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Does Market Overvaluation Promote Corporate Innovation?

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Abstract:

We test how market overvaluation affects corporate investment, innovative activities, and innovative success among middle market and larger firms. Middle market firms invest more heavily in R&D than larger firms, but larger firms generate much more patents. We find a strong positive association between equity overvaluation and subsequent R&D spending; this effect is three times as large for middle market firms as for larger firms. In contrast, there is no correlation between misvaluation and capital expenditure among middle market firms. This effect comes mainly from the direct catering channel, but also via the effect of misvaluation on equity issuance. The sensitivity of R&D to misvaluation is greater among growth, overvalued, financially unconstrained, and high turnover firms. Overvaluation is also associated with greater innovative output, measured by patent and citation counts, but this effect is weaker than the effect on R&D expenditure, and is only present among middle market firms. This suggests that there are substantial agency costs associated with overvalued equity. Overvaluation does not improve innovative efficiency (the ratio of patents to R&D) even among middle market firms.

Key Words: stock misvaluation, innovation, corporate investment, behavioral finance, market efficiency

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1 Introduction

Both efficient and inefficient market theories imply that higher stock prices should be associated with higher corporate investment—both the creation of tangible assets through capital expenditures, and the creation of intangible assets through research and development (R&D). Under the q theory of investment (Tobin (1969)), markets are efficient, so that a high stock price reflects strong growth opportunities. It follows that a high-priced firm should invest more. Such additional capital expenditures should increase future cash flows, and additional R&D expenditure should lead to greater innovative output, as reflected in new discoveries, techniques, or products.

Under what we call *the misvaluation hypothesis* of innovation, firms respond to overvaluation by investing more in innovative activities, resulting higher future innovative output. Equity overvaluation can stimulate investment by encouraging the firm to raise more equity capital (Stein (1996), Baker, Stein, and Wurgler (2003), Gilchrist, Himmelberg, and Huberman (2005)), thereby exploiting new shareholders for the benefit of existing shareholders, under the additional premise that firms are inclined to invest internal cash.[1] If the market overvalues a firm's new investment opportunities, the firm may commit to additional investment in order to obtain a high price for newly issued equity.

However, the misvaluation hypothesis does not require equity issuance. A manager who likes having a high short run stock price may invest heavily, even at the expense of long-term value, in order to induce or cater to optimistic market expectations (Stein

[1]Several authors provide evidence suggesting that firms time new equity issues to exploit market misvaluation, or manage earnings to incite such misvaluation—see, e.g., Ritter (1991), Loughran and Ritter (1995), Teoh, Welch, and Wong (1998b, 1998a), Teoh, Wong, and Rao (1998), Baker and Wurgler (2000), Henderson, Jegadeesh, and Weisbach (2006) and Dong, Hirshleifer, and Teoh (2012). There is also evidence that overvaluation is associated with greater use of equity as a means of payment in takeover (Dong et al. (2006)).

(1996), Polk and Sapienza (2009), Jensen (2005)).

Even if overvaluation encourages tangible or innovative investment, from a social viewpoint, it is crucial to understand whether the additional investment yields a commensurate payoff. The primary focus of this paper is innovation, so we examine the relationship of misvaluation with innovative expenditures (R&D), with total innovative output in the form of patents or patent citations; and with the efficiency of innovation (the ratio of patents or citations to R&D; see Hirshleifer, Hsu, and Li (2013)). Total innovative output tends to be increasing with R&D unless additional increments to R&D are negatively productive, whereas innovative efficiency can quite easily decline with R&D.

In this paper we test the misvaluation hypothesis of corporate innovation using an approach designed to distinguish traditional effects from misvaluation effects, and to probe the sources of misvaluation effects. This approach is to test the relationship between investment (either capital expenditures or R&D) or innovative output (patents or patent citations) with a single overall measure of misvaluation. A key feature of how we identify misvaluation as a predictor of investment or innovative output is that we examine the deviation of market price from a *forward-looking* measure of fundamental value.[2] Doing so filters from our misvaluation proxy the contaminating effects of prospects for future profit growth. Removing such contamination is crucial, since, as the q theory of investment implies, current investment should increase with the quality of investment opportunities; and because firms with better management teams should have higher q (Lang, Stulz, and Walkling (1989)) and optimally should invest more.

To do so, we apply the residual income model of Ohlson (1995) to obtain a measure of fundamental value, sometimes called 'intrinsic value' (V), and measure misvaluation

[2] In this respect our approach differs from that of Chirinko and Schaller (2001, 2012), who develop structural models of stock prices under efficient markets, in order to measure market misvaluation and its effect on corporate investment in Japan and the U.S.

by VP, the ratio of this value to market price.[3] Intrinsic value reflects both current book value and the discounted value of analyst forecasts of future earnings in excess of what would be expected based upon that book value. Since intrinsic value reflects growth prospects and opportunities, normalizing market price by intrinsic value filters out the extraneous effects of firm growth to provide a purified measure of misvaluation.

In contrast, misvaluation measures such as Tobin's q or equity market-to-book rely for their fundamental benchmarks on a backward looking value measure, book value. Such valuation ratios therefore reflect information about the ability of the firm to generate high returns on its assets. Indeed, many studies have viewed Tobin's q or related variables as proxies for earnings growth prospects, investment opportunities, or managerial effectiveness. So it is hard to distinguish misvaluation from other rational effects based solely on q or market-to-book as misvaluation measures.[4] Furthermore, Tobin's q is a measure of total firm misvaluation (setting aside the confounding with growth prospects). However, a better measure of the firm's access to underpriced equity capital is its *equity* misvaluation.

Training a purer measure of misvaluation upon the relationship between misvaluation and innovative activity allows us to probe the economic sources of these effects. We do so in three ways. First, we test the distinctive predictions of the misvaluation hypothesis for tangible versus intangible investments (capital expenditures versus R&D) as well as innovative output. Second, we explore the issue of whether the effect of misvaluation on investment and on innovative output operates through equity issuance. Third, we

[3] This measure of misvaluation has been applied in a number of studies to the prediction of subsequent returns (Frankel and Lee (1998), and Lee, Myers, and Swaminathan (1999)), repurchases (D'Mello and Shroff (2000)), and takeover-related behaviors (Dong et al. (2006)).

[4] To the extent that our purification is imperfect, variation in our purified measure would still reflect firm growth rather than misvaluation. If this problem were severe we would expect our measure to have a high absolute correlation with q. In our sample, the correlation with q is not especially strong (-0.274). Nevertheless, as a further precaution, we additionally control for growth prospects as proxied by book-to-market in our tests.

examine how investment and innovation sensitivities to misvaluation vary across size, financial constraint, turnover, growth, and valuation subsamples. This allows us to make comparisons of the effects of misvaluation among middle market firms (with annual sales between $10 million and $1 billion) versus larger firms (sales above $1 billion).

With regard to the first issue, we expect misvaluation to be especially important for innovative investment activities; empirically we identify a sharp contrast between the effect of misvaluation on the creation of intangible versus tangible assets.[5] This is an important topic, since R&D is a key source of technological innovation, and quantitatively is a major component of corporate investment, especially for middle market firms. Indeed, in our sample since 1997, R&D has been higher than capital expenditure for middle market firms though not for larger firms.

One reason to expect misvaluation to be more important for innovative investment is that, under the misvaluation hypothesis, measured misvaluation should be most strongly related to the form of investment that investors are most prone to misvaluing. Intangible investments such as R&D have relatively uncertain payoff, and therefore should tend to be relatively hard to value compared to ordinary capital expenditures.[6] Intangible investment projects will tend to present managers with greater opportunities for funding with overvalued equity, and for catering to project misvaluation. We find that middle market firms invest more heavily in R&D than large firms do, so this suggests that

[5] A previous literature examines the effects of misvaluation on equity issuance and on capital expenditures. With respect to R&D, Polk and Sapienza (2009) use the firm characteristic of high versus low R&D as a conditioning variable in some of their tests of the relation between misvaluation and capital expenditures. Baker, Stein, and Wurgler (2003) examine several measures of investment, one of which is the sum of capital expenditures and R&D, but do not examine whether misvaluation affects capital expenditures and R&D differently.

[6] Psychological evidence suggests that biases such as overconfidence will be more severe in activities (such as long-term research and product development) for which feedback is deferred and highly uncertain; see, e.g., Einhorn (1980). In the investment model of Panageas (2005), investment is most affected by market valuations when the disagreement about the marginal product of capital is greatest. Furthermore, there is evidence that greater valuation uncertainty is associated with stronger behavioral biases in the trades of individual investors (Kumar (2009)).

misvaluation is especially important for middle market firms.

A second reason why we expect stronger misvaluation effects on innovative investment is that industry- or market-wide overvaluation can help solve externality problems in innovation; a breakthrough by one firm can open opportunities for other firms. Network externalities in technology adoption and innovation have been emphasized, for example, in Katz and Shapiro (1986). Network externalities help explain the rise of innovative centers such as Silicon Valley. Owing to the self-reinforcing feature of positive network externalities, investment can be highly sensitive to determinants of the incentive to invest, such as overvaluation. Large diversified firms can to some extent internalize such externalities by exploiting breakthroughs in multiple divisions, so the innovative activities of middle market firms may be more strongly influenced by the network externality effects of misvaluation.

Thus, the misvaluation hypothesis predicts a stronger relation between misvaluation and R&D expenditures than between misvaluation and capital expenditures. Furthermore, the sensitivity of R&D expenditures to misvaluation should be especially strong among middle market firms.

Empirically, we find that misvaluation has a remarkably strong effect on R&D expenditure; the effect of a one standard deviation increase in overvaluation is much stronger than the effect of one standard deviation increases in cash flows, or of growth opportunities as proxied by book-to-market. In contrast, there is no correlation between misvaluation and capital expenditure among middle market firms. Furthermore, the sensitivity of R&D to misvaluation is three times as large for middle market firms as for larger firms.

There are good reasons to expect that misvaluation will affect R&D through both the equity issuance channel and the catering channel. With respect to the issuance channel, existing evidence indicates that misvaluation affects equity issuance (e.g., Dong, Hirshleifer, and Teoh (2012)), and that the ability of firms to innovate through R&D expenditures is highly dependent on financing (Li (2011)). On the other hand, innovative projects generate the kind of uncertain, exciting prospects that may incite overvaluation.

To weigh the importance of the different channels through which overvaluation operates, we conduct a path analysis of the R&D expenditure response to equity overvaluation. This reveals that over 85% of the total effect of misvaluation on R&D spending is through the direct catering channel; the remaining effect comes mainly from the equity channel. The debt channel contributes a mere 0.5% of the total effect. Such a disproportion between equity versus debt effects is exactly what would be expected under the misvaluation hypothesis, as the value of equity is more sensitive than the value of debt to firm misvaluation.

This evidence is consistent with the hypothesis that overvaluation induces firms to raise cheap equity capital to finance intangible investment, consistent with the models of Stein (1996) and Baker, Stein, and Wurgler (2003). Moreover, consistent with the theory of Jensen (2005) and the model of Polk and Sapienza (2009), misvaluation effects can operate outside the equity channel, and our evidence is consistent with these catering effects of misvaluation operating strongly on innovative expenditure.

With regard to the third issue, we probe further into the sources of the misvaluation effect by considering different subsamples which, under different hypotheses, should affect the strength of the relation between misvaluation and innovative investment and outcomes. The sorting variables for identifying subsamples include measures of financial constraints, firm size, share turnover, as well as growth opportunities and the degree of misvaluation.

We first find that misvaluation affects R&D expenditure much more strongly among growth firms than among value firms. This is consistent with the hypothesis that catering is effective when the firm possesses growth prospects. Also consistent with this interpretation, we find that innovative output, measured by patent counts and citations, is positively associated with overvaluation only among growth firms. In contrast, capital expenditure is only marginally related to overvaluation among growth firms, and unrelated to overvaluation in value firms.

Baker, Stein, and Wurgler (2003) find that the capital expenditures of financially constrained firms (where financial constraint is measured using the index of Kaplan and Zingales (1997)) are more sensitive to stock price than the capital expenditures of less constrained firms. Using our purified measure of misvaluation, equity VP, we find that capital expenditure is only positively associated with misvaluation among financially constrained firms, consistent with the hypothesis of Baker, Stein, and Wurgler (2003).[7] Among constrained firms, capital expenditure is negatively associated with overvaluation.

The effects for innovative investments are much stronger, and contrast sharply. We find that the R&D expenditures and innovative output of financially constrained firms (high KZ index) are *less* sensitive to market misvaluation than that of non-distressed firms.

A possible explanation for the contrast between the findings for capital expenditures and for R&D is that distressed firms are ill-positioned to take advantage of opportunities to build intangible assets, both because such assets generate real options which require future financial flexibility, and because stakeholders such as employees, suppliers, or customers are reluctant to commit to long-term relationships (Titman (1984)). Indeed, Bhagat and Welch (1995) find an inverse relationship between leverage and R&D among U.S. firms. The absence of complementary inputs from stakeholders for such initiatives

[7]Baker, Stein and Wurgler also perform tests using future realized stock returns to proxy for prior misvaluation. These tests are not their primary focus, presumably because it is challenging to identify an appropriate benchmark for risk adjustment—the risk of a stock is likely to be correlated with investment, leverage, and financial constraints. However, it is encouraging that both contemporaneous and ex post proxies for misvaluation provide confirmation of the Baker, Stein, and Wurgler (2003) model.

suggests that among financially constrained (high-KZ) firms R&D will be less sensitive to overvaluation than among low-KZ firms.

Polk and Sapienza (2009) propose that the sensitivity of investment to misvaluation should be higher when managers have a stronger focus on short-run stock prices, because a short horizon makes overvalued projects more attractive. Polk and Sapienza use turnover as a proxy for short-term focus by shareholders. We find that the sensitivity of R&D, but not capital expenditures, to misvaluation is higher among high-turnover firms. This suggests that pressures to maintain short-term valuation are more important for intangible than for tangible investment.

There are also reasons to expect the effects of misvaluation on investment to depend on firm size. Middle market firms may be more prone to misvaluation than large firms owing to lower transparency. On the other hand, middle market firms have less access to equity markets, potentially limiting their ability to respond to overvaluation by issuing equity to increase investment. Our finding that middle market firms have higher sensitivity than large firms of R&D and innovation output (but not capital expenditures) to misvaluation suggests that the catering and financing effects of overvaluation are more important for middle market firms than larger firms.

Finally, for two reasons, we expect misvaluation to have a stronger marginal effect on investment among overvalued firms. First, when there are fixed costs of issuing equity, overvalued firms should be more likely to issue than undervalued firms. A marginal shift in misvaluation does not change the scale of equity issuance for a firm that refrains from issuing equity at all. So among undervalued firms, we expect a relatively small effect on issuance and investment of a reduction in the undervaluation. A similar point holds if projects have a minimum efficient scale. In contrast, when overvaluation is sufficient to induce project adoption, greater overvaluation encourages greater scale of issuance and investment. Alternatively, managers of overvalued firms may be particularly anxious to undertake overvalued investments in order to cater to optimistic investor perceptions (Jensen (2005)).

Second, when there are positive network externalities, overvaluation will tend to have a nonlinear increasing effect on innovation; the sensitivity of innovative investment to incremental valuation is greater when valuation is high, owing to the larger base of innovative activities to build upon.

We test the hypothesis that misvaluation has a stronger marginal effect on investment among overvalued firms by sorting firms based upon VP ratios, and examining the relation of investment to valuation within quintiles. Empirically, we find that this hypothesis is confirmed for R&D; the sensitivity of R&D expenditure to VP is much higher among overvalued firms.

We also find that despite the much stronger sensitivity of R&D expenditure to VP among overvalued firms, there is only a modestly higher sensitivity of innovative *output* (patents or citations) among overvalued firms. This suggests that much of the increase in R&D spending of overvalued firms is motivated by catering rather than real innovation opportunities.

Finally, we examine the relation between equity overvaluation and innovative efficiency, measured by the ratio of innovative output to R&D expenditure. Based on the idea that there are network externalities in innovative activities, Shleifer (2000) argued that overvaluation during the millennial high-tech boom was socially beneficial in its encouragement of internet-related innovation. But overvaluation can also have adverse effects. Overvaluation-motivated investment does not necessarily generate commensurate output. Whether overvaluation results in a loss in efficiency of innovative activity, either in total or on the margin, is therefore an empirical question.

We find a negative association between overvaluation and innovation efficiency in the full sample; overvalued firms are less effective at converting R&D activity into patents and citations. This severely reduces the sensitivity of innovative output to overvaluation relative to the sensitivity of R&D to overvaluation. This evidence is consistent with agency costs of overvalued equity (Jensen (2005) and Polk and Sapienza (2009)).

Despite the fact that the investment of middle market firms is tilted more heavily than that of larger firms toward R&D rather than tangible investment, large firms have far greater innovative output as measured by patent and patent citation counts. For example, large firms produce an average 36.5 patents per year, far exceeding 2.3 patents for middle market firms. This suggests that middle market firms may face barriers in converting R&D expenditures into patentable discoveries, or alternatively that middle market firms find it profitable to focus on non-patentable forms of innovation (e.g., using secrecy to maximize first-mover advantage rather than acquiring patent protection). We find that, among middle market firms, greater overvaluation does not improve innovative efficiency. As with the full sample result, this is consistent with agency costs of overvalued equity.

A previous literature tests whether market valuations affect investment by examining whether stock prices have incremental predictive power above and beyond proxies for the quality of growth opportunities such as cash flow or firm profitability (Barro (1990), Blanchard, Rhee, and Summers (1993), Morck, Shleifer, and Vishny (1990), and Welch and Wessels (2000)). Bhagat and Welch (1995) find a weak link between past returns and R&D expenditures among U.S. firms. Such tests do not clearly distinguish the q theory of investment from the misvaluation hypothesis, since, even after controlling for profits, stock prices (or past returns) can reflect investment opportunities.

Other papers have used indirect approaches to test for the effects of misvaluation on investment. One approach is to examine whether tight financial constraints make investment more sensitive to firm value. Motivated by an extension of the model of

Stein (1996), Baker, Stein, and Wurgler (2003) find, consistent with their model, that the investment of financially constrained, or 'equity-dependent' firms is more sensitive to stock prices than that of firms that are not financially constrained.

This evidence is consistent with the idea that misvaluation affects investment more when the only effective way to fund investment is to raise new equity capital. However, Baker et al's misvaluation measure, Tobin's q, is also a measure of prospects for profit growth. Thus, an alternative interpretation of this evidence that better profit growth prospects increase investment more among financially constrained firms.[8]

Another approach to testing the misvaluation hypothesis is to relate investment to variables that are expected to correlate with misvaluation, such as discretionary accruals (Polk and Sapienza (2009)), and dispersion in analyst forecasts of earnings (Gilchrist, Himmelberg, and Huberman (2005)). These papers provide several findings consistent with misvaluation effects.[9] The intuitions for these variables as misvaluation proxies are appealing.[10] However, such tests are still indirect in the sense that they focus upon particular hypothesized correlates of misvaluation, rather than trying to measure directly the overall misvaluation of the firm's equity.[11]

[8]Baker, Stein, and Wurgler discuss how strong profit growth prospects can mitigate adverse selection problems with the funding of investments. Similarly, strong profit growth prospects mitigate debt overhang problems by increasing the expected payoff to providers of new equity.

[9]Polk and Sapienza find that discretionary accruals are positively related to investment and that this effect is stronger among firms with higher R&D intensity (which are presumably harder to value correctly), and among firms that have high share turnover (a measure of the degree to which current shareholders have short time horizons). This suggests that managers invest in order to boost the short-term stock price, a 'catering' policy. Polk and Sapienza also find (see also Titman, Wei, and Xie (2004)) that capital expenditures negatively predict returns, consistent with high-investment firms being overvalued. Gilchrist, Himmelberg, and Huberman (2005) find that greater dispersion in analyst forecasts of earnings is associated with higher aggregate equity issuance and capital expenditures.

[10]Discretionary accruals are hypothesized to be related to misvaluation because investors fail to distinguish between cash flows and accounting adjustments to earnings. Dispersion of analyst forecasts is hypothesized to correlate with investment because optimistic investors buy the stock but pessimists fail to sell short. Some authors, however, have argued that the ability of these variables to predict returns reflects rational risk effects.

[11]For example, sometimes investors may be in agreement in overvaluing a firm. Such overvaluation would not be captured by a dispersion of analyst forecast measure. Similarly, a firm can be misvalued even when there is no active attempt by managers to manipulate earnings, and misvaluation can vary for

2 Data and Methodology

Our sample includes U.S. firms listed on NYSE, AMEX, or NASDAQ that are covered by CRSP and COMPUSTAT and are subject to the following restrictions. We require firms to have the earnings forecast data from I/B/E/S, in addition to possessing the necessary accounting items, for the calculation of the residual income model value to price (VP) ratio. Consequently, our sample starts from 1976 when I/B/E/S reporting begins. Finally, we exclude financial firms (firms with one-digit SIC of 6) and utility firms (two-digit SIC of 49). Our final sample has a total of 62,815 firm-year observations with non-missing equity misvaluation measures between 1976 and 2012. Our misvaluation measures, BP and VP, are described below.

We examine the relation between firm innovation (innovative input as measured by R&D, and innovative output and efficiency variables described below) and the misvaluation level of the firm's equity. We relate the firms' innovation activity during each fiscal year to the firms' misvaluation measure that is calculated at the beginning of the fiscal year. For example, for a firm with December fiscal year end, we relate the misvaluation measure calculated at the end of December 2003 to the innovation activity for fiscal year ending in December 2004.

Our sample includes firms with different fiscal year-ends. To line up firms in calendar time for the cross-sectional analysis, we use June as the cut-off. We allow for a four-month gap from the fiscal year end for the accounting data to be publicly available. Under this timing convention, for calendar year t, we include firms with fiscal year ends no later than February of year t, and no earlier than March of year $t-1$. Note, therefore, that for the majority of firms, the investment expenditures actually occur one calendar year prior. For example, for year 2005, the investment expenditures for

reasons other than variations in current earnings (as affected by accruals). These considerations suggest that it is useful to test the misvaluation hypothesis using a more inclusive measure of misvaluation.

firms with December fiscal year end (the majority of firms) actually occur between January and December of 2004, and the misvaluation measure is calculated in December 2003. The timing for innovative output is similar. We compare the investment and innovative output levels cross-sectionally among sample firms each year, and aggregate the comparison results across time.

2.1 Innovative Output and Efficiency Measures

Data from patent citations are constructed from the November 2011 edition of the patent database of Kogan, Papanikolaou, Seru, and Stoffman (see Kogan et al. (2013)). This database covers U.S. patent grants patent citations from up to 2010. Patents are included in the database only if they are eventually granted. Furthermore, there is on average a two-year lag between patent application and patent grant. Since the latest year in the database is 2010, we end our observations of patent citations in 2008 to reduce measurement bias caused by the application-grant period lag. Since we require non-missing observations of our key misvaluation measure, our data of patents and citations all start from 1976.

We measure innovative output by four variables. The first and simplest measure is the number of patents applied by the firm each year ($NPAT$). However, simple patent counts imperfectly capture innovation success as patent innovations vary widely in their technological and economic importance. Following the literature (e.g., Hall, Jaffe, and Trajtenberg (2001, 2005)), we measure the importance of patents by their citation counts. Our second measure of innovative output is the sum of citations received by patents applied for each year, adjusted by technological class and year fixed effects ($TTCITES$).

We also use the generality and originality of patents as two additional innovative output measures. Following Trajtenberg, Henderson, and Jaffe (1997), we define the generality of patent i as:

$$GENERALITY_i = 1 - \sum_{j}^{n_i} s_{ij}^2$$

where s_{ij} denotes the fraction of citations received by patent i that belong to patent class j, out of n_i patent classes (note that the sum is the Herfindahl concentration index). Thus, if a patent is cited by subsequent patents that belong to a wide (narrow) range of fields the generality measure will be high (low). Originality of patent i is defined in the same way, except that it refers to citations made by patent i. Thus, if a patent cites previous patents that span a wide (narrow) set of technologies the originality score will be high (low).

In all of our portfolio sorts and regression tests, we use log transformed values of these four patent and citation measures to control for the effects of extreme outliers.

Finally, following Hirshleifer, Hsu, and Li (2013), we define innovative efficiency by the ratio of innovative output as measured by $NPAT$ or $TTCITES$ by the R&D expenditure, denoted as IE_NPAT and $IE\_TTCITES$, respectively.[12]

2.2 Investment and Control Variables

We measure firms' investment activities using the following accounting data from COMPUSTAT annual files: Research and Development expenditures (item XRD) and capital expenditures (item CAPX). Our investment variables, RD and $CAPX$, are scaled by previous year total assets (item AT).[13] As in previous studies on investment and valua-

[12] We have verified out test results using patent and citation variables constructed from the 2006 edition of the NBER patent database (Hall, Jaffe, and Trajtenberg (2001, 2005)). Results using the NBER patent data are similar to those reported in the paper when we keep the same sample period, with somewhat lower significance levels.

[13] Some studies use net plant, property, and equipment (PP&E) as well as total assets scalings. However, this paper includes non-manufacturing firms for which intangible assets are especially important, and compares the effects of misvaluation on the creation of intangible assets through R&D with the effect on tangible asset creation through capital expenditures. A scaling that reflects both kinds of assets seems most appropriate for this purpose.

tion, all variables, include the ones described below, are winsorized at the 1st and 99th percentile to mitigate the influence of outliers.

Panel A of Table 1 reports summary statistics of the investment and innovation variables. We do not delete a firm-year observation simply because a certain variable is missing.

We need equity and debt issuances to examine the equity and debt channel of the effect of misvaluation on investment. We measure firms' equity and debt issuances using accounting data from the COMPUSTAT annual files. Following Baker and Wurgler (2002), equity issuance (EI) is measured as the change in book equity minus the change in retained earnings [Δ book equity (COMPUSTAT item CEQ) + Δ deferred taxes (item TXDB) $-$ Δ retained earnings (item RE)] scaled by lagged assets, and debt issuance (DI) is the change in assets minus the change in book equity [Δ total assets (item AT) - Δ book equity (item CEQ) $-\Delta$ deferred taxes (item TXDB)] scaled by lagged assets. Thus, these are net issuance variables. The payment of a dividend out of retained earnings does not affect these measures, since the reduction in book equity is offset by the reduction in retained earnings.

In the multivariate tests, we also control for other investment determinants. These control variables include cash flow [item IB + item DP + RD] scaled by lagged assets [missing RD (item XRD) is set to zero]. In addition, we include leverage (LEV) defined as (item DLTT + item DLC)/(item DLTT + item DLC + item SEQ), and (to control for profitability and perhaps firm risk) return on assets (ROA) defined as earnings before depreciation (item OIBDP) plus R&D expenses (missing RD is set to zero) scaled by total assets. Also, since DeAngelo, DeAngelo, and Stulz (2010) find that mature firms are less likely to issue new equity, we control for firm age. Following DeAngelo, DeAngelo, and Stulz (2010), we define AGE as the number of years between the beginning of fiscal year and the delisting date, truncated at 20 (results are not sensitive to this truncation).

Finally, to further control for firm risk we include the loadings of the Fama-French three factors estimated using monthly returns over the previous five years or at least two years due to missing observations. Table 1, Panel B presents summary statistics of these control variables.

2.3 Motivation for and Calculation of Mispricing Proxies

The reliability of the inferences we draw about the misvaluation hypothesis of corporate investment rests upon the quality of our misvaluation proxies, BP and primarily VP. The validity of our approach, however, does *not* require that either book value or residual income value be a better proxy for rational fundamental value than market price. We merely require that these measures contain substantial incremental information about fundamentals above and beyond market price. We would expect them to do so if a significant portion of variations in market price derives from misvaluation.

In support of the BP proxy, an extensive literature finds that firms' BP ratios are remarkably strong and robust predictors of the cross-section of subsequent one-month returns (see, e.g., the review of Daniel, Hirshleifer, and Teoh (2002)). Psychology-based theoretical models imply that BP is a proxy for misvaluation, and thereby will predict subsequent abnormal returns (see, e.g., Barberis and Huang (2001) and Daniel, Hirshleifer, and Subrahmanyam (2001)). Market values reflect both mispricing, risk, and differences in true unconditional expected cash flows (or scale). Book value can help filter out irrelevant scale differences, and so BP can provide a less noisy measure of mispricing (see Daniel, Hirshleifer, and Subrahmanyam (2001)). On the other hand, BP is a natural proxy for risk as well. An active debate remains about the extent to which BP-based return predictability reflects a rational risk premium or correction of mispricing.[14]

[14]See, e.g., Fama and French (1996) and Daniel and Titman (1997), and the review of Daniel, Hirsh-

The association of BP with subsequent abnormal returns suggests that there is a misvaluation or risk component to the variation of BP. However, BP has been used as a proxy not just for misvaluation or for risk, but also for growth opportunities and for the degree of information asymmetry (Martin (1996)). Furthermore, proxies for Tobin's q that are highly correlated with BP have been employed to measure the quality of corporate growth opportunities and the degree of managerial discipline. A further source of noise in BP for our purposes is that book value, the numerator of BP, is influenced by firm and industry differences in accounting methods.

We calculate BP as a ratio of equity rather than total asset values, because it is equity rather than total misvaluation that is likely to matter for corporate investment decisions; a similar point applies for VP. This would be the case, for example, for a firm with overvalued stock to raise equity rather than debt capital to finance an investment project.

There is also strong support for VP as an indicator of mispricing. Lee, Myers, and Swaminathan (1999) find that aggregate residual income values predict one-month-ahead returns on the Dow 30 stocks better than aggregate BP. Frankel and Lee (1998) find that V is a better predictor than book value of the cross-section of contemporaneous stock prices, and that VP is a predictor of the one-year-ahead cross-section of returns. Furthermore, Ali, Hwang, and Trombley (2003) report that the abnormal returns associated with high VP are partially concentrated around subsequent earnings announcements. They also report that after controlling for a large set of possible risk factors (including beta, size, book/market, residual risk, and loadings from the Fama and French (1996) three-factor model), VP continues to predict future returns significantly. These findings

leifer, and Teoh (2002). Some more recent empirical papers addressing factor risk versus mispricing as explanations for the BP premium include Griffin and Lemmon (2002), Cohen, Polk, and Vuolteenaho (2003) and Vassalou and Xing (2004).

make VP an attractive index of mispricing.[15]

There are other possible indices of misvaluation.[16] The residual income value has at least two important advantages over book value as a fundamental measure. First, it is designed to be invariant to accounting treatments (to the extent that the 'clean surplus' accounting identity obtains; see Ohlson (1995)), making VP less sensitive to such choices. Second, in addition to the backward-looking information contained in book value, it also reflects analyst forecasts of future earnings.

Of course, it is possible that in the process of filtering out extraneous information, some genuine information about mispricing is also filtered out from VP. In our sample, the correlation of BP with VP is fairly low, 0.233. Thus, VP potentially offers useful independent information beyond BP regarding misvaluation. This is to be expected, as much of the variation in book/market arises from differences in growth prospects or in managerial discipline that do not necessarily correspond to misvaluation.

Turning to procedure, we calculate the BP proxy as the ratio of book value of equity to market value of equity. Each month for each stock, book equity (Item 60) is measured at the end of the prior fiscal year.[17] Market value of equity is measured at the end of the month.

Our estimation procedure for VP is similar to that of Lee, Myers, and Swaminathan (1999). For each stock in month t, we estimate the residual income model (RIM) price,

[15]For example, D'Mello and Shroff (2000) apply VP to measure mispricing of equity repurchasers. As in Dong et al. (2006), our focus is on measuring market pricing errors relative to publicly available information. We therefore calculate our misvaluation proxies solely using contemporaneous information (current price, book value, and analyst forecasts).

[16]An alternative measure which we do not examine is the earnings/price ratio. Earnings price ratios have several drawbacks for our purposes. First, earnings/price is not as strong a predictor of month-ahead stock returns as book/market (see, e.g., Fama and French (1996)), suggesting that it is a less accurate measure of mispricing. Second, short-term earnings fluctuations will tend to shift earnings/price even if the degree of misvaluation is unchanged. Third, and relatedly, negative earnings are more common than negative book values, leading more frequently to negative values of earnings/price.

[17]Using the definition as in Baker and Wurgler (2002) for book equity value does not change our results materially but reduces our sample size.

denoted by $V(t)$. With the assumption of "clean surplus" accounting, which states that the change in book value of equity equals earnings minus dividends, the intrinsic value of firm stock can be written as the book value plus the discounted value of an infinite sum of expected residual incomes (see Ohlson (1995)),

$$V(t) = B(t) + \sum_{i=1}^{\infty} \frac{E_t[\{ROE(t+i) - r_e(t)\}\ B(t+i-1)]}{[1+r_e(t)]^i},$$

where E_t is the expectations operator, $B(t)$ is the book value of equity at time t (negative $B(t)$ observations are deleted), $ROE(t+i)$ is the return on equity for period $t+i$, and $r_e(t)$ is the firm's annualized cost of equity capital.

For practical purposes, the above infinite sum needs to be replaced by a finite series of $T-1$ periods, plus an estimate of the terminal value beyond period T. This terminal value is estimated by viewing the period T residual income as a perpetuity. Lee, Myers, and Swaminathan (1999) report that the quality of their $V(t)$ estimates was not sensitive to the choice of the forecast horizon beyond three years. The residual income valuations are also likely to be less sensitive to errors in terminal value estimates than in a dividend discounting model; pre-terminal values include book value, so that terminal values are based on residual earnings rather than full earnings (or dividends).[18] Of course, the residual income $V(t)$ cannot perfectly capture growth, so our misvaluation proxy VP does not perfectly filter out growth effects. However, since V reflects forward-looking earnings forecasts, a large portion of the growth effects contained in BP should be filtered out of VP.

We use a three-period forecast horizon:

$$\begin{aligned} V(t) &= B(t) + \frac{[f^{ROE}(t+1) - r_e(t)]\, B(t)}{1+r_e(t)} + \frac{[f^{ROE}(t+2) - r_e(t)]\, B(t+1)}{[1+r_e(t)]^2} \\ &\quad + \frac{[f^{ROE}(t+3) - r_e(t)]\, B(t+2)}{[1+r_e(t)]^2\, r_e(t)}, \end{aligned} \tag{1}$$

[18]For example, D'Mello and Shroff (2000) found that in their sample of repurchasing firms, firms' terminal value was on average 11% of their total residual income value, whereas using a dividend discount model the terminal value was 58% of total value.

where $f^{ROE}(t+i)$ is the forecasted return on equity for period $t+i$, the length of a period is one year, and where the last term discounts the period $t+3$ residual income as a perpetuity.[19]

Forecasted ROE's are computed as

$$f^{ROE}(t+i) = \frac{f^{EPS}(t+i)}{\bar{B}(t+i-1)}, \quad \text{where} \quad \bar{B}(t+i-1) \equiv \frac{B(t+i-1)+B(t+i-2)}{2},$$

and where $f^{EPS}(t+i)$ is the forecasted EPS for period $t+i$.[20] We require that each of these f^{ROE}'s be less than 1.

Future book values of equity are computed as

$$B(t+i) = B(t+i-1) + (1-k)\, f^{EPS}(t+i),$$

where k is the dividend payout ratio determined by

$$k = \frac{D(t)}{EPS(t)},$$

and $D(t)$ and $EPS(t)$ are respectively the dividend and EPS for period t. Following Lee, Myers, and Swaminathan (1999), if $k < 0$ (owing to negative EPS), we divide dividends by ($0.06 \times$ total assets) to derive an estimate of the payout ratio, i.e., we assume that earnings are on average 6% of total assets. Observations in which the computed k is greater than 1 are deleted from the study.

The annualized cost of equity, $r_e(t)$, is determined as a firm-specific rate using the CAPM, where the time-t beta is estimated using the trailing five years (or, if there is not enough data, at least two years) of monthly return data. The market risk premium

[19] Following Lee, Myers, and Swaminathan (1999) and D'Mello and Shroff (2000), in calculating the terminal value component of V we assume that expected residual earnings remain constant after year 3, so that the discount rate for the perpetuity is the firm's cost of equity capital.

[20] If the EPS forecast for any horizon is not available, it is substituted by the EPS forecast for the previous horizon and compounded at the long-term growth rate (as provided by I/B/E/S). If the long-term growth rate is not available from I/B/E/S, the EPS forecast for the first preceding available horizon is used as a surrogate for $f^{EPS}(t+i)$.

assumed in the CAPM is the average annual premium over the riskfree rate for the CRSP value-weighted index over the preceding 30 years. Any estimate of the CAPM cost of capital that is outside the range of 5%-20% is winsorized to lie at the border of the range. Previous studies have reported that the predictive ability of VP was robust to the cost of capital model used (Lee, Myers, and Swaminathan (1999)) and to whether the discount rate was allowed to vary across firms (D'Mello and Shroff (2000)).

The benchmark for fair valuation is not equal to 1 for either ratio, for two reasons. First, book is an historical value that does not reflect growth. Second, residual income model valuations have been found to be too low on average. Thus, our tests consider relative comparisons these misvaluation proxies: higher (lower) values of BP or VP indicate relative undervaluation (overvaluation).

Panel C of Table 1 reports summary statistics the two valuation ratios. We retain negative V values caused by low earnings forecasts, because such cases should also be informative about overvaluation. We use VP as a measure of undervaluation (rather than P/V as a measure of overvaluation), because negative values of P/V should indicate over- rather than under- valuation. For consistency we also use BP rather than P/B. Removing negative VP observations (about 5% of the sample) tends to reduce statistical significance levels in our tests without materially altering the results.

2.4 Conditioning Variables

Previous research has documented that proxies for the degree of financial constraints and the degree of investor short-termism affect the relationship between misvaluation and capital expenditures. As discussed in the introduction, there is theoretical motivation for such tests. Here we offer tests for these effects using an overall contemporaneous measure of misvaluation, VP, that is purified of growth effects. The first conditioning variables we examine is the KZ index, as defined in Kaplan and Zingales (1997), a measure of financial constraints. Baker, Stein, and Wurgler (2003) show that corporate investment should be more sensitive to stock valuation level in financially constrained firms (high KZ index). Following Lamont, Polk, and Saa-Requejo (2001) and Baker, Stein, and Wurgler (2003), the original KZ index for year t is defined as

$$KZ_t(five\ variable) = -1.002CF_t - 39.368DIV_t - 1.315C_t + 3.139LEV_t + 0.283q_t,$$

where CF_t is cash flow scaled by lagged total assets; DIV_t is cash dividends scaled by lagged assets; C_t is cash balances scaled by lagged assets; LEV_t is leverage , and q_t is Tobin's q.

Since q contains market price, it should be correlated with market misvaluation, and has been used as a misvaluation proxy in past literature. To avoid using a conditioning variable for financial constraint that contains the misvaluation effects we are testing for, following Baker, Stein, and Wurgler (2003) we construct a four-variable version of the KZ index (excluding q) for year t:

$$KZ_t = -1.002CF_t - 39.368DIV_t - 1.315C_t + 3.139LEV_t.$$

Second, firm size, as measured by total assets, is a natural conditioning variable relating to multiple effects. Middle market firms may be more prone to market misvaluation than large firms because of greater uncertainty and information asymmetry between investors and insiders, and lower liquidity. Middle market firms also tend to have less access to external capital.

Third, Polk and Sapienza (2009) examine a catering theory that the investment sensitivity to misvaluation will be higher when there is a higher fraction of short-term investors. They document that the sensitivity of capital expenditures to misvaluation is higher for stocks with high share turnover (here, measured as monthly trading volume as a percentage of total number of shares outstanding).[21]

[21] It has been suggested that the trading volumes in NASDAQ and NYSE/AMEX may not be directly

Panel D of Table 1 reports summary statistics of the conditioning variables that potentially influence valuation-sensitivity. These three variables are not highly correlated with each other, with the highest correlation being only 0.052 (between the KZ index and total assets). In the tests to follow, we examine how market valuations affect capital expenditures and R&D investment in the full sample, as well as in subsamples formed based upon these variables.

2.5 Time Patterns in Investment and Valuations

Table 2 reports yearly descriptive information for our sample during 1976-2012. Capital expenditures are relatively stable over time, but there is a marked decrease after 2001, suggesting that companies generally cut capital spending after the burst of the stock market bubble. This decrease in $CAPX$ is coupled with a drastic drop in cash flow in 2002 (untabulated). R&D activities, on the other hand, have wider variations but generally increase over time, and decline slightly after 2001. As mentioned in the introduction, after 1996, RD overtakes $CAPX$ as the larger component of corporate investment, growing much larger toward the end of the sample period. These facts emphasize the importance of examining RD in addition to $CAPX$.

Table 2 also shows that overall, VP is higher than BP, suggesting, as expected, that residual earnings add value to stocks on average. The VP mean (median) of 0.79 (0.69) is substantially greater than the BP mean (median) of 0.62 (0.61). VP has a higher mean than BP each year in the sample except for the following recession years: 2002-2003 and 2008-2010.

comparable. Our conclusions with respect to share turnover are qualitatively unchanged when, following LaPlante and Muscarella (1997), we divide the NASDAQ trading volume by a factor of 2, or when we separate the NASDAQ and NYSE/AMEX listed firms in the tests.

3 How Misvaluation Affects Innovation: Portfolio Tests

This section provides portfolio tests of the effect of misvaluation on corporate investment and innovation. Although VP is designed to filter out earnings growth prospects, such filtering may be imperfect for a number of reasons. For example, we do not possess analyst forecasts to dates arbitrarily far in the future. Since book value is not forward-looking, BP should contain a mixture of information about growth prospects and misvaluation (see, e.g., the model of Daniel, Hirshleifer, and Subrahmanyam (2001)). Therefore, as a more stringent test for misvaluation effects, we perform a double filter of growth prospects from price by testing the relation between VP and issuance after controlling for BP. This test is stringent in the sense that controlling for BP may also remove from VP some of the information about misvaluation.

We perform 2-way sorts of firms into portfolios by BP and VP. Each year, firms are sorted into quintile portfolios according to the beginning-of-fiscal-year BP, and independently, on VP. The intersection of the BP- and VP-quintiles creates 25 BP-VP portfolios. The valuation portfolios are formed annually to ensure that any effects we identify are cross-sectional, and therefore not driven by time-series swings in market valuation and investment activities. Each year mean investment or innovative output levels are computed for each quintile. Finally, time-series mean levels for each quintile is computed.

Table 3 reports the time-series means of R&D and innovative output variables for each portfolio. We also report the inter-quintile difference along BP and VP and the mean innovation-valuation sensitivity ratios β_{BP} and β_{VP} as defined in the table caption, and the associated t-statistics.

Panel A reports the findings for RD. Holding BP constant, across each BP-column, we observe that greater overvaluation (lower VP) is associated with greater RD, consistent with overvaluation encouraging R&D spending. For example, among growth firms (BP1), the most overvalued firms invest 16.15% in R&D as a percentage of total assets, nearly twice the level the most undervalued firms invest on R&D (8.51%), with the difference statistically significant ($t = 6.09$).[22] Across the BP portfolios, the most overvalued firms (VP1) outspend the most undervalued firms (VP5) in R&D in every subgroup.

Holding misvaluation as measured by VP constant, across each VP-row, we also see that growth firms issue more equity. For example, measured by the innovation-to-BP ratio β_{BP}, this sensitivity ratio varies from 4.85 ($t = 7.70$) among most overvalued firms to 4.09 ($t = 5.67$) among most undervalued firms.

Turning to Panel B, we first note that, holding VP constant, we continue to observe that growth firms invest more in capital expenditure than value firms. However, in sharp contrast, there is no evidence that overvaluation as measured by VP boosts capital expenditure, holding BP constant. In fact, among value firms (BP3-BP5), there is quite strong evidence that *under*valued firms invest more in capital expenditure (with t-statistic of the difference in β_{VP} exceeding 2.52 in magnitude). Since capital spending is capitalized rather than expensed, one interpretation of this finding is that undervalued firms tend to engage in capital expenditure in an attempt to increase valuation. This finding highlights the importance of using VP as an improved misvaluation measure which filters out growth opportunities contained in BP and allied variables.

In Panels C through F, we see that innovative output, measured by patent or citations counts, also increases with overvaluation, especially among the top two growth firms (BP1 and BP2). For example, measuring output by $TTCITES$ (Panel D), innovative

[22] The difference between the most overvalued and undervalued firms, 8.18%, is not exactly equal to the difference between 16.15% and 8.51% because of a missing observation of RD in the BP1-VP5 portfolio in 1976.

output of the top valuation quintile is much higher than that of the bottom quintile, with a significant innovation-to-VP ratio ($t > 3.0$) in the top two growth quintiles. However, holding BP fixed, the relation between innovative output and VP is nonlinear with the output level peaking in the middle VP quintiles (most often BP2 or BP3). This may suggest that, even though the most overvalued firms tend to have the highest R&D expenditures, part of the investment is driven by catering incentives to maintain short-term high valuation.

4 Multivariate Tests

We perform multivariate tests with additional controls to verify the robustness of the innovation-valuation relations documented in the previous section, and perform tests to evaluate whether misvaluation effects on innovation operate through equity issuance. The controls we use include cash flow scaled by lagged assets, leverage, equity and debt issuance scaled by lagged assets, firm age, and 2-digit SIC major industry dummies as defined by Moskowitz and Grinblatt (1999).

Polk and Sapienza (2009) point out that in general equity issuance constitutes a relatively low fraction of the capital used by firms for capital investment. This helps explain why much of the misvaluation effect on investment does not operate through equity issuance. Nevertheless, the misvaluation hypothesis in general suggests that overvaluation should increase equity issuance and investment (Stein (1996), Baker, Stein, and Wurgler (2003), Gilchrist, Himmelberg, and Huberman (2005)), and as discussed in the introduction, there is evidence that equity issuance is associated with overvaluation. These past findings suggest that it is interesting to test whether misvaluation influences investment through the issuance of overvalued securities.

We report five regression specifications for each dependent variable. In model (1), our baseline specification, we include both BP and VP to examine whether there is incremental explanatory power from VP as a misvaluation measure given BP. If so, this provides a fairly stringent confirmation that the identified effect is a result of misvaluation, rather than the earnings growth fundamentals that are correlated with book/market. In model (2), we add equity and debt issuances to gauge the effect of VP through the financing channel. The cross-sectional test of Table 3 suggests nonlinear effects of VP and BP on innovation. Therefore, in models (3) to (5), we include square terms of VP and BP as well as their interaction in the regression to provide a robustness check of the effect of misvaluation on innovation.

4.1 Full Sample Tests

Table 4 presents regression results for the full sample. We present estimation of the effect of VP on RD and innovative output measures: the number of patents ($NPAT$), patent citations ($TTCITES$), generality and originality of patents, innovative efficiency measured by patent and citation counts scaled by R&D expenditure, and return on R&D spending ($RORD$).

The strength of the positive association between misvaluation and R&D is impressive. The coefficient on VP is highly significant in all specifications. In regression (1), which controls for BP, VP has a coefficient of -3.17 ($t = -15.14$).

To gauge the economic importance of the investment-valuation relation, we examine the effect of a one-standard-deviation shift in VP on investment levels; and compare this to the effect of a comparable shift in cash flow. Table 1 shows that the standard deviations of VP and cash flow are 0.69 and 14.69%, respectively (where cash flow is expressed as a percent of total assets). According to the RD regression specification (1), a one-standard-deviation shift in VP therefore implies a 2.19% (3.17×0.69) change in RD (where investment is expressed as a percent of total assets.) This compares with a 1.18% (0.08×14.69) change in RD for a one-standard-deviation shift in cash flow, implying that the effect of misvaluation on corporate R&D investment is about twice the size of the effect of cash flow. A similar analysis reveals that the effect of VP on RD is more than 8 times greater than the effect of BP.

In sharp contrast with the strong relation between misvaluation and R&D, and consistent with the portfolio evidence of Table 3, there is no significant relation between VP and $CAPX$; in model (1), VP actually has a positive point estimate (coefficient = 0.11; $t = 0.67$).

A comparison of models (1) and (2) for each of the dependent variables shows that the coefficient on VP decreases only modestly when the equity and debt issuance variables EI and DI are included. This is similar to the findings of Polk and Sapienza (2009) for $CAPX$ using discretionary accruals as a misvaluation proxy, and suggests that the financing channel explains little of the misvaluation effect.

Also consistent with the cross-sectional evidence, we find that equity overvaluation is associated with higher innovative output. VP in the $NPAT$ regression is significant and negative (coefficient = -0.07; $t = -2.25$). Similar results hold when we use measures of patent citation, generality, and originality measures ($TTCITES$, $GENERALITY$ and $ORIGINALITY$).[23]

However, the conclusion is quite different for innovative efficiency measures (IE_NPAT, $IE\_TTCITES$, and $RORD$); we find a significant and positive effect of VP on all of the efficiency measures. For example, in Panel C, we find VP has a strong positive effect on $TTCITES$ (coefficient = 1.14; t = 4.00), indicating that equity overvaluation is negatively associated with innovation efficiency. This suggests that even though overvaluation encourages the overall output of intangible investment, the sensitivity of

[23]The insignificance of VP in the $TTCITES$ and $GENERALITY$ regressions appears to be a result of including the last few years of observations in the test. These observations may have a data truncation bias because it may take years to accumulate patent citations and patents applied for in the last few years of the sample may not have enough time to receive citations. Using data ending 2004, VP in the $TTCITES$ and $GENERALITY$ regressions become negative and significant at the 5% level.

patent and citation counts to VP is much lower than the sensitivity of R&D expenditure to VP. The results therefore suggest that much of the R&D spending is motivated by catering rather than real business growth considerations. These finding supports the argument of Jensen (2005) and Polk and Sapienza (2009) that equity overvaluation leads to substantial agency costs in the form of wasteful corporate spending. This evidence also suggests that such overvaluation-driven spending is mainly in the form of intangible, R&D expenditure rather than tangible, capital expenditure; and that firms are less effective in converting R&D expenditure into patents and citations.

4.1.1 Effects of Misvaluation on Innovation: Middle Market versus Large Firms

In order to gain insights into how the effects of stock misvaluation on corporate innovation vary among middle market firms and large firms, we conduct an analysis separately for these two subsamples. Middle market firms are firms with annual sales between $10 million and $ 1 billion, and large firms are firms with sales above $1 billion. (Fewer than 3% of our sample firms are small firms with sales below $10 million, so we focus our analysis on middle market and large firms.)

Tables A1 and A2 break summary statistics about our sample separately for middle market and large firms. We see that middle market firms invest more heavily on R&D than large firms do. Since 1997, R&D has been higher than capital expenditure as a portion of total assets for middle market firms; in contrast, among large firms R&D is lower than capital expenditure throughout the sample period. Despite the relative importance of intangible investment for middle market firms, large firms have far higher innovative output measured by patent and patent citation counts. For example, large firms produce an average of 36.54 patents per year, far exceeding 2.25 patents for middle market firms. As mentioned earlier this suggests either that middle market firms face more severe obstacles than do larger firms in converting R&D expenditures into patentable discoveries, or that middle market firms focus more on non-patentable forms of innovation.

In untabulated tests we run investment and innovation regressions separately for middle market and large firms. As discussed in the previous subsection, stock misvaluation, as measured by VP, has a strong effect on R&D in the full sample. Our subsample analysis reveals that this is especially true for middle market firms. Among middle market firms, overvaluation is strongly associated with subsequent R&D spending (VP coefficient $= -3.46; t = -15.01$); among large firms, the effect of VP on R&D is still significant but much weaker (coefficient $= -1.04; t = -8.76$) than the effect among middle market firms.

Using the same method as in the previous subsection, we estimate the economic impact of misvaluation, growth opportunity, and other control variables on corporate investment and innovation. Specifically, we use coefficient estimates of regression Model (1) of Table 4 for the full sample, and for middle market and large firms, combined with information about the standard deviation of each variable, to calculate the impact of a one standard deviation change in VP and other variables on investment and innovation. Table A3 reports the economic impact estimates. We see that the sensitivity of R&D to VP is about four times as strong among middle market firms as among large firms (-2.43 versus -0.61). Among middle market firms, the sensitivity of R&D to VP it stronger than the sensitivities to cash flow (2.19), firm age (-1.73), leverage (-1.26), ROA (0.84), and BP (0.12).

Overvaluation has a positive effect on innovative output (patent counts $NPAT$ and citation counts $TTCITES$) only among middle market firms. Even among middle market firms, the economic impact of VP on innovative output is limited. For example, a one standard deviation increase in overvaluation leads to an increase of 0.08 in $Log(1+$

$NPAT$), corresponding to an increase in the number of patents of 0.27 per year, assuming the firm generates an average of 2.25 patents per year.

Accordingly, overvaluation does not improve innovative efficiency, measured by IE_NPAT, $IE\_TTCITES$, and $RORD$, even among middle market firms. In particular, VP has an adverse effect (a positive coefficient) on IE_NPAT and $IE\_TTCIETS$ for both middle market and large firms, with the highest impact among all independent variables. This result suggests that even among middle market firms, the additional innovative output induced by overvaluation is in despite of a decrease in the efficiency of converting R&D activity into patents, citations, and profitability.

4.1.2 The Financing Channel

There are theoretical arguments for why misvaluation should affect investment, either through equity issuance or directly for purposes of influencing the the current stock price (Stein (1996), Baker, Stein, and Wurgler (2003), Gilchrist, Himmelberg, and Huberman (2005), Jensen (2005), and Polk and Sapienza (2009)). To measure the extent to which the effect of misvaluation on investment operates through the equity and debt channels, we perform a path analysis following Badertscher, Shanthikumar, and Teoh (2014).

Path analysis is a method of describing whether an independent variable affects the dependent variable directly or via the influence of intermediate variables. We perform a path analysis by estimating the following regressions:

$$\begin{aligned} RD &= a_1 + b_1 VP + c_1 EI + d_1 DI + controls + u_1 \\ EI &= a_2 + b_2 VP + controls + u_2 \\ DI &= a_3 + b_3 VP + controls + u_3, \end{aligned}$$

All regressions includes 2-digit SIC major industry dummies in addition to the control variables (BP, CF, LEV, ROA, AGE, $\Delta INTCOV$, ΔCR, and $CASH$) in the independent variables.

Panels A and B of Table 5 indicate the control variables for each regression. The estimated value of b_1 captures the direct effect of VP on investment. The estimated value of $b_2 \times c_1$ captures the effect of VP through the equity channel, and $b_3 \times d_1$ captures the effect of VP through the debt channel.

Intuitively, since VP is included in the first regression, the coefficients on EI and DI will be the same as they would be if these variables were orthogonalized with respect to VP. In other words, the coefficients on these variables give the general relationship of these financing variables on investment. If the relation of equity issuance or debt issuance to investment is similar regardless of whether this issuance was induced by VP, the effect of VP operating through the debt and equity channels is captured by the corresponding coefficients in the first equation, with the direct effect captured by the VP coefficients. The next two equations give the coefficients needed to rescale the EI and DI coefficients in the first equation to reflect the sensitivity of the financing variable to VP.

Table 5 reports key coefficient estimates from the regressions. The percentages at the bottom of Panel C summarizes the portion of the total effect of VP that is through each of the financing mechanisms, and the direct portion of the effect unexplained by the equity and debt paths. The vast majority of the effect of VP on RD, 87.5%, of the total effect comes from the direct catering channel. The equity channel contributes 12.6% of the total effect, while only -0.1% is through the debt channel. The finding that overvaluation's effect on RD is stronger through the equity channel than through the debt channel is reasonable because equity issuance is more sensitive than debt issuance to overvaluation. Also, overvaluation has a negative effect on RD through the debt channel because the effect of overvaluation on debt issuance is negative.

4.2 Subsample Tests

Different versions of the misvaluation hypothesis offer interesting predictions about the sensitivity of investment to misvaluation in different subsamples of firms. We therefore perform several subsample tests.

One set of tests involves examining separately firms that are in different misvaluation quintiles. When a firm is undervalued, fixed costs of equity issuance may limit equity-financed investment. If undervalued firms issue less equity (see Loughran and Ritter (1995), Baker and Wurgler (2000), Baker, Stein, and Wurgler (2003), Dong, Hirshleifer, and Teoh (2012)), then a reduction in the undervaluation may not increase equity issuance and investment much. In contrast, if firms that are overvalued often issue equity, then an increase in overvaluation is likely to increase the scale of issuance and investment among issuers substantially. Similarly, if projects have a minimum technologically efficient scale, then a reduction in undervaluation may matter little for an inframarginal project that is being rejected anyway, whereas an increase in overvaluation is likely to increase the scale of the adopted project.

An alternative line of reasoning based upon catering potentially yields a similar implication. Managers of overvalued firms may be particularly anxious to undertake overvalued investments in order to satisfy investors' overly optimistic perceptions. The prevalence of such managerial behavior are discussed by Jensen (2005), who warns that such effects are likely to be found among overvalued firms.

Thus, arguments based upon the equity channel and based upon catering both imply that investment will be more sensitive to valuation among overvalued firms. We test these ideas by measuring the investment sensitivity to misvaluation within subsamples of firms sorted into misvaluation quintiles.

The main empirical prediction of Baker, Stein, and Wurgler (2003) is that the sensitivity of investment to misvaluation is strongest among equity-dependent firms. We test this by measuring investment sensitivities in subsamples sorted by the Kaplan/Zingales index. To test for the effect of investor time horizon upon catering incentives (Polk and Sapienza (2009)), we perform subsample tests sorting by turnover. Finally, we examine how the effects of misvaluation on investment vary with firm size.

The lower transparency and liquidity of small firms implies stronger misvaluation effects (see also footnote 25). However, if the cost of issuing equity for small firms is very high (so that even overvalued small firms seldom issue equity), limited access of small firms to equity markets can dampen the sensitivity of their equity-financed investment to misvaluation. Furthermore, the managers of small firms are likely to face stronger pressures to cater to investor beliefs than large firms, because small firms are likely to be held by a less sophisticated investor base (small investors), and are more subject to hostile acquisitions and delisting pressures than large firms when market valuations are low. Our tests provide separate measures for the direct (catering) and indirect (equity channel) sensitivity of investment to misvaluation. Thus, tests sorting by firm-size provide insight into the differing constraints and pressures faced by small versus large firms.

We report the subsample results in Tables 6 and 7. For each subsample, we report the VP coefficient in model (1) of Table 4, which provides the effect of VP on investment and innovative output after controlling for the effects of growth and other potential effects of cash flow, leverage, age, and firm-specific risk.

4.2.1 Growth-Subsample Regressions

Panel A of Table 6 describes how the investment and innovation sensitivity to misvaluation level as measured by VP varies across firms in different growth quintiles. Within each quintile, we regress innovative input (RD), capital expenditure ($CAPX$), and innovative output and efficiency measures ($NPAT$, $TTCITES$, $GENERALITY$, $ORIGINALITY$, $IE\_TTCITES$, or $RORD$) on VP, BP, and other controls.

We find that the effect of misvaluation on RD is much stronger among growth firms ($-8.10; t = 8.03$) than among value firms ($-1.80; t = 8.55$). The interquintile difference in VP coefficient between growth and value quintiles is statistically significant ($6.30; t = 6.11$). This is intuitive since the catering incentive should be stronger among firms with higher prospects. A similar pattern exists for $NPAT$, $TTCITES$, $GENERALITY$, and $ORIGINALITY$). For example, the interquintile difference in VP coefficient on $TTCITES$ is highly significant (0.30; $t = 4.48$). There is also some evidence that the misvaluation effect on $CAPX$ is stronger among growth firms, with a marginally significant interquintile difference in VP coefficient ($1.05; t = 1.79$).

There is little evidence that overvaluation boosts innovative efficiency (measured by $TTCITES$ and $RORD$). In all the tests of innovative efficiency, VP has either a significantly positive or insignificant coefficient in the innovative efficiency regression. There is, however, evidence that growth firms are less bad in converting overvalued-driven R&D into patents and citations, judging by the positive and significant interquintile difference in VP coefficients on $IE\_TTCITES$ ($1.24; t = 3.13$).

4.2.2 Valuation-Subsample Regressions

Panel B describes the relation between investment sensitivity to misvaluation level as measured by VP among firms in different misvaluation categories. It is evident that the misvaluation effect on RD is much stronger among overvalued firms. In fact, for the most undervalued quintile, this effect is significantly positive, rather than negative, though the economic magnitude is much smaller. The inter-quintile difference in VP coefficients between the top and bottom valuation quintiles is large and statistically significant (15.34, $t = 15.51$).

However, in sharp contrast, the VP effect on $CAPX$ is in the opposite direction for each of the VP quintiles; its effect is significantly positive, rather than negative, indicating that undervalued firms tend to engage in more capital expenditures. Since capital expenditures are capitalized rather than expensed, a possible interpretation is that undervalued firms have the incentive to capitalize spending in an effort to increase equity valuation. This is consistent with the evidence of McConnell and Muscarella (1985) that the market on average reacts positively to the announcement of increases in capital expenditures.

There is also evidence that overvalued firms have more innovative output as a result of heightened level of R&D investment. The sensitivities of $NPAT$, $TTCITES$, $GENERALITY$ and $ORIGINALITY$ to overvaluatioin are all significantly higher among overvalued firms than among undervalued firms. However, innovative efficiency as measured by $IE\_TTCITES$ and $RORD$ shows a positive sensitivity to VP across most of VP quintiles. Taken together, these facts suggest that the heightened sensitivity of R&D spending to overvaluation in the top valuation quintiles appears to have more to do with catering than with genuine innovation prospects.

4.2.3 KZ-Subsample Regressions

Baker, Stein, and Wurgler (2003) provide evidence that financially constrained firms have greater sensitivity of investment to misvaluation. Our tests differ in two main ways. First, we examine equity BP instead of total firm q, based on our argument that it is equity misvaluation that is most relevant for equity financing decisions. Second, we examine VP, our misvaluation proxy that is purified of growth effects, along with tests that include BP as an additional control for growth.

Panel C of Table 6 shows that, consistent with the prediction of Baker, Stein, and Wurgler (2003), high-KZ firms have capital expenditures that are more sensitive to overvaluation than low-KZ firms. The VP effect on $CAPX$ is significantly negative only for the highest-KZ quintile (-0.61; $t = -2.60$). The effect for the two lowest-KZ quintile are significantly positive, and the difference in the VP effect on $CAPX$ between the top and bottom quintiles is statistically significant (-1.40; $t = -4.24$).

Thus, the evidence supports the Baker, Stein, and Wurgler financial constraints theory as applied to tangible investments (capital expenditures). However, the results also confirm strongly that other forces are operating when it comes to the relation between misvaluation and intangible investment (R&D).

Why is the R&D of unconstrained (low-KZ) firms especially sensitive to misvaluation? And why are the effects of financial constraints on misvaluation sensitivity so different for tangible versus intangible investment? A plausible explanation is that firms that are financially constrained are limited in their freedom to engage profitably in R&D because such investments require financial flexibility (Li (2011)).[24]

For firms that are more financially constrained, an increase in overvaluation may encourage equity issuance for purpose of investing in R&D relatively little compared to firms with low financial constraints. In other words, if the possibility of distress greatly reduces the expected profitability of a firm's intangible investment, greater overvaluation may do little to make such investment attractive.

Overvaluation also boosts firms' innovative output among the two least financially constrained quintiles. Nevertheless, innovative efficiency as measured by IE_NPAT, $IE\_TTCITES$, and $RORD$ shows a lower sensitivity to VP among low-KZ firms. This suggests (similar to our earlier findings) that the much of the increased R&D expen-

[24]One reason for this is that stakeholders such as employees, suppliers, or customers may be reluctant to commit to long-term relationships with a firm that is subject to distress, and the inputs of such stakeholders may be especially important for the success of investments designed to generate intangible assets. Furthermore, intangible investments generate real options, making it especially valuable for the firm to have the flexibility to spend heavily in the future. For example, firms with heavy R&D activity such as pharmaceutical firms tend to maintain low leverage ratios, presumably to maintain flexibility in investment.

ditures among overvalued low-KZ firms derive from the agency costs associated with overvalued equity.

4.2.4 Size-Quintile Regressions

Panel A of Table 7 reports the effect of VP within quintiles sorted by total assets. Middle market firms show a much higher sensitivity of RD to misvaluation than do large firms. For example, the VP effect on RD for the smallest-firm quintile is -3.89 ($t = -9.93$), more than four times the effect for the largest-firm quintile (-0.94; $t = -7.35$). However, for $CAPX$, there is no clear trend in the VP effects across the size quintiles.

Why do middle market firms have higher sensitivity of R&D to misvaluation? First, middle market firms may be more prone to misvaluation because of lower availability of information to investors and lower liquidity.[25] Moreover, the opacity of middle market firms may apply especially strongly to R&D projects, implying a greater effect of misvaluation on R&D for middle market firms.

There is also a corresponding increase in sensitivity of $NPAT$ and $TTCITES$ to overvaluation moving from large to middle market firms, indicating that some of the intangible investment aided by overvaluation is effective in promoting innovation among middle market firms. However, VP has a uniformly positive association with innovative efficiency, so that overvalued firms are less efficient. This indicates that middle market firms are not better at converting overvaluation-driven R&D activity into valuable innovation.

4.2.5 Turnover-Quintile Regressions

Turning to the effects of investor time horizons on investment, Panel B of Table 7 reports the misvaluation effects on innovation for the turnover quintiles. We see that high-

[25] To the extent that middle market firms are more prone to misvaluation, the signal-to-noise ratio for a misvaluation proxy should be higher among middle market firms, implying a stronger relation between measured misvaluation and investment.

turnover firms have higher sensitivity than low-turnover firms of R&D to misvaluation. However, this is not the case for $CAPX$, for which there seems to be no clear pattern in the VP coefficient across the turnover quintiles.

R&D is highly sensitive to VP among both high and low turnover firms, with a much greater VP effect (-3.62; $t = -8.08$) for highest-turnover firms than for lowest-turnover firms (-2.42; $t = -7.79$). This suggests that catering effects are stronger among firms with less stable investor bases. There is a similar pattern of increasing sensitivity of $NPAT$ and $TTCITES$ to overvaluation. For example, the interquintile difference in VP coefficient in the $NPAT$ regression is statistically significant ($-0.10; t = -1.97$). However, there is no corresponding increase in sensitivity of innovative efficiency to overvaluation from low to high turnover firms.

5 Conclusion

We test how market overvaluation affects corporate innovative activity, and innovative success among middle market and larger firms. As a reference for comparison, we also study the relationship between tangible investment, in the form of capital expenditures, to misvaluation. We use R&D expenditures as a proxy for innovative investment, and patents or patent citations as measures of innovative success. Our proxy for equity misvaluation is the ratio of a residual income valuation, which discounts future earnings to value the firm's equity, to price (VP). Our misvaluation measure is designed to filter out growth prospects to focus on the effects of mispricing.

We find a strong positive association between equity overvaluation and subsequent R&D spending, after controlling for other determinants of investment and R&D. This effect is much stronger for R&D than for capital expenditures. The stronger effect of misvaluation on R&D rather than on tangible investments is consistent with the hypothesis that misvaluation effects are stronger for investments that are harder to value.

We find that investment by middle market firms is tilted more heavily, as compared with larger firms, toward R&D than capital expenditures. Furthermore, the sensitivity of R&D to misvaluation is three times as large for middle market firms as for larger firms. This is consistent with the possibilities that middle market firms have relatively strong catering incentives or capital constraints, or inability to internalize network externalities, and therefore are more sensitive to market misvaluation. In contrast, there is no correlation between misvaluation and capital expenditure among middle market firms. We also find that misvaluation affects R&D investment both through the equity issuance channel, and, consistent with Polk and Sapienza (2006), especially through direct catering to investors.

To further probe the economic sources of these effects, we examine whether the sensitivity of capital expenditures or R&D to misvaluation varies across subsamples of firms sorted by growth, misvaluation, the degree of financial constraint, and the investor time horizon. We find that the misvaluation effect on R&D is much stronger among growth firms than among value firms, consistent with the hypothesis that catering is more effective when the firms have greater growth opportunities. We only find a marginally higher sensitivity of capital expenditures to overvaluation among growth firms.

We discuss several reasons why misvaluation effects should be stronger among more overvalued firms (i.e., why overvaluation should have a nonlinear effect), notably including positive network externalities to innovative activity. Empirically we find that misvaluation affects R&D much more strongly among overvalued firms.

We find that the capital expenditures of financially constrained firms (as proxied with the Kaplan/Zingales index) are more sensitive to market misvaluation than that of non-distressed firms, consistent with the theory of Baker, Stein, and Wurgler (2003). In contrast, we find that the R&D expenditures of financially constrained firms are much *less* sensitive to market misvaluation than those of unconstrained firms. This finding presents an intriguing puzzle. A possible explanation is that the benefits to exploiting overvaluation to finance intangible growth opportunities may be lower when financial constraints reduce flexibility and the willingness of stakeholders to provide complementary inputs.

In tests for the effect of investor time horizon, we find that the sensitivity of R&D, but not capital expenditures, to valuation is higher among high-turnover firms. This suggests that catering pressures to maintain short-term valuation are more relevant for intangible than for tangible investment, consistent with the hypothesis that intangible investments are more prone to being misvalued by investors.

Owing to the greater opacity and lower liquidity of middle market firms, middle market firms should be more prone to misvaluation than large firms, which suggests greater misvaluation effects for middle market firms. For the equity channel, however, a potentially opposing effect is that large firms have greater access to equity markets than middle market firms. Empirically, we find that middle market firms do not have a higher sensitivity of capital expenditures to misvaluation than do large firms, but do have a much higher sensitivity of R&D to misvaluation in both the direct effect of misvaluation and through the equity channel.

We also explore whether overvaluation promotes innovative output and efficiency. Although middle market firms invest more heavily in R&D, larger firms generate a relatively much greater number of patents, which suggests that middle market firms face more severe barriers to bringing research to fruition as patents, or alternatively that middle market firms focus on types of innovation that are not as easily patentable.

We find that innovative output, measured by patent counts and citations, is positively associated with overvaluation only among growth firms. In contrast, capital expenditure is only marginally related to overvaluation even among growth firms. Overvaluation is also associated with greater innovative output measured by patent and citation counts, but this effect is weaker than the effect on R&D expenditure, and is only present among middle market firms.

Among the full sample, we find a negative association between overvaluation and innovation efficiency. This reflects the fact that the sensitivity of innovative output to overvaluation is much lower than the sensitivity of R&D to overvaluation. Even among middle market firms, overvaluation does not improve innovative efficiency (the ratio of patents to R&D). This suggests that there are substantial agency costs associated with overvalued equity (Jensen (2005) and Polk and Sapienza (2009)).

In sum, we find that there is strong evidence in favor of the misvaluation hypothesis using an overall measure of market misvaluation that filters out earnings growth prospects by using a forward-looking fundamental measure. The effects of misvaluation are very different for capital expenditures than for R&D, and conditional tests provide further insight into the sources of misvaluation effects. Middle market firms are particularly sensitive to overvaluation, which promotes both greater innovative investment and output, but not innovative efficiency. Indeed, among larger firms, overvaluation increases innovative output at the cost of reduced innovative efficiency.

The evidence of strong misvaluation effects on corporate innovation and investment activity in the cross-section raises the question of whether misvaluation drives aggregate patterns of innovation and investment. Existing studies have not resolved sharply whether the relation between stock prices and investment derives from rational effects or misvaluation. The use of an overall aggregate misvaluation proxy from which contaminating growth effects are removed, and the separate examination of tangible versus intangible investment and output measures, may provide insight into whether and why misvaluation affects innovation and investment in the macro-economy.

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Table 1. Summary Statistics of Innovation Input and Outputs, Valuation, and Control Variables

The sample includes U.S. non-financial firms listed on NYSE, AMEX and NASDAQ with COMPUSTAT and I/B/E/S coverage during 1976-2012. Patent and citation counts data (November 2011 version) is provided by Kogan et al. (2013); we end the patent and citation data in 2008 to reduce truncation biases caused by the delay in patent approval and citation counts. Innovation input is R&D expenditure scaled by lagged total assets (*RD*). Capital expenditures scaled by lagged total assets (*CAPX*) is also reported. Variables for the patents applied for in a fiscal year include: number of patents (*NPAT*); number of citations adjusted for the effects of year and technological class (*TTCITES*); the generality and originality measures of patents as defined by Hall, Jaffe, and Trajtenberg (2001); innovative efficiency defined as *NPAT* or *TTCITES* scaled by R&D expenditure (*IE_NPAT* and *IE_TTCITES*). Return on R&D (*RORD*) is operating income before depreciation and R&D expense divided by R&D expense. *CF* is cash flow (income before extraordinary items + depreciation + *RD*) over the fiscal year scaled by lagged assets (missing *RD* is set to zero in the *CF* calculation). Leverage (*LEV*) is defined as (long-term debt + current liabilities)/(long-term debt + current liabilities + shareholders' equity). *ROA* is operating income before depreciation and R&D expenses scaled by total assets for the prior fiscal year. *AGE* is the number of years between the beginning of the fiscal year and the listing date of the firm in CRSP, truncated at 50. *BP* is the book equity to price ratio. *VP* is the residual-income-value to price ratio. *KZ* index is a measure of financial constraints as defined in Kaplan and Zingales (1997) but with Tobin's *q* omitted, with high index indicating high level of constraints. *Turnover* is monthly trading volume scaled by the number of shares outstanding. Except for the innovation input and output variables, and cash flow (*CF*), equity issuance (*EI*) and debt issuance (*DI*), which are measured over each fiscal year, all other control variables, valuation variables, and valuation sensitivity variables are measured in the month preceding the beginning of each fiscal year. We choose the most recent fiscal year accounting data available at the end of June each year so that each sample firm appears once for a particular year. Total assets and sales figures are in 2012 dollars. All ratio variables are winsorized at the 1st and 99th percentiles.

	N	Mean	Std Dev	Median	P1	P99
Innovation Input and Output Variables						
RD (%)	39657	8.18	12.13	3.95	0.00	59.77
CAPX (%)	62130	8.05	9.19	5.30	0.22	48.01
NPAT	54625	13.84	91.72	0.00	0.00	267.00
TTCITES	53533	12.52	81.04	0.00	0.00	240.25
GENERALITY	53533	5.02	35.03	0.00	0.00	97.86
ORIGINALITY	54546	6.17	44.06	0.00	0.00	116.49
IE_NPAT ($\times 10^{-3}$)	29117	4.35	8.68	1.18	0.00	42.42
IE_TTCITES ($\times 10^{-3}$)	28241	4.38	9.71	0.75	0.00	50.36
Return on R&D (%)	33234	8.60	17.65	3.56	-4.22	108.32
Control Variables for Innovation Regressions						
CF (%)	62667	12.67	14.69	12.51	-35.59	54.57
ROA (%)	62630	17.59	13.16	16.92	-23.57	59.00
LEV	62815	0.27	0.23	0.25	0.00	0.84
AGE	62815	15.09	13.67	10.75	0.42	50.00
EI (%)	62713	7.19	29.43	0.99	-14.42	126.99
DI (%)	62806	7.61	22.66	2.87	-26.94	110.21
Valuation Variables						
BP	62815	0.62	0.61	0.46	0.03	3.34
VP	62815	0.79	0.69	0.72	-1.25	3.25
Variables Affecting the Innovation-Valuation Sensitivity						
KZ Index	61228	-0.11	1.51	0.01	-6.91	2.43
Turnover (%)	61526	13.13	14.54	7.87	0.53	71.63
Total Assets ($M)	62806	3386.53	18130.66	456.55	17.53	49383.64
Sales ($M)	62773	3240.53	13309.14	497.97	1.73	48637.76

Table 2. Corporate Investment, Innovative Output, and Equity Valuations by Year

This table reports the mean values of corporate investment (*RD* and *CAPX*), innovative output (patent and citation counts), and valuation variables (*BP* and *VP*) for each year. The sample includes U.S. non-financial firms listed on NYSE, AMEX and NASDAQ with COMPUSTAT and I/B/E/S coverage during 1976-2012. Patent and citation data is provided by Kogan et al. (2013) (November 2011 version); we end the patent and citation data in 2008 to reduce truncation biases.

Year	*N*	*RD* (%)	*CAPX* (%)	*NPAT*	*TT CITES*	*GENERALITY*	*ORIGINALITY*	*IE-NPAT* (10^{-3})	*IE-TT CITES* (10^{-3})	*BP*	*VP*
1976	431	3.18	9.48	28.33	26.74	11.82	9.72	16.19	14.87	0.98	1.36
1977	587	3.45	10.58	23.36	22.27	9.78	8.11	14.61	13.31	0.79	1.14
1978	675	3.43	11.84	19.92	18.78	8.36	7.43	12.39	11.59	0.84	1.25
1979	1003	3.44	11.84	13.38	12.51	5.65	4.97	11.08	10.79	0.96	1.37
1980	1043	3.66	11.58	13.77	12.92	5.91	5.27	9.70	9.45	0.91	1.18
1981	1039	3.67	11.52	13.49	12.98	5.94	5.24	8.23	7.68	0.85	1.10
1982	1062	4.03	9.62	12.66	12.22	5.64	5.05	6.71	6.17	0.90	1.39
1983	1165	4.86	8.64	11.00	10.63	4.94	4.30	5.32	5.02	0.83	1.12
1984	1322	5.56	10.60	10.21	10.08	4.60	4.04	5.51	5.47	0.58	0.82
1985	1454	6.05	10.41	9.10	9.25	4.16	3.63	5.39	5.50	0.71	1.24
1986	1420	5.95	9.42	9.86	10.06	4.60	4.01	5.52	6.44	0.64	0.92
1987	1468	5.67	8.96	9.46	9.43	4.41	3.89	5.45	5.61	0.61	0.81
1988	1515	6.07	9.00	9.78	9.82	4.55	4.07	5.19	5.30	0.66	0.96
1989	1501	6.37	8.75	11.56	11.59	5.45	4.76	5.48	5.38	0.63	1.09
1990	1577	6.79	8.65	11.71	11.86	5.52	4.80	4.98	5.18	0.63	1.00
1991	1548	7.01	7.65	12.03	12.41	5.69	4.92	4.57	4.51	0.82	1.14
1992	1661	7.64	7.85	11.54	12.14	5.53	4.89	3.91	3.96	0.63	0.87
1993	1813	8.68	8.79	11.19	11.70	5.37	4.90	4.51	4.58	0.55	0.74
1994	1959	9.01	9.59	11.36	12.09	5.51	5.03	4.09	4.33	0.48	0.72
1995	2187	9.80	9.87	12.26	12.66	5.93	5.58	4.97	5.38	0.53	0.89
1996	2346	9.78	9.84	12.47	13.02	6.00	5.65	3.68	3.97	0.49	0.81
1997	2524	10.82	9.84	13.87	14.44	6.53	6.32	3.44	4.10	0.45	0.69
1998	2600	10.79	9.41	13.88	14.19	6.33	6.46	3.50	3.77	0.43	0.64
1999	2441	10.58	8.11	15.50	15.39	6.61	7.31	3.21	3.40	0.59	0.72
2000	2253	10.76	8.38	18.16	17.92	6.98	8.81	3.05	3.16	0.59	0.71
2001	2185	8.57	6.54	20.04	18.87	6.57	9.77	3.32	3.69	0.72	0.75
2002	2120	9.22	5.31	20.85	17.94	5.63	10.13	3.02	3.01	0.68	0.48
2003	2008	9.19	5.34	21.93	17.02	4.57	10.73	3.22	2.89	0.84	0.71
2004	2021	8.65	5.86	19.74	13.46	3.00	9.65	2.55	1.92	0.46	0.54
2005	2057	8.59	6.11	17.84	10.24	1.80	8.49	2.09	1.43	0.42	0.46
2006	2051	9.54	6.68	14.39	6.63	0.92	6.71	1.62	0.95	0.43	0.49
2007	2036	9.27	7.05	8.84	3.33	0.34	4.02	1.14	0.51	0.42	0.49
2008	2088	8.89	6.52	4.13	1.10	0.08	1.78	0.42	0.16	0.51	0.47
2009	2031	8.82	4.34							1.10	0.77
2010	1942	8.20	5.20							0.65	0.58
2011	1921	8.17	6.08							0.53	0.66
2012	1761	8.76	6.11							0.66	0.74
All	62815	8.18	8.05	13.84	12.52	5.02	6.17	4.35	4.38	0.62	0.79

Table 3. Innovation Measures of Two-Way Sorted Portfolios

Each year during 1976-2012 (or 1976-2008 for patent and citation data), firms are sorted into quintile portfolios according to the beginning-of-previous-fiscal-year book to price ratio (*BP*), and independently, on residual-income-model-value to price ratio (*VP*). The intersection of the BP- and VP-quintiles creates 25 BP-VP portfolios. Each year, mean innovation input or output is computed for each portfolio. Finally, time-series mean of innovation for each quintile is computed. This table reports the time-series mean values of innovation variables for each portfolio. Also reported are the inter-quintile innovation difference along BP and VP and the innovation-valuation sensitivity ratios, and the associated *t*-statistics. The mean and *t*-statistic of the innovation-valuation sensitivity ratios, $\beta_{BP} = \Delta Innovation / \Delta(BP)$, and $\beta_{VP} = \Delta Innovation / \Delta(VP)$, are calculated based on the time-series of the yearly ratio of inter-quintile spread in innovation to the spread in *BP* or *VP*.

Panel A. R&D expenditure scaled by lagged total assets (*RD*), for the fiscal year right after valuation measurement (same timing below).

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	t (β_{BP})
VP1 (Overvalued)	16.15	14.13	14.32	13.03	8.69	7.46	8.15	4.85	7.70
VP2	9.23	7.14	6.99	6.90	5.63	3.60	10.98	3.09	8.51
VP3	7.46	5.32	5.04	4.86	4.27	3.19	5.69	2.86	5.60
VP4	6.62	5.14	3.73	3.54	3.16	3.44	8.08	3.24	7.38
VP5 (Undervalued)	8.51	5.98	4.07	3.63	3.28	5.00	5.63	4.09	5.67
VP1 – VP5	8.18	8.16	10.25	9.40	5.40				
t (VP1–VP5)	6.09	7.40	8.96	8.89	7.22				
β_{VP}	5.48	5.80	6.93	5.91	2.67				
t (β_{VP})	6.09	7.28	8.70	8.00	7.06				

Panel B. Capital expenditure scaled by lagged total assets (*RD*).

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	t (β_{BP})
VP1 (Overvalued)	11.77	8.84	7.70	6.14	4.92	6.85	9.42	4.28	10.40
VP2	11.52	9.06	8.32	7.20	5.33	6.19	14.45	5.03	14.59
VP3	10.55	9.32	8.60	7.30	5.78	4.78	11.69	4.20	11.98
VP4	10.14	9.34	8.35	7.28	5.99	4.16	6.29	3.63	6.83
VP5 (Undervalued)	10.98	9.78	8.53	7.97	6.14	4.76	3.53	3.41	4.41
VP1 – VP5	0.65	-0.94	-0.83	-1.83	-1.23				
t (VP1–VP5)	0.45	-1.98	-2.40	-5.57	-4.38				
β_{VP}	0.60	-0.60	-0.63	-1.14	-0.60				
t (β_{VP})	0.81	-1.96	-2.52	-5.15	-4.03				

Panel C. Total patent count each year [log(1+*NPAT*)].

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	$t(\beta_{BP})$
VP1 (Overvalued)	0.94	0.98	0.88	0.73	0.62	0.33	4.37	0.20	4.76
VP2	0.98	1.04	1.00	0.93	0.73	0.25	2.98	0.17	2.49
VP3	0.95	1.09	1.01	0.94	0.70	0.25	2.61	0.20	2.77
VP4	0.85	1.06	1.03	0.93	0.70	0.15	1.40	0.17	2.00
VP5 (Undervalued)	0.62	0.70	0.73	0.80	0.65	-0.03	-0.28	0.01	0.13
VP1 – VP5	0.33	0.28	0.15	-0.06	-0.04				
t (VP1–VP5)	2.68	3.41	1.80	-0.71	-0.50				
β_{VP}	0.19	0.17	0.10	-0.03	-0.01				
$t(\beta_{VP})$	2.31	3.06	1.75	-0.49	-0.35				

Panel D. Year and technology class-adjusted citation count [log(1+*TTCITES*)].

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	$t(\beta_{BP})$
VP1 (Overvalued)	0.91	0.94	0.83	0.67	0.55	0.36	4.90	0.22	5.42
VP2	0.96	0.99	0.95	0.87	0.65	0.31	3.72	0.22	3.34
VP3	0.90	1.01	0.95	0.88	0.64	0.26	2.76	0.21	2.91
VP4	0.77	1.00	0.95	0.86	0.63	0.14	1.44	0.15	2.05
VP5 (Undervalued)	0.52	0.62	0.67	0.73	0.58	-0.06	-0.55	-0.02	-0.26
VP1 – VP5	0.40	0.32	0.16	-0.06	-0.03				
t (VP1–VP5)	3.44	4.00	1.97	-0.70	-0.49				
β_{VP}	0.24	0.20	0.11	-0.03	-0.01				
$t(\beta_{VP})$	3.07	3.80	1.88	-0.50	-0.37				

Panel E. Patent generality [log(1+*GENERALITY*)].

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	$t(\beta_{BP})$
VP1 (Overvalued)	0.61	0.63	0.54	0.44	0.36	0.25	4.40	0.15	4.72
VP2	0.67	0.70	0.65	0.60	0.44	0.23	3.70	0.16	3.44
VP3	0.63	0.74	0.68	0.63	0.45	0.18	2.61	0.14	2.73
VP4	0.52	0.71	0.69	0.63	0.45	0.07	0.95	0.08	1.45
VP5 (Undervalued)	0.33	0.42	0.47	0.53	0.43	-0.10	-1.16	-0.06	-0.99
VP1 – VP5	0.28	0.21	0.07	-0.09	-0.07				
t (VP1–VP5)	3.09	3.62	1.29	-1.53	-1.36				
β_{VP}	0.17	0.13	0.05	-0.05	-0.03				
$t(\beta_{VP})$	2.78	3.46	1.22	-1.40	-1.34				

Panel F. Patent originality [log(1+*ORIGINALITY*)].

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	t (β_{BP})
VP1 (Overvalued)	0.65	0.68	0.58	0.47	0.40	0.26	4.55	0.16	4.91
VP2	0.71	0.76	0.71	0.65	0.49	0.23	3.36	0.15	2.93
VP3	0.69	0.79	0.73	0.66	0.47	0.22	2.98	0.18	3.20
VP4	0.63	0.78	0.72	0.65	0.47	0.15	2.02	0.16	2.60
VP5 (Undervalued)	0.42	0.50	0.50	0.56	0.44	-0.03	-0.32	0.01	0.09
VP1 – VP5	0.24	0.18	0.08	-0.08	-0.05				
t (VP1–VP5)	2.65	2.85	1.31	-1.26	-0.85				
β_{VP}	0.14	0.11	0.06	-0.04	-0.02				
t (β_{VP})	2.22	2.43	1.33	-1.04	-0.69				

Panel G. Innovation efficiency measured as patent count scaled by R&D expenditure (*IE_NPAT*).

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	t (β_{BP})
VP1 (Overvalued)	4.57	5.07	4.76	4.20	6.12	-1.55	-1.63	-0.95	-1.72
VP2	4.53	5.21	5.70	6.19	7.11	-2.58	-1.81	-1.43	-2.14
VP3	5.15	6.45	5.81	5.84	5.97	-0.81	-0.91	-0.63	-0.77
VP4	3.81	5.98	6.27	5.77	5.66	-1.51	-2.47	-1.25	-2.50
VP5 (Undervalued)	2.60	3.72	4.21	5.80	5.72	-2.75	-4.09	-1.96	-4.29
VP1 – VP5	1.68	1.04	0.55	-1.60	0.40				
t (VP1–VP5)	2.57	2.12	0.94	-2.91	0.47				
β_{VP}	1.02	0.61	0.36	-0.97	0.30				
t (β_{VP})	2.57	1.90	0.99	-2.70	0.69				

Panel H. Innovation efficiency measured as *TTCITES* scaled by R&D expenditure (*IE_TTCITES*).

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	t (β_{BP})
VP1 (Overvalued)	5.19	5.37	5.35	4.66	5.40	-0.20	-0.20	-0.18	-0.27
VP2	4.81	5.41	5.69	5.76	6.36	-1.54	-1.09	-0.64	-0.95
VP3	4.81	5.88	5.72	5.72	5.52	-0.71	-0.96	-0.54	-0.82
VP4	3.48	5.55	5.70	5.34	5.30	-1.54	-2.42	-1.34	-2.53
VP5 (Undervalued)	2.34	3.30	4.18	5.24	5.04	-2.22	-3.75	-1.67	-3.94
VP1 – VP5	2.63	1.82	1.17	-0.58	0.36				
t (VP1–VP5)	4.10	3.04	1.82	-0.83	0.38				
β_{VP}	1.69	1.12	0.77	-0.36	0.33				
t (β_{VP})	4.07	2.84	1.96	-0.84	0.62				

Panel I. Return on R&D (*RORD*).

	BP1 (Growth)	BP2	BP3	BP4	BP5 (Value)	BP1 – BP5	*t* (BP1–BP5)	β_{BP}	*t* (β_{BP})
VP1 (Overvalued)	5.16	5.67	6.01	4.49	4.13	1.03	1.79	0.75	2.28
VP2	8.37	8.30	7.69	7.80	6.86	1.51	1.33	1.10	1.35
VP3	12.59	11.26	10.36	10.22	8.70	3.89	2.53	3.74	2.67
VP4	14.15	13.58	15.05	13.81	9.91	4.29	1.58	3.72	1.66
VP5 (Undervalued)	14.86	15.76	15.85	14.52	10.93	4.66	1.07	2.79	1.11
VP1 – VP5	-10.13	-10.46	-9.84	-10.03	-6.80				
t (VP1–VP5)	-2.39	-7.98	-5.10	-9.10	-7.55				
β_{VP}	-6.28	-7.44	-6.75	-6.31	-3.34				
t (β_{VP})	-2.97	-8.06	-5.03	-7.58	-7.47				

Table 4. Regressions of Innovative Input and Output on Valuation Measures: Full Sample

The dependent variable is R&D scaled by total assets, or one of following innovation (log transformed) output variables: number of patents applied for during the year (*NPAT*); number of citations for patents applied for during the year, adjusted for the effects of year and technological class (*TTCITES*); number of citations from patents applied for during the year, adjusted by the weighting index of Hall, Jaffe, and Trajtenberg (2001, 2005) (*QCITES*); the generality and originality measures of patents applied for during the year as defined by Hall, Jaffe, and Trajtenberg (2001). The dependent variables also include innovative efficiency defined as *NPAT*, *TTCITES*, or *QCITES* scaled by R&D expenditure (*IE_NPAT*, *IE_TTCITES*, or *IE_QCITES*), with these three efficiency variables winsorized at the 1% and 99% levels. The independent variables include beginning-of-year *VP* (the residual-income-model-value to price ratio) and *BP* (book to price ratio). *CF* is cash flow (income before extraordinary items + depreciation + *RD*) scaled by lagged assets (missing *RD* is set to zero in the *CF* calculation). *LEV* is beginning-of-year leverage defined as (long-term debt + current liabilities)/(long-term debt + current liabilities + shareholders' equity). *ROA* is operating income before depreciation and R&D expenses scaled by total assets, for the prior fiscal year. *AGE* is the number of years between the beginning of the fiscal year and the listing date of the firm in CRSP, truncated at 50; we use log transformed value of *AGE* in the regression. *EI* is equity issuance and *DI* is debt issuance. *MKT*, *SMB*, and *HML* are the loadings of the Fama-French 3 factors estimated using monthly returns in the 5 (or at least 2) years prior to the beginning of the fiscal year. All regressions include 2-digit SIC major industry dummies. T-statistics are reported in parentheses. Standard errors are clustered by firm and year. The sample includes U.S. non-financial, non-utility firms listed on NYSE, AMEX and NASDAQ with COMPUSTAT and I/B/E/S coverage during 1976-2012. The patent counts data (*NPAT*) sample period is 1976-2008, and patent citations data (*TTCITES* and *QCITES*) period is 1976-2004.

Panel A. The dependent variable is *RD*, *CAPX*, or Log(1+*NPAT*).

	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	RD					*CAPX*					*Log(1+NPAT)*				
VP	-3.17	-2.69	-4.03	-10.49	-8.66	0.11	0.13	0.17	0.15	0.34	-0.07	-0.07	-0.13	-0.25	-0.24
	(-15.14)	(-14.71)	(-16.32)	(-20.05)	(-21.76)	(0.67)	(0.90)	(0.78)	(0.52)	(1.37)	(-2.25)	(-2.15)	(-2.83)	(-4.26)	(-4.18)
$(VP)^2$				3.14	2.55				0.04	-0.04				0.06	0.06
				(14.37)	(15.19)				(0.73)	(-0.75)				(5.06)	(4.93)
(VP)(BP)*			1.13	1.21	0.83			-0.03	0.01	-0.05			0.06	0.04	0.04
			(8.67)	(7.06)	(6.19)			(-0.45)	(0.13)	(-0.75)			(2.87)	(2.79)	(2.73)
BP	-0.38	0.58	-0.18	-2.76	0.16	-1.56	-0.98	-0.95	-2.85	-1.44	-0.00	0.00	-0.04	-0.12	-0.10
	(-1.87)	(3.35)	(-0.84)	(-3.81)	(0.28)	(-9.39)	(-7.43)	(-5.99)	(-7.48)	(-4.51)	(-0.09)	(0.07)	(-1.10)	(-1.47)	(-1.29)
$(BP)^2$				0.04	-0.43				0.38	0.16				0.02	0.01
				(0.22)	(-3.18)				(5.61)	(2.64)				(0.97)	(0.81)
CF	0.08	0.09	0.09	0.09	0.10	0.12	0.11	0.11	0.11	0.11	0.01	0.01	0.01	0.01	0.01
	(5.87)	(8.38)	(8.55)	(7.34)	(9.91)	(10.53)	(10.92)	(10.91)	(10.02)	(10.57)	(6.59)	(6.61)	(6.62)	(6.46)	(6.49)
ROA	0.01	0.05	0.06	0.04	0.08	0.02	0.04	0.04	0.02	0.03	0.01	0.01	0.01	0.01	0.01
	(0.95)	(4.07)	(4.38)	(3.44)	(6.65)	(2.21)	(3.34)	(3.34)	(1.84)	(3.04)	(7.94)	(8.15)	(8.23)	(8.53)	(8.65)
LEV	-8.04	-6.94	-6.81	-7.17	-6.18	3.29	3.72	3.72	3.20	3.67	0.14	0.15	0.16	0.16	0.16
	(-14.25)	(-13.45)	(-13.17)	(-12.62)	(-11.91)	(6.09)	(7.06)	(7.03)	(5.83)	(6.84)	(1.87)	(1.95)	(2.02)	(2.02)	(2.07)
AGE	-1.74	-1.18	-1.14	-1.21	-0.82	-1.09	-0.83	-0.83	-1.05	-0.83	0.45	0.45	0.45	0.46	0.46
	(-10.31)	(-8.77)	(-8.57)	(-8.57)	(-6.90)	(-8.57)	(-7.48)	(-7.49)	(-8.25)	(-7.32)	(11.25)	(11.31)	(11.33)	(11.56)	(11.57)
MKT	1.11	0.98	0.84	1.02	0.93	-0.33	-0.33	-0.33	-0.32	-0.32	0.16	0.16	0.15	0.15	0.15
	(5.89)	(6.28)	(5.41)	(6.60)	(7.11)	(-2.12)	(-2.21)	(-2.15)	(-2.00)	(-2.10)	(6.23)	(6.16)	(5.83)	(5.97)	(5.92)
SMB	1.45	1.20	1.17	1.29	1.08	-0.15	-0.20	-0.20	-0.13	-0.19	-0.17	-0.17	-0.17	-0.17	-0.18
	(8.40)	(8.15)	(7.95)	(8.08)	(7.90)	(-1.70)	(-2.43)	(-2.41)	(-1.53)	(-2.29)	(-8.46)	(-8.53)	(-8.57)	(-8.67)	(-8.70)
HML	-1.32	-1.10	-1.05	-1.14	-0.98	0.33	0.37	0.36	0.34	0.36	-0.12	-0.12	-0.12	-0.12	-0.12
	(-12.32)	(-10.10)	(-9.50)	(-11.57)	(-9.55)	(2.60)	(3.04)	(3.02)	(2.67)	(3.02)	(-6.71)	(-6.63)	(-6.46)	(-6.57)	(-6.51)
EI		0.15	0.14		0.14		0.03	0.03		0.03		0.00	0.00		0.00
		(11.82)	(11.80)		(12.50)		(6.51)	(6.54)		(6.45)		(3.28)	(3.11)		(2.51)
DI		0.01	0.01		0.02		0.09	0.09		0.09		-0.00	-0.00		-0.00
		(1.81)	(1.85)		(2.48)		(13.95)	(13.95)		(13.82)		(-0.70)	(-0.73)		(-0.68)
Intercept	10.22	6.31	7.20	11.51	7.01	9.79	7.77	7.74	10.23	7.90	-0.84	-0.86	-0.81	-0.75	-0.77
	(13.15)	(10.34)	(11.91)	(16.20)	(12.41)	(13.73)	(13.24)	(12.56)	(13.02)	(12.31)	(-7.45)	(-7.62)	(-6.88)	(-6.11)	(-6.21)
Observations	35,506	35,472	35,472	35,506	35,472	55,735	55,657	55,657	55,735	55,657	48,636	48,563	48,563	48,636	48,563
R-squared	0.3217	0.4612	0.4652	0.3800	0.4973	0.0940	0.1569	0.1569	0.0954	0.1571	0.2829	0.2832	0.2838	0.2850	0.2850

Panel B. The dependent variable is Log(1+*TTCITES*), Log(1+*GENERALITY*)], or Log(1+*ORIGINALITY*)].

	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	Log(1+TTCITES)					*Log(1+GENERALITY)*					*Log(1+ORIGINALITY)*				
VP	-0.05	-0.05	-0.11	-0.21	-0.20	-0.01	-0.01	-0.03	-0.09	-0.08	-0.07	-0.06	-0.12	-0.20	-0.19
	(-1.62)	(-1.51)	(-2.10)	(-3.29)	(-3.16)	(-0.35)	(-0.27)	(-0.76)	(-1.62)	(-1.51)	(-2.60)	(-2.53)	(-3.15)	(-4.22)	(-4.21)
$(VP)^2$				0.05	0.05				0.03	0.03				0.05	0.04
				(4.28)	(4.10)				(2.62)	(2.46)				(4.92)	(4.88)
(VP)(BP)*			0.05	0.04	0.04			0.02	0.02	0.02			0.05	0.04	0.04
			(2.41)	(2.38)	(2.29)			(1.33)	(1.39)	(1.31)			(2.90)	(2.68)	(2.66)
BP	0.00	0.01	-0.03	-0.11	-0.09	0.02	0.02	0.00	-0.02	-0.01	-0.02	-0.02	-0.06	-0.15	-0.15
	(0.05)	(0.25)	(-0.82)	(-1.25)	(-1.04)	(0.71)	(0.92)	(0.10)	(-0.31)	(-0.11)	(-0.94)	(-0.81)	(-1.76)	(-2.42)	(-2.29)
$(BP)^2$				0.02	0.01				0.00	0.00				0.03	0.02
				(0.93)	(0.75)				(0.25)	(0.07)				(2.02)	(1.88)
CF	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(6.93)	(6.95)	(6.94)	(6.73)	(6.76)	(6.33)	(6.34)	(6.32)	(6.15)	(6.17)	(5.83)	(5.83)	(5.83)	(5.64)	(5.66)
ROA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(8.63)	(8.86)	(8.89)	(9.00)	(9.16)	(9.25)	(9.48)	(9.44)	(9.52)	(9.73)	(6.92)	(7.01)	(7.10)	(7.35)	(7.34)
LEV	0.14	0.15	0.16	0.15	0.16	0.15	0.15	0.15	0.15	0.16	0.15	0.16	0.16	0.16	0.16
	(1.95)	(2.03)	(2.10)	(2.07)	(2.13)	(2.49)	(2.56)	(2.59)	(2.58)	(2.64)	(2.45)	(2.50)	(2.58)	(2.54)	(2.56)
AGE	0.41	0.41	0.42	0.42	0.42	0.32	0.33	0.33	0.33	0.33	0.35	0.36	0.36	0.36	0.36
	(9.96)	(10.06)	(10.06)	(10.14)	(10.20)	(8.60)	(8.69)	(8.68)	(8.64)	(8.70)	(11.21)	(11.25)	(11.26)	(11.47)	(11.46)
MKT	0.16	0.16	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.10	0.12	0.12	0.12	0.12	0.12
	(6.07)	(6.00)	(5.73)	(5.81)	(5.76)	(4.86)	(4.80)	(4.70)	(4.70)	(4.65)	(5.85)	(5.79)	(5.43)	(5.60)	(5.57)
SMB	-0.17	-0.17	-0.17	-0.17	-0.17	-0.13	-0.14	-0.14	-0.14	-0.14	-0.14	-0.15	-0.15	-0.15	-0.15
	(-8.10)	(-8.21)	(-8.24)	(-8.26)	(-8.35)	(-7.71)	(-7.79)	(-7.79)	(-7.80)	(-7.86)	(-8.70)	(-8.71)	(-8.73)	(-8.86)	(-8.85)
HML	-0.13	-0.13	-0.13	-0.13	-0.13	-0.10	-0.10	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09
	(-7.19)	(-7.09)	(-6.95)	(-7.08)	(-7.00)	(-6.65)	(-6.57)	(-6.50)	(-6.57)	(-6.50)	(-6.13)	(-6.08)	(-5.90)	(-6.00)	(-5.97)
EI		0.00	0.00		0.00		0.00	0.00		0.00		0.00	0.00		0.00
		(4.42)	(4.24)		(3.56)		(3.35)	(3.25)		(2.90)		(2.36)	(2.16)		(1.51)
DI		-0.00	-0.00		-0.00		0.00	0.00		0.00		-0.00	-0.00		-0.00
		(-0.13)	(-0.15)		(-0.13)		(0.86)	(0.84)		(0.88)		(-0.40)	(-0.43)		(-0.46)
Intercept	-0.82	-0.85	-0.80	-0.75	-0.78	-0.72	-0.74	-0.72	-0.69	-0.71	-0.68	-0.70	-0.65	-0.60	-0.61
	(-7.26)	(-7.50)	(-6.74)	(-5.94)	(-6.11)	(-7.52)	(-7.74)	(-7.17)	(-6.49)	(-6.66)	(-7.61)	(-7.75)	(-6.96)	(-6.16)	(-6.20)
Observations	47,630	47,557	47,557	47,630	47,557	47,630	47,557	47,557	47,630	47,557	48,567	48,494	48,494	48,567	48,494
R-squared	0.2683	0.2688	0.2693	0.2700	0.2702	0.2544	0.2548	0.2550	0.2551	0.2554	0.2619	0.2620	0.2627	0.2643	0.2641

Panel C. The dependent variable is *IE_NPAT*. *IE_TTCITES*, or *RORD*.

	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	IE_NPAT					*IE_TTCITES*					*RORD*				
VP	1.22	1.22	1.38	1.72	1.74	1.14	1.13	1.14	1.53	1.56	2.05	1.99	2.76	3.75	3.59
	(4.12)	(4.12)	(3.21)	(3.18)	(3.23)	(4.00)	(4.01)	(2.66)	(2.85)	(2.88)	(6.27)	(6.09)	(6.04)	(7.58)	(7.29)
(VP)^2				-0.35	-0.36				-0.35	-0.36				-0.49	-0.45
				(-2.41)	(-2.47)				(-2.41)	(-2.45)				(-2.82)	(-2.55)
(VP)(BP)*			-0.14	-0.02	-0.03			-0.01	0.11	0.10			-0.68	-0.67	-0.64
			(-0.69)	(-0.15)	(-0.21)			(-0.03)	(0.61)	(0.56)			(-2.93)	(-2.81)	(-2.73)
BP	0.88	0.88	0.98	2.65	2.71	0.50	0.51	0.51	1.88	1.95	-1.60	-1.59	-1.18	-1.51	-1.55
	(2.43)	(2.39)	(2.14)	(3.06)	(3.03)	(1.43)	(1.44)	(1.19)	(2.15)	(2.16)	(-4.37)	(-4.28)	(-3.51)	(-1.80)	(-1.78)
(BP)^2				-0.54	-0.55				-0.43	-0.45				0.18	0.19
				(-2.99)	(-2.97)				(-2.41)	(-2.41)				(0.90)	(0.91)
CF	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.05	0.05	0.05	0.05
	(1.91)	(1.88)	(1.87)	(2.19)	(2.18)	(2.20)	(2.18)	(2.18)	(2.36)	(2.34)	(8.32)	(8.14)	(7.96)	(7.48)	(7.36)
ROA	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.04	-0.04	-0.04	-0.05	-0.05
	(-2.61)	(-2.61)	(-2.67)	(-2.58)	(-2.48)	(-2.32)	(-2.27)	(-2.30)	(-2.31)	(-2.20)	(-3.90)	(-4.18)	(-4.30)	(-4.49)	(-4.64)
LEV	0.01	0.02	0.01	0.07	0.11	0.05	0.07	0.07	0.10	0.14	9.81	9.79	9.72	9.54	9.56
	(0.02)	(0.04)	(0.02)	(0.14)	(0.20)	(0.08)	(0.12)	(0.12)	(0.16)	(0.22)	(7.73)	(7.68)	(7.62)	(7.37)	(7.33)
AGE	0.24	0.24	0.24	0.15	0.16	-0.13	-0.12	-0.12	-0.20	-0.20	0.37	0.33	0.32	0.29	0.27
	(1.45)	(1.46)	(1.44)	(0.92)	(0.96)	(-0.76)	(-0.75)	(-0.75)	(-1.19)	(-1.17)	(1.09)	(0.97)	(0.92)	(0.84)	(0.77)
MKT	-0.16	-0.16	-0.15	-0.18	-0.18	-0.13	-0.13	-0.13	-0.16	-0.16	-0.95	-0.94	-0.86	-0.88	-0.88
	(-1.20)	(-1.20)	(-1.06)	(-1.32)	(-1.34)	(-0.95)	(-0.96)	(-0.94)	(-1.16)	(-1.18)	(-3.83)	(-3.79)	(-3.54)	(-3.70)	(-3.67)
SMB	-0.27	-0.27	-0.27	-0.26	-0.27	-0.18	-0.19	-0.18	-0.17	-0.18	-0.94	-0.92	-0.90	-0.90	-0.88
	(-2.14)	(-2.16)	(-2.15)	(-2.13)	(-2.17)	(-1.45)	(-1.47)	(-1.48)	(-1.40)	(-1.45)	(-5.20)	(-5.04)	(-4.94)	(-5.02)	(-4.89)
HML	0.28	0.28	0.27	0.26	0.26	0.20	0.20	0.20	0.19	0.19	1.33	1.31	1.29	1.29	1.28
	(2.40)	(2.41)	(2.39)	(2.29)	(2.32)	(1.57)	(1.58)	(1.59)	(1.50)	(1.52)	(7.82)	(7.76)	(7.63)	(7.69)	(7.65)
EI		-0.00	-0.00		0.00		0.00	0.00		0.00		-0.01	-0.01		-0.01
		(-0.20)	(-0.07)		(1.17)		(0.20)	(0.21)		(0.92)		(-4.05)	(-3.85)		(-3.37)
DI		0.00	0.00		0.00		0.00	0.00		0.00		0.02	0.02		0.02
		(0.30)	(0.30)		(0.56)		(0.39)	(0.39)		(0.55)		(3.78)	(3.73)		(3.56)
Intercept	2.74	2.74	2.64	2.21	2.13	3.75	3.73	3.72	3.39	3.29	8.30	8.43	7.95	8.03	8.12
	(3.74)	(3.67)	(3.42)	(2.80)	(2.61)	(4.40)	(4.32)	(4.13)	(3.67)	(3.47)	(7.28)	(7.25)	(7.16)	(7.23)	(7.14)
Observations	25,992	25,959	25,959	25,992	25,959	25,190	25,157	25,157	25,190	25,157	29,882	29,849	29,849	29,882	29,849
R-squared	0.0304	0.0304	0.0305	0.0336	0.0337	0.0176	0.0175	0.0175	0.0196	0.0196	0.1493	0.1499	0.1505	0.1504	0.1509

Table 5. Path Analysis of the Link between R&D Investment and Misvaluation

This analysis is based on a sample during 1976-2004. The variables in Panel A are defined in Table 1. In Panel B, *ΔINTCOV* is change in the interest coverage ratio (earnings before interest, taxes, and deprecation divided by interest expense), and *ΔCR* is change in the current ratio (total current assets divided by total current liabilities). We follow Badertscher, Shanthikumar, and Teoh (2014) to break the total effect of *VP* on investment into three parts: the direct effect, the effect through the equity issuance channel, and the effect through the debt issuance channel.

Panel A. Regression of *RD* on *VP*, *EI*, *DI*, and control variables.

	RD
VP	-2.6906
	(-14.71)
EI	0.1457
	(11.82)
DI	0.0126
	(1.81)
BP	0.5768
	(3.35)
CF	0.0872
	(8.38)
ROA	0.0529
	(4.07)
LEV	-6.9368
	(-13.45)
AGE	-1.1770
	(-8.77)
MKT	0.9839
	(6.28)
SMB	1.1983
	(8.15)
HML	-1.0991
	(-10.10)
Intercept	6.3108
	(10.34)
Observations	35,472
R-squared	0.4612

Panel B. Regression of *EI* or *DI* on *VP* and control variables.

	(1) *EI*	(2) *DI*
VP	-2.6690	0.2108
	(-7.57)	(0.69)
BP	-2.6758	-5.8982
	(-7.49)	(-11.87)
Δ*INTCOV*	-0.0008	-0.0132
	(-0.50)	(-9.04)
Δ*CR*	3.8420	-1.8626
	(5.14)	(-7.00)
CASH	0.3369	0.0053
	(7.56)	(0.32)
Intercept	5.5762	11.7872
	(8.63)	(11.19)
Observations	52,269	52,269
R-squared	0.1198	0.0454

Panel C. Path analysis results for the effects of *VP* on R&D.

	Coefficient	t-stat
Direct	-2.6906	(-14.71)
Equity channel		
VP → *EI*	-2.6690	(-7.57)
EI → *RD*	0.1457	(11.82)
VP effect on *RD*	-0.3889	
Direct channel		
VP → *DI*	0.2108	(0.69)
DI → *RD*	0.0126	(1.81)
VP effect on *RD*	0.0027	
Total *VP* effect on *RD*	-3.0768	
% Direct	87.45%	
% Equity path	12.64%	
% Debt path	-0.09%	

Table 6. Investment Sensitivity to Valuation by Quintiles Sorted by Growth, *VP*, and KZ

The investment or innovation regressions as specified in Model (1) of Table 4 are performed separately by quintiles sorted by growth in Panel A, by *VP* in Panel B, and KZ in Panel C. The yearly sorting variables are based on beginning-of-fiscal-year values. The dependent variables are one of the following: R&D investment (*RD)*, capital expenditure (*CAPX*), patent counts (*NPAT*), time and technology adjusted patent citations *(TTCITES*), patent generality and originality, innovation efficiency *(IE_TTCITES*), and return on R&D (*RORD*); we use log transformed values for patent counts (*NPAT*, *TTCITES*, and *ORIGINALITY*). For each regression, this table reports only the *VP* coefficient (*b*) and the *t*-statistic (*t*) using standard errors clustered by both year and firm. The bottom row reports the difference in coefficients between quintiles 1 and 5, based on the coefficients and standard errors of *VP* for the two quintiles. The sample includes U.S. non-financial, non-utility firms listed on NYSE, AMEX and NASDAQ with CRSP/COMPUSTAT and I/B/E/S coverage during 1976-2012; the sample period for patents and citations is 1976-2008.

Panel A	*RD*		*CAPX*		*NPAT*		*TTCITES*		*ORIGINALITY*		*IE_TTCITES*		*RORD*	
BP Quintile	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
1 (Growth)	-8.10	(-8.03)	-0.96	(-1.66)	-0.27	(-4.17)	-0.28	(-4.39)	-0.21	(-3.87)	-0.41	(-1.28)	2.48	(3.43)
2	-2.84	(-3.68)	-0.00	(-0.01)	-0.17	(-2.71)	-0.15	(-2.56)	-0.12	(-2.27)	-0.41	(-0.89)	2.77	(5.10)
3	-4.22	(-6.96)	0.25	(0.90)	-0.15	(-3.19)	-0.12	(-2.65)	-0.11	(-2.78)	0.17	(0.48)	1.96	(3.95)
4	-3.05	(-8.12)	0.21	(0.84)	-0.09	(-2.86)	-0.07	(-2.33)	-0.06	(-2.63)	0.51	(1.30)	1.07	(1.82)
5 (Value)	-1.80	(-8.55)	0.09	(0.84)	0.01	(0.42)	0.02	(0.80)	0.00	(0.34)	0.83	(3.58)	1.56	(4.70)
Difference 5 – 1	6.30	(6.11)	1.05	(1.79)	0.28	(4.09)	0.30	(4.48)	0.21	(3.72)	1.24	(3.13)	-0.92	(-1.16)

Panel B	*RD*		*CAPX*		*NPAT*		*TTCITES*		*ORIGINALITY*		*IE_TTCITES*		*RORD*	
VP Quintile	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
1 (Overvalued)	-13.50	(-15.63)	1.73	(4.34)	-0.16	(-2.14)	-0.12	(-1.49)	-0.14	(-2.37)	2.65	(2.80)	2.86	(3.69)
2	-5.62	(-9.18)	5.92	(6.20)	-0.49	(-2.48)	-0.35	(-1.67)	-0.53	(-3.25)	8.75	(5.44)	7.49	(3.63)
3	-3.37	(-7.18)	4.43	(7.26)	-0.00	(-0.01)	0.12	(0.79)	-0.10	(-0.88)	8.78	(6.31)	3.92	(1.89)
4	-1.99	(-5.44)	2.81	(4.77)	0.32	(3.31)	0.41	(3.74)	0.18	(2.27)	6.98	(6.27)	3.27	(1.83)
5 (Undervalued)	1.84	(3.82)	0.92	(3.83)	0.08	(2.62)	0.12	(3.15)	0.04	(1.93)	1.24	(3.03)	-0.03	(-0.03)
Difference 5 – 1	15.34	(15.51)	-0.81	(-1.74)	0.24	(2.91)	0.24	(2.70)	0.18	(2.88)	-1.41	(-1.37)	-2.89	(-2.54)

Panel C	*RD*		*CAPX*		*NPAT*		*TTCITES*		*ORIGINALITY*		*IE_TTCITES*		*RORD*	
KZ Quintile	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
1 (Unconstrained)	-4.49	(-11.48)	0.79	(3.37)	-0.26	(-4.44)	-0.22	(-3.69)	-0.23	(-4.68)	1.50	(3.73)	3.32	(6.39)
2	-4.23	(-9.96)	0.52	(3.02)	-0.16	(-4.41)	-0.15	(-3.81)	-0.14	(-4.73)	0.87	(2.40)	1.85	(6.34)
3	-2.64	(-6.11)	0.24	(1.50)	-0.05	(-1.34)	-0.02	(-0.62)	-0.05	(-1.52)	1.40	(3.76)	1.88	(4.80)
4	-2.43	(-5.89)	-0.30	(-1.32)	-0.04	(-1.16)	-0.02	(-0.67)	-0.03	(-1.26)	1.23	(3.37)	1.57	(2.67)
5 (Constrained)	-1.31	(-5.08)	-0.61	(-2.60)	-0.02	(-0.89)	-0.01	(-0.57)	-0.02	(-1.05)	0.26	(0.65)	1.29	(1.89)
Difference 5 – 1	3.18	(6.80)	-1.40	(-4.24)	0.24	(3.82)	0.21	(3.28)	0.21	(4.10)	-1.24	(-2.20)	-2.03	(-2.36)

Table 7. Investment Sensitivity to Valuation by Quintiles Sorted by Size and Turnover

The investment or innovation regressions as specified in Model (1) of Table 4 are performed separately by quintiles sorted by size (total assets) in Panel A and by turnover in Panel B. The yearly sorting variables are based on beginning-of-fiscal-year values. The dependent variables are one of the following: R&D investment (*RD)*, capital expenditure (*CAPX*), patent counts (*NPAT*), time and technology adjusted patent citations *(TTCITES*), patent generality and originality, innovation efficiency *(IE_TTCITES*), and return on R&D (*RORD*); we use log transformed values for patent counts (*NPAT*, *TTCITES*, and *ORIGINALITY*). For each regression, this table reports only the *VP* coefficient (*b*) and the *t*-statistic (*t*) using standard errors clustered by both year and firm. The bottom row reports the difference in coefficients between quintiles 1 and 5, based on the coefficients and standard errors of *VP* for the two quintiles. The sample includes U.S. non-financial, non-utility firms listed on NYSE, AMEX and NASDAQ with CRSP/COMPUSTAT and I/B/E/S coverage during 1976-2012; the sample period for patents and citations is 1976-2008.

Panel A	*RD*		*CAPX*		*NPAT*		*TTCITES*		*ORIGINALITY*		*IE_TTCITES*		*RORD*	
Size Quintile	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
1 (Small)	-3.89	(-9.93)	0.10	(0.59)	-0.10	(-7.40)	-0.08	(-5.20)	-0.06	(-6.92)	0.45	(1.42)	1.59	(5.61)
2	-3.04	(-10.00)	-0.09	(-0.40)	-0.12	(-4.32)	-0.10	(-3.87)	-0.09	(-4.39)	1.19	(2.64)	2.07	(3.71)
3	-2.67	(-9.84)	-0.20	(-0.75)	-0.07	(-2.22)	-0.05	(-1.69)	-0.06	(-2.60)	1.37	(2.31)	2.81	(3.72)
4	-1.64	(-9.10)	-0.19	(-0.70)	-0.04	(-1.17)	-0.03	(-0.94)	-0.05	(-1.96)	1.60	(4.11)	3.74	(4.39)
5 (Large)	-0.94	(-7.35)	0.54	(2.49)	0.03	(0.49)	0.06	(1.05)	-0.02	(-0.39)	1.44	(4.31)	1.09	(1.45)
Difference 5 – 1	2.95	(7.16)	0.44	(1.58)	0.13	(2.12)	0.14	(2.24)	0.04	(0.77)	0.99	(2.14)	-0.50	(-0.62)

Panel B	*RD*		*CAPX*		*NPAT*		*TTCITES*		*ORIGINALITY*		*IE_TTCITES*		*RORD*	
Turnover Quintile	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
1 (Low)	-2.42	(-7.79)	-0.02	(-0.09)	-0.06	(-2.53)	-0.04	(-1.72)	-0.05	(-2.81)	1.09	(3.18)	1.79	(4.13)
2	-2.87	(-8.15)	0.16	(0.72)	-0.04	(-1.14)	-0.02	(-0.55)	-0.05	(-1.57)	1.47	(4.18)	2.06	(3.98)
3	-2.89	(-9.58)	0.20	(0.87)	-0.02	(-0.58)	-0.01	(-0.32)	-0.03	(-0.74)	1.31	(3.96)	1.94	(4.33)
4	-3.78	(-8.82)	0.09	(0.37)	-0.04	(-0.97)	-0.02	(-0.47)	-0.05	(-1.30)	0.55	(1.37)	1.30	(2.50)
5 (High)	-3.62	(-8.08)	0.30	(1.14)	-0.16	(-3.57)	-0.13	(-3.03)	-0.14	(-3.66)	1.17	(2.99)	2.05	(5.05)
Difference 5 – 1	-1.20	(-2.20)	0.32	(0.98)	-0.10	(-1.97)	-0.09	(-1.83)	-0.09	(-2.15)	0.08	(0.15)	0.26	(0.44)

Appendix A1. Summary Statistics for Middle Market and Large Firms (Full Sample in Table 1)

Panel A. Middle Market Firms (Sales between $10 Million and $1 Billion).

	N	Mean	Std Dev	Median	P1	P99
			Innovation Input and Output Variables			
RD (%)	24860	9.15	11.48	5.72	0.00	55.00
CAPX (%)	38877	8.48	10.23	5.15	0.24	53.78
NPAT	34762	2.25	8.28	0.00	0.00	35.00
TTCITES	34097	2.35	10.08	0.00	0.00	39.63
GENERALITY	34097	0.83	3.24	0.00	0.00	13.16
ORIGINALITY	34716	1.01	3.70	0.00	0.00	16.07
IE_NPAT ($\times 10^{-3}$)	18730	4.13	9.20	0.44	0.00	46.70
IE_TTCITES ($\times 10^{-3}$)	18153	4.34	10.68	0.14	0.00	56.26
Return on R&D	21226	6.36	14.53	2.66	-5.10	78.70
			Control Variables for Innovation Regressions			
CF (%)	39224	13.31	15.67	13.05	-35.81	59.02
ROA (%)	39222	18.08	13.94	17.28	-22.53	59.22
LEV	39304	0.23	0.23	0.18	0.00	0.83
AGE	39304	10.54	9.32	7.83	0.42	46.50
EI (%)	39277	8.42	29.56	1.30	-14.42	128.43
DI (%)	39300	8.24	24.18	2.87	-28.46	119.59
			Valuation Variables			
BP	39304	0.63	0.62	0.45	0.03	3.34
VP	39304	0.75	0.70	0.66	-1.25	3.31
			Variables Affecting the Innovation-Valuation Sensitivity			
KZ Index	37978	-0.19	1.57	-0.09	-8.06	2.39
Turnover (%)	38219	12.93	14.82	7.48	0.48	71.63
Total Assets ($M)	39300	376.63	522.41	225.19	18.10	2476.35
Sales ($M)	39304	316.75	265.23	234.42	13.61	970.59

Panel B. Large Firms (Sales above $1 Billion).

	N	Mean	Std Dev	Median	P1	P99
			Innovation Input and Output Variables			
RD (%)	13371	3.60	4.97	1.83	0.00	21.39
CAPX (%)	21622	7.39	6.47	5.71	0.49	31.58
NPAT	18469	36.54	154.84	1.00	0.00	579.00
TTCITES	18127	32.38	136.40	0.18	0.00	567.52
GENERALITY	18127	13.19	59.19	0.00	0.00	227.75
ORIGINALITY	18454	16.27	74.55	0.14	0.00	270.32
IE_NPAT ($\times 10^{-3}$)	9189	4.99	7.78	2.58	0.00	36.00
IE_TTCITES ($\times 10^{-3}$)	8973	4.56	7.46	2.09	0.00	33.31
Return on R&D	10623	14.28	22.33	6.67	0.43	141.60
			Control Variables for Innovation Regressions			
CF (%)	21805	13.12	9.69	12.34	-12.01	42.95
ROA (%)	21804	18.17	9.12	16.96	1.03	48.01
LEV	21864	0.35	0.21	0.34	0.00	0.86
AGE	21864	23.96	16.00	20.25	1.00	50.00
EI (%)	21792	1.54	11.44	0.51	-14.42	33.42
DI (%)	21861	6.12	17.79	2.94	-22.04	81.28
			Valuation Variables			
BP	21864	0.63	0.59	0.47	0.06	3.36
VP	21864	0.92	0.58	0.83	-0.01	3.00
			Variables Affecting the Innovation-Valuation Sensitivity			
KZ Index	21702	0.13	1.22	0.20	-3.78	2.49
Turnover (%)	21662	13.38	13.94	8.43	0.71	71.63
Total Assets ($M)	21861	9041.52	29913.62	2689.39	365.90	119098.53
Sales ($M)	21864	8734.10	21497.25	2971.31	1018.26	102290.60

Appendix A2. Investment and Innovation Variables for Middle Market and Large Firms (Full Sample in Table 2)
This table reports the mean values of corporate investment (*RD* and *CAPX*), (patent and citation counts), and valuation variables (*BP* and *VP*) for each year.

Panel A. Middle Market Firms (Sales between $10 Million and $1 Billion).

Year	*N*	*RD* (%)	*CAPX* (%)	*NPAT*	*TT CITES*	*GENE RALI TY*	*ORIG INAL ITY*	*IE-NPAT* (10^{-3})	*IE-TT CITES* (10^{-3})	*BP*	*VP*
1976	169	3.75	10.48	2.82	2.55	1.22	1.04	15.39	14.88	0.88	1.37
1977	230	4.42	12.02	2.48	2.52	1.16	0.90	15.27	14.81	0.76	1.14
1978	278	4.06	14.14	2.50	2.39	1.05	0.93	14.35	13.70	0.75	1.19
1979	520	3.90	12.46	1.97	2.01	0.92	0.73	12.31	12.88	0.89	1.28
1980	563	4.24	11.94	1.94	1.97	0.87	0.73	10.76	10.59	0.85	1.06
1981	571	4.17	11.88	2.04	2.11	0.90	0.78	9.43	8.80	0.80	0.96
1982	601	4.64	9.62	1.55	1.54	0.73	0.63	6.37	5.90	0.83	1.20
1983	720	5.85	8.88	1.36	1.30	0.61	0.52	5.11	4.95	0.78	0.98
1984	881	6.30	11.03	1.36	1.53	0.66	0.57	5.29	5.45	0.52	0.71
1985	987	6.50	10.78	1.28	1.50	0.64	0.53	5.21	5.50	0.69	1.15
1986	977	6.62	9.56	1.49	1.84	0.74	0.62	5.50	6.99	0.63	0.87
1987	1019	6.31	9.27	1.35	1.59	0.66	0.54	5.47	5.83	0.62	0.79
1988	1048	6.68	9.17	1.38	1.65	0.68	0.57	5.26	5.37	0.69	0.98
1989	1013	6.94	8.87	1.48	1.69	0.74	0.63	5.79	5.73	0.64	1.08
1990	1066	7.40	8.71	1.61	1.91	0.81	0.66	5.04	5.42	0.64	1.03
1991	1044	8.05	7.63	1.69	2.06	0.87	0.71	4.64	4.72	0.84	1.17
1992	1113	8.38	7.98	1.72	2.20	0.88	0.70	3.75	3.91	0.64	0.88
1993	1238	9.08	9.39	2.02	2.57	1.01	0.86	4.68	4.93	0.56	0.76
1994	1354	9.37	10.42	2.03	2.46	0.99	0.88	3.96	4.33	0.49	0.73
1995	1533	9.33	10.71	2.38	2.64	1.13	1.04	4.90	5.53	0.53	0.92
1996	1637	10.30	10.54	2.00	2.26	0.94	0.86	3.60	3.99	0.50	0.83
1997	1740	11.50	10.45	2.48	2.74	1.11	1.04	3.24	4.04	0.46	0.71
1998	1776	11.62	9.73	2.34	2.54	1.01	1.01	3.35	3.77	0.44	0.64
1999	1644	11.39	8.48	2.65	2.92	1.13	1.20	3.14	3.48	0.62	0.75
2000	1488	12.52	8.83	3.21	3.59	1.25	1.52	2.88	3.12	0.60	0.69
2001	1386	9.58	6.81	3.25	3.80	1.12	1.61	3.13	3.72	0.77	0.70
2002	1330	10.39	5.47	3.84	4.09	1.09	1.91	2.84	3.01	0.74	0.39
2003	1242	10.51	5.60	4.14	3.96	0.96	2.04	3.24	2.99	0.90	0.60
2004	1222	10.06	6.15	3.74	3.01	0.60	1.88	2.39	1.82	0.49	0.45
2005	1223	9.80	6.14	2.93	2.34	0.38	1.42	2.07	1.46	0.44	0.38
2006	1184	10.90	6.86	2.55	1.57	0.23	1.23	1.58	0.97	0.45	0.41
2007	1140	10.13	7.45	1.67	0.95	0.10	0.83	1.15	0.52	0.43	0.43
2008	1163	9.95	6.78	0.67	0.25	0.02	0.30	0.40	0.15	0.52	0.41
2009	1096	9.65	4.14							1.13	0.70
2010	1121	9.71	5.79							0.71	0.51
2011	1077	9.50	6.58							0.56	0.59
2012	910	10.38	6.48							0.71	0.68
All	39304	9.15	8.48	2.25	2.35	0.83	1.01	4.13	4.34	0.63	0.75

Panel B. Large Firms (Sales above $1 Billion).

Year	*N*	*RD* (%)	*CAPX* (%)	*NPAT*	*TT CITES*	*GENERALITY*	*ORIGINALITY*	*IE-NPAT* (10^{-3})	*IE-TT CITES* (10^{-3})	*BP*	*VP*
1976	262	2.88	8.83	44.69	42.32	18.64	15.28	16.59	14.87	1.05	1.36
1977	357	2.91	9.64	36.67	34.81	15.26	12.69	14.27	12.55	0.80	1.14
1978	397	3.06	10.23	32.09	30.24	13.48	11.96	11.33	10.43	0.90	1.30
1979	482	2.98	11.19	25.56	23.75	10.72	9.50	9.86	8.70	1.02	1.46
1980	480	3.04	11.17	27.62	25.79	11.84	10.59	8.60	8.27	0.97	1.31
1981	468	3.12	11.08	27.47	26.33	12.12	10.69	6.91	6.45	0.91	1.28
1982	460	3.27	9.61	27.18	26.10	12.03	10.82	7.12	6.50	1.00	1.64
1983	443	3.29	8.26	26.70	25.79	11.98	10.46	5.70	5.17	0.92	1.35
1984	424	3.72	9.48	28.89	28.19	12.96	11.37	6.19	5.73	0.69	1.07
1985	445	3.84	9.71	26.73	26.72	12.09	10.65	5.70	5.26	0.77	1.48
1986	430	3.80	8.98	28.99	28.87	13.41	11.76	5.16	4.81	0.67	1.04
1987	435	3.74	8.30	28.65	27.99	13.28	11.85	5.48	5.10	0.59	0.87
1988	447	3.99	8.74	29.79	29.24	13.77	12.42	5.05	4.78	0.61	0.95
1989	460	3.98	8.75	34.22	33.72	16.01	14.06	4.91	4.61	0.60	1.15
1990	488	4.01	8.53	34.16	33.93	15.98	13.99	4.94	4.55	0.61	0.99
1991	488	3.74	7.44	34.31	34.82	16.11	14.01	4.57	4.13	0.79	1.11
1992	511	3.72	7.49	33.54	34.32	15.93	14.23	4.35	3.97	0.62	0.91
1993	508	3.60	7.48	34.57	34.92	16.48	15.16	4.24	3.84	0.55	0.80
1994	530	3.88	7.88	36.42	37.75	17.61	16.16	4.56	4.24	0.50	0.80
1995	561	3.98	8.32	40.22	41.02	19.51	18.44	4.49	4.27	0.52	0.99
1996	630	3.79	8.19	40.90	42.24	19.74	18.66	4.14	4.06	0.50	0.88
1997	674	4.20	8.20	45.22	46.50	21.40	20.79	3.90	3.83	0.45	0.76
1998	716	4.10	8.77	44.20	44.76	20.26	20.77	3.94	3.86	0.41	0.71
1999	709	3.74	7.56	46.84	45.84	19.98	22.19	3.56	3.30	0.51	0.75
2000	706	3.69	7.24	51.03	49.49	19.61	24.77	3.45	3.41	0.58	0.81
2001	729	3.77	6.16	53.61	48.78	17.40	26.14	3.86	3.59	0.66	0.90
2002	715	3.45	5.05	54.53	45.05	14.51	26.38	3.58	3.10	0.59	0.72
2003	710	3.45	5.08	54.71	40.78	11.14	26.73	3.44	2.92	0.71	0.98
2004	749	3.44	5.54	47.29	31.24	7.06	23.07	3.09	2.26	0.43	0.73
2005	767	3.58	5.98	43.19	23.58	4.20	20.47	2.38	1.56	0.40	0.64
2006	800	3.88	6.42	33.16	14.41	1.98	15.39	1.88	1.00	0.41	0.66
2007	820	3.67	6.43	19.73	6.81	0.70	8.86	1.23	0.51	0.41	0.62
2008	851	3.75	6.14	9.24	2.36	0.16	3.96	0.49	0.18	0.51	0.61
2009	858	3.32	4.48							1.05	0.96
2010	769	3.24	4.57							0.57	0.74
2011	793	3.38	5.57							0.50	0.80
2012	792	3.53	5.73							0.62	0.88
All	21864	3.60	7.39	36.54	32.38	13.19	16.27	4.99	4.56	0.63	0.92

Appendix A3. Economic Impact of Regression Variables on RD, CAPX, and innovative output and efficiency, for the Full Sample, Middle Market Firms, and Large Firms

This table reports the impact of a one-standard-deviation change in an explanatory variable on each of the dependent variables, based on regression Model (1) of Table 4. The dependent variables are one of the following: R&D investment (*RD)*, capital expenditure (*CAPX*), patent counts (*NPAT*), time and technology adjusted patent citations *(TTCITES*), patent originality, innovation efficiency *(IE_TTCITES*), and return on R&D (*RORD*); we use log transformed values for patent counts (*NPAT, TTCITES,* and *ORIGINALITY*) and for AGE.

Panel A. Full Sample.

	RD	*CAPX*	*NPAT*	*TTCITES*	*ORIGINALITY*	*IE_TTCITES*	*RORD*
VP	-2.19	0.08	-0.05	-0.03	-0.05	0.61	1.41
BP	-0.23	-0.95	0.00	0.00	-0.01	-0.06	-0.98
CF	1.18	1.76	0.15	0.15	0.15	0.15	0.88
ROA	0.13	0.26	0.13	0.13	0.13	-0.26	-0.53
LEV	-1.84	0.75	0.03	0.03	0.03	0.00	2.24
AGE	-1.92	-1.20	0.50	0.45	0.39	0.07	0.41

Panel B. Subsample of Middle Market Firms (Sales between $10 Million and $1 Billion).

	RD	*CAPX*	*NPAT*	*TTCITES*	*ORIGINALITY*	*IE_TTCITES*	*RORD*
VP	-2.43	-0.13	-0.08	-0.06	-0.06	0.54	1.45
BP	0.12	-1.25	0.00	-0.01	-0.01	-0.16	-0.81
CF	2.19	1.88	0.16	0.16	0.00	0.16	0.94
ROA	0.84	0.28	0.00	0.00	0.00	-0.14	-0.14
LEV	-1.26	1.30	-0.03	-0.02	-0.02	0.43	1.65
AGE	-1.73	-1.26	0.09	0.06	0.05	0.01	0.35

Panel C. Subsample of Large Firms (Sales above $1 Billion).

	RD	*CAPX*	*NPAT*	*TTCITES*	*ORIGINALITY*	*IE_TTCITES*	*RORD*
VP	-0.61	0.34	-0.02	-0.01	-0.03	0.73	1.08
BP	0.70	-0.09	0.11	0.12	0.07	0.06	-2.17
CF	1.55	1.74	0.19	0.19	0.19	0.10	0.68
ROA	1.64	0.64	0.27	0.27	0.18	-0.55	-3.56
LEV	0.10	0.43	0.09	0.09	0.09	-0.69	0.72
AGE	0.13	-0.39	0.51	0.48	0.42	0.22	-1.91