Innovation Strategy of Private Firms*

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Abstract

We compare innovation strategies of public and private firms based on a large sample over the period 1997-2008. We find that public firms' patents rely more on existing knowledge, are more exploitative, and are less likely in new technology classes, while private firms' patents are broader in scope and more exploratory. We investigate whether these strategies are due to differences in firm information environments, CEO risk preferences, firm life cycles, corporate acquisition policies, or investment horizons between these two groups of firms. Our evidence suggests that the shorter investment horizon associated with public equity markets is a key explanatory factor.

Keywords: innovation strategy; exploratory innovation; exploitative innovation; investment horizons; private firms; public firms
JEL Classification: G32; O32

1. Introduction

Technological innovation represents modern corporations' endeavor to develop and accumulate knowledge, and has long been recognized as a key factor in corporate competitive advantages (Hall, 1993; Peteraf, 1993; Cockburn, Henderson, and Stern, 2000). The literature has identified two distinct strategies in organizational learning trajectories: exploratory innovation and exploitative innovation (Levinthal and March, 1993; McGrath, 2001; Benner and Tushman, 2002; Smith and Tushman, 2005; Manso, 2011). Exploratory innovation requires new knowledge or a departure from existing knowledge, and its payoffs take longer to realize and are of higher uncertainty. Exploitative innovation builds on existing knowledge, and its payoffs are realized faster with less uncertainty. Prior work has shown distinct effects of exploratory and exploitative innovation on new product development and revenue growth (see, for example, Katila and Ahuja, 2002; He and Wong, 2004; Uotila, Maula, Keil, and Zahra, 2009).

Due to data availability, most of our knowledge about corporate innovation activities at the micro level is based on evidence from public (i.e., stock-market listed) firms, despite the fact that there are far more privately-held (i.e., unlisted) firms than public firms in the economy and these private firms make significant contribution to corporate innovation and national output. Our paper aims to fill a gap in the literature by constructing a new database of both private and public firms' patenting activities to study their differences in corporate innovation strategy. Our paper and its findings also shed light on the increasing ubiquity of the so-called "unicorns" – highly innovative firms with big successes but choose to stay private.

There are a number of important differences between private and public firms that have implications on corporate innovation activities. On the one hand, access to public equity relaxes financial constraints and encourages high risk-taking learning in public firms, resulting in the

generation of more exploratory innovation that is broader in scope than that in private firms. On the other hand, the pressure to deliver near-term results and the presence of an active takeover market lead public firm managers to take short-cuts by engaging in low risk-taking learning, resulting in the generation of more exploitative innovation that is narrower in scope than that in private firms. Our use of both private and public firms highlights the contrasting effects of the financing hypothesis and the investment horizon hypothesis on innovation strategy. Further, the innovation strategy of private firms is in itself of great interest to finance scholars due to a lack of data prior to our study.

In this study, we compile a new dataset of patent and financial information on both large private and public firms over the period 1997-2008 to help identify the key influences of public equity markets on innovation strategy. It is worth noting that our sample mainly consists of mature private and public firms that did not change their listing status during the sample period, and thus their innovation strategies are less likely driven by their intention to go public. To our knowledge, our sample is one of the largest datasets to study private firms' innovation activities.

We find that public firms' patents are more exploitative (i.e., mainly making use of existing knowledge) and less exploratory (i.e., in pursuit of new knowledge) than private firms' patents. We also show that public firms' patents tend to be narrower in scope but greater in depth in terms of the knowledge domain, and that public firms produce fewer patents in technology classes previously unknown to these firms. These findings support the predictions of the investment horizon hypothesis.

We recognize that our investigation is vulnerable to endogeneity concerns, that is, instead of influencing corporate innovation strategy, public equity market listing choices are made jointly with innovation strategy. We employ a number of approaches to addressing these

concerns: propensity score matching method, a transitioning sample of IPO firms, two-stage least squares regressions using the local stock market participation rate as an instrumental variable, and a sample of withdrawn IPO deals using the market return as an instrumental variable. We find that the differences in strategy—exploratory versus exploitative innovation, innovation scope versus depth, and patenting in new technology classes—between private and public firms remain after controlling for endogeneity.

We also consider other possible explanations for our findings—differences between private and public firms in their information environments, CEO risk preferences, firm life cycles, and corporate acquisition policies that might impact on innovation strategy. Our analysis suggests that none of the above could be the main driver of our findings.

To sharpen our evidence for the underlying forces behind the different innovation strategies of private and public firms, we conduct within-public firm analyses by sorting firms into short- and long-horizon subsamples based on the vesting horizon of their CEOs' equity incentive portfolios, their exposure to hostile takeovers, and their susceptibility to transient institutional investors. We find that the differences in innovation strategy between short-horizon public firms and private firms are more pronounced than the differences between long-horizon public firms and private firms. We conclude that the shorter investment horizon associated with public equity markets leads to an innovation strategy that emphasizes exploitation.

Our paper is one of the first studies providing large sample evidence on the innovative activities of privately-held U.S. firms. Most studies to date on private firms' innovation employ only a small sample of transitioning firms such as LBO target firms or IPO firms (Lerner, Sørensen, and Strömberg, 2011; Aggarwal and Hsu, 2014; Bernstein, 2015) or a sample of startup firms (Barrot, 2016). In contemporaneous work, Acharya and Xu (2017) examine the

relation between firms' dependence on external capital and innovation output—patent and citation counts—using a large sample of private and public firms, and find that public firm status is associated with higher patent and citation counts. Extending their work, we focus on innovation strategy. Our results suggest that, although public firms have more patents, their patents rely more on existing knowledge and are less exploratory. This finding provides new insights into the real consequences of becoming a publicly-listed firm, considering that an exploratory innovation strategy is important for firms to survive and thrive through technological innovation waves in the long run (McGrath, 2001; Lavie, Stettner, and Tushman, 2010).

The paper is organized as follows. We review the related literature and develop our hypotheses in Section 2. In Section 3, we describe our sample, key variables, and empirical approach. We present the results in Sections 4-7. We conclude in Section 8.

2. Prior Literature and Hypothesis Development

2.1. Investment horizon and innovation strategy

Compared to private firms, public firms emphasize short-term performance imposed by the public equity market (Porter, 1992; Graham, Harvey, and Rajgopal, 2005) for a number of reasons. First, public firm managers can easily sell their equity holdings in the stock market (upon vesting). Their ability to take advantage of short-term price fluctuations to profit from equity sales encourages these managers to pursue short-term projects at the expense of long-term fundamental values (Stein, 1989; Bolton, Scheinkman, and Xiong, 2006; Gopalan, Milbourn, Song, and Thakor, 2014; Edmans, Fang, and Lewellen, 2016). In contrast, private firm managers have few ways to cash out and have to hold their equity stakes for a long period of time. Second, while a temporary undervaluation may increase the likelihood for a public firm to be taken over

at an unfavorable price (Stein, 1988), private firms with their non-publicly-traded stocks are faced with very little threat of hostile takeovers. As a result, public firm managers are more willing to cut long-term risky investment to meet short-term performance targets. Lastly, short-term shareholders in public firms tend to put pressure on managers to sacrifice long-term investments in order to meet short-term earnings targets (Bushee, 1998; Bereskin, Hsu, and Rotenberg, 2016). Such short-term pressure is much weaker in private firms because the lack of stock liquidity forces private firm shareholders to take a long investment horizon (Ferreira, Manso, and Silva, 2014). The above discussions together with the fact that exploitative innovation results in immediate performance outcome (Levinthal and March, 1993) lead to our first hypothesis (the investment horizon hypothesis):

Hypothesis 1: Private firms' innovation is more exploratory (less exploitative) than public firms' innovation.

2.2. Financing and innovation strategy

Being publicly-listed as opposed to privately-held is associated with a number of important differences that can potentially impact corporate innovation strategy. Under the financing channel, private firms are subject to more financing frictions than public firms and rely mainly on debt financing (Brav, 2009; Gao, Harford, and Li, 2013), which typically does not encourage innovative behavior (Aghion, Bond, Klemm, and Marinescu, 2004; Atanassov, Nanda, and Seru, 2007). Public firms' easier access to funding also generates financial slack that protects them from uncertainty associated with innovative activities, and thus fosters a culture of experimentation (Nohria and Gulati, 1996) and encourages the pursuit of long-term risky R&D projects (Cohen, Levin, and Mowery, 1987; Aghion, Angeletos, Banerjee, and Manova, 2010). Finally, public firms' stocks are freely traded, allowing public firm shareholders to achieve better

portfolio diversification and risk-sharing, which in turn encourages more corporate risk-taking (King and Levine, 1993; Faccio, Marchica, and Mura, 2011). The above discussions together with the fact that the costs to exploiting activities are lower than those to exploring activities (Levinthal and March, 1993) lead to our second and alternative hypothesis (the financing hypothesis):

Hypothesis 2: Public firms' innovation is more exploratory (less exploitative) than private firms' innovation.

Our empirical analysis is designed to test these two hypotheses and also to explore alternative explanations driven by other differences between private and public firms, including differences in information environments (Bhattacharya and Ritter, 1983; Cohen and Levinthal, 1994), CEO risk preferences, firm life cycles (Asker, Farre-Mensa, and Ljungqvist, 2015), and corporate acquisition policies (Maksimovic, Phillips, and Yang, 2013).

3. Sample and Empirical Framework

3.1. Sample formation

Our primary data sources are the Capital IQ database,[1] the National Bureau of Economic Research (NBER) Patent Citations Date File (Hall, Jaffe, and Trajtenberg, 2005, 2010 update), and the Harvard Business School (HBS) U.S. Patent Inventor Database (Li, Lai, D'Amour, Doolin, Sun, Torvik, Yu, and Fleming, 2014).[2] Public firms are those traded on the New York

[1] Capital IQ provides accounting information on private U.S. firms with a similar level of detail as that provided by Compustat on public U.S. firms; both data providers are subsidiaries of Standard & Poor's. Gao et al. (2013), Gao and Li (2015), and Gao, Harford, and Li (2017) also use Capital IQ for their studies of cash policy, CEO compensation, and CEO turnover in private firms, respectively.

[2] The NBER patent database (available at https://sites.google.com/site/patentdataproject/Home/downloads) consists of patent application date, award (grant) date, patent assignee (i.e., firm names), assignee location (country, state, and city), Standard & Poor's firm identifier (GVKEY, only for publicly-listed firms), NBER assignee identifier (PDPASS), citations made, and citation received by all patents awarded by the U.S. Patent and Trademark Office (USPTO) for the period 1976-2006. The HBS patent database (available at http://hdl.handle.net/1902.1/12367) is

Stock Exchange (NYSE), American Stock Exchange (AMEX), or National Association of Securities Dealers Automated Quotations (NASDAQ).

The Capital IQ data on private U.S. firms is based on the following mandatory disclosure requirements by the Securities and Exchange Commission (SEC). First, a private firm must file an Exchange Act registration statement if it has more than $10 million in total assets and a class of equity securities, like common stock, with 500 or more shareholders. After that, the company is required to continue reporting via annual and quarterly reports and proxy statements. Second, if a private firm decides on a registered public offering, the Securities Act of 1933 requires it to file a registration statement (Form S-1) with the SEC that contains basic financial information. We were able to include about 93% of the private firms in our sample based on their meeting the first criterion. As a result, our sample of private firms is fairly comparable in size to public firms; these firms do not have a strong presence of either private equity or venture capital as they tend to stay private for a long time.

We start with a list of unique non-financial U.S. firms covered in Capital IQ for the period 1997-2008. Our sample starts in 1997 because the data coverage in Capital IQ is poor before 1995. We employ a lead-lag specification and a three-year window to measure innovation strategy. Our sample ends in 2008 because the patent information from the HBS database is available until 2010 and there is a well-known two-to-three-year lag between the patent application and award dates (Hall et al., 2005). We obtain in two stages the patent and citation data for Capital IQ firms by manually matching with the NBER and HBS patent databases. In the first stage, we obtain the patent records for 3,453 private firms for the period 1976-2006 by manually matching the NBER patent database to the Capital IQ database by firm name and

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constructed in a similar manner as the NBER patent database, and contains more details about patent inventors for the period 1975-2010.

address. In the second stage, we obtain updated patent information for the period 2007-2010 by manually matching the HBS patent database to the Capital IQ database through the bridge of the merged NBER/HBS patent database before 2007.

We further require that all sample firm-year observations have basic financial information. To mitigate the reverse causality concern that innovation strategy drives going public/private decisions (rather than the public/private status driving innovation strategy), we remove firms that ever experienced going-public (1,341 IPOs) or going-private transactions (92 deals). In other words, our sample of private firms always stay private and our sample of public firms always stay public.[3]

Our focus is on corporate innovation strategy, so we need to examine a sample of innovative firms (i.e., firms with patents, Bloom, Schankerman, and Van Reenen, 2013; Aghion, Van Reenen, and Zingales, 2013). Innovative firms in year *t* are identified as firms filing at least one patent over the three-year period from year *t-2* to year *t* during the sample period 1997-2008. The final sample consists of 13,463 public firm-year observations representing 2,426 unique public firms, and 1,729 private firm-year observations representing 829 unique private firms for the period 1997-2008.

3.2. Measures of innovation strategy

Following Benner and Tushman (2002), we use a firm's existing expertise—the combination of its portfolio of patents and citations made by its existing patents over the past five years—to characterize the nature of its innovative effort. Exploratory innovation goes beyond existing expertise, while exploitative innovation deepens existing expertise. A patent is categorized as "exploratory" if 80% or more of its citations are based on new knowledge outside of a firm's

[3] It is worth noting that including those going-public/going-private firms in our analyses does not change our main findings. Further, those going-public firms will be used in our identification tests later on.

existing expertise (i.e., not citing the firm's existing patents or the citations made by those patents); while a patent is categorized as "exploitative" if 80% or more of its citations are based on a firm's existing expertise (i.e., the firm's existing patents and the citations made by those patents).[4]

At the firm level, the variable *Explore* in year *t* is the number of exploratory patents applied for in year *t-2* to year *t* divided by the total number of patents applied for over the same period. We use the application year (instead of the award year) to better capture the exact timing of the underlying innovative activities behind a patent. The variable *Exploit* in year *t* is the number of exploitative patents applied for in year *t-2* to year *t* divided by the total number of patents applied for over the same period. Both variables range between zero and one.

Following Katila and Ahuja (2002), we also employ two alternative measures of innovation strategy. Innovation scope captures the frequency a firm acquires new knowledge outside of its existing knowledge which consists of citations made by its existing patents over the past five years. At the firm level, the variable *Scope* in year *t* is the number of new citations made by patents applied for in year *t-2* to year *t* divided by the total number of citations made by all patents applied for over the same period. New citations are citations that have never been made by the firm in the past five years. The scope variable ranges between zero and one. The variable *Depth* in year *t* is the number of repeated citations made by patents applied for in year *t-2* to year *t* divided by the total number of citations made by all patents applied for over the same period. Repeated citations are citations that have been made by the firm in the past five years. The depth variable is equal to or greater than zero.

Finally, following Balsmeier, Fleming, and Manso (2017), we construct the variable *New-class* in year *t* as the number of patents applied for in year *t-2* to year *t* in technology classes

[4] It is worth noting that our main findings remain unchanged if we use 60% as the cutoff.

where the given firm had no other patent applied for in any previous years (starting 1976) divided by the total number of patents applied for over the same period. This measure captures exploratory innovation as it reflects a firm's effort to search in unknown areas.

3.3. Explanatory variables

Our main variable of interest, *Public*, is an indicator variable that takes the value of one if firm *i* is a public firm, and zero otherwise. We also consider the following set of explanatory variables that may affect innovation strategy; all explanatory variables are measured in year *t-2*. $Ln(Patent\ stock)$ is the logarithm of the total number of granted patents to firm *i* at the end of year *t-3* controlling for the size of a firm's patent portfolio and existing knowledge. $Ln(Total\ assets)$ is the logarithm of total assets of firm *i* controlling for the effect of firm size on innovation strategy. $Leverage$ is the ratio of total debt to total assets controlling for the effect of financial leverage on innovation strategy. ROA is return on assets capturing the influence of profitability on innovation strategy. $Sales\ growth$ is the growth rate of sales controlling for business prospects and growth opportunities. $Capex$ is the ratio of capital expenditures to total assets capturing the effect of physical investments on innovation strategy. $R\&D$ is the ratio of R&D expenditures to total assets capturing the effect of intangible investments on innovation strategy. PPE is the ratio of net property, plant, and equipment to total assets controlling for asset tangibility. $Ln(Firm\ age)$ is the logarithm of firm *i*'s vintage capturing the effect of firm life cycles on innovation strategy. Variable definitions are provided in Appendix 1.

4. Results

4.1. Summary statistics

Table 1 provides descriptive statistics for the entire sample. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. We first show that public firms are more innovative in terms of innovation output (*Patent count*). On average, public firms produce 78.1 patents per three-year period, while private firms produce 19.3 patents per three-year period. The average citation count within the award year and subsequent three years for public firms' patents is 302.1, while the average for private firms' patents is 64.8. The two-sample tests of differences (i.e., the t-test and Wilcoxon-test) reject the null that public and private firms have the same level of innovation output at the 1% level.

We further show that, on average, 48% of public firms' patents are exploratory, while 58% of private firms' patents are exploratory. Such a difference is economically important (representing a lower ratio of exploratory patents by 10 percentage points or 17% in public firms than in private firms), and statistically significant at the 1% level. In contrast, 12% of public firms' patents are exploitative, while 9% of private firms' patents are exploitative. Again, such a difference is economically important (representing a higher ratio of exploitative patents by three percentage points or 25% in public firms than in private firms), and statistically significant at the 1% level. Comparing innovation scope and depth between public and private firms, we find that the average scope (depth) for public firms is 0.75 (0.21), while the average scope (depth) for private firms is 0.81 (0.12); these differences are also significant at the 1% level. We further find that, on average, 30% of public firms' patents are in new technology classes, while 44% of private firms' patents are in new technology classes. These differences are both economically and statistically significant. Overall, the summary statistics provide some support for the

investment horizon hypothesis that public ownership is associated with more exploitative innovation, less exploratory innovation, greater innovation depth, narrower innovation scope, and fewer patents in new technology classes.[5] It is worth noting that our evidence also confirms the finding of Acharya and Xu (2017) that public firms do more innovation than private firms due to the former's easier access to financing.

In terms of other firm characteristics, we show that public firms are larger, have lower leverage, better operating performance, higher capital expenditures and R&D, and lower PPE, and are slightly older than private firms.

4.2. Baseline results

To empirically test our two hypotheses, we run the following panel data regression (for brevity, we omit firm subscript *i* and time subscript *t*, and *t* is from 1997 to 2008):

$$Innovation\ strategy = \alpha + \beta_1 Public\ + \beta_2 Ln(Patent\ stock) + \beta_3 Ln(Total\ assets) + \beta_4 Leverage + \beta_5 ROA + \beta_6 Sales\ growth + \beta_7 Capex + \beta_8 R\&D + \beta_9 PPE + \beta_{10} Ln(Firm\ age) + Industry \times Year\ FEs + \varepsilon, \quad (1)$$

where $Innovation\ strategy$ denotes one of the five measures for innovation strategy—*Explore*, *Exploit, Depth*, *Scope*, and *New-class* of firm *i* in year *t*. We also include industry times year fixed effects to control for unobserved industry- and year-specific heterogeneity such as competitive pressure and industry-specific business cycles. Industries are based on Fama and French's (1997) 48 industry classifications. We do not include firm fixed effects because our main variable of interest, $Public$, largely overlaps with firm fixed effects.[6] The coefficient on the

[5] In Appendix 2, we present the correlation matrix of innovation measures. We show that exploratory (exploitative) innovation is negatively (positively) associated with patent count, citation count, and innovation depth, and is positively (negatively) associated with innovation scope and new-class patents.

[6] In our main analysis, all sample firms remain either public or private throughout the sample period. Nonetheless, when we conduct similar analysis using a sample of IPOs with firm fixed effects, we obtain similar results.

Public indicator variable thus measures the difference in innovation strategies between public and private firms that cannot be accounted for by differences in firm characteristics and industry and year fixed effects. Our statistical inferences are based on standard errors clustered at the firm level that correct for the time-series correlation in firm-level innovation strategies.

Table 2 presents the regression results. Columns (1)-(2) and (3)-(4) compare public and private firms in exploratory versus exploitative innovation, and innovation scope versus depth, respectively, and column (5) compares public and private firms in new-class patents. We show that the coefficients on the *Public* indicator variable are negative when the dependent variable is *Explore*, *Scope*, or *New-class*, and are positive when the dependent variable is *Exploit* or *Depth*. All these coefficients are significant at or below the 5% level. Taking column (1) (where the dependent variable is *Explore*) for example, the coefficient on the *Public* indicator is –0.062 and significant at the 1% level. The economic magnitude is also sizeable: An average public firm produces about six percentage points fewer exploratory patents than an average private firm, relative to the sample average *Explore* of 48 percentage points in public firms (i.e., a difference of approximately 13%). Taking column (5) (where the dependent variable is *New-class*) for example, the coefficient on the *Public* indicator is –0.056 and significant at the 1% level. This result indicates that an average public firm produces about six percentage points fewer patents in new technology classes than an average private firm, relative to the sample average *New-class* of 30 percentage points in public firms (i.e., a difference of approximately 19%). These results are consistent with the prediction of the investment horizon hypothesis.

We also find that a firm's patent stock is negatively associated with its exploratory innovation (innovation scope and new-class patents) and positively associated with its exploitative innovation (innovation depth). This is not surprising, as firms with bigger patent

portfolios, *ceteris paribus*, have larger pools of existing knowledge (their own patents or past citations) for them to exploit and are thus less likely to cite outside their existing knowledge or to produce patents outside their existing technology classes. We further show that large firms and firms with better operating performance are associated with more exploratory patents and greater innovation scope. Interestingly, we do not find any significant association between R&D and exploratory innovation, innovation scope, or the number of patents in new technology classes.[7] Lastly, we show that older firms tend to produce more exploratory patents and are associated with broader innovation scope and more patents in new technology classes.

4.3. The propensity score-matched sample

We employ a matching technique to examine the differences in innovation strategy between public and private firms. The matching procedure controls for selection based on observable firm characteristics. Our data are well suited to the matching approach given that we have a much larger pool of potential matches in the innovative public firm sample compared to the treatment group—the innovative private firm sample (2,426 unique public firms versus 829 unique private firms), which increases the likelihood of finding close matches for the private firms among the public firms.

The matching procedure that we employ is a one-to-one nearest neighbor matching without replacement (Heckman, Ichimura, and Todd, 1997). The matching starts with a probit regression where the public firm indicator variable is the dependent variable, using three different specifications to capture the choice between being a public or private firm (Bharath and Dittmar, 2010; Gao et al., 2013). In Model 1, the variables we use to match are *Ln(Total assets),*

[7] This finding is, however, consistent with the literature that higher R&D expenditures do not necessarily lead to more innovation. Jaffe (2000) and Lanjouw and Schankerman (2004) report that the surge of R&D investment since the 1980s does not generate commensurate patents. The *Economist* (1990) also notes that "*American industry went on an R&D spending spree, with few big successes to show for it.*"

and industry times year fixed effects. In Model 2, the variables we use to match are *Ln(Total assets)*, *Ln(Patent stock)*, and industry times year fixed effects. In Model 3, the variables we use to match are all the explanatory variables in Table 2, except that we do not include the *Public* indicator variable. Then, using the predicted probabilities—propensity scores—from the estimated probit regressions, we match to each private firm-year observation a public firm-year observation that minimizes the absolute value of the difference between propensity scores.

Table 3 presents differences in the measures of innovation strategy between the propensity score-matched public firms and private firms using three different matching criteria. We find statistically significant differences between public and private firms in their innovation strategies: Public firms tend to produce less exploratory innovation, and are associated with narrower innovation scope and fewer patents in new technology classes. These differences are also economically important. Taking column (5) (where the dependent variable is *New-class*) for example, an average public firm produces about four percentage points fewer patents in new technology classes than its propensity score-matched private firm under Model (3), relative to the sample average *New-class* of 30 percentage points in public firms (i.e., a difference of approximately 13%). These results are consistent with the investment horizon hypothesis.

4.4. Using a transitioning sample of IPO firms

We next examine innovation strategy for a set of firms during our sample period that undergo a transition in ownership status from private to public.[8] Using the transitioning sample together with firm fixed effects directly addresses the sample selection concern about our baseline

[8] Examining cases in which firms transition from public to private status is an alternative way to address the potential sample selection concern. However, as Asker et al. (2015) discussed, it is extremely difficult to obtain financial information on firms that go private (unless they meet the SEC disclosure requirements). For this reason, we do not examine the going private transactions.

findings, because we compare the same firm as both a private and public firm, controlling for selection based on time-invariant unobservable firm characteristics, including managerial skills and risk preferences.

Prior work has shown that IPOs tend to cluster in time and in industry (Pagano, Panetta, and Zingales, 1998; Lowry, 2003), and that sales, capital expenditures, and other performance variables experience a consistently positive rise over the years before and after the IPO (Chemmanur, He, and Nandy, 2010). We use matched private control firms to difference out these observable factors to capture the effect of going public on innovation strategy.

There are 392 IPOs involving innovative private firms over the sample period 1997-2008, allowing us to compare these transitioning firms' innovation strategies before versus after IPOs. For each IPO firm we find an innovative private control firm that is in the same industry and has a similar propensity to go public in the year prior to the IPO using a set of firm characteristics including firm size, capital expenditures, R&D, sales growth, leverage, ROA, and firm age that are shown to be important in the going public decision (Chemmanur et al., 2010). We also require that those private control firms stay private over the sample period 1997-2008.

We run the following panel data regression employing a sample of IPO firms and their matched private control firms over the period from (up to) five years before to (up to) five years after the IPO:

$$\begin{aligned} Innovation\ strategy \\ = \alpha + \beta_1 PostIPO + \beta_2 Ln(Patent\ stock) + \beta_3 Ln(Total\ assets) + \beta_4 Leverage \\ + \beta_5 ROA + \beta_6 Sales\ growth + \beta_7 Capex + \beta_8 R\&D + \beta_9 PPE + \\ \beta_{10} Ln(Firm\ age) + Firm\ FEs + Year\ FEs + \varepsilon, \end{aligned} \quad (2)$$

where $Innovation\ strategy$ denotes one of the five measures for innovation strategy—*Explore*, *Exploit*, *Scope*, *Depth*, and *New-class* of firm *i* in year *t*. The indicator variable, *PostIPO*, takes

the value of one if a firm-year observation is after the IPO year for an IPO firm, and zero otherwise. This variable always takes the value of zero for the control firms. We include firm fixed effects in order to examine within-firm variations under the public/private status. We also include year fixed effects to account for variations over time associated with market conditions that may influence the IPO timing. The coefficient on the *PostIPO* indicator variable captures the change in innovation strategy around the IPO after controlling for firm and year fixed effects (a difference-in-differences estimation approach).

Table 4 presents the regression results. In columns (1), (3), and (5) where the dependent variable is *Explore*, *Scope*, and *New-class*, respectively, we show that the coefficients on *PostIPO* are all negative and significant. This finding indicates that compared to their private control firms, the IPO firms experience a decline in their exploratory innovation, a slowdown in expanding innovation scope, and a decrease in the number of patents in new technology classes after their transition from private to public status. In columns (2) and (4) where the dependent variable is *Exploit* and *Depth*, respectively, we show that the coefficients on *PostIPO* are all positive and significant. This finding indicates that compared to their private control firms, the IPO firms experience an increase in their exploitative innovation and an increased focus on existing knowledge after their transition from private to public status.

Bernstein (2015) finds that patent quality declines after firms go public. Our evidence on the changes in innovation strategy after IPOs complements his findings and echoes his point that there is a complex trade-off between public and private ownership as far as corporate innovation is concerned.

4.5. The two-stage least squares regression

Any time two groups of firms are compared, one should be concerned that some underlying difference between the two groups is the true cause of the results. It is possible that some omitted variables drive both a firm's being public/private decision and its innovation strategy. We apply the two-stage least squares (2SLS) regression with an instrumental variable (IV) to relate the exogenous variation in firm listing status to innovation strategy and thus help establish causality.

Following Gao et al. (2017), our IV is the state-level household stock market participation rate. It is widely documented that households tend to hold stocks of local public firms (Coval and Moskowitz, 1999) and thus households participate more in the stock market if there are a large number of local public firms (Brown, Ivkovic, Smith, and Weisbenner, 2008). For this reason, we expect a positive association between local households' stock market participation and the prevalence of local public firms (satisfying the relevance condition).

We construct the state-level household stock market participation rate based on the Panel Study of Income Dynamics (PSID) database, which is a survey of representative U.S. individuals and families compiled by the University of Michigan. The state-level household stock market participation rate is computed as the number of households that make non-zero stock investments divided by the total number of households in a state. We use the survey data in 1984, which is the earliest year with available information on household stock holdings. Since there is about a fifteen-year gap between 1984 when our IV is measured and our sample period 1997-2008, our IV is unlikely to directly influence corporate innovation strategy almost fifteen years later (other than through the channel of being publicly listed, satisfying the exclusion condition).

In the first stage, we run a linear probability regression with the *Public* indicator variable as the dependent variable.[9] The independent variables include the state-level household stock market participation rate and the firm characteristics used in Equation (1) except the public firm indicator variable. In the second stage, we re-estimate Equation (1) by using the predicted value of the public firm indicator variable obtained from the first stage.

Table 5 column (1) presents the results of the first-stage regression. The coefficient on the IV is positive and significant at the 1% level, indicating that households' participation in the stock market almost fifteen years ago is positively associated with the prevalence of local public firms now. Columns (2)-(6) present the second-stage regression results. We still find that public firms have significantly less exploratory innovation, narrower innovation scope, and fewer patents in new technology classes than private firms. Overall, the documented public-private firm differences in innovation strategy are robust to addressing the endogeneity associated with public status.

4.6. Using a sample of withdrawn IPO deals

So far we have tried to deal with the endogeneity problem by employing propensity score matching, a transitioning sample of IPO firms, and 2SLS regressions. Nonetheless, these approaches have shortcomings. For example, the timing of an IPO is endogenous and firms may choose to do it when they are becoming less exploratory. The decision to locate in a state with high stock market participation may be related to a firm's exploratory innovation. To address these concerns, we employ a sample of withdrawn IPO deals following Bernstein (2015) to further help establish causality.[10]

[9] We use a linear probability model instead of a logit model because in the context of 2SLS, only the former yields consistent second-stage estimates (Angrist, 2001; Angrist and Krueger, 2001).
[10] We thank an anonymous referee for this suggestion.

We collect all withdrawn IPO deals over the sample period 1997-2008 from the Thomson Reuters SDC Platinum. Each firm in our IPO sample used in Table 4 is matched to a withdrawn IPO control firm that filed the IPO in the same year, in the same industry, and closest in firm size in the year prior to the IPO filing. We track IPO firms' and matched IPO withdrawn firms' patenting activities from year *-5* to year *+5* centered at the IPO year (year 0). Panel A of Table 6 presents the results. We find that IPO firms experience an increase in their exploitative innovation, an increased focus on existing knowledge, and a decrease in their number of patents in new technology classes after their transition from private to public status. Taking column (1) (where the dependent variable is *Explore*) for example, the coefficient on *PostIPO* is –0.041 and significant at the 1% level, indicating a decrease in the ratio of exploratory patents by about four percentage points after the IPO relative to firms that filed but withdrew their IPOs.

To address the concern that a firm might withdraw its IPO for some unobserved reasons that are correlated with its innovation strategy, we follow Bernstein (2015) using market returns (i.e., returns on the CRSP value-weighted index) in the first two months of the book-building phase as the instrumental variable for the IPO completion. Panel B of Table 6 presents the results. The sample in Panel B is the same as that in Panel A, except that we only focus on the post-IPO period following Bernstein (2015).

In column (1), we show that the return on the aggregate stock market index is positively and significantly associated with the IPO completion, consistent with Bernstein (2015). In columns (2)-(6), we find that the coefficient on the predicted value of the *IPO completion* indicator obtained from column (1) is negative and significant when the dependent variable is *Explore*, *Scope*, or *New-class*, and the same coefficient is positive and significant when the dependent variable is *Exploit*. These results indicate that after addressing the endogeneity

problem associated with the IPO completion, IPO firms experience an increase in their exploitative innovation, an increased focus on existing knowledge, and a decrease in their number of patents in new technology classes after their transition from private to public status as compared to firms that withdrew their IPOs.

5. Other Public-Private Firm Differences and Their Effects on Innovation Strategy

We next examine whether our main findings can be attributed to public-private firm differences in information environments, CEO risk preferences, firm life cycles, or corporate acquisition policies.

5.1. Differences in information environments

Public firms are required to disclose more information than private firms, leading public firms to be more transparent. This difference in information environments may play a role in explaining their different innovation strategies. On the one hand, firms tend to focus on exploitations when they know that their innovation effort is closely scrutinized, and do not want to share knowledge from their explorations with other firms (Cohen and Levinthal, 1994). Given that public firms' innovative activities are closely watched by market participants and their peer firms (Bhattacharya and Ritter, 1983; Aggarwal and Hsu, 2014), public firms may strategically choose to focus on exploitative innovation rather than exploratory innovation.

On the other hand, greater disclosure reduces the information asymmetry between corporate insiders and outsiders, which in turn reduces the cost of financing and lowers the likelihood of a firm being undervalued by the stock market and thus being taken over. Therefore, greater transparency can facilitate public firms engaging in long-term exploratory innovation. *A*

priori, it is unclear whether the more transparent information environment of public firms makes them focus more or less on exploratory innovations than private firms.

To empirically examine the relation between the quality of firm information environment and innovation strategy, we divide our public firm sample into the high and low analyst-coverage subsamples based on the sample median number of analyst earnings forecasts. We then estimate Equation (1) by replacing the *Public* indicator variable by the new high and low analyst-coverage public firm indicator variables. Table 7 presents the results.

We find that while both groups of the public firms have significantly less exploratory innovation (narrower innovation scope), more exploitative innovation (greater innovation depth), and fewer patents in new technology classes than the private firms, the differences are more pronounced between the low analyst-coverage (i.e., less transparent) public firms and the private firms than those between the high analyst-coverage (i.e., more transparent) public firms and the private firms.

Overall, these results suggest that the more transparent information environment of public firms actually encourages these firms to focus more on exploratory innovation and less on exploitative innovation compared to private firms. Thus, the difference in information environments between public and private firms does not explain our main findings.

5.2. Differences in CEO risk preferences

It is natural to expect that public firm CEOs are more likely to be professional managers, while private firm CEOs are more likely to be entrepreneurs. Given that entrepreneurs could be more risk-prone than professional managers, can this difference in risk preferences of public and private firm CEOs explain these firms' differences in innovation strategy? We employ two approaches to investigating this possibility.

First, in Table 8 Panel A, we re-estimate Equation (1) using a subsample of firms incorporated prior to 1980. A firm incorporated prior to 1980 is more likely to be a mature firm by the 2000s (our sample period), and less likely to be in the "entrepreneurial" stage of its life cycle. We find that in this subsample of mature firms, public firms still produce more exploitative and less exploratory innovation than private firms. Second, in Table 8 Panel B, we re-estimate Equation (2) using a subsample of IPOs whose founders keep the CEO position until five years after the IPO (108 IPO cases), which allows us to clearly delineate the impact of listing status on innovation strategy by keeping the entrepreneur's risk preference constant. We still find that, after going public, these firms' innovation strategies become less exploratory and more exploitative. We conclude that our findings of more exploratory and less exploitative innovation in private firms than in public firms are unlikely to be mainly driven by their CEOs' risk preferences.

5.3. Differences in firm life cycles

One could argue that our evidence is also consistent with firm life cycles that provide incentives for entrepreneurs and employees to innovate more aggressively long before going public. Once becoming public, firms are in a different life cycle in which they still innovate, but also, compared to private firms, try more aggressively to commercialize their ideas into products. We point out that this life-cycle interpretation of our main findings is not supported by the empirical evidence. We find that larger older firms do more exploratory innovation, while smaller younger firms do more exploitative innovation, as shown in Table 2. We conclude that our main findings are unlikely driven by differences in firm life cycles.

5.4. Differences in corporate acquisition policies

While our paper focuses on a firm's organically-generated patents, a firm could also acquire patents via mergers and acquisitions (M&As). Given that public firms participate more in M&As than private firms (Maksimovic et al., 2013), it is possible that the difference in corporate acquisitiveness explains these firms' different innovation strategies.

To empirically examine this possibility, we first obtain information on a firm's acquisition activities from the SDC database and compute its acquisition expenditures as the sum of the transaction values of all deals it makes in a given year normalized by its total assets. We then divide our public firm sample into the high and low acquisitive subsamples based on the sample median of acquisition expenditures. Finally, we estimate Equation (1) by replacing the *Public* indicator variable by the new high and low acquisitive public firm indicator variables. If corporate acquisitiveness explains the different innovation strategies between public and private firms, we expect the difference to be more pronounced between the high acquisitive public firms and the private firms than that between the low acquisitive public firms and the private firms. Table 9 presents the results.

We find that while both groups of the public firms have significantly less exploratory innovation, more exploitative innovation, and fewer patents in new technology classes than the private firms, the differences are more pronounced between the low acquisitive public firms and the private firms than those between the high acquisitive public firms and the private firms: The high acquisitive public firms are in fact doing more exploratory innovation than the low acquisitive public firms. Thus, we show that differences in acquisition activities between public and private firms do not explain differences in their innovation strategies.

In summary, we conclude that our main findings are unlikely driven by public-private firm differences in information environments, CEO risk preferences, firm life cycles, or corporate acquisition activities.

6. More Evidence on Investment Horizon Hypothesis

To provide further evidence that investment horizon is the key explanation for the different innovation strategies of public and private firms, we sort public firms into short- and long-horizon subsamples based on known sources of the short-term performance pressure associated with public equity markets. If investment horizon is indeed the key driving force, we would expect that the differences in innovation strategy between short-horizon public firms and private firms would be more pronounced than the differences between long-horizon public firms and private firms.

6.1. The vesting horizon of CEOs' equity portfolios

Manso (2011), Gopalan et al. (2014), and Edmans et al. (2016) show that when the vesting period of a CEO's stock and option grants is short, the CEO will be more concerned about the short-term performance and thus more short-term-oriented. Following their argument, we first compute a CEO's vested equity portfolio as the value of her vested stock and option grants normalized by the value of her portfolio of stock and option grants. Based on the sample median of CEOs' vested equity portfolios, we divide the public firm sample into short-horizon public firm subsample (where the CEO's vested equity portfolio is above the sample median), and long-horizon public firm subsample (where the CEO's vested equity portfolio is below the sample

median). We then estimate Equation (1) by replacing the *Public* indicator variable by the new short- and long-horizon public firm indicator variables. Table 10 Panel A presents the results.[11]

In columns (1), (3), and (5), we show that the coefficients on both the short- and long-horizon public firm indicator variables are negative and significant, indicating that both groups of the public firms produce significantly less exploratory innovation, have significantly narrower innovation scope, and produce fewer patents in new technology classes than the private firms. More importantly, the effect of the short-horizon public firm indicator variable on exploratory innovation and innovation scope is significantly larger than that of the long-horizon public firm indicator variable. Taking column (1) (where the dependent variable is *Explore*) for example, the coefficient on the short-horizon public indicator variable is −0.068 and significant at the 1% level, while the coefficient on the long-horizon public indicator variable is −0.044 and significant at the 1% level. The F-statistic reported at the bottom indicates that these two coefficients are significantly different at the 1% level.

In columns (2) and (4), we find that while both groups of the public firms produce significantly more exploitative innovation and have significantly greater innovation depth than the private firms, the differences are more pronounced between short-horizon public firms and private firms than those between long-horizon public firms and private firms. The F-statistic indicates that the coefficients on the short- and long-horizon public indicators are significantly different at or lower than the 10% level.

Our results suggest that CEO short-term incentives may be an underlying force behind our findings that public firms do less exploratory (more exploitative) innovation, have narrower

[11] The information on CEOs' (total) vested stock and option grants is obtained from ExecuComp. Because ExecuComp only covers S&P1500 firms, the sample size in this panel is smaller than that used in Table 2.

innovation scope (greater innovation depth), and produce fewer patents in new technology classes than private firms.[12]

6.2. The threat of hostile takeovers

In the myopia model of Stein (1988, 1989), in the presence of asymmetric information, shareholders and the stock market cannot properly evaluate managers' investments in long-term high-risk projects, leaving those firms more likely to be undervalued by the market and their greater vulnerability to takeovers. To prevent firm misevaluation and/or takeover, managers are likely to invest more in short-term low-risk projects instead of long-term risky projects. Given that exploratory innovation is typically more long-term and high-risk in nature, we expect that the pressure from the market for corporate control could be another underlying force behind public firms' less exploratory innovation, greater innovation depth, and fewer patents in new technology classes.

We obtain a sample of announced hostile bids from the SDC database over the sample period 1997-2008. We then estimate a firm's predicted probability of becoming a hostile takeover target by running a probit regression with the following explanatory variables: M/B, firm size, ROA, leverage, cash holdings, sales growth, and industry times year fixed effects (Cremers, Nair, and John, 2009; Fang, Tian, and Tice, 2014). Based on the sample median of this predicted probability, we divide the public firm sample into short- and long-horizon public firm subsamples. Finally, we estimate Equation (1) by replacing the *Public* indicator variable by the new short- and long-horizon public firm indicator variables. Table 10 Panel B presents the results.

[12] Malmendier and Tate (2005) note that overconfident CEOs delay exercising their vested stock and option grants, hence mitigating the short-term incentives associated with their holdings. Their findings actually strengthen our results because we do not exclude overconfident CEOs who are less sensitive to short-term incentives provided by their vested stock and option grants.

We show that both groups of the public firms produce significantly less exploratory innovation, have significantly narrower innovation scope, and produce significantly fewer patents in new technology classes than the private firms, and that the effect of the short-horizon public firm indicator variable on exploratory innovation (innovation scope and new-class patents) is significantly larger than that of the long-horizon public firm indicator variable. Our results suggest that firms' exposure to hostile takeovers may be another underlying force behind our findings that public firms do less exploratory (more exploitative) innovation, have narrower innovation scope (greater innovation depth), and produce fewer patents in new technology classes than private firms.

6.3. The presence of transient institutional investors

Bushee (1998) shows that transient institutional investors create short-term pressure on managers to cut R&D expenditures in order to meet short-term earnings targets. Following Bushee's (1998, 2001) definition of transient institutional investors, we first compute the transient institutional ownership as the number of shares owned by transient institutional investors normalized by the number of shares owned by all institutional investors. We then divide our public firms into short- and long-horizon public firm subsamples based on the sample median of the transient institutional ownership. We estimate Equation (1) by replacing the *Public* indicator variable by the new short- and long-horizon public firm indicator variables. Table 10 Panel C presents the results.

We show that both groups of the public firms produce significantly less exploratory (more exploitative) innovation, have significantly narrower innovation scope (greater innovation depth), and produce fewer patents in new technology classes than the private firms, and that the effect of the short-horizon public firm indicator variable on innovation strategy is significantly

greater than that of the long-horizon public firm indicator variable (in four out of five cases). Our results suggest that the presence of the transient institutional investors may be the third underlying force behind our findings that public firms do less exploratory (more exploitative) innovation, have narrower innovation scope (greater innovation depth), and produce fewer patents in new technology classes than private firms.

Overall, Table 10 provides additional evidence suggesting that shorter investment horizon associated with public equity markets explains the different innovation strategies adopted by public and private firms.

7. Alternative Measures of Innovation Strategy

In this section, following Jaffe (1989), Cirillo, Brusoni, and Valentini (2013), and Balsmeier et al. (2017) we consider three additional measures to capture a firm's exploratory vs. exploitative innovation strategy.[13]

The first variable *New-claim* in year *t* is the number of new claims made by patents applied for in year *t-2* to year *t* in technology classes where the given firm had no other patent applied for in any previous years (starting 1976) divided by the total number of claims made by patents applied for over the same period, following Cirillo et al. (2013) and Balsmeier et al. (2017). The total number of claims reflects the effort a firm puts into the patenting process (Balsmeier et al., 2017), and the ratio of new claims made by patents in new technology classes captures a firm's effort to explore unknown areas (Cirillo et al., 2013).

The second variable *Self-citation* in year *t* is the number of self-citations (i.e., citing other patents owned by the same firm) made by patents applied for in year *t-2* to year *t* divided by the total number of citations made by patents applied for over the same period. More self-citations

[13] We thank an anonymous referee for this suggestion.

indicate search within previously known areas of expertise suggesting a more exploitative innovation strategy, while fewer self-citations indicate a broadening search to areas that are new to a firm suggesting a more exploratory innovation strategy (Balsmeier et al., 2017).

The third variable *Cosine-similarity* is constructed following Jaffe (1989) and Balsmeier et al. (2017). We compute the cosine similarity between the distribution of technology classes of patents applied for in year *t-2* to year *t* and that of the patent portfolio held by the same firm up to year *t-3*. This is a continuous measure of whether a firm stays or deviates from known research areas. A high value indicates a more exploitative innovation strategy.

We then estimate our baseline model in Equation (1) using these three new measures as the dependent variable, and the results are reported in Table 11. We find that public firms' patents make fewer new claims but more self-citations, and have greater similarity with their prior patent portfolio, than private firms' patents. Taking column (1) (where the dependent variable is *New-claim*) for example, the coefficient on the *Public* indicator is –0.036 and significant at the 1% level. The economic magnitude is also sizeable: An average public firm makes about four percentage points fewer new claims than an average private firm, relative to the sample average *New-claim* of 34 percentage points in public firms (i.e., a difference of approximately 10%).

Overall, using a number of alternative measures of innovation strategy, we continue to find that public firms have more exploitative (less exploratory) innovation strategies than private firms.

8. Conclusions

In contrast to prior research focusing on innovation activities of publicly-listed firms, in this paper, we study the differences in corporate innovation strategies between private and public firms by constructing a new dataset on private U.S. firms' patents and citations.

Using a sample of public and large private firms and their patent records over the period 1997-2008, we show that private firms are more aggressive in their innovation strategies—their patents are more exploratory and broader in scope, while public firms are more conservative in their strategies—their patents are more exploitative, rely more on existing knowledge, and are less likely in new technology classes. The evidence from propensity score matching method, a transitioning sample of IPO firms, the two-stage least squares regression, and a sample of withdrawn IPO deals suggests that these findings are unlikely driven by endogeneity. We investigate and find that these different innovation strategies between private and public firms are not due to differences in information environments, CEO risk preferences, firm life cycles, or corporate acquisition policies. We further conduct within-public firm analyses to sharpen our evidence for investment horizon being the underlying force behind the different innovation strategies. We conclude that the longer investment horizon associated with private ownership leads to an innovation strategy that emphasizes exploration and scope.

Appendix 1: Variable definitions

Variable	*Definition*
Firm Characteristics	
Public	An indicator variable that takes the value of one if a firm is publicly listed, and zero otherwise.
Leverage	Total debt normalized by total assets.
ROA	Return on assets, computed as EBIT normalized by total assets.
Sales growth	Sales (*t-2*) / Sales (*t-3*) – 1.
Capex	Capital expenditures normalized by total assets.
R&D	R&D expenditures normalized by total assets.
PPE	Net property, plant, and equipment normalized by total assets.
Firm age	Firm age since a firm's incorporation.
Stock market participation rate	The number of households who make non-zero stock investment normalized by the total number of households in a given state in 1984.
PostIPO	An indicator variable that takes the value of one if a firm-year observation is after the IPO (year *0*) for an IPO firm, and zero otherwise.
Market return	The return on the CRSP value-weighted index in the first two months of the book-building period of an IPO firm.
IPO completion	An indicator variable that takes the value of one if a firm completes its IPO, and zero otherwise.
Long-horizon public	An indicator variable that takes the value of one if the value of a public firm CEO's vested stock and option grants as the percentage of the value of her total holdings of stock and option grants is below the sample median, and zero otherwise; alternatively, an indicator variable that takes the value of one if a public firm's probability of becoming a hostile takeover target is below the sample median, and zero otherwise; alternatively, an indicator variable that takes the value of one if a public firm's transient institutional ownership is below the sample median, and zero otherwise.
Short-horizon public	An indicator variable that takes the value of one if the value of a public firm CEO's vested stock and option grants as the percentage of the value of her total holdings of stock and option grants is above the sample median, and zero otherwise; alternatively, an indicator variable that takes the value of one if a public firm's probability of becoming a hostile takeover target is above the sample median, and zero otherwise; alternatively, an indicator variable that takes the value of one if a public firm's transient institutional ownership is above the sample median, and zero otherwise.
High analyst-coverage	An indicator variable that takes the value of one if the number of analyst earnings

public	forecasts made on a public firm is above the sample median, and zero otherwise.
Low analyst-coverage public	An indicator variable that takes the value of one if the number of analyst earnings forecasts made on a public firm is below the sample median, and zero otherwise.
High acquisitive public	An indicator variable that takes the value of one if a public firm's acquisition expenditures (normalized by total assets) are above the sample median, and zero otherwise.
Low acquisitive public	An indicator variable that takes the value of one if a public firm's acquisition expenditures (normalized by total assets) are below the sample median, and zero otherwise.
Measures of Innovation	
Patent count	For firm *i* in year *t*, the number of patent applications that are made by firm *i* in year *t-2* to year *t* (our sample period *t* starts in 1997 and ends in 2008), and are later awarded by the USPTO by the end of 2010. We set this variable to zero for firm-year observations without any patent records in our patent database.
Citation count	This measure is constructed in three steps. First, for each patent with application year *t* (our sample period *t* starts in 1997 and ends in 2008), we count the number of citations it receives since the award year to the end of 2010. The truncation bias in the citations received by a patent arises because citations are received many years after the innovation was created. So in the second step, we account for this bias by scaling the number of citations from the first step by a corresponding adjustment factor shown in Table 5 of Hall, Jaffe, and Trajtenberg (2005). Third, for firm *i* in year *t*, we sum up the scaled number of citations from the second step across all patents with application in year *t-2* to year *t*.
Patent stock	The total number of granted patents applied for by firm *i* up to year *t-3*. All patents recorded in the NBER/HBS merged patent dataset are included. We set this variable to zero for firm-year observations without any patent record in our patent database.
Explore	This measure is constructed in three steps following Benner and Tushman (2002). First, for each patent applied for by firm *i* in year *t-2* to year *t*, we calculate the percentage of its citations that are based on existing expertise—the combination of firm *i*'s portfolio of patents and citations made by its portfolio of patents over the past five years (i.e., year *t-7* to year *t-3*). Second, a patent is categorized as "exploratory" if more than or equal to 80% of its citations are outside of firm *i*'s existing expertise as defined in the first step. Finally, we calculate firm *i*'s exploratory ratio in year *t* as the number of exploratory patents applied for in year *t-2* to year *t* divided by the total number of patents applied for over the same period.
Exploit	This measure is constructed in three steps following Benner and Tushman (2002). First, for each patent applied for by firm *i* in year *t-2* to year *t*, we calculate the percentage of its citations that are based on existing expertise—the combination of firm *i*'s portfolio of patents, and citations made by its portfolio of patents over the past five years (i.e., year *t-7* to year *t-3*). Second, a patent is categorized as "exploitative" if more than or equal to 80% of its citations are based on firm *i*'s existing expertise as defined in the first step. Finally, we compute firm *i*'s exploitative ratio in year *t* as the number of exploitative patents applied for in year *t-2* to year *t* divided by the total number of patents applied for over the same period.
Scope	This measure is constructed following Katila and Ahuja (2002). We compute firm *i*'s scope ratio in year *t* as the number of new citations made by awarded patents

	applied for by firm *i* in year *t-2* to year *t* divided by the total number of citations made by awarded patents applied for by firm *i* over the same period. New citations are citations that are made by one of firm *i*'s awarded patents applied for in year *t-2* to year *t* but that were never cited by firm *i*'s awarded patents applied for in the past five years (i.e., year *t-7* to year *t-3*). The scope ratio is between zero and one.
Depth	This measure is constructed following Katila and Ahuja (2002). We compute firm *i*'s depth ratio in year *t* as the number of repeated citations made by awarded patents applied for by firm *i* in year *t-2* to year *t* divided by the total number of citations made by awarded patents applied for by firm *i* over the same period. Repeated citations are citations that are made by both one of firm *i*'s awarded patents applied for in year *t-2* to year *t* and one of firm *i*'s awarded patents applied for in the past five years (i.e., year *t-7* to year *t-3*). If one particular citation was cited twice over the five-year window, it is counted as two repeated citations. The depth ratio is equal to or greater than zero.
New-class	This measure is constructed following Balsmeier et al. (2017). We compute firm *i*'s new-class ratio in year *t* as the number of patents applied for in year *t-2* to year *t* in technology classes where the given firm had no other patent applied for in any previous years (starting 1976) divided by the total number of patents applied for over the same period.
New-claim	This measure is constructed following Cirillo et al. (2013) and Balsmeier et al. (2017). We compute firm *i*'s new-claim ratio in year *t* as the number of new claims made by patents applied for in year *t-2* to year *t* in classes where the given firm had no other patent applied for in any previous years (starting 1976) divided by the total number of claims made by patents applied for over the same period.
Self-citation	This measure is constructed following Balsmeier et al. (2017). We compute firm *i*'s self-citation ratio in year *t* as the number of self-citations (i.e., citing other patents owned by the same firm) made by patents applied for in year *t-2* to year *t* divided by the total number of citations made by patents applied for over the same period.
Cosine-similarity	This measure is constructed following Jaffe (1989) and Balsmeier et al. (2017). We compute firm *i*'s cosine similarity in year *t* between patents applied for in year *t-2* to year *t* and the patent portfolio held by the same firm up to year *t-3.* Specifically, the cosine similarity is computed as $$\frac{P_{t-3\ or\ before} P'_{t-2\ to\ t}}{\sqrt{P_{t-3\ or\ before} P'_{t-3\ or\ before}} \sqrt{P_{t-2\ to\ t} P'_{t-2\ to\ t}}},$$ where the vector $P_{t\text{-}3\ or\ before} = (P_{t\text{-}3\ or\ before,1}, ..., P_{t\text{-}3\ or\ before,J})$ is the number of patents applied for by firm *i* in year *t-3* or before in each technology class, the vector $P_{t\text{-}2\ to\ t} = (P_{t\text{-}2\ to\ t,1}, ..., P_{t\text{-}2\ to\ t,J})$ is the number of patents applied for by firm *i* in year *t-2* to year *t* in each technology class, and $j \in (1,J)$ is the technology class index.

Appendix 2: The correlation matrix of innovation measures

This table presents the pairwise Pearson correlation coefficients among all innovation measures used in this paper. The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. All the coefficients are significant at the 1% level.

	1	2	3	4	5	6	7	8	9	10
1 Ln(Patent count)	1									
2 Ln(Citation count)	0.90	1								
3 Explore	-0.36	-0.20	1							
4 Exploit	0.07	0.08	-0.54	1						
5 Scope	-0.22	-0.18	0.73	-0.79	1					
6 Depth	0.21	0.20	-0.37	0.47	-0.58	1				
7 New-class	-0.44	-0.37	0.43	-0.31	0.40	-0.24	1			
8 New-claim	-0.47	-0.42	0.46	-0.36	0.45	-0.28	0.80	1		
9 Self-citation	0.31	0.27	-0.40	0.36	-0.46	0.18	-0.39	-0.36	1	
10 Cosine-similarity	0.40	0.37	-0.25	0.19	-0.28	0.20	-0.71	-0.63	0.31	1

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Table 1. Summary statistics

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t*. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Test statistics of the t-test and the Wilcoxon-test of the differences in innovation measures and firm characteristics between public firms and private firms are presented in the last two columns. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	Public firms					Private firms					Tests of difference	
	Mean (1)	StdDev (2)	P25 (3)	Median (4)	P75 (5)	Mean (6)	StdDev (7)	P25 (8)	Median (9)	P75 (10)	*t*-test (1) – (6)	Wilcoxon *z*-test (4) – (9)
Patent count	78.12	234.52	3.00	10.00	38.00	19.33	66.42	1.00	3.00	10.00	58.79***	7***
Citation count	302.09	974.15	6.58	27.62	130.63	64.81	315.19	1.69	7.55	29.28	237.28***	20.07***
Explore	0.48	0.30	0.26	0.44	0.67	0.58	0.35	0.30	0.50	1.00	-0.1***	-0.06***
Exploit	0.12	0.18	0.00	0.06	0.17	0.09	0.19	0.00	0.00	0.09	0.03***	0.06***
Scope	0.75	0.27	0.61	0.81	1	0.81	0.27	0.72	1	1	-0.06***	-0.19***
Depth	0.21	0.46	0.00	0.00	0.21	0.12	0.37	0.00	0.00	0.03	0.09***	0***
New-class	0.30	0.34	0.03	0.15	0.50	0.44	0.42	0	0.33	1	-0.14***	-0.17***
New-claim	0.34	0.36	0.04	0.18	0.61	0.51	0.43	0.05	0.46	1	-0.17***	-0.28***
Self-citation	0.08	0.09	0.01	0.05	0.11	0.04	0.07	0.00	0.01	0.05	0.04***	0.04***
Cosine-similarity	0.71	0.28	0.56	0.80	0.93	0.61	0.33	0.35	0.70	0.88	0.10***	0.10***
Patent stock	390.28	1263.70	8.00	34.00	141.00	76.06	263.63	1.00	8.00	35.00	314.22***	26***
Total assets ($M)	3425	9017	106	416	1977	2664	7642	22	176	1121	761***	240***
Leverage	17.20%	18.03%	0.69%	12.99%	28.18%	40.80%	30.76%	13.70%	38.13%	62.69%	-23.60%***	-25.14%***
ROA	4.57%	16.89%	-0.86%	8.00%	14.40%	1.08%	25.04%	0.00%	5.66%	13.74%	3.49%***	2.34%***
Sales growth	26.53%	69.12%	0.00%	11.00%	29.20%	28.34%	86.71%	0.00%	0.99%	17.50%	-1.81%***	10.01%***
Capex	5.32%	4.65%	2.26%	4.02%	6.80%	4.42%	5.58%	0.00%	2.82%	6.30%	0.90%***	1.20%***
R&D	8.24%	10.12%	1.07%	5.20%	11.80%	7.40%	20.03%	0.00%	0.00%	3.91%	0.84%***	5.20%***
PPE	21.43%	16.48%	8.78%	17.17%	29.82%	27.98%	20.16%	11.85%	23.28%	40.74%	-6.55%***	-6.11%***
Firm age	40	39	13	23	61	38	40	6	20	64	2*	3***

Table 2. Differences in innovation strategies between public and private firms

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t*. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
Public	-0.062***	0.028***	-0.045***	0.031**	-0.056***
	(0.012)	(0.008)	(0.011)	(0.015)	(0.016)
Ln(Patent stock)	-0.063***	0.022***	-0.052***	0.094***	-0.111***
	(0.003)	(0.002)	(0.002)	(0.005)	(0.003)
Ln(Total assets)	0.018***	-0.013***	0.022***	-0.022***	0.027***
	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)
Leverage	-0.013	0.007	-0.010	-0.024	0.009
	(0.018)	(0.011)	(0.016)	(0.029)	(0.020)
ROA	0.066***	-0.042***	0.068***	-0.059*	0.025
	(0.022)	(0.014)	(0.021)	(0.033)	(0.025)
Sales growth	-0.007*	0.000	-0.008**	0.015**	-0.001
	(0.004)	(0.002)	(0.003)	(0.007)	(0.004)
Capex	0.059	0.035	-0.044	0.127	0.045
	(0.084)	(0.051)	(0.075)	(0.110)	(0.093)
R&D	-0.040	0.016	-0.049	0.037	-0.072
	(0.042)	(0.027)	(0.039)	(0.074)	(0.050)
PPE	-0.043	-0.006	0.007	-0.076*	-0.034
	(0.029)	(0.018)	(0.026)	(0.045)	(0.033)
Ln(Firm age)	0.009**	-0.008***	0.018***	-0.038***	0.010**
	(0.004)	(0.002)	(0.004)	(0.005)	(0.005)
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Constant	0.332***	0.267***	0.365***	0.428***	0.222
	(0.123)	(0.057)	(0.096)	(0.102)	(0.156)
Observations	15,192	15,192	15,192	15,192	15,192
Adj R2	32%	12%	23%	16%	41%

Table 3. Propensity score-matched public firms and private firms

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Innovative firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t*. This table presents differences in the measures of innovation strategy between the propensity score-matched public firms and the private firms. We match each private firm to a public firm using the nearest neighbor algorithm. In Model 1, the variables we use to match are Ln(total assets) and industry times year fixed effects. In Model 2, the variables we use to match are Ln(total assets), Ln(patent stock), and industry times year fixed effects. In Model 3, the variables we use to match are all the explanatory variables in Table 2, except for the public firm indicator variable. To test pairwise differences in means between the two samples (i.e., matched public firms – private firms), we use bootstrapped standard errors based on 50 replications without replacement which are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
Model 1	-0.079***	0.037***	-0.058***	0.043***	-0.075***
	(0.012)	(0.007)	(0.010)	(0.013)	(0.016)
Model 2	-0.034***	0.021***	-0.020**	0.003	-0.015
	(0.012)	(0.007)	(0.009)	(0.012)	(0.017)
Model 3	-0.036***	0.020***	-0.028***	0.010	-0.035**
	(0.012)	(0.007)	(0.008)	(0.012)	(0.017)

Table 4. Using a transitioning sample of IPO firms

This table examines changes in innovation strategy around IPOs. The sample consists of 392 IPOs by innovative firms and their matched private firms over the sample period 1997-2008. We match each IPO firm to an innovative private firm that (1) is in the same industry, (2) stays private during the entire sample period, and (3) has the closest propensity score in the year prior to the IPO using the nearest neighbor algorithm. The variables we use to match include: Ln(total assets), leverage, ROA, sales growth, capital expenditures, R&D, and firm age. We track IPO firms' and matched private control firms' patenting activities from year *-5* to year *+5* centered at the IPO year (year *0*). All the control variables used in Table 2 are also included in this regression but unreported for brevity. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
PostIPO	-0.037***	0.036***	-0.038***	0.115***	-0.034***
	(0.010)	(0.007)	(0.011)	(0.029)	(0.012)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Firm/Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	3,605	3,605	3,605	3,605	3,605
Adj R2	26%	15%	27%	11%	27%

Table 5. The two-stage least squares regressions

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t*. Column (1) reports the first-stage linear probability regression with the public firm indicator variable as the dependent variable, and the state-level stock market participation rate in 1984 as the instrumental variable. Columns (2)-(6) report the second-stage OLS regressions where the dependent variables are different measures of innovation strategy and we replace the public firm indicator variable by its predicted value from the first stage. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) First stage predicting *Public*	(2) Explore	(3) Exploit	(4) Scope	(5) Depth	(6) New-class
Public		-0.098**	0.091***	-0.103***	0.105*	-0.104**
		(0.040)	(0.027)	(0.038)	(0.056)	(0.043)
Ln(Patent stock)	0.009***	-0.062***	0.021***	-0.052***	0.066***	-0.110***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.002)
Ln(Total assets)	0.029***	0.019***	-0.014***	0.024***	-0.010***	0.028***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)	(0.002)
Leverage	-0.517***	-0.031	0.038**	-0.038*	0.011	-0.021
	(0.017)	(0.023)	(0.016)	(0.022)	(0.038)	(0.026)
ROA	0.002	0.066***	-0.042***	0.069***	-0.061**	0.027*
	(0.019)	(0.015)	(0.010)	(0.014)	(0.024)	(0.017)
Sales growth	-0.010**	-0.007**	0.001	-0.008***	0.015***	-0.002
	(0.004)	(0.003)	(0.002)	(0.003)	(0.005)	(0.004)
Capex	0.605***	0.083	-0.008	-0.006	0.156	0.072
	(0.076)	(0.065)	(0.044)	(0.061)	(0.107)	(0.072)
R&D	-0.146***	-0.045	0.024	-0.056**	0.167***	-0.087***
	(0.039)	(0.029)	(0.020)	(0.027)	(0.048)	(0.033)
PPE	-0.211***	-0.053**	0.010	-0.008	-0.080**	-0.048**
	(0.026)	(0.022)	(0.015)	(0.020)	(0.036)	(0.024)
Ln(Firm age)	0.028***	0.010***	-0.010***	0.020***	-0.053***	0.012***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.005)	(0.003)
Stock market participation (IV)	0.109***					
	(0.030)					
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.404***	0.347***	0.242***	0.389***	0.181	0.248*
	(0.057)	(0.119)	(0.081)	(0.113)	(0.197)	(0.127)
Observations	15,192	15,192	15,192	15,192	15,192	15,192
Adj R2	28%	31%	11%	23%	14%	40%
F statistics of the test: IV = 0	12.85***					

Table 6. Using a sample of withdrawn IPO deals

This table examines changes in innovation strategy around IPOs. The sample consists of 392 IPOs by innovative firms and their matched withdrawn IPO firms over the sample period 1997-2008. We match each IPO firm to a withdrawn IPO firm that filed the IPO in the same year, in the same industry, and closest in firm size in the year prior to the IPO filing. We track IPO firms' and matched withdrawn IPO control firms' patenting activities from year *-5* to year *+5* centered at the IPO year (year *0*). In Panel A, we employ a difference-in-differences specification similar to Table 4. All the control variables used in Table 2 are also included in this regression but unreported for brevity. In Panel B, we run two-stage least squares regressions. Column (1) reports the first-stage linear probability regression with the IPO completion indicator variable as the dependent variable, and the market return in the first two months of the book-building phase as the instrumental variable. Columns (2)-(6) report the second-stage OLS regressions where the dependent variables are different measures of innovation strategy and we replace the IPO completion indicator variable by its predicted value from the first stage. The sample in Panel B is the same as that in Panel A, except that we focus on the post-IPO period following Bernstein (2015). All the control variables used in Table 2 are also included in this regression but unreported for brevity. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: IPO firms versus firms in withdrawn IPO deals

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
PostIPO	-0.041***	0.032***	-0.037*	0.160	-0.065***
	(0.015)	(0.010)	(0.021)	(0.175)	(0.017)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Firm/Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	2,154	2,154	2,154	2,154	2,154
Adj R2	21%	22%	24%	26%	36%

Panel B: IPO firms versus firms in withdrawn IPO deals using the market return as the instrumental variable

	(1) First stage predicting *IPO completion*	(2) Explore	(3) Exploit	(4) Scope	(5) Depth	(6) New-class
IPO completion		-0.934***	0.433***	-0.458**	0.211	-0.141*
		(0.196)	(0.114)	(0.218)	(0.745)	(0.083)
Market return (IV)	0.328***					
	(0.044)					
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,097	1,097	1,097	1,097	1,097	1,097
Adj R2	61%	65%	51%	24%	34%	44%
F statistics of the test: IV = 0	14.23***					

Table 7. Differences in firm information environments and innovation strategy

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t*. We divide the public firm sample into the high and low analyst-coverage subsamples based on the median number of analyst earnings forecasts. We then estimate Equation (1) by replacing the public firm indicator variable with the high analyst-coverage public firm (above the median) and low analyst-coverage public firm (below the median) indicator variables. The F-statistic to test the equality of coefficients on *High analyst-coverage public* = *Low analyst-coverage public* is provided at the bottom of the table. All the control variables used in Table 2 are also included in this regression but unreported for brevity. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
High analyst-coverage public (a)	-0.045***	0.021**	-0.031**	0.007	-0.054***
	(0.014)	(0.009)	(0.012)	(0.019)	(0.017)
Low analyst-coverage public (b)	-0.076***	0.032***	-0.054***	0.035**	-0.070***
	(0.012)	(0.008)	(0.011)	(0.018)	(0.017)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	14,599	14,599	14,599	14,599	14,599
Adj R2	32%	12%	24%	13%	41%
F-statistic of the test: (a) = (b)	11.35***	3.71*	6.59**	2.94*	2.74*

Table 8. Differences in CEO risk preferences and innovation strategy

Panel A replicates Table 2 by limiting data to a subsample of firms that were incorporated prior to 1980. The sample consists of 6,663 public firm-year observations and 909 private firm-year observations. Panel B replicates Table 4 by limiting data to a subsample of 108 IPO firms whose founders are the CEOs until year *+5* (the IPO year being year *0*). All the control variables used in Table 2 are also included in this regression but unreported for brevity. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Public and private firms incorporated prior to 1980

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
Public	-0.068***	0.022**	-0.046***	0.024	-0.001
	(0.017)	(0.011)	(0.016)	(0.020)	(0.023)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	7,572	7,572	7,572	7,572	7,572
Adj R2	37%	15%	19%	17%	41%

Panel B: IPO firms whose founders keep the CEO position up to year *+5* and matched private control firms

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
PostIPO	-0.025	0.029**	-0.044*	0.095*	-0.060*
	(0.020)	(0.014)	(0.025)	(0.057)	(0.031)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Firm/Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	977	977	977	977	977
Adj R2	30%	15%	27%	12%	36%

Table 9. Differences in corporate acquisitiveness and innovation strategy

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t*. We divide the public firm sample into the high and low acquisitive subsamples based on the median value of acquisition expenditures (normalized by total assets). We then estimate Equation (1) by replacing the public firm indicator variable with the high acquisitive public firm (above the median) and low acquisitive public firm (below the median) indicator variables. The F-statistic to test the equality of coefficients on *High acquisitive public = Low acquisitive public* is provided at the bottom of the table. All the control variables used in Table 2 are also included in this regression but unreported for brevity. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
High acquisitive public (a)	-0.055***	0.022***	-0.037***	0.019	-0.046***
	(0.012)	(0.008)	(0.011)	(0.016)	(0.016)
Low acquisitive public (b)	-0.066***	0.032***	-0.051***	0.030*	-0.062***
	(0.012)	(0.008)	(0.011)	(0.016)	(0.016)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	15,192	15,192	15,192	15,192	15,192
Adj R2	32%	11%	24%	14%	41%
F-statistic of the test: (a) = (b)	3.86**	6.68***	7.93***	1.48	6.88***

Table 10. Differences in investment horizon within public firms

The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t.* We divide the public firm sample into the short- and long-horizon subsamples based on the median value of CEOs' vested equity portfolios (Panel A), the median predicted probability of a firm becoming a hostile takeover target (Panel B where we first estimate a firm's likelihood of becoming a hostile takeover target by running a probit regression with the following explanatory variables: M/B, firm size, ROA, leverage, cash holdings, sales growth, and industry times year fixed effects), and the median transient institutional ownership (Panel C). We then estimate Equation (1) by replacing the public firm indicator variable with the short-horizon public firm (above the median) and long-horizon public firm (below the median) indicator variables. The F-statistic to test the equality of coefficients on *Short-horizon public = Long-horizon public* is provided at the bottom of the table. All the control variables used in Table 2 are also included in this regression but unreported for brevity. All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Investment horizon caused by CEOs' vested equity portfolios

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
Short-horizon public (a)	-0.068***	0.053***	-0.037***	0.057**	-0.094***
	(0.014)	(0.011)	(0.013)	(0.026)	(0.019)
Long-horizon public (b)	-0.044***	0.043***	-0.025*	0.033	-0.084***
	(0.015)	(0.011)	(0.013)	(0.026)	(0.019)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	8,576	8,576	8,576	8,576	8,576
Adj R2	36%	14%	25%	18%	42%
F-statistic of the test: (a) = (b)	11.12***	5.21**	3.30*	3.79*	1.92

Panel B: Investment horizon caused by the threat of hostile takeovers

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
Short-horizon public (a)	-0.069***	0.031***	-0.054***	0.035**	-0.063***
	(0.012)	(0.008)	(0.011)	(0.016)	(0.016)
Long-horizon public (b)	-0.050***	0.024***	-0.031***	0.009	-0.045***
	(0.013)	(0.008)	(0.011)	(0.018)	(0.017)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	15,192	15,192	15,192	15,192	15,192
Adj R2	32%	11%	24%	14%	41%
F-statistic of the test: (a) = (b)	7.11***	2.36	11.95***	4.59**	4.46**

Panel C: Investment horizon caused by the presence of transient institutional investors

	(1) Explore	(2) Exploit	(3) Scope	(4) Depth	(5) New-class
Short-horizon public (a)	-0.068***	0.034***	-0.053***	0.037**	-0.069***
	(0.013)	(0.008)	(0.011)	(0.016)	(0.017)
Long-horizon public (b)	-0.061***	0.023***	-0.039***	0.017	-0.049***
	(0.013)	(0.008)	(0.011)	(0.018)	(0.017)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year FEs	Yes	Yes	Yes	Yes	Yes
Observations	14,855	14,855	14,855	14,855	14,855
Adj R2	32%	11%	24%	14%	40%
F-statistic of the test: (a) = (b)	1.41	5.89**	6.12**	3.54*	7.66***

Table 11. Alternative measures of innovation strategy

This table replicates Table 2 using alternative measures of innovation strategy. The sample consists of 13,463 public firm-year observations (2,426 unique public firms) and 1,729 private firm-year observations (829 unique private firms) from 1997-2008, obtained from matching Capital IQ with the NBER/HBS patent databases. Sample firms in year *t* are required to have at least one patent over the three-year period from year *t-2* to year *t.* All dollar values are in 2008 dollars. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are provided in Appendix 1. Robust standard errors clustered at the firm level are reported in parentheses. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) New-claim	(2) Self-citation	(3) Cosine-similarity
Public	-0.036***	0.014***	0.079***
	(0.014)	(0.004)	(0.019)
Ln(Patent stock)	-0.127***	0.025***	0.063***
	(0.003)	(0.001)	(0.004)
Ln(Total assets)	0.029***	-0.012***	-0.008**
	(0.003)	(0.001)	(0.004)
Leverage	-0.008	-0.001	-0.044*
	(0.019)	(0.007)	(0.022)
ROA	0.029	-0.006	0.060**
	(0.025)	(0.009)	(0.027)
Sales growth	-0.010**	0.002	0.006
	(0.004)	(0.001)	(0.004)
Capex	-0.127	0.000	0.302***
	(0.092)	(0.029)	(0.103)
R&D	-0.048	0.009	0.053
	(0.048)	(0.016)	(0.055)
PPE	0.036	0.023**	-0.038
	(0.033)	(0.011)	(0.040)
Ln(Firm age)	0.033***	0.002	-0.045***
	(0.004)	(0.001)	(0.005)
Industry × Year FEs	Yes	Yes	Yes
Constant	0.143	0.336***	0.628***
	(0.162)	(0.074)	(0.166)
Observations	15,192	15,192	15,192
Adj R2	43%	27%	24%