	X	X	X	X	X	X
Equipment			X	X	X			X
Health Care	X	X	X	X	X	X	X	X
Metal			X	X				
Retailer and wholesaler		X		X		X		X
Other						X		
IPOX indexes								
IPOX-Composite	N/A	X	N/A	X	N/A	X	N/A	X
IPOX-100	N/A	X	N/A	X	N/A	X	N/A	X
IPOX-30	N/A	X	N/A	X	N/A	X	N/A	X

Table 6
Optimal IPO Portfolio Weights and Sharpe Ratios

The period for the test is from July 1980 to December 2002 (270 months). One-year and three-year portfolios are formed by IPOs that have gone public during the prior 12 months and 36 months. NPWC stands for the case of no portfolio weight constraint. UWC stands for the unit weight constraint in which the portfolio weight is between –1 and 1. The mean monthly risk-free rate (1-month T-bill rate) used in computing the Sharpe ratios is 0.5%.

	One-Year				Three-Year			
	EW		VW		EW		VW	
	NPWC	UWC	NPWC	UWC	NPWC	UWC	NPWC	UWC
Full Sample								
Optimal IPO Portfolio Weight	0.332	0.180	0.494	0.309	0.366	0.169	0.488	0.246
Sharpe Ratio	0.505	0.491	0.526	0.508	0.504	0.491	0.512	0.497
Venture Backed								
Optimal IPO Portfolio Weight	0.322	0.199	0.201	0.128	0.442	0.209	0.244	0.112
Sharpe Ratio	0.512	0.497	0.504	0.492	0.516	0.499	0.502	0.490
Prestigious Lead Underwriters								
Optimal IPO Portfolio Weight	0.528	0.319	0.509	0.335	0.500	0.245	0.522	0.274
Sharpe Ratio	0.528	0.509	0.533	0.515	0.515	0.498	0.527	0.501
Business Services Industry								
Optimal IPO Portfolio Weight	0.462	0.282	0.373	0.242	0.478	0.236	0.091	0.031
Sharpe Ratio	0.559	0.535	0.538	0.520	0.521	0.502	0.493	0.486
Computer Industry								
Optimal IPO Portfolio Weight	0.336	0.220	0.257	0.173	0.492	0.252	0.329	0.175
Sharpe Ratio	0.523	0.508	0.519	0.505	0.533	0.512	0.519	0.503
Health Care Industry								
Optimal IPO Portfolio Weight	0.189	0.135	0.139	0.106	0.221	0.157	0.117	0.085
Sharpe Ratio	0.509	0.498	0.502	0.492	0.501	0.493	0.495	0.488