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THE LONG-TERM PERFORMANCE OF IPOS, REVISTED*

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The Long-Term Performance of IPOs, Revisited*

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Abstract

Prior research on IPO long-term performance, focusing on three- to five-year post-issue periods, shows that the apparent IPO underperformance disappears when different risk exposures across IPO and mature firms are accounted for by using a Carhart (1997) factor model. We show that a sample of 7,487 U.S. IPOs between 1975 and 2014 continues to significantly underperform mature firms in terms of Carhart-alphas over the first year after going public when using conventional portfolio sorts. This result prevails across various sub-samples, and also withstands a battery of robustness checks extending the Carhart (1997) factor model with multiple firm characteristics in a statistically robust setting. Further econometric tests, however, reveal that the apparently robust IPO underperformance is likely to be the result of omitted, yet persistent, firm-specific factors rendering IPO firms different from mature firms. Specifically, we find IPO underperformance to disappear when accounting for unobservable heterogeneity across firms.

Keywords: IPO underperformance, long-term performance evaluation, time horizon, firm characteristics, firm fixed effects

JEL classification: G14, G24, G32

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1. Introduction

In a seminal paper, Ritter (1991) documents a significant underperformance of IPO firms over the first three years after going public. Loughran and Ritter (1995, 2000) find a strong underperformance of IPOs over a five-year period following the issue date. Brav and Gompers (1997), Brav, Geczy, and, Gompers (2000), and Gompers and Lerner (2003) show that IPO firms are strongly tilted towards small and high-growth companies which has been the worst-performing investment style over the last several decades. Consistently, these studies show that the apparent underperformance of IPO firms disappears when controlling for size and the book-to-market ratio, concluding that IPO firms do not perform worse than similar non-issuing companies.

In this paper, we first show that IPO underperformance is highly dependent on the time horizon over which post-IPO performance is measured. We document an economically large and statistically significant underperformance of IPO firms over the first year after going public – even when differences in size, book-to-market, and momentum are accounted for. In a sample of 7,487 U.S. firms going public from 1975 to 2014, this underperformance amounts to a risk-adjusted -1.92% per quarter. Thereafter, underperformance gradually declines to an insignificant risk-adjusted -0.71% over three years and a borderline significant underperformance of 0.70% per quarter five years after going public. We also show that IPO underperformance is not confined to, but by far largest in the first year after going public, making up for about 50% of total underperformance over the first five years. Hence, while prior research on long-term IPO performance focuses on three- and five-year time horizons, and apparently solved the IPO underperformance puzzle by controlling for size and the book-to-market ratio, we reopen the quest for a solution to this puzzle by showing that there is a statistically significant and economically meaningful underperformance of IPO firms over the first year after going public, even when the usual risk factors are accounted for.[1]

[1] In the ten-year period 2007-2016, the top four academic finance journals (JF, RFS, JFE, and JFQA) published a total of 114 papers on IPOs, whereof 24 articles analyze the long-term performance of IPOs. Only two of these papers use factor models to evaluate long-term performance (Lyandres, Sun, and Zhang, 2008; Bessembinder and Zhang, 2013). Both of these papers focus on a five-year post-issue period.

To further explore this finding, we form sub-samples based on firm size, issuing activity, time period, venture capital involvement, IPO underpricing, and stock exchange listing. Loughran and Ritter (1995) and Gao, Ritter, and Zhu (2013) find small-firm IPOs to exhibit worse long-term performance than large-firm IPOs. Ritter and Welch (2002) and Gao, Ritter, and Zhu (2013) show the sensitivity of results with regard to the time period analyzed. Specifically, Gao, Ritter, and Zhu (2013) report a significant drop in U.S. IPO activity, in particular for small IPOs, after the burst of the internet bubble in 2000. Loughran and Ritter (1995) document that firms going public during times of high issuing activity, have the lowest long-term returns. Brav and Gompers (1997) show that venture-backed IPO firms perform significantly better than nonventure-backed IPOs. A large body of literature documents an underpricing of IPOs, i.e., a positive return from the offer price to the closing price of the first trading day (e.g., Ritter, 1984, 1987; Rock, 1986; Beatty and Ritter, 1986; Carter and Manaster, 1990; Loughran and Ritter, 2004). Finally, Loughran (1993) relates the poor performance of small NASDAQ stocks in comparison to similarly sized NYSE stocks to the long-run underperformance of IPOs. Out of the 12 analyzed sub-samples, we find a Carhart (1997) four-factor model to explain one-year IPO underperformance in only two out of 12 sub-samples. Consistent with prior research, we find no significant underperformance in the sub-samples of large-firm and venture-backed IPOs. Hence, for the vast majority of sub-samples, we continue to find a significant underperformance over the first year after going public.

All regression results described hitherto are based on conventional portfolio sorts (Jaffe, 1974; Mandelker, 1974). This method compares the risk-adjusted performance of portfolios of mature companies to the risk-adjusted performance of portfolios of IPO firms, by first calculating period-by-period excess returns of each portfolio and then regressing these excess returns on a set of market factors (e.g., the four Carhart factors) to identify the risk-adjusted performance of the respective portfolio. However, this classical approach comes with a series of limitations: First, in unbalanced panels, conventional portfolio sorts underweight observations from periods with large cross-sections and overweight observations from periods with small cross-sections. Loughran and Ritter (2000) argue that tests that weight firms equally have more power than tests that weight each time period equally. Second and most importantly, an analysis based on portfolio sorts has to be limited to very few firm characteristics for the number of sub-groups that have to be compared to each other not becoming too large. For instance, it is no problem

to compare the performance of venture-backed to nonventure-backed IPO firms, but it becomes more unwieldy and difficult to interpret, the more characteristics are added, in particular if they are continuous and require the construction of quintile or decile portfolios.

To overcome these issues and account for a variety of firm characteristics in our analysis, we employ a generalized version of the conventional portfolio sorts approach, proposed by Hoechle, Schmid, and Zimmermann (2018). This "generalized portfolio sorts" (or GPS) model allows us to explore potential reasons for the economically and statistically significant underperformance of IPO firms in the first year after going public. The GPS-model relies on estimating a pooled linear regression with cross-sectional correlation consistent Driscoll and Kraay (1998) standard errors. The model specification is such that the individual firms' quarterly excess returns are regressed on the market factors (e.g., the four Carhart factors), a set of individual firm characteristics, and all interaction terms between the market factors and the firm characteristics. Hence, the GPS-model allows us to decompose the (Carhart-)alpha into firm specific components. It thereby remedies a major drawback of the portfolio sorts approach by allowing for the inclusion of continuous and multivariate firm characteristics in the analysis. In addition, the GPS-model preserves a major advantage of the portfolio sorts approach, which is to ensure valid statistical inference in the presence of cross-sectional (and temporal) dependence.[2] This latter characteristic distinguishes conventional portfolio sorts, and by extension the GPS-model, from the widely used buy-and-hold abnormal return (BHAR) approach (e.g., see Barber and Lyon, 1997) which is not robust to cross-sectional dependence (Fama, 1998).[3] In contrast to both the conventional portfolio sorts and the BHAR approach, the GPS-model allows us to simultaneously control for various explanations for the apparent IPO underperformance which have been put forward in previous research in a statistically robust setting. Recent applications of the GPS-model include Doskeland and Hvide (2011), Jenkinson, Jones, and Martinez (2016), and Dahlquist, Martinez, and Söderlind (2017).

[2] Hoechle, Schmid, and Zimmermann (2018) show both theoretically and empirically, that their regression-based technique is capable to perfectly replicate the results of the conventional calendar time portfolio approach in a single step rather than in two. Consequently, the GPS-model has the same statistical properties as the conventional portfolio sorts approach.

[3] The BHAR approach is based on calculating the average difference between buy-and-hold returns of IPO firms and respective buy-and-hold returns of matched control firms.

To identify relevant firm characteristics that may proxy for pricing-relevant differences between IPO and mature firms, and thus help in explaining IPO underperformance, we rely on previous research. Lyandres, Sun, and Zhang (2008) test an investment-based explanation for IPO underperformance. Consistent with theoretical models by Cochrane (1991) and Carlson, Fisher, and Giammarino (2004), that suggest a negative relation between investments and expected returns, they show that IPO firms invest more than mature firms and thus achieve lower returns in the long run. Brau, Couch, and Sutton (2012) attribute long-term IPO underperformance to an increased acquisition activity of IPO firms. They show that only IPO firms that acquire another company during the first year after going public underperform in the long run. Eckbo and Norli (2005) identify stock turnover as a driver of IPO underperformance. They argue that the higher liquidity of IPO stocks reduces systematic risk exposure and thus explains lower expected returns. Furthermore, they suggest a "turbo-charging" effect of leverage. Higher leverage increases factor loadings in a multi-factor model. Consequently, Eckbo and Norli (2005) argue that the lower leverage ratios of IPO firms decrease their systematic risk exposure resulting in lower expected equity returns. Mauer, Wang, Wang, and Zhang (2015) provide evidence that globally diversified IPO firms perform better than purely domestic IPO firms over three- and five-year periods after going public. Bessembinder and Zhang (2013) augment the BHAR method to account for volatility, illiquidity, and investments besides the four Carhart factors. Controlling for these characteristics, they find that the performance of IPO stocks does not significantly differ from the performance of non-IPO stocks over a five-year post-issue period.

Our GPS-model estimations reveal that the first-year IPO underperformance puzzle cannot be solved when simultaneously accounting for differences between IPO and mature firms in their risk-factor exposure as well as for differences related to a set of firm-level characteristics. Differences in investments, international business activity, or leverage and liquidity between IPO and mature firms cannot explain the significant one-year IPO underperformance in isolation. Even when fully exploiting the benefits of the GPS-model by simultaneously controlling for the full set of firm-level characteristics in our multivariate setting, we find that IPO underperformance over the first year after going public

cannot be explained. In additional tests, we show that the finding of a significant one-year IPO underperformance is also insensitive to using another factor model, such as the market model or a Fama-French (1993) three-factor model, or to the inclusion of industry fixed effects.

Conventional portfolio sorts, and by extension the GPS-model of Hoechle, Schmid, and Zimmermann (2018), rely on the random effects assumption to hold. This requires firm fixed effects (if present) to be uncorrelated with the characteristic(s) underlying the portfolio construction, i.e., most important the variable measuring whether a firm is classified as IPO or mature firm. If the random effects assumption does not hold, regression estimates are biased due to unobserved heterogeneity across firms. Based on a Hausman (1978) type specification test, suggested by Hoechle, Schmid, and Zimmerman (2018), we reject the random effects assumption across all tested models, suggesting that prior results suffer from an omitted variables bias resulting in biased regression estimates. In fact, when reestimating our GPS-models with firm fixed effects, we find IPO underperformance to disappear altogether. This result holds when only accounting for the four Carhart (1997) factors, but also when including various sets of firm-level control variables. Moreover, accounting for firm fixed effects increases the relative performance of IPO versus mature firms across all tested sub-samples. A significant underperformance only prevails in the sub-set of small-firm IPOs, but even there underperformance is substantially lower when firm fixed effects are included. Sub-samples of large-firm or non-NASDAQ IPOs, as well as IPOs going public in the second sample half (i.e., after the burst of the dotcom bubble) or during cold-issue periods show a significant outperformance when accounting for firm fixed effects. Hence, the apparent IPO underperformance puzzle seems in large parts to be driven by unobserved heterogeneity across IPO and mature firms. Consistently, we find the firm fixed effects of IPO firms to be on average negative and significantly smaller than the firm fixed effects of mature firms. The difference in firm fixed effects between IPO and mature firms is economically large, amounting to about 3.5 percentage points per quarter. Reflecting the higher likelihood of extreme out- or underperformance over short time periods, firm fixed effects of IPO firms with short duration in the sample are most extreme, both positive and negative, but with more negative than positive observations. We find no strong general pattern in IPO firm fixed effects over time but substantially smaller, i.e., more negative, IPO fixed effects after the

burst of the dotcom bubble and during the financial crisis and a higher time-series variation of IPO firm fixed effects around peaks of NBER recession periods.

The remainder of the paper is organized as follows. Section 2 presents the sample selection and data. Section 3 analyzes the time horizon over which IPOs underperform as well as various sub-samples based on the conventional calendar time portfolio sorts method. Section 4 presents the empirical results on multidimensional explanations of the one-year IPO underperformance documented in the previous section. Section 5 reports results from models that account for firm fixed effects. Section 6 concludes.

2. Sample and Data

Our sample of IPO firms is based on an updated version of the Field-Ritter dataset of company founding dates as used in Field and Karpoff (2002) and Loughran and Ritter (2004). The dataset consists of 10,145 U.S. companies going public between January 1975 and December 2014. We exclude all unit offerings, American Depository Receipts (ADRs), closed-end funds, Real Estate Investment Trusts (REITs), and partnerships. We also exclude firms in regulated industries, i.e., financial firms (SIC codes 6000-6999) and utilities (SIC codes 4900-4999). Following Ritter (1991), we only consider IPOs with an offering price of at least $1.[4] We also exclude 224 companies for which the IPO month differs from the first month with stock price data available on the Center for Research in Security Prices (CRSP) database. All these filters result in a final sample of 7,487 U.S. IPOs.

Information on monthly stock prices for all issuing and non-issuing firms is obtained from the CRSP database from 1975 to 2015.[5] Applying the filters listed above leads to stock price and return data for 12,936 U.S. companies from 1975 to 2015, of which 7,487 firms went public during this period and are thus classified as IPO firms. For the remaining 5,449 companies, for which the initial issuing date is either unknown or before 1975, the first five years of observations available on CRSP are dropped to ensure that these firms are mature and do not confound the statistical analysis. In addition to these 5,449

[4] We find similar results, if we only consider IPOs with an offering price of at least $5.
[5] While we analyze firms going public between 1975 and 2014, we include one additional year of monthly stock price information to be able to analyze IPO performance over the first year after going public for all IPOs in our sample.

"mature-only" firms, IPO firms are considered mature firms as of the sixth year after going public. Thus, mature firms have been listed for a minimum of five years when entering our sample.

Data on the four Carhart (1997) factors are obtained from Kenneth French's data library.[6] Financial data on our sample firms, issuing and mature, is obtained from Compustat. The variables are explained in sub-section 4.2 below. Data from the Compustat historical segments database is used to determine the level of international business activity of each firm. IPO-specific information, such as the degree of underpricing measured by the first-day return and whether the IPO is backed by a venture capitalist, are obtained from Thomson Reuters' Securities Data Company (SDC) platform.

3. Do IPOs underperform?

3. 1 Over which time horizon do IPOs underperform?

We analyze IPO performance over varying time horizons ranging from one to 40 quarters. For space reasons, we restrict the tabulated results to one, three, and five years after going public. To the best of our knowledge, there is no prior study investigating explicitly the time horizon over which IPO firms underperform. We analyze IPO long-term performance using conventional portfolio sorts, also referred to as calendar time portfolio approach, which allows for a direct comparison with prior studies on IPO long-term performance. The dependent variable, y_{it}, is the firm's quarterly excess return in quarter *t*. We form portfolios of mature firms and portfolios of IPO firms, with IPO firms being defined as firms going public within the last one, three, or five years. We use a Carhart (1997) four-factor model with Newey-West standard errors and equal-weighted observations. In robustness tests, we either use a market model or a Fama-French (1993) three-factor model.[7]

We equal-weight our portfolios for several reasons. First, Loughran and Ritter (2000) show that equal-weighting has higher power to uncover long-term return anomalies than value-weighting. Second, Brav, Geczy, and Gompers (2000) argue that equal-weighting is more appropriate for analyzing IPO

[6] The data can be downloaded at: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/ data_library.html
[7] These results are reported in Tables A.2 and A.3 in the appendix.

underperformance due to power considerations. Finally, prior research shows that the underperformance, if observable, is larger in equal-weighted portfolios or only shows in equal-weighted portfolios (e.g., Ritter, 1991; Loughran and Ritter, 1995, 2000; Brav and Gompers, 1997; Brav, Geczy, and Gompers, 2000; Gompers and Lerner, 2003; Eckbo and Norli, 2005; Lyandres, Sun, and Zhang, 2008). Consistently, we find underperformance only in equal-weighted portfolios but not in value-weighted portfolios. The exception is the sub-sample of smaller stocks in our sample. Indeed, we find that the non-existence of IPO underperformance in value-weighted portfolios is driven by the performance of the largest decile of IPO firms in our sample. When splitting the full sample of IPO and mature firms into size tertiles, quartiles, quintiles, or deciles, we find no IPO underperformance in the largest tertile, quartile, quintile, and decile of firms using either equal- or value-weighting.[8] However, we continue to find a significant underperformance of IPO firms in the smaller half, the smaller two tertiles, three quarters, four quintiles, and even in the smaller 90% of all stocks in our sample in both equal-weighted and value-weighted portfolios. Hence, a small number of very large and well-performing IPO firms is responsible for the absence of any underperformance in value-weighted portfolios.

The conventional portfolio sorts results for time horizons of one, three, and five years after going public are reported in Table 1. The first column, labeled "Mature", presents the coefficient estimates and t-statistics (in parentheses) for the portfolios of mature companies that have been listed for a minimum of five years. The alpha in this column represents the risk-adjusted performance of mature firms and the four coefficient estimates on the risk factors *RMRF, SMB, HML,* and *MOM* are the risk factor exposures of mature firms. Columns labeled "IPO" show coefficient estimates and t-statistics (in parentheses) from a Carhart (1997) four-factor model regression of the excess return of the portfolios of IPO firms, defined as firms going public within the last year (Column 2), last three years (Column 4), and last five years (Column 6). Coefficient estimates reported in the columns labeled "Δ (IPO-Mature)" show the results from Carhart (1997) four-factor model regressions of the difference in portfolio returns

[8] We calculate cut-off points separately for IPO and mature firms.

of mature firms and IPO firms for the three alternative definitions of IPO firms. A negative and significant alpha in columns "Δ (IPO-Mature)" indicates that the risk-adjusted performance of IPO firms is significantly below that of more mature companies.

The results show that while mature firms significantly outperform the four Carhart (1997) factors, firms that went public within the last year significantly underperform by roughly 1.2% per quarter or 4.8% p.a. The resulting underperformance of IPO firms versus mature firms amounts to 1.9% per quarter, or 7.6% p.a., and is significant at the 1% level. In contrast, firms that went public within the last three (Column 4) or five years (Column 6) do not underperform common benchmarks. The underperformance of IPO firms versus mature firms is consequently much lower for IPO firms that went public within the last three (Column 5) or last five years (Column 7). In terms of economic magnitude, the underperformance amounts to about 0.7% per quarter, or 2.8% p.a., and is statistically insignificant in Column 5 and of similar magnitude but borderline significant in Column 7. Moreover, the results in Table 1 show that the market beta of IPO firms is significantly larger than that of more mature companies and that IPO firms have a significantly larger exposure to the SMB_t factor and a significantly smaller exposure to the HML_t factor than mature companies. These findings point to the growth-stock nature of IPOs which has been shown to explain part of the IPO underperformance (e.g., Brav and Gompers, 1997; Brav, Geczy, and Gompers, 2000; Gompers and Lerner, 2003). However, we continue to find an economically large and statistically significant underperformance of IPO firms over the first year after going public and a smaller, borderline significant underperformance over five years after going public. To check whether all the underperformance is concentrated in the first year after going public and the marginally significant underperformance over five years just picks up this underperformance in the first year, we separately analyze each of the first five years after going public. To this end, we reestimate the regressions reported in Table 1 and define the IPO dummy as equal to one either in the first, second, third, fourth, or fifth year after going public. The results are reported in Table A.1 in the appendix. By construction, the results in the first specification (Columns 2 and 3) are identical to those in the first specification reported in Table 1. The underperformance in the second year after going public is about half the size of that in the first year, about 4.1% p.a., and significant at the 5% level. In the third and fifth year after going public there is no significant underperformance. The underperformance in the

fourth year is larger and borderline significant. In summary, the results in Table A.1 show that the underperformance is by far largest in the first year, making up for about 50% of total underperformance over the first five years, but is not confined to the first year after going public.

To provide a more complete picture of the relation between time horizon and IPO performance, Figure 1 displays the evolution of the intercept (alpha) estimated from Carhart (1997) four-factor model regressions of the return difference between portfolios of IPO and mature firms, with IPO firms defined as firms going public within the last quarter to firms going public within the last 10 years. The figure reveals that IPO underperformance peaks around three quarters after going public and then gradually decreases over the subsequent years corroborating the results from Table 1. In the first three quarters after going public, risk-adjusted quarterly returns of IPO firms are 2.066% smaller than those of mature firms. This translates into an annual underperformance of roughly 8 percent. In the remainder of the paper, we focus on one-year post-issue periods when putting IPO underperformance to further scrutiny.[9]

To verify the robustness of our results, we perform a similar portfolio sorts analysis using either the market or the Fama-French (1993) three-factor model instead of the Carhart (1997) four-factor model. Results, reported in Tables A.2 and A.3 in the appendix, confirm prior findings that the IPO underperformance puzzle cannot be solved by simply adjusting for differences in the risk-factor exposure of IPO and mature firms. In contrast to the Carhart (1997) four-factor model, we find an economically sizable and statistically significant underperformance of IPO firms over all three time horizons, up to five years after going public, for both the market model and the Fama-French (1993) three-factor model. Across all three factor models, we find the underperformance to be highest one year after the IPO and then to gradually decrease over time.

3.2 Sub-sample tests

Prior research documents significant differences in IPO long-term underperformance with regard to firm size, time period, IPO market activity, venture capital (VC) involvement, the degree of IPO underpricing, and stock exchange listing. Related to firm size, Ritter (1991), Loughran and Ritter (1995),

[9] The risk-adjusted quarterly underperformance of -1.920 % is only negligibly smaller for one-year as compared to three-quarter post-issue periods. In unreported tests, we find our results to remain qualitatively unchanged if we use a post-issue period of three quarters instead of one year.

and Gao, Ritter, and Zhu (2013) all find small-firm IPOs to exhibit worse long-term performance than large-firm IPOs. Gao, Ritter, and Zhu (2013) show that in the period 1980-2009 small-firm IPOs underperform by an average of 17.3% over three years after going public, while large-firm IPOs even outperform style-matched mature firms over the same period. Ritter and Welch (2002), among others, show the sensitivity of results with regard to the time period analyzed. Specifically, they argue that the time-variation in issuing activity, underpricing, and long-run underperformance of IPOs deserves more attention. They find that the long-term performance of IPOs is highly sensitive to the choice of time period analyzed, varying from a style-adjusted three-year underperformance of 74.2% to an outperformance of 51.3% based on annually starting three-year time periods between 1980 and 2001. Moreover, Gao, Ritter, and Zhu (2013) report a significant drop in U.S. IPO activity, in particular for small IPOs, after the burst of the internet bubble in 2000. Figure A.1 in the appendix shows the annual number of companies going public in the United States from 1975 to 2014 and confirms the general pattern reported in Gao, Ritter, and Zhu (2013). Analyzing issue periods, Loughran and Ritter (1995) and Helwege and Liang (2004) document that firms going public during periods of high issuing activity perform worse than firms going public in a cold market environment. Research by Brav and Gompers (1997) shows that venture-backed IPO firms perform significantly better than nonventure-backed IPOs. Using a Fama-French (1993) three-factor model, they find that long-term underperformance disappears for venture-backed IPO companies, while it persists for nonventure-backed firms. There is a large body of literature documenting an underpricing of IPOs, i.e., a positive return from the offer price to the closing price of the first trading day (e.g., Ritter, 1984, 1987; Rock, 1986; Beatty and Ritter, 1986; Carter and Manaster, 1990; Loughran and Ritter, 2004). Carter, Dark, and Singh (1998), for example, show that there is a significant positive relation between underpricing and long-term underperformance that operates via underwriter reputation. Finally, Loughran (1993) demonstrates that the low performance of IPOs can explain the positive return difference between small NYSE-listed securities and similarly-sized NASDAQ stocks. Moreover, Eckbo and Norli (2005) show that typically NYSE/AMEX IPOs are larger than NASDAQ IPOs in terms of market value. This association supports prior findings that only small-firm IPOs underperform in the long run.

In this sub-section, we split our sample along these categories to analyze whether IPO underperformance over the first year after going public persists across sub-samples. Specifically, we build sub-samples based on firm size, time period (i.e., before versus after the burst of the dotcom bubble), issuing activity, VC involvement, underpricing, and stock exchange listing. For firm size, time period, issue period, and exchange listing we form portfolios of the respective sub-samples of both, IPO and mature firms. Since VC involvement and underpricing are specific IPO firm characteristics, we use the full portfolio of mature firms in these regressions and only form sub-samples of IPO firms. As in sub-section 3.1, we analyze IPO long-term performance of these sub-samples based on Carhart (1997) four-factor model regressions of equal-weighted portfolios of mature firms, IPO firms, and the return differential between the two. IPO firms are defined as firms going public within the last year, because results in sub-section 3.1 show that this is close to the peak in underperformance. The dependent variable, y_{it}, is the firm's quarterly excess return in quarter *t*.

The results are reported in Table 2. To save space, only coefficient estimates and t-statistics for the alpha are displayed. The column labels "Mature", "IPO", and "Δ (IPO-Mature)" are defined as in Table 1. Rows (1) and (2) in Table 2 show results from estimating portfolio sorts regressions separately for small (1) and large firms (2). We split our sample into small and large firms according to whether the firm-quarter observation is equal to or above or below the median market capitalization. As IPO firms are on average substantially smaller than mature firms, we calculate median values separately for IPO firms and for mature companies. Our results confirm the findings of Gao, Ritter, and Zhu (2013) that small-firm IPOs perform worse than large-firm IPOs. Small IPO firms that went public within the last year significantly underperform the four Carhart (1997) factors by roughly 6.2% per quarter. Regressing the difference between the two portfolios, we find small-firm IPOs to underperform small mature firms over the first year after going public by a risk-adjusted 7.178% per quarter which is significantly different from zero at the 1% level. In contrast, results in row (2) show no significant underperformance of large-firm IPOs compared to large mature companies – even in the first year after going public.

Based on the significant drop in U.S. IPO activity following the burst of the internet bubble in 2000, and the change in IPO characteristics (Gao, Ritter, and Zhu, 2013), IPO long-term performance may also have persistently changed at this time. Hence, we split our sample period into two sub-periods, 1975-2000 and 2001-2015. The results are reported in rows (3) and (4) in Table 2. While IPO firms only significantly underperform the benchmark before 2000, we find a similar difference in portfolio excess returns of mature firms and IPO firms across the two time periods which is statistically significant at the 5% level in both cases. Accordingly, the IPO underperformance puzzle remains unsolved, irrespective of the underlying time period. In later results we can even show that the magnitude of IPO underperformance has increased over time.[10]

Next, we account for issuing activity and split the sample into hot and cold issue periods. Similar to Helwege and Liang (2004), we define the top quartile of sample quarters with respect to the number of IPOs as hot issue periods, the lowest two quarters as cold, and the remaining quarters as neutral issue periods, respectively. In the analyzed sample, quarters with *at least* 73 IPOs are classified as *HOT* and quarters with *at most* 33 offerings as *COLD*. The remaining quarters are classified as neutral and not included in the regression specification. Rows (5) and (6) in Table 2 report the results. Consistent with prior research (Helwege and Liang, 2004), we find a higher underperformance of firms going public during periods of high issuing activity. The difference in portfolio returns of mature firms and IPO firms during hot issue periods amounts to a quarterly risk-adjusted -2.585%, while it is only -1.814% in cold issue periods. However, IPO underperformance over the first year after going public remains negative and economically and statistically (at the 5% level) significant, even in a cold market environment.

To test for differences in IPO underperformance related to VC involvement, we split our IPO sample based on whether an IPO firm is backed by a venture capitalist or not. Table 2 shows the results from estimating portfolio sorts regressions separately for venture-backed (7) and nonventure-backed (8) IPO firms. Consistent with Brav and Gompers (1997), we find nonventure-backed IPOs to significantly underperform the Carhart (1997) four factors by -1.842% per quarter over the first year after going

[10] Figure 3 displays the relative risk-adjusted performance of IPO firms versus mature firms over the first year after going public over a rolling 15-year estimation window from 1990 to 2015 and documents a steady increase in IPO underperformance.

public, whereas venture-backed IPO firms do not underperform the benchmark. Accordingly, we also find no significant difference in the performance of venture-backed IPO firms and mature companies, while nonventure-backed IPOs significantly underperform mature firms.

To investigate whether IPO long-term performance is related to the degree of underpricing, we split our IPO sample based on the median first-day return. IPO firms with a first-day return above or equal to the median of 6.19% are classified as highly underpriced and firms below the median as IPOs with low underpricing. Table 2 shows estimation results separately for IPO firms with high underpricing (9) and low underpricing (10). Results indicate no relevant differences between the two sub-samples. Highly underpriced IPO firms as well as lowly underpriced firms both significantly underperform the benchmark and the difference to mature firms is significantly different from zero at the 1% level in both cases.

Finally, we test for differences in IPO underperformance related to the primary exchange a stock is listed on. To this end, we divide the full sample into two sub-samples based on whether a stock is listed on NASDAQ or another exchange.[11] Results from estimating the respective portfolio sorts regressions are reported in Table 2. We find both NASDAQ and non-NASDAQ listed IPO-firms to perform significantly worse over the first year after going public than comparable mature firms. The return differences are significant at the 1% (non-NASDAQ) and 5%-level (NASDAQ), respectively. Contrary to prior results by Loughran (1993) we even find a higher underperformance of non-NASDAQ IPO firms over our 41-year sample period from 1975 to 2015.

Hence, except for the sub-samples of large and venture-backed IPOs, IPO firms perform significantly worse than mature firms on a risk-adjusted basis over the first year after going public. Thus, while the IPO underperformance puzzle over three- to five-year post-issue periods has been solved by prior research, for example by applying factor-models such as the Carhart (1997) model, the underperformance over the first year after going public continues to be a puzzle.

[11] In our sample, 75% of IPO firms and 52% of mature firms are listed on NASDAQ.

4. Firm characteristics and IPO underperformance

4.1 The GPS-regression model

In this sub-section, we attempt to explain IPO underperformance with differences in a variety of firm characteristics between IPO firms and mature firms. Since the conventional portfolio sorts approach, applied in the previous section, does not allow for the inclusion of continuous and multivariate firm characteristics, we attempt to explain the long-term underperformance of IPO firms using the "generalized portfolio sorts" (or GPS) approach of Hoechle, Schmid, and Zimmermann (2018). The GPS-model involves estimating on the firm level a pooled OLS regression with Driscoll and Kraay (1998) standard errors. Therefore, its estimation results are heteroscedasticity consistent and robust to very general forms of cross-sectional and temporal dependence. In fact, Hoechle, Schmid, and Zimmermann (2018) show both theoretically and empirically, that their generalized technique is capable to perfectly replicate the results of the conventional calendar time portfolio approach in a single step rather than in two. Consequently, the GPS-model has the same statistical properties as the conventional portfolio sorts approach while allowing for the inclusion of continuous and multivariate investor characteristics in the analysis. In contrast, the widely used BHAR approach (e.g., Loughran and Ritter, 1995; Gompers and Lerner, 2003; Bessembinder and Zhang, 2013) is not robust to cross-sectional dependence (Fama, 1998). Moreover, the GPS-model resolves Loughran and Ritter's (2000) critique that by equal-weighting each time period instead of each observation the portfolio sorts approach has lower power to detect abnormal returns. By employing a pooled OLS regression, the GPS-model equal-weights observations by default.[12]

Similar to portfolio sorts regressions, the dependent variable, y_{it}, in all our GPS-models is the excess return in quarter *t*. By lagging all explanatory variables by one quarter, we mitigate endogeneity concerns. Our basic regression specification consists of pooled OLS regressions with the following structure:

$$y_{it} = \big((\boldsymbol{p_{it}} \otimes \boldsymbol{z_{it}}) \otimes \boldsymbol{x_t}\big)\beta + \upsilon_{it} \tag{1}$$

[12] Note that by estimating the GPS-model by weighted least squares (WLS) instead of OLS other weights can be applied (see Hoechle, Schmid, and Zimmermann, 2018).

Vector $\boldsymbol{p}_{it}$ contains a constant and a dummy variable, D_{it}^{τ}, that equals one if the company is classified as IPO firm and zero otherwise. We classify firms as IPO firm during the first τ years after going public. Hence, vector $\boldsymbol{p}_{it}$ is defined as follows throughout our entire analysis:

$$\boldsymbol{p}_{it} = [1 \;\; D_{it}^{\tau}] \tag{2}$$

Vector $\boldsymbol{x}_t$ includes a set of market risk factors to determine the risk-adjusted performance of IPO firms. We rely on the Carhart (1997) four-factor model. Hence, vector $\boldsymbol{x}_t$ is defined as:

$$\boldsymbol{x}_t = [1 \;\; RMRF_t \;\; SMB_t \;\; HML_t \;\; MOM_t] \tag{3}$$

where $RMRF_t$ is constructed as the value-weighted return of all CRSP firms in excess of the risk-free rate (the market factor), SMB_t is the return on a zero-investment size portfolio, and HML_t and MOM_t denote the returns on a zero-investment book-to-market and momentum portfolio, respectively.

Firm characteristics are included in vector $\boldsymbol{z}_{it}$. We change and extend the composition of this vector throughout our analysis to include various company-level variables put forward in previous research as potential explanations for the apparent underperformance of IPO firms. Vector $\boldsymbol{z}_{it}$ includes a constant and a varying set of M firm characteristics $\boldsymbol{z}_{m,it}$ (m = 1,…, M):

$$\boldsymbol{z}_{it} = \left[1 \;\; z_{1,it} \;\; \ldots \;\; z_{M,it}\right] \tag{4}$$

The variables in vectors $\boldsymbol{p}_{it}$ and $\boldsymbol{z}_{it}$ are allowed to vary across both the time dimension and the cross-section. In contrast, the risk factors in vector $\boldsymbol{x}_t$ vary over time, but not across firms.

4.2 Variable construction

Based on previous research, we consider the following firm characteristics as potential determinants of IPO underperformance. Lyandres, Sun, and Zhang (2008) and Brau, Couch, and Sutton (2012) show that higher investments and an increased acquisition-activity of IPO firms explains IPO underperformance. To measure firms' investment activity, we define *Capex/Sales*, *R&D/Sales*, and *Acquisitions/Sales* as quarterly capital expenditures, R&D expenditures, and acquisitions, all scaled by sales.[13]

[13] Note that our measure of acquisition spending is based on Compustat and only includes acquisitions paid in cash, neglecting stock-based acquisitions.

Mauer, Wang, Wang, and Zhang (2015) show that globally diversified IPO firms exhibit better long-term performance than purely domestic IPOs. Following Mauer, Wang, Wang, and Zhang (2015), we define *IBA* (international business activity) as a dummy variable which is equal to one if a firm reports either foreign sales or exports. As *IBA* is constructed on the basis of yearly data, the dummy variable is equal to one for IPOs if they report international business activity during their first year after going public. Eckbo and Norli (2005) suggest a leverage- and liquidity-related explanation for long-term IPO underperformance. Consequently, we calculate *Leverage* as total assets net of common equity divided by total assets. To measure liquidity, we define *ATurn*, the abnormal turnover, calculated for each stock and quarter as the difference between a stock's trading volume and the median trading volume of all stocks in the same size decile. To mitigate the effect of outliers, all ratios are winsorized at the 1st and 99th percentiles. Since our main focus is on the alpha of the regression, we ensure the validity of our model specification by de-meaning all continuous firm-level characteristics (e.g., Dittmar and Lundblad, 2017). Cross-sectionally de-meaning variables removes any (time) trends that would otherwise show up in the regression constant. Thus, without this adjustment, the alpha would be influenced by the sample mean of the respective continuous variables. By construction, this adjustment is not necessary for binary variables, such as for example *IBA*.

4.3 Descriptive statistics

Table 3 reports descriptive statistics (mean, median, 25th, and 75th percentiles) of all these variables for the set of 7,487 IPO and 9,517 mature firms, respectively. Moreover, Table 3 presents the statistical significance of the difference between mean and median of mature firms and IPO firms based on a standard two-sample t-test and Wilcoxon rank-sum test, respectively, for each firm characteristic. As results presented in Table 1 show the highest IPO underperformance over approximately a one-year post-issue period, descriptive statistics on IPO firms are based on the first year after going public.

An analysis of the differences between IPO and mature firms may provide some preliminary evidence as to which factors might be relevant for explaining IPO underperformance in the multivariate tests. IPO firms exhibit both higher capital and R&D expenditures, and spend more on acquisitions. Thus, differences in acquisition- and investment-behavior may contribute towards explaining IPO

underperformance, as suggested by Lyandres, Sun, and Zhang (2008) and Brau, Couch, and Sutton (2012). We also find IPO firms to exhibit lower international business activity (*IBA*) than mature firms. As the likelihood of international expansions grows over the lifecycle of a company, this result is not surprising. Mauer, Wang, Wang, and Zhang (2015) show that globally diversified IPO firms exhibit better long-term performance than purely domestic IPOs. Hence, differences in international business activity may further contribute towards explaining long-term IPO underperformance. Results in Table 3 also suggest that IPO firms operate with lower leverage ratios. This is not surprising as a new issuance of equity reduces leverage (e.g., Alti, 2006). Moreover, IPO firms are usually more restricted in borrowing due to fewer assets and lower current earnings (Eckbo and Norli, 2005). Eckbo and Norli (2005) argue that lower leverage ratios are associated with lower risk and therefore lower expected returns of IPO stocks. Finally, we document a higher liquidity of IPO stocks than of stocks of mature firms. The mean and median *ATurn* of IPO firms are higher during the first year after going public than the mean and median *ATurn* of mature firms. This is in line with findings by Eckbo and Norli (2005) who show that a higher liquidity of IPO stocks reduces systematic risk exposure and thus explains lower expected returns. We find all differences in mean and median firm characteristics of IPO and mature firms related to investments, internationality, leverage, and liquidity to be statistically signficant at the 1% level.

Figure 2 displays the time series of median (average for *Acquisitions/Sales* and *IBA*) firm characteristics of IPO firms over five years after going public. The graphs contrast these time series with the median (average for *Acquisitions/Sales* and *IBA*) values of all 9,517 mature firms from 1975 to 2015. Consistent with Table 3, the graphs reveal substantial differences in all characteristics over the first year after going public. Additionally, all graphs show that differences between IPO and mature firms tend to decline over time. Three and five years after going public, IPO firms are more comparable to mature firms with regard to capital expenditures, acquisitions, international business activity, leverage, and stock liquidity as measured by *ATurn.* Only R&D expenses continue to differ substantially between IPO and mature firms. Hence, if the aggregate of these characteristics is able to explain a significant part of long-term IPO underperformance, we would expect this underperformance to be significantly reduced three- to five-years after going public as IPO firms become more similar to mature firms. This is exactly

what we find in Table 1. For this reason, the subsequent sub-section aims at explaining the one-year underperformance of IPOs with differences between IPO and mature firms related to the aggregate of the above discussed characterisics.

4.4 Multivariate analysis using the GPS-model

In this sub-section, we attempt to explain IPO underperformance by adding various firm characteristics to our GPS-model. Specifically, we extend vector $\boldsymbol{z}_{it}$ to include firm characteristics related to investments, internationality, and leverage and liquidity. As Table 1 shows that IPO underperformance is highest approximately one year after going public, we set $\tau = 1$ and define vector $\boldsymbol{p}_{it} = \left[1\ D_{it}^{1}\right]$ throughout the whole section. The composition of vector $\boldsymbol{x}_t$ is set up as shown in equation (3). Results for the above specified regressions are reported in Table 4. Each model estimation is subdivided into two columns: Column "Mature" presents coefficient estimates and t-statistics (in parentheses) for firm characteristics of companies that have been listed for a minimum of five years. Column "Δ (IPO-Mature)" reports coefficient estimates and t-statistics of interaction terms between the IPO dummy, D_{it}^{1}, and the firm characteristics in vector $\boldsymbol{z}_t$. For brevity, coefficient estimates for the four risk factors (*RMRF*, *SMB*, *HML*, and *MOM*) and their interaction terms are not reported. Our primary focus is on the coefficient estimate for the IPO dummy. If a firm characteristic, or a set of characteristics, is able to explain IPO underperformance, the coefficient estimate for the IPO dummy, which is reported in the first row of Column "Δ (IPO-Mature)", will turn insignificant. As a starting point, we reestimate the regression reported as first specification in Table 1 using the GPS-model. Hoechle, Schmid, and Zimmermann (2018) show both theoretically and empirically that the GPS-model exactly replicates the results from portfolio sorts, if the GPS model is estimated with weighted least squares and weights are defined as $w_{it}^{IPO} = 1/N_t^{IPO}$ and $w_{jt}^{Mature} = 1/N_t^{Mature}$. Since the number of IPO firms in our sample is smaller than the number of mature firms, this results in a higher portfolio weight of IPO firms. To fully exploit the benefits of the OLS-based regression specification, as discussed in sub-section 4.1, the GPS-model relies on equal weights for IPO and mature firms such that $\widetilde{w}_{it}^{IPO} \equiv \widetilde{w}_{jt}^{Mature} = \frac{1}{N_t^{IPO}+N_t^{Mature}}$.

Hence, the results in Model (1) of Table 4 are similar to, but do not exactly match those in the first specification of Table 1.[14]

The first firm characteristic examined relates to differences in the investment behavior of IPO and mature firms. Theoretical models suggest a negative relation between investments and expected returns (e.g., Cochrane, 1991; Carlson, Fisher, and Giammarino, 2004). A related explanation for IPO underperformance in the long run stems from Lyandres, Sun, and Zhang (2008). They argue that IPO firms invest more and consequently achieve lower long-term returns. In addition, Brau, Couch, and Sutton (2012) explain IPO long-term underperformance with an increased acquisition activity of IPO firms. Empirically, acquiring firms are associated with lower long-term returns (e.g., Loughran and Vijh, 1997; Rau and Vermaelen, 1998). Brau, Couch, and Sutton (2012) show that only IPO firms that acquire during the first year after going public underperform. Moreover, Arikan and Stulz (2016) show that acquisition rates are higher during the first years after going public when compared to mature firms. This finding is confirmed in Table 3 which shows that IPO firms, besides having higher capital and R&D expenditures, undertake more or larger acquisitions than mature firms. It is thus possible that such differences in investment-behavior between IPO and mature firms are responsible for the documented underperformance of IPO firms. Hence, in our first GPS-model specification, we define vector $\boldsymbol{z}_{it}$ as:

$$\boldsymbol{z}_{it} = \left[1 \; Capex_{i,t-1} \;\; RD_{i,t-1} \;\; miRD_{i,t-1} \;\; Acq_{i,t-1}\right] \tag{5}$$

where $Capex_{i,t-1}$ is quarterly capital expenditures scaled by sales, $RD_{i,t-1}$ quarterly R&D expenditures scaled by sales, $miRD_{i,t-1}$ a dummy variable which is set to one if R&D expenditures are missing, and to zero otherwise, and Acq_{it} is defined as the value of quarterly acquisitions scaled by sales.[15] All three continuous variables $Capex_{i,t-1}$, $RD_{i,t-1}$, and $Acq_{i,t-1}$ are de-meaned to ensure that the regression-alpha is not biased. Results are reported in Model (2) in Table 4.[16] Most important, investments are unable

[14] Note that when weighting observations of IPO firms with $w_{it}^{IPO} = 1/N_t^{IPO}$ and observations of mature firms with $w_{jt}^{Mature} = 1/N_t^{Mature}$ in the GPS-model, the results in Model (1) of Table 4 exactly match those in the first specification of Table 1, as illustrated and proven in Hoechle, Schmid, and Zimmermann (2018).

[15] If R&D expenditures are not reported, the dummy $miRD_{it}$ is set to one and RD_{it} is set to zero (e.g., Gompers, Ishii, and Metrick, 2010).

[16] Due to data availability of capital expenditures and acquisitions, this regression specification only covers the years between 1984 and 2015. The same holds for the full model specification presented in equation (8).

to explain the one-year IPO underperformance. The coefficient estimate for D_{it}^{1} remains negative and significant at the 5% level. Moreover, all coefficient estimates of the interaction terms between the IPO dummy and $Capex_{i,t-1}$, $RD_{i,t-1}$, $miRD_{i,t-1}$, and $Acq_{i,t-1}$ are insignificant. Hence, in such a multivariate setting, there is no difference in the performance of IPO and mature firms with respect to capital and R&D expenditures as well as acquisition activities. However, consistent with prior research, we generally find higher capital expenditures and higher acquisition rates to be associated with significantly lower returns. In unreported results, we find that including an investment factor constructed parallel to Lyandres, Sun, and Zhang (2008), instead of our four separate investment variables, into the regression specification leads to similar results.

Next, we examine differences in internationality as a possible explanation for the one-year underperformance of IPO firms. Mauer, Wang, Wang, and Zhang (2015) show that globally diversified IPO firms perform significantly better over three- and five-year periods after going public than purely domestic IPOs. Our descriptive statistics in Table 3 confirm that IPO firms are on average less globally diversified than mature firms. Hence, differences in international business activity may explain (part of) the underperformance of IPO firms in the long run. We define vector $\boldsymbol{z}_{it}$ as:

$$\boldsymbol{z}_{it} = [1 \quad IBA_i] \tag{6}$$

The results are reported in Model (3) in Table 4 and show that controlling for differences in internationality between IPO and mature firms cannot explain the one-year underperformance of IPOs. The coefficient estimate for the IPO dummy remains negative and significant at the 1% level. The coefficient estimate of the interaction term between *IBA* and the IPO dummy is positive and significant at the 5% level. Hence, globally diversified IPO firms perform significantly better than domestic IPO firms. This finding supports prior analyses by Mauer, Wang, Wang, and Zhang (2015).

Eckbo and Norli (2005) suggest a liquidity- and leverage-based explanation for IPO underperformance. They argue that the relatively low leverage ratio of IPO firms might be important in explaining IPO underperformance as leverage has a "turbo charging" effect on the factor loadings in a multifactor model. Consequently, they expect IPO stocks to respond stronger to leverage-related risk factors such

as the stock market return, credit spread, term spread, or unexpected inflation. They also find that a higher liquidity of IPO stocks reduces systematic risk exposure and thus explains lower expected returns. To investigate their conjecture empirically, they estimate a number of multifactor models including Carhart's (1997) four-factor model augmented with a liquidity-based risk factor and a seven-factor macro model where the size, book-to-market, and momentum factors are replaced with the liquidity-based factor and a set of five macroeconomic risk factors. Their results reveal that IPO firms exhibit significant factor loadings on these liquidity- and leverage-related factors. Most importantly, the alphas of their models are insignificant which indicates that IPO underperformance over a five-year period can be explained by their factor models. To investigate the importance of this liquidity- and leverage-based explanation of IPO underperformance for the much higher one-year IPO underperformance, we specify vector $\boldsymbol{z}_{it}$ as:

$$\boldsymbol{z}_{it} = \begin{bmatrix} 1 & Leverage_{i,t-1} & ATurn_{i,t-1} \end{bmatrix} \tag{7}$$

Both variables are de-meaned. Results are reported in Model (4) in Table 4. Most important, the IPO dummy variable remains negative and significant at the 1% level. Hence, we find that differences in stock liquidity between IPO and mature firms and the lower leverage of IPO firms cannot explain the one-year underperformance of IPOs versus mature firms.

Next, to take full advantage of our multivariate GPS-model we jointly include all control variables used in the three specifications before. Specifically, the full GPS-specification controls for differences in firm characteristics between IPO and mature firms related to investments, internationality, liquidity, and leverage. Consequently, vector $\boldsymbol{z}_{it}$ is specified as displayed in equation (8).[17]

$$\boldsymbol{z}_{it} = 1\ Capex_{i,t-1}\ \ RD_{i,t-1}\ \ miRD_{i,t-1}\ \ Acq_{i,t-1}\ IBA_i\ Leverage_{i,t-1}\ \ ATurn_{i,t-1} \tag{8}$$

The results from this specification are reported in Model (5) of Table 4. Most important, results show that even accounting for all firm differences simultaneously cannot explain the one-year under-

[17] Again, this specification only considers the years between 1984 and 2015 due to data availability issues related to investments.

performance of IPO firms, as the coefficient estimate of the IPO dummy remains negative and is economically and statistically highly significant. In Model (5) of Table 4, the coefficient estimate for the IPO dummy indicates a risk-adjusted quarterly underperformance of 4.268% when controlling for differences in firm characteristics between IPO and mature firms related to investments, internationality, liquidity, and leverage.

In unreported results, we extend the full model specification in equation (8) by additionally accounting for firm size, hot and cold issue periods, and whether the firm is listed on NASDAQ and find results similar to Model (5) of Table 4. Even this extended specification cannot explain the one-year IPO underperformance. We reestimate the models in Table 4 including industry fixed effects based on a Fama-French 12 industry classification and find the results to remain qualitatively unchanged. In other unreported tests, we replace the Carhart (1997) four-factor model by the two alternative factor models discussed in Section 3. Again, even accounting for all differences in firm characteristics between IPO and mature firms related to investments, internationality, leverage, and liquidity in our full GPS-model, as outlined in equation (8), we cannot explain IPO underperformance in the first year using either the market or the Fama-French (1993) three-factor model, respectively.

Finally, we test the robustness of the one-year IPO underperformance result by applying our full GPS-model, i.e., using vector $\boldsymbol{z}_{it}$ as defined in equation (8), on all 12 sub-samples employed in Table 2, i.e., sub-samples based on firm size, time and issue period, VC involvement, IPO underpricing, and stock exchange listing. A detailed description of the construction and economic reasoning behind all sub-samples can be found in sub-section 3.2 above. The results, reported in Table A.4, show that our full GPS-model is only able to explain the one-year underperformance of large-firm and cold-issue IPOs. As shown in Table 2, IPO underperformance in the sub-samples of large-firm IPOs can already be explained with a Carhart (1997) four-factor model. That our full GPS-model explains the one-year underperformance of IPO firms going public during a cold IPO market with little issuing activity, confirms the prior findings by Loughran and Ritter (1995) who document that firms going public during times of high issuing activity have lower long-term returns than cold-issue IPOs. Our results extend this finding by showing that when controlling for the different firm characteristics of cold-issue IPOs and mature

firms related to investments, internationality, liquidity, and leverage, any underperformance of cold-issue IPOs disappears, even for the first year after going public. More importantly, however, the full GPS-model cannot explain the significant underperformance of IPO vs. mature firms across all the other ten sub-samples, including the sub-sample of VC-backed IPOs that were insignificant in the univariate tests reported in Table 2. Hence, the one-year underperformance of IPOs is remarkably robust across sub-samples as well.

In summary, the findings reported in this section suggest that IPO underperformance over time horizons around one year after going public remains a puzzle. Possible explanations brought forward in prior research all cannot resolve the statistically significant and economically large underperformance of IPO firms over the first year after going public. Hence, we turn to a new explanation based on firm fixed effects.

5. Firm fixed effects and IPO underperformance

The conventional portfolio sorts approach, and by extension the GPS-model of Hoechle, Schmid, and Zimmermann (2018) employed in Section 4, relies on the random effects assumption to hold. Specifically, results from portfolio sorts are valid if and only if firm fixed effects (if present) are uncorrelated with the characteristic(s) underlying the portfolio construction. If the random effects assumption does not hold, results are affected by unobserved heterogeneity across firms resulting in biased regression estimates.

In this section, we first test whether the random effects assumption holds in our regression models of IPO (under)performance. Specifically, we apply a Hausman (1978) type specification test proposed by Hoechle, Schmid, and Zimmerman (2018) to test the null hypothesis that the random effects assumption holds.[18] When conducting such Hausman (1978) type specification tests, we reject the null hypothesis of random effects in all tested specifications reported in Table 4, with F-test statistics ranging from

[18] For details, see Hoechle, Schmid, and Zimmermann (2018), in particular Section 2.3.2.

9.0 to 95.6, suggesting that our results in Section 4 suffer from an omitted variables bias. Hence, coefficient estimates are likely to be biased.

To account for this omitted variables bias resulting from omitted time-invariant firm characteristics, we reestimate the regressions in Table 4 augmented with firm fixed effects. The results are reported in Table 5. Most importantly, when including firm fixed effects the underperformance of IPO firms over the first year after going public disappears altogether when only including the four Carhart (1997) factors, but no firm-level variables in vector $\boldsymbol{z}_{it}$. This result survives the inclusion of various sets of firm-level control variables in vector $\boldsymbol{z}_{it}$ in Models (2) to (5). Hence, when accounting for firm fixed effects, the performance of IPO firms over the first year after going public is not significantly different from that of mature firms based on a Carhart (1997) four-factor model. Consequently, the apparent one-year underperformance of IPO firms is likely driven by unobserved heterogeneity across IPO and mature firms. In other words, the importance of firm fixed effects in explaining IPO underperformance indicates the existence of one (or several) time-invariant firm-specific factor(s) that differ between IPO and mature firms and are significantly correlated with returns. As these unobserved firm-specific factors, or fixed effects, capture the lower performance of IPO relative to mature firms, we expect the fixed effects of IPO firms to be significantly lower on average than those of mature firms. In fact, when analyzing the fixed effects from estimating regression model (1) in Table 5, we find the fixed effects of IPO firms to be on average negative and about 3.5 percentage points lower than time-invariant effects of mature firms. Based on a standard two-sample t-test this difference is statistically significant at the 1% level.[19]

To better understand the role of firm fixed effects in explaining IPO performance, we next replicate Table 2, which looks at different sub-samples of IPO firms, using a GPS-model augmented with firm fixed effects. The results are reported in Table 6. In general, the table shows that accounting for the negative IPO fixed effects increases the relative performance of IPO versus mature firms. For example, the first specification shows that the underperformance of small IPO firms prevails, but is at -2.6% per

[19] In unreported tests, we reestimate Table 5 using either the market model or a Fama-French (1993) three-factor model instead of the Carhart (1997) four-factor model. Again, we find no significant underperformance across all tested specifications. When using the Fama-French three-factor model, we even find a significant outperformance in the smaller specifications.

quarter substantially smaller than the -7.2% reported in Table 2. The insignificant outperformance of large-firm IPOs of 1.1% per quarter increases to a significant 4.3% in Table 6, when firm fixed effects are accounted for. More generally, when accounting for firm fixed effects, the underperformance of IPO firms disappears in all but one sub-sample, the sub-sample of small IPO firms in the first model in row (1). Besides the sub-sample of large IPOs in row (2), IPOs going public in the period 2001-2015, IPOs going public in cold issue periods, and non-NASDAQ firms going public show a significant outperformance when firm fixed effects are accounted for. Hence, also across sub-samples, the inclusion of firm fixed effects in our models has a significant effect on the documented IPO performance. It is important to note that the results in Table 6, as those in Table 2, are univariate in terms of firm-level variables. In fact, as the 2001-2015 period was mostly characterized by cold issue periods with a larger fraction of large-firm IPOs going public than in the first sample half (see Gao, Ritter, and Zhu, 2013), a similar set of IPO firms may cause the documented outperformance in at least three of these sub-samples.

Next, we plot the magnitude of each firm's fixed effect against the time a firm is in our sample in Figure 4. Panel A shows this relationship for all firms, Panel B for IPO firms only. Since the likelihood of extreme out- or underperformance is higher over a short time period, we expect the absolute magnitude of firm fixed effects to be reduced with increasing in-sample time. Figure 4 confirms this conjecture, both for all firms as well as for IPO firms. As expected, we find firm fixed effects to converge towards zero with increasing in-sample time. In contrast, many firms that are in the sample only for a few years, show large fixed effects, with more mass below the zero-line (i.e., more negative than positive extreme values).

Finally, we check whether IPO firm fixed effects show strong variation over time. In Figure 5, we plot the average IPO firm fixed effect for each quarter between 1975 and 2015. In Panel A, the fixed effects are equal-weighted across IPO firms, and in Panel B value-weighted based on the IPO firms' market capitalization. Overall, we do not find strong general patterns in IPO firm fixed effects, such as for example distinct "fixed effects waves". However, both the equally- as well as the value-weighted fixed effects decrease substantially in 2000 after the burst of the dotcom bubble and in 2008 during the

financial crisis. More generally, the variation seems to increase around peaks of recession periods, following the NBER definition and indicated by dashed lines in Figure 5. Finally, the value-weighted fixed effect tends to be generally larger (i.e., more positive) than equal-weighted fixed effects, consistent with large-firm IPOs outperforming small-firm IPOs.

In summary, the results in this section show that standard models used to measure long-term IPO performance suffer from an omitted variables bias. A simple specification test shows that the random effects assumption generally does not hold. In fact, when reestimating our GPS-models with firm fixed effects, IPO underperformance disappears. Hence, the apparent one-year underperformance of IPO firms reported in Sections 3 and 4 is likely driven by unobserved heterogeneity across IPO and mature firms. Consistent with the firm fixed effects picking up the previous underperformance of IPO firms, we find the fixed effects of IPO firms to be on average significantly lower than those of mature firms.

6. Conclusion

Prior research on IPO long-term performance claims to have solved the IPO underperformance puzzle, but focuses on three- to five-year post-issue time horizons only. Most importantly, Brav and Gompers (1997), Brav, Geczy, and, Gompers (2000), and Gompers and Lerner (2003) show that IPO firms are strongly tilted towards small and high-growth companies and that the apparent underperformance of IPOs documented in the 1990s (Ritter, 1991; Loughran and Ritter, 1995, 2000) disappears when the different risk exposures between IPO and mature firms are accounted for by using multi-factor models such as the Carhart (1997) four-factor model.

In the first part of this paper, we show that a sample of 7,487 U.S. IPOs going public between 1975 and 2014 continues to significantly underperform mature firms in terms of Carhart-alphas over the first year after going public at a risk-adjusted 1.920% per quarter. Thereafter, IPO underperformance gradually declines to a borderline significant underperformance of only 0.7% per quarter over five years post IPO. Hence, our results suggest that while multi-factor models, such as a Carhart (1997) four-factor model, can explain a three- or five-year IPO underperformance by different factor exposures between IPO and mature firms, our results show that the underperformance over the first year after going public

cannot be explained by such factor models. When looking at sub-samples of IPO (and mature) firms, we find only large-firm and venture-backed IPOs not to perform significantly worse than mature firms over the first year after going public when accounting for the four Carhart (1997) factors. For all the other ten sub-samples considered, IPO underperformance over the first year after going public cannot be explained by the Carhart (1997) four-factor model.

In the second part of the paper, we extend the Carhart (1997) four-factor model with firm-level characteristics related to investments, internationality, leverage, and liquidity, in an attempt to explain IPO underperformance over the first year after going public. We apply the generalized portfolio sorts approach (GPS) of Hoechle, Schmid, and Zimmermann (2018), which allows to decompose the Carhart-alpha into firm-specific characteristics, to explain one-year IPO underperformance using a multitude of firm characteristics in a statistically robust setting. However, we find that even when simultaneously controlling for a large set of firm-level characteristics in our multivariate GPS-model, we are not able to explain IPO underperformance over the first year after going public, neither in the full sample nor in various sub-samples (with the exception of large-firm and cold-issue IPOs).

In the third part of the paper, we take full advantage of the GPS-model of Hoechle, Schmid, and Zimmermann (2018) to conduct Hausman (1978) type specification tests for the presence of firm fixed effects. All these tests reject the null hypothesis of random effects, suggesting the presence of firm fixed effects. Hence, estimation results from conventional portfolio sorts, and by extension of GPS-models estimated with OLS (see Hoechle, Schmid, and Zimmermann, 2018), suffer from omitted variables bias and thus are likely biased. In fact, when reestimating the GPS-model specifications augmented with firm fixed effects, the first-year IPO underperformance disappears. Thus, the apparently strong and robust one-year IPO underperformance seems to be entirely driven by unobserved heterogeneity across IPO and mature firms. In fact, we find firm fixed effects of IPO firms to be on average significantly lower than those of mature firms. Moreover, (IPO) firms with a short sample duration are mostly responsible for this finding, as such firms show more extreme out- and underperformance. Over time, we find IPO firm fixed effects to be significantly lower after the burst of the dotcom bubble and in the financial crisis and to be more volatile during recessions.

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Table 1: Over which time horizon do IPOs underperform?

This table presents coefficient estimates and t-statistics (in parentheses) from Carhart (1997) four-factor model regressions of portfolios of mature and IPO firms. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. All observations within a period are equal-weighted. *RMRF* is the quarterly value-weighted return of all CRSP firms in excess of the risk-free rate and *SMB* is the return of a zero-investment size portfolio. *HML* and *MOM* are the returns of a zero-investment book-to-market and momentum portfolio, respectively. Column 1 reports coefficient estimates and t-values from a Carhart (1997) four-factor model regression of a portfolio of mature firms which have been listed for a minimum of five years. Columns 2, 4, and 6 report coefficient estimates and t-values from a Carhart (1997) four-factor model regression of a portfolio of IPO firms, defined as firms going public within the last year (Column 2), the last three years (Column 4), and the last five years (Column 6). Columns 3, 5, and 7 report results from regressions of the difference in portfolio returns between IPO and mature firms, with IPO firms defined as firms going public within the last year (Column 3), the last three years (Column 5), and the last five years (Column 6). The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature firms between 1975 and 2015. t-values are based on Newey-West standard errors. Significance at the 1%, 5%, and 10% levels is indicated by ***,**, and *, respectively.

Time post IPO:		up to 1 year		up to 3 years		up to 5 years	
	Mature	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Alpha	0.725 ***	-1.196 **	-1.920 ***	0.0164	-0.708	0.0244	-0.700 *
	(2.83)	(-2.07)	(-3.22)	(0.03)	(-1.55)	(0.05)	(-1.86)
RMRF	0.987 ***	1.152 ***	0.165 **	1.135 ***	0.148 **	1.118 ***	0.131 ***
	(30.91)	(16.06)	(2.23)	(18.18)	(2.60)	(19.73)	(2.80)
SMB	1.090 ***	1.337 ***	0.247 **	1.380 ***	0.290 ***	1.417 ***	0.327 ***
	(21.53)	(11.75)	(2.09)	(13.95)	(3.22)	(15.76)	(4.40)
HML	0.167 ***	-0.738 ***	-0.904 ***	-0.627 ***	-0.794 ***	-0.454 ***	-0.621 ***
	(3.99)	(-7.85)	(-9.29)	(-7.68)	(-10.69)	(-6.12)	(-10.14)
MOM	-0.153 ***	0.0837	0.237 ***	-0.327 ***	-0.174 ***	-0.287 ***	-0.134 ***
	(-4.83)	(1.18)	(3.21)	(-5.28)	(-3.09)	(-5.10)	(-2.88)
# obs.	163	163	163	163	163	163	163
# firms	9,517	7,487	12,936	7,487	12,936	7,487	12,936
R^2	0.944	0.855	0.513	0.889	0.561	0.901	0.57

Table 2: Relative performance of IPO versus mature firms across various sub-samples

This table presents coefficient estimates and t-statistics (in parentheses) from Carhart (1997) four-factor model regressions of portfolios of mature and IPO firms for a set of sub-samples. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. All observations within a period are equal-weighted. Sub-samples are formed based on median firm size, as measured by market capitalization, based on a sample split into before and after 2000, based on hot and cold issue periods, defined as a period during which more than 72.5 IPOs (*Hot*) or less than 33 IPOs (*Cold*) took place, based on whether the IPO firm is backed by a venture capitalist, based on the median IPO underpricing as measured by the first-day return, and whether the firm is listed on NASDAQ. To save space, only coefficient estimates and t-statistics for the alpha are displayed. All regression specifications are based on a Carhart (1997) four-factor model. The following risk factors are included but not displayed. *RMRF* is the quarterly value-weighted return of all CRSP firms in excess of the risk-free rate and *SMB* is the return of a zero-investment size portfolio. *HML* and *MOM* are the returns of a zero-investment book-to-market and momentum portfolio, respectively. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature firms between 1975 and 2015. t-values are based on Newey-West standard errors. Significance at the 1%, 5%, and 10% levels is indicated by ***,**, and *, respectively.

			Mature	IPO	Δ(IPO-Mature)	# obs
Firms size	Small firms	(1)	1.004 **	-6.196 ***	-7.178 ***	163
			(2.02)	(-6.86)	(-8.02)	
	Large firms	(2)	0.490 ***	1.537 *	1.098	163
			(3.01)	(1.95)	(1.29)	
Time Period	1975-2000	(3)	0.374	-1.676 **	-2.050 **	104
			(1.14)	(-2.01)	(-2.37)	
	2001-2015	(4)	0.918 **	-1.350	-2.268 **	59
			(2.22)	(-1.62)	(-2.63)	
Issue Period	Hot	(5)	0.605	-1.981	-2.585 *	40
			(1.00)	(-1.42)	(-1.74)	
	Cold	(6)	0.917 **	-0.896	-1.814 **	84
			(2.36)	(-1.07)	(-2.09)	
VC	VC-backed	(7)	0.725	1.011	0.276	163
			(2.83)	(1.09)	(0.31)	
	non-VC backed	(8)	0.725	-1.842 ***	-2.567 ***	163
			(2.83)	(-3.36)	(-4.64)	
Underpricing	High	(9)	0.725	-1.304 *	-2.010 ***	163
			(2.83)	(-1.84)	(-2.66)	
	Low	(10)	0.725	-1.090 *	-1.814 ***	163
			(2.83)	(-1.83)	(-3.17)	
Stock Exchange	NASDAQ	(11)	1.650 ***	-0.0779	-1.777 **	163
			(5.27)	(-0.11)	(-2.38)	
	Non-NASDAQ	(12)	-0.134	-2.874 ***	-2.740 ***	163
			(-0.49)	(-4.34)	(-4.29)	

Table 3: Descriptive statistics

This table presents descriptive statistics of the following firm characteristics: capex scaled by sales, R&D expenditures and acquisitions scaled by sales as well as international business activity (*IBA*), book leverage and the abnormal stock turnover (*ATurn*). All characteristics are winsorized at the 1st and 99th percentiles. *IBA* is a dummy variable that is equal to one if a firm either reports exports or foreign sales. Leverage is calculated as total assets net of common equity divided by total assets, *ATurn* is abnormal turnover, defined as the difference between a stocks's trading volume and the median trading volume of all stocks in the same size decile. The table reports the mean, median, and 25th and 75th percentiles of each characteristic for 7,487 IPO firms and 9,517 mature firms between 1975 and 2015. A standard two-sample t-test is used to test for differences in means and a Wilcoxon rank-sum test to test for differences in medians. Significance of the difference between mean and median characteristics of mature and IPO firms at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

		Differences in firm characteristics of IPO and mature firms		
		IPO firms	Mature firms	Difference
Number of firms		7,487	9,517	
Capex/Sales	mean	0.34	0.18	0.16 ***
	median	0.12	0.08	0.04 ***
	25th percentile	0.05	0.03	
	75th percentile	0.33	0.17	
R&D/Sales	mean	0.37	0.11	0.26 ***
	median	0.12	0.04	0.08 ***
	25th percentile	0.02	0.01	
	75th percentile	0.30	0.10	
Acquisitions/Sales	mean	0.10	0.05	0.05 ***
	median	0.00	0.00	
	25th percentile	0.00	0.00	
	75th percentile	0.00	0.00	
IBA	mean	0.15	0.26	-0.11 ***
	median	0.00	0.00	
	25th percentile	0.00	0.00	
	75th percentile	0.00	1.00	
Leverage	mean	0.36	0.51	-0.15 ***
	median	0.32	0.52	-0.20 ***
	25th percentile	0.17	0.38	
	75th percentile	0.54	0.65	
Aturn	mean	0.19	0.12	0.07 ***
	median	0.03	-0.01	0.04 ***
	25th percentile	-0.07	-0.09	
	75th percentile	0.22	0.07	

Table 4: Firm characteristics and IPO performance

This table presents coefficient estimates and t-statistics (in parentheses) from estimating a pooled OLS regression with Driscoll-Kraay standard errors based on equation (1). Driscoll-Kraay standard errors are heteroskedasticity consistent and robust to cross-sectional dependence and autocorrelation up to four lags. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. Explanatory variables are based on a Kronecker product of the risk factors *RMRF*, *SMB*, *HML* and *MOM* and a set of firm characteristics. Coefficient estimates for the risk factors and respective interactions are not reported for space reasons. Firm characteristics are defined as follows. *Capex/Sales* and *R&D/Sales* represent quarterly capital and R&D expenditures scaled by sales. *Missing R&D* is a dummy variable which is set to one for firms which do not report R&D expenditures and to zero otherwise. *Acquisitions/Sales* shows the value of quarterly acquisitions scaled by sales. *IBA* represents a dummy variable that is equal to one if a firm has international business activity. *Leverage* represents the book leverage which is calculated as total assets net of common equity divided by total assets. *ATurn* is the abnormal turnover which is defined as the difference between a stocks's trading volume and the median trading volume of all stocks in the same size decile. All continuous firm characteristics are de-meaned to ensure that the regression-alpha is not biased by the sample mean. Coefficient estimates and t-values for these explanatory variables are summarized in the columns labeled *Mature*. Mature firms have been listed for a minimum of five years. Additionally, the table displays coefficient estimates and t-statistics of a full set of interaction terms between the explanatory variables and an IPO dummy. The IPO dummy equals one during the first year after the respective initial issue date. Results for the interaction terms are presented in the columns labeled *Δ (IPO-Mature)*. Model (1) presents the base case with no additional firm characteristic, Model (2) accounts for investments, Model (3) for internationality and Model (4) for leverage and liquidity, and Model (5) accounts for all characteristics at the same time. In each regression specification the respective firm characteristics are included in vector z_{it}. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature-only firms between 1975 and 2015. Significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

Model	(1)		(2)		(3)		(4)		(5)	
Characteristic	Base Model		Investments		Internationality		Leverage and Liquidity		All	
	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)
Alpha	0.727 **	-2.352 ***	1.419 ***	-3.708 **	0.590	-2.636 ***	0.776 ***	-3.063 ***	1.501 ***	-4.268 ***
	(2.43)	(-2.75)	(3.79)	(-2.40)	(1.54)	(-2.82)	(2.72)	(-4.09)	(3.44)	(-3.49)
Capex/Sales			-2.109 ***	0.351					-2.331 ***	1.415
			(-4.30)	(0.39)					(-4.90)	(1.54)
R&D/Sales			-0.566	0.168					-1.108 **	0.935
			(-0.99)	(0.17)					(-2.41)	(0.99)
missing R&D			-1.132 ***	1.996					-0.904 ***	1.623
			(-3.24)	(1.42)					(-3.04)	(1.35)
Acquisitions/Sales			-2.005 ***	-0.329					-1.842 ***	-0.572
			(-5.11)	(-0.39)					(-5.10)	(-0.62)
IBA					0.168	1.694 **			-0.460	2.719 ***
					(0.48)	(2.03)			(-1.31)	(3.23)
Leverage							-1.601 **	3.529	-0.285	2.591
							(-1.98)	(1.37)	(-0.42)	(1.13)
Aturn							0.423	-0.832	0.831 **	-0.138
							(1.12)	(-0.88)	(2.25)	(-0.13)
# obs.	401,020		285,982		383,197		333,099		259,113	
# firms	12,936		10,811		12,372		11,814		10,287	
R^2	0.135		0.141		0.138		0.149		0.160	

Table 5: Firm characteristics and IPO performance including firm fixed effects

This table presents coefficient estimates and t-statistics (in parentheses) from estimating a pooled OLS regression with Driscoll-Kraay standard errors based on equation (1) with firm fixed effects. Driscoll-Kraay standard errors are heteroskedasticity consistent and robust to cross-sectional dependence and autocorrelation up to four lags. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. Explanatory variables are based on a Kronecker product of the risk factors *RMRF*, *SMB*, *HML* and *MOM* and a set of firm characteristics. Coefficient estimates for the risk factors and respective interactions are not reported for space reasons. Firm characteristics are defined as follows. *Capex/Sales* and *R&D/Sales* represent quarterly capital and R&D expenditures scaled by sales. *Missing R&D* is a dummy variable which is set to one for firms which do not report R&D expenditures and to zero otherwise. *Acquisitions/Sales* shows the value of quarterly acquisitions scaled by sales. *IBA* represents a dummy variable that is equal to one if a firm has international business activity. *Leverage* represents the book leverage which is calculated as total assets net of common equity divided by total assets. *ATurn* is the abnormal turnover which is defined as the difference between a stocks's trading volume and the median trading volume of all stocks in the same size decile. All continuous firm characteristics are de-meaned to ensure that the regression-alpha is not biased by the sample mean. Coefficient estimates and t-values for these explanatory variables are summarized in the columns labeled *Mature*. Mature firms have been listed for a minimum of five years. Additionally, the table displays coefficient estimates and t-statistics of a full set of interaction terms between the explanatory variables and an IPO dummy. The IPO dummy equals one during the first year after the respective initial issue date. Results for the interaction terms are presented in the columns labeled *Δ (IPO-Mature)*. Model (1) presents the base case with no additional firm characteristic, Model (2) accounts for investments, Model (3) for internationality and Model (4) for leverage and liquidity, and Model (5) accounts for all characteristics at the same time. In each regression specification the respective firm characteristics are included in vector z_{it}. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature-only firms between 1975 and 2015. Significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

Model	(1)		(2)		(3)		(4)		(5)	
Characteristic	Base Model		Investments		Internationality		Leverage and Liquidity		All	
	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)	Mature	Δ(IPO-Mature)
Alpha	0.464	0.649	1.177 ***	0.0458	0.577	0.0184	0.503 *	0.814	1.906 ***	-0.160
	(1.60)	(0.83)	(3.33)	(0.04)	(1.48)	(0.02)	(1.87)	(1.28)	(5.15)	(-0.16)
Capex/Sales			-4.239 ***	2.370 **					-4.248 ***	3.080 ***
			(-8.09)	(2.41)					(-8.69)	(2.97)
R&D/Sales			-1.016 *	1.121					-1.281 **	2.017
			(-1.80)	(0.94)					(-2.53)	(1.64)
missing R&D			-1.316 ***	0.893					-1.116 ***	0.988
			(-2.89)	(0.79)					(-3.04)	(1.12)
Acquisitions/Sales			-2.762 ***	0.556					-2.623 ***	0.0372
			(-7.68)	(0.70)					(-7.58)	(0.04)
IBA					-0.567	1.527			-1.976 ***	3.275 ***
					(-1.07)	(1.50)			(-4.88)	(2.73)
Leverage							2.284 **	-0.226	4.166 ***	-0.305
							(2.00)	(-0.09)	(3.45)	(-0.13)
Aturn							1.596 ***	2.971	1.964 ***	3.411 ***
							(3.38)	(3.23)	(4.12)	(3.63)
# obs.	401,020		285,982		383,197		333,099		259,113	
# firms	12,936		10,811		12,372		11,814		10,287	
R^2 (within)	0.136		0.143		0.139		0.151		0.163	

Table 6: Relative performance of IPO versus mature firms across various sub-samples, accounting for firm fixed effects

This table presents coefficient estimates and t-statistics (in parentheses) from estimating a pooled OLS regression with Driscoll-Kraay standard errors for a set of sub-samples based on equation (1) with firm fixed effects. Driscoll-Kraay standard errors are heteroskedasticity consistent and robust to cross-sectional dependence and auto-correlation up to four lags. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. Sub-samples are formed based on median firm size, as measured by market capitalization, based on a sample split into before and after 2000, based on hot and cold issue periods, defined as a period during which more than 72.5 IPOs (*Hot*) or less than 33 IPOs (*Cold*) took place, based on whether the IPO firm is backed by a venture capitalist, based on the median IPO underpricing as measured by the first-day return, and based on whether the firm is listed on NASDAQ. To save space, only coefficient estimates and t-statistics for the alpha are displayed. All regression specifications are based on a fixed effect Carhart (1997) four-factor model. The following risk factors are included but not displayed. *RMRF* is the quarterly value-weighted return of all CRSP firms in excess of the risk-free rate and *SMB* is the return of a zero-investment size portfolio. *HML* and *MOM* are the returns of a zero-investment book-to-market and momentum portfolio, respectively. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature firms between 1975 and 2015. Significance at the 1%, 5%, and 10% levels is indicated by ***,**, and *, respectively.

			Mature		Δ(IPO-Mature)		# obs	# firms
Firms size	Small firms	(1)	0.682		-2.581	***	206,790	10,024
			(1.40)		(-3.65)			
	Large firms	(2)	0.036		4.328	***	194,230	7,520
			(0.20)		(4.58)			
Time Period	1975-2000	(3)	0.152		-0.0517		261,171	10,998
			(0.48)		(-0.07)			
	2001-2015	(4)	0.793	*	1.988	*	139,849	5,431
			(1.82)		(1.85)			
Issue Period	Hot	(5)	0.0180		0.313		108,795	9,035
			(0.03)		(0.18)			
	Cold	(6)	0.799	*	2.814	***	200,283	10,236
			(1.92)		(3.12)			
VC	VC-backed	(7)	0.605	**	0.657		382,906	10,858
			(2.13)		(0.46)			
	non-VC backed	(8)	0.543	*	0.603		389,407	11,581
			(1.90)		(1.06)			
Underpricing	High	(9)	0.563	**	0.843		385,763	11,188
			(1.98)		(0.78)			
	Low	(10)	0.584	**	0.569		386,625	11,265
			(2.04)		(0.98)			
Stock Exchange	NASDAQ	(11)	2.109	***	-0.741		136,532	5,063
			(6.15)		(-0.79)			
	Non-NASDAQ	(12)	-0.471		1.984	**	264,488	8,800
			(-1.58)		(2.54)			

Figure 1: Evolution of risk-adjusted IPO underperformance over time

This figure plots the quarterly risk-adjusted performance difference between IPOs and mature companies for different definitions of IPO firms. IPO firms are defined as firms going public within the last τ quarters, with τ = 1, 2, …, 40. Risk-adjusted performance differences are measured by the intercept (alpha) estimated from Carhart (1997) four-factor model regressions of the return difference between portfolios of IPO and mature firms. Additionally, the 90th percentile confidence intervals are displayed. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature-only firms (which have been listed for a minimum of five years) between 1975 and 2015.

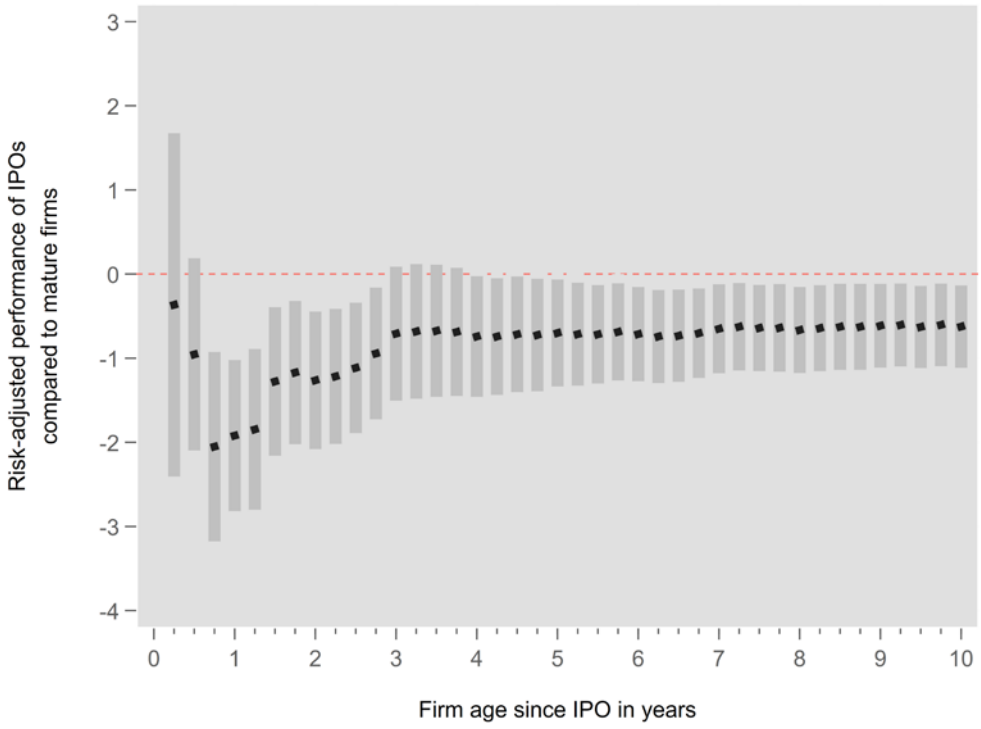


Figure 2: Evolution of characteristics over time

The charts in this figure plot the time series of the median capital and R&D expenditures per sales, the average value of acquisitions per sales, average international business activity, median leverage, as well as median abnormal turnover for 7,487 IPO firms over five years following their initial issue date. The graphs contrast these time series with the median (average for acquisitions and IBA) values of all mature companies from 1975 to 2015. Mature firms have been listed for a minimum of five years. *Leverage* is calculated as total assets net of common equity divided by total assets. *IBA* represents a dummy variable that is equal to one if a firm has international business activity. *ATurn* is the abnormal turnover which is defined as the difference between a stock's trading volume and the median trading volume of all stocks in the same size decile.

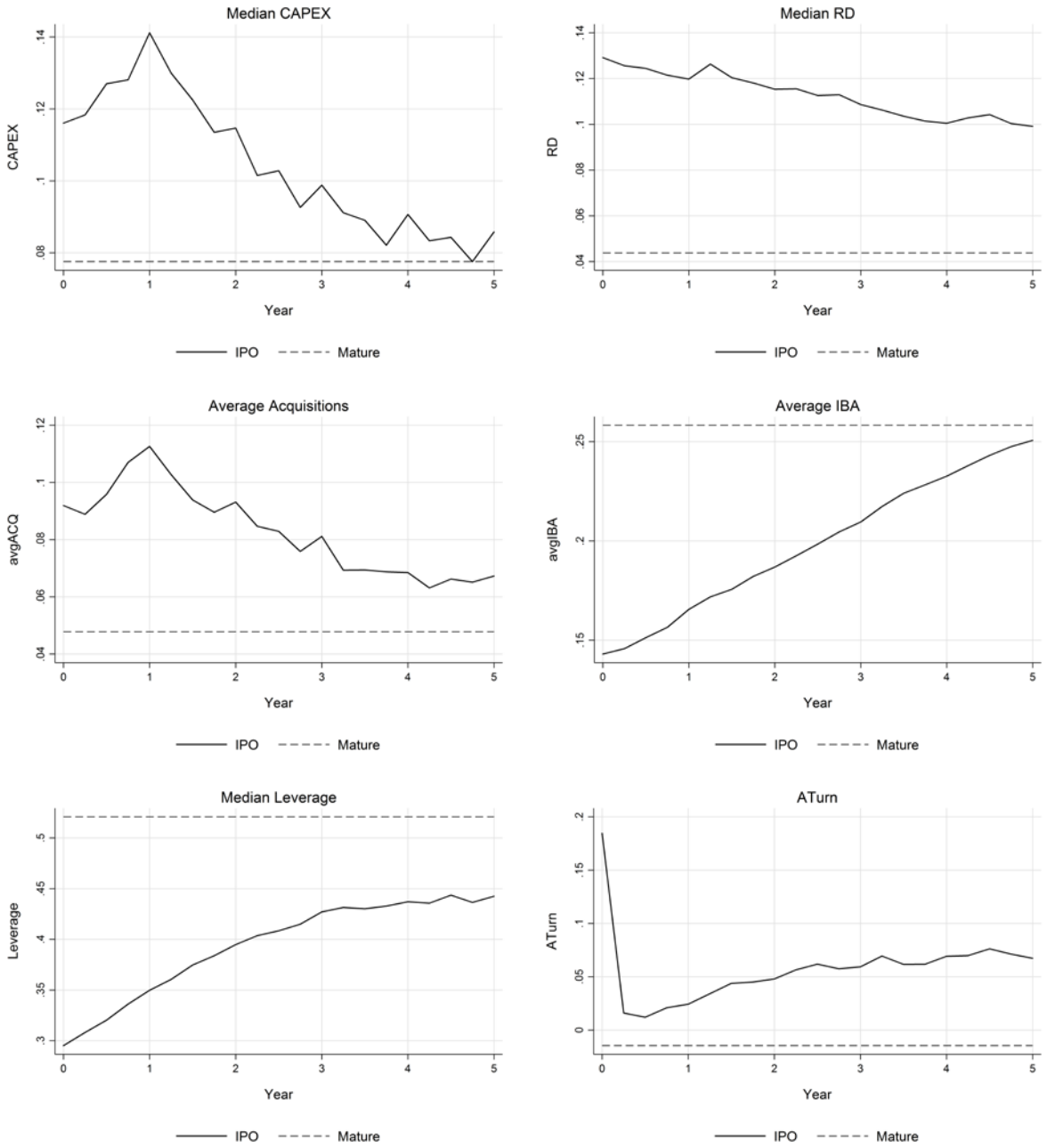


Figure 3: The evolution of IPO underperformance over the sample period
This figure plots the risk-adjusted performance of IPO firms over the first year after going public in comparison to mature firms over a rolling 15-year estimation window that ends in the respective year displayed on the horizontal axis. Risk-adjusted performance differences are based on a Carhart (1997) four-factor model. Additionally, the 90th and 95th percentile confidence intervals are displayed. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,419 mature-only firms (which have been listed for a minimum of five years) between 1975 and 2015. Since data availability starts in 1975, the figure plots rolling estimations from 1990 to 2015.

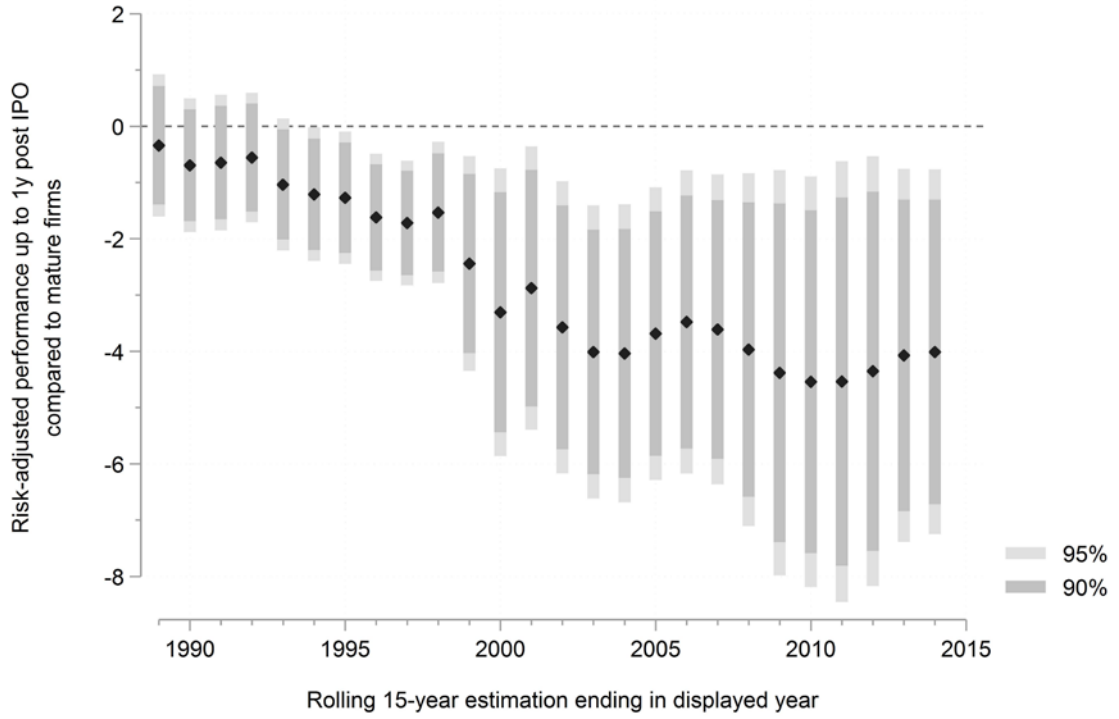
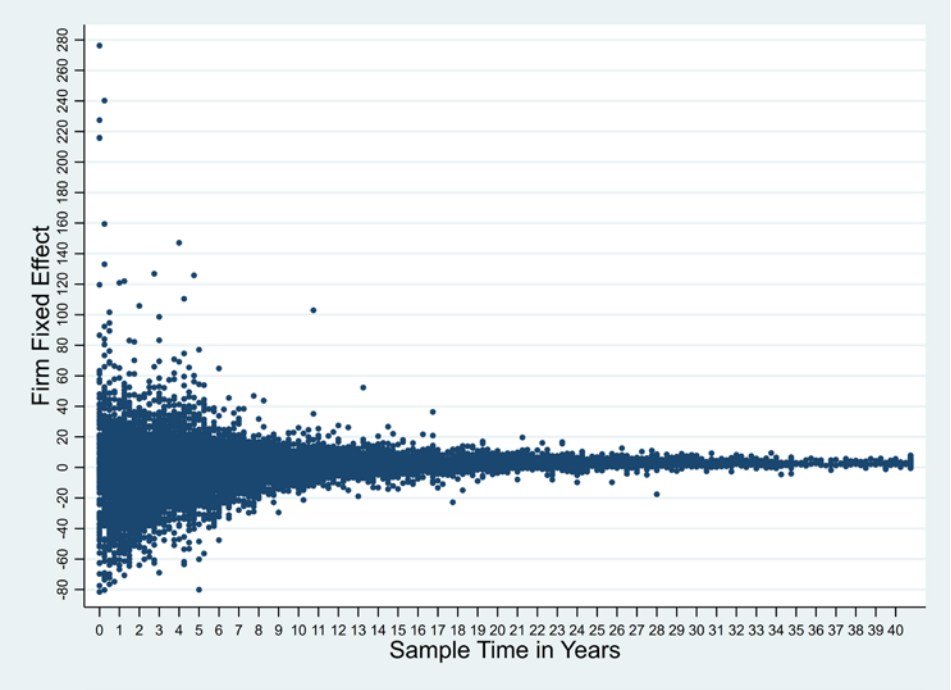


Figure 4: Magnitude of firm fixed effects in relation to in-sample time

This figure plots the magnitude of firm fixed effects against the time (in years) the respective firm is in the sample. Panel A includes the full sample of 7,487 IPO firms and 5,449 mature-only firms (which have been listed for a minimum of five years) and Panel B only depicts IPO firm fixed effects. Firms are classified as IPO firms over the first year after going public.

Panel A: Magnitude of firm fixed effects in relation to in-sample time – Full Sample



Panel B: Magnitude of firm fixed effects in relation to in-sample time – IPO Firms

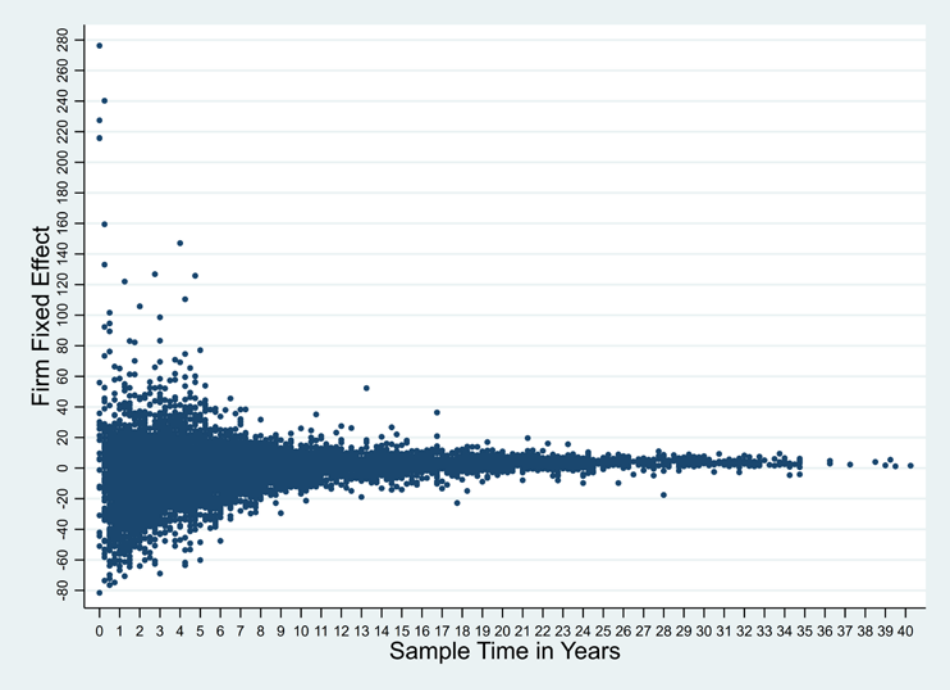
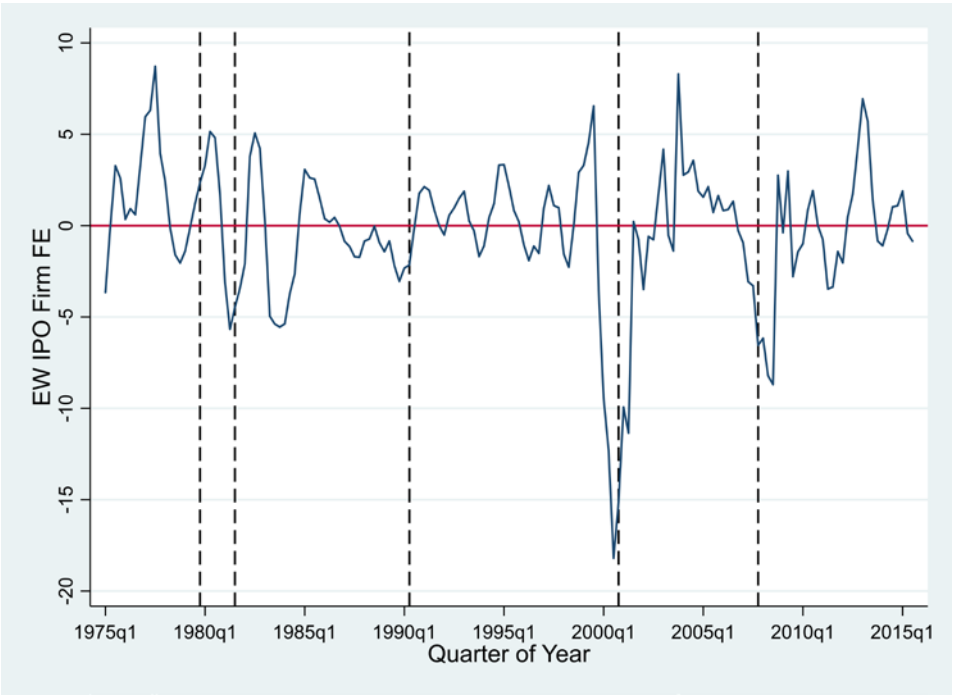


Figure 5: The evolution of IPO firm fixed effects over time
This figure plots the average IPO firm fixed effect for each quarter between 1975 and 2015. It only includes firm fixed effects of the 7,487 IPO firms over the first year after going public. NBER recession peaks are indicated by dashed lines. Panel A shows average IPO firm fixed effects based on equal-weighted observations and Panel B shows average IPO firm fixed effects using value-weighting based on the IPO firm's market capitalization.

Panel A: Equal-weighted IPO firm fixed effects over time



Panel B: Value-weighted IPO firm fixed effects over time

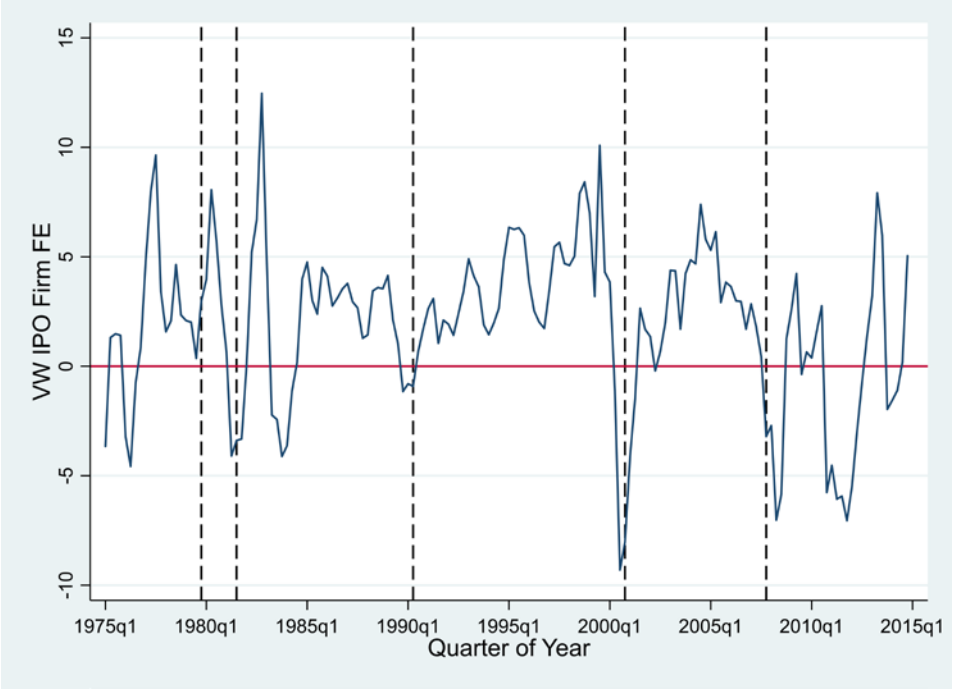


Table A.1: IPO underperformance over single years

This table presents coefficient estimates and t-statistics (in parentheses) from Carhart (1997) four-factor model regressions of portfolios of mature and IPO firms. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. All observations within a period are equal-weighted. *RMRF* is the quarterly value-weighted return of all CRSP firms in excess of the risk-free rate and *SMB* is the return of a zero-investment size portfolio. *HML* and *MOM* are the returns of a zero-investment book-to-market and momentum portfolio, respectively. Column 1 reports coefficient estimates and t-values from a Carhart (1997) four-factor model regression of a portfolio of mature firms which have been listed for a minimum of five years. Columns 2, 4, 6, 8 and 10 report coefficient estimates and t-values from a Carhart (1997) four-factor model regression of a portfolio of IPO firms separately over the first (Column 2), second (Column 4), third (Column 6), fourth (Column 8), and fifth (Column 10) year after going public. Columns 3, 5, 7, 9 and 11 report results from regressions of the difference in portfolio returns between mature firms and IPO firms, with returns over the first (Column 3), second (Column 5), third (Column 7), fourth (Column 9), and fifth (Column 11) year post initial issue date. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature firms between 1975 and 2015. t-values are based on Newey-West standard errors. Significance at the 1%, 5%, and 10% levels is indicated by ***,**, and *, respectively.

	1st year			2nd year		3rd year		4th year		5th year	
	Mature	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)
Alpha	0.725 ***	-1.196 **	-1.920 ***	-0.284	-1.019 **	0604	-0.146	-0.186	-0.970 *	0.668	-0.148
	(2.83)	(-2.07)	(-3.22)	(-0.52)	(-2.07)	(1.00)	(-0.29)	(-0.29)	(-1.69)	(1.08)	(-0.28)
RMRF	0.987 ***	1.152 ***	0.165 **	1.112 ***	0.132 **	1.118 ***	0.136 **	1.148 ***	0.170 **	1.000 ***	0.0253
	(30.91)	(16.06)	(2.23)	(15.99)	(2.11)	(14.62)	(2.15)	(13.80)	(2.32)	(12.80)	(0.39)
SMB	1.090 ***	1.337 ***	0.247 **	1.317 ***	0.240 **	1.361 ***	0.287 ***	1.228 ***	0.145	1.615 ***	0.537 ***
	(21.53)	(11.75)	(2.09)	(12.10)	(2.44)	(11.24)	(2.87)	(9.17)	(1.23)	(12.66)	(5.01)
HML	0.167 ***	-0.738 ***	-0.904 ***	-0.733 ***	-0.879 ***	-0.316 ***	-0.462 ***	-0.183 *	-0.327 ***	-0.0.271	-0.169 *
	(3.99)	(-7.85)	(-9.29)	(-7.96)	(-10.58)	(-3.13)	(-5.54)	(-1.68)	(-3.40)	(-0.26)	(-1.95)
MOM	-0.153 ***	0.0837	0.237 ***	-0.386 ***	-0.226 ***	-0.406 ***	-0.245 ***	-0.299 ***	-0.137 *	-0.200 ***	-0.0353
	(-4.83)	(1.18)	(3.21)	(-5.73)	(-3.71)	(-5.49)	(-4.01)	(-3.74)	(-1.95)	(-2.67)	(-0.56)
# obs.	163	163	163	159	159	155	155	151	151	147	147
# firms	9,517	7,487	12,936	7,106	12,555	6,180	11,629	5,353	10,802	4,658	10,107
R^2	0.944	0.855	0.513	0.837	0.554	0.842	0.386	0.810	0.218	0.827	0.243

Table A.2: Over which time horizon do IPOs underperform? – Market model

This table presents coefficient estimates and t-statistics (in parentheses) from market model regressions of portfolios of mature and IPO firms. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. All observations within a period are equal-weighted. *RMRF* is the quarterly value-weighted return of all CRSP firms in excess of the risk-free rate. Column 1 reports coefficient estimates and t-values from a market model regression of a portfolio of mature firms which have been listed for a minimum of five years. Columns 2, 4, and 6 report coefficient estimates and t-values from a market model regression of a portfolio of IPO firms, defined as firms going public within the last year (Column 2), the last three years (Column 4), and the last five years (Column 6). Columns 3, 5, and 7 report results from regressions of the difference in portfolio returns between IPO and mature firms, with IPO firms defined as firms going public within the last year (Column 3), the last three years (Column 5), and the last five years (Column 6). The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature-only firms between 1975 and 2015. t-values are based on Newey-West standard errors. Significance at the 1%, 5%, and 10% levels is indicated by ***,**, and *, respectively.

Time post IPO:		up to 1 year		up to 3 years		up to 5 years	
	Mature	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Alpha	0.921 *	-1.595 **	-2.516 ***	-1.159	-2.079 ***	-0.817	-1.738 ***
	(1.87)	(-2.02)	(-3.48)	(-1.54)	(-3.78)	(-1.15)	(-3.85)
RMRF	1.244 ***	1.642 ***	0.398 ***	1.667 ***	0.423 ***	1.616 ***	0.371 ***
	(21.74)	(17.90)	(4.73)	(19.11)	(6.61)	(19.56)	(7.07)
# obs.	163	163	163	163	163	163	163
# firms	9,517	5,449	12,936	5,449	12,936	5,449	12,936
R^2	0.746	0.666	0.122	0.694	0.213	0.704	0.237

Table A.3: Over which time horizon do IPOs underperform? – Fama-French three-factor model

This table presents coefficient estimates and t-statistics (in parentheses) from Fama-French (1993) three-factor model regressions of portfolios of mature and IPO firms. The dependent variable, y_{it}, is the quarter *t* portfolio excess return in %. All observations within a period are equal-weighted. *RMRF* is the quarterly value-weighted return of all CRSP firms in excess of the risk-free rate. *SMB* is the return of a zero-investment size portfolio and *HML* is the return of a zero-investment book-to-market portfolio. Column 1 reports coefficient estimates and t-values from a Fama-French (1993) three-factor model regression of a portfolio of mature firms which have been listed for a minimum of five years. Columns 2, 4, and 6 report coefficient estimates and t-values from a Fama-French (1993) three-factor model regression of a portfolio of IPO firms, defined as firms going public within the last year (Column 2), the last three years (Column 4), and the last five years (Column 6). Columns 3, 5, and 7 report results from regressions of the difference in portfolio returns between IPO and mature firms, with IPO firms defined as firms going public within the last year (Column 3), the last three years (Column 5), and the last five years (Column 6). The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature-only firms between 1975 and 2015. t-values are based on Newey-West standard errors. Significance at the 1%, 5%, and 10% levels is indicated by ***,**, and *, respectively.

Time post IPO:		up to 1 year		up to 3 years		up to 5 years	
	Mature	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)	IPO	Δ(IPO-Mature)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Alpha	0.288	-0.957 *	-1.245 **	-0.915 *	-1.203 ***	-0.793 *	-1.081 ***
	(1.12)	(-1.77)	(-2.17)	(-1.80)	(-2.75)	(-1.73)	(-3.01)
RMRF	1.015 ***	1.137 ***	0.122	1.194 ***	0.179 ***	1.170 ***	0.155 ***
	(30.26)	(16.09)	(1.63)	(17.99)	(3.13)	(19.51)	(3.31)
SMB	1.117 ***	1.322 ***	0.205 *	1.437 ***	0.320 ***	1.467 ***	0.350 ***
	(20.78)	(11.67)	(1.70)	(13.51)	(3.49)	(15.26)	(4.64)
HML	0.226 ***	-0.770 ***	-0.997 ***	-0.500 ***	-0.727 ***	-0.343 ***	-0.569 ***
	(5.30)	(-8.57)	(-10.41)	(-5.93)	(-9.97)	(-4.49)	(-9.51)
# obs.	163	163	163	163	163	163	163
# firms	9,517	5,449	12,936	5,449	12,936	5,449	12,936
R^2	0.936	0.853	0.481	0.869	0.534	0.885	0.548

Table A.4: Firm Characteristics and IPO performance - Sub-sample tests

This table presents coefficient estimates and t-statistics (in parentheses) from estimating a pooled OLS regression with Driscoll-Kraay standard errors based on equation (1). Driscoll-Kraay standard errors are heteroskedasticity consistent and robust to cross-sectional dependence and autocorrelation up to four lags. The table displays sub-samples based on median firm size as measured by market capitalization, based on different time periods, based on the issue period that indicates whether the IPO took place during a quarter with more than 72.5 IPOs (*Hot*) or less than 33 IPOs (*Cold*), based on whether the IPO firm is backed by a venture capitalist,based on the median IPO underpricing as measured by the first-day return, and based on whether the firm is listed on NASDAQ. The dependent variable y_{it} is defined as the firms' quarterly excess return in %. Explanatory variables are based on a Kronecker product of the risk factors *RMRF*, *SMB*, *HML* and *MOM* and a set of firm characteristics. For simplicity, coefficient estimates for the risk factors and respective interactions are not reported. Regressions include all firm characteristics related to investments, internationality, leverage and liquidity (compare Table 4, model 5) at once which are defined parallel to Table 4. For simplicity reasons only the alpha is reported. Columns labeled *Mature* show coefficient estimates and t-values for the alpha of mature firms that have been listed for a minimum of five years. Additionally, the table displays coefficient estimates and t-statistics of a full set of interaction terms between the explanatory variables and an IPO dummy. The IPO dummy equals one during the first year after the respective initial issue date. Results for the alpha of the interaction term are presented in the columns labeled *Δ (IPO-Mature)*. The sample comprises an unbalanced panel of 7,487 IPO firms and 5,449 mature-only firms between 1975 and 2015. Significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

			Mature		Δ(IPO-Mature)		# obs	# firms	R^2
Firms size	Small firms	(1)	2.090	***	-7.641	***	120,944	7,314	0.129
			(2.92)		(-6.38)				
	Large firms	(2)	0.725	*	-0.984		138,158	6,455	0.241
			(1.94)		(-0.62)				
Time Period	1975-2000	(3)	1.655	***	-5.827	***	140,344	8,457	0.14
			(2.77)		(-4.83)				
	2001-2015	(4)	1.364	***	-2.281	*	118,769	4,897	0.199
			(2.85)		(-1.85)				
Issue Period	Hot	(5)	0.809		-6.340	***	82,049	7,415	0.148
			(0.95)		(-4.24)				
	Cold	(6)	1.742	**	1.272		108,982	7,501	0.201
			(2.42)		(1.12)				
VC	VC-backed	(7)	1.501	***	-3.861	**	248,942	8,507	0.161
			(3.44)		(-2.31)				
	non-VC backed	(8)	1.501	***	-4.597	***	252,458	9,116	0.156
			(3.44)		(-3.65)				
Underpricing	High	(9)	1.501	***	-4.256	***	250,783	8,823	0.16
			(3.44)		(-3.33)				
	Low	(10)	1.501	***	-3.956	***	250,648	8,807	0.156
			(3.44)		(-3.12)				
Stock Exchange	NASDAQ	(11)	3.062	***	-2.625	*	110,746	4,321	0.178
			(5.45)		(-1.90)				
	Non-NASDAQ	(12)	-0.045		-6.657	***	148,356	5,990	0.149
			(-0.09)		(-5.06)				

Figure A.1: The number of U.S. IPOs per year

This figure presents the annual number of firms going public in the United States from 1975 to 2014.