Innovation Stocks and IPO Performance

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ABSTRACT

We investigate the information content of patents in the market for initial public offerings (IPOs) by examining the relationship between patents and first-day stock returns in a sample of 1488 IPOs by manufacturing firms. In industries characterized by complex product technologies (comprised of a large number of patentable elements), we find a positive association between patents and underpricing, suggesting greater information asymmetry (between informed and uninformed investors) concerning the value of the firm. In contrast, in industries characterized by discrete product technologies (consisting of a few patentable elements), we find a negative association between patents and underpricing, suggesting a lower degree of information asymmetry.

INNOVATION STOCKS AND IPO PERFORMANCE

There is substantial evidence that on average, initial public offerings (IPOs) are underpriced, meaning the stock is sold to initial investors at a discounted price. While various explanations for the underpricing phenomena have been offered (see Certo, Covin, Daily, and Dalton (2001), for a discussion of the different theoretical explanations of underpricing), one of the more enduring explanations is Rock's (1986) notion of information asymmetry. In order to induce uninformed investors to buy stock in companies when they are uncertain about the true value of the shares, issuing firms provide a premium in the form of a discounted price. Firms and underwriters underprice IPOs to induce investors without full information to participate in the market. An increase (decrease) in the level of uncertainty about the true value leads to a commensurate increase (decrease) in the amount of underpricing.

An implication of Rock's (1986) model is that characteristics of the IPO that provide credible information about firm value will reduce information asymmetry and reduce underpricing. For example, the prestige of the firm underwriting the IPO and the presence of venture capital (VC) backing have been examined as signals of firm quality that affect underpricing (Barry, Muscarella, Peavy, & Vetsuypens, 1990; Carter & Manaster, 1990; Megginson & Weiss, 1991). These signals are indirect, however, because they are based on external entities whose influence on the IPO process may be confounded by factors unrelated to firm value. For example, Loughran and Ritter (2001) argue that the agency problem between underwriters and IPO firms led prestigious underwriters to underprice new issues in the 1990s.

One cause of uncertainty in firm value is the innovation efforts undertaken by the firm. Innovation is a recognized source of competitiveness and is often fundamental to creating and maintaining firm value. However, innovation is an inherently uncertain process and its impact

on firm value is only realized in the future. Information asymmetries are likely to be particularly severe for innovative firms due to the unique nature of much research and development (R&D). Accordingly an accurate signal about the innovation quality of a firm at the time of the IPO may yield important information about its performance in the IPO market.

In this paper we develop a model to examine whether information contained in patents held by the IPO firm is associated with the value of the firm's innovation or information asymmetry due to uncertainty about the value of the underlying R&D. Specifically, we argue that in industries characterized by discrete product technologies (consisting of a few patentable elements), patents contain information about the firm innovation value. In these cases patents will reduce underpricing because (i) they are a direct signal of innovation value and (ii) they represent a primary value creation ability of the firm. The opposite is true in industries characterized by complex product technologies (comprised of a large number of patentable elements). In those industries, patents signal the magnitude of the R&D effort, leading to greater underpricing in order to compensate investors for the increased information asymmetry between informed and uninformed investors about the value of the firm.

Empirical results from a sample of 1488 IPOs issued by manufacturing firms during 1981 – 1998 strongly support our hypotheses. After controlling for venture backing and underwriter reputation we find that in industries characterized by discrete technologies, the presence of patents leads to less underpricing, suggesting a lower degree of information asymmetry. In industries where technology is more complex, the presence of patents leads to increased underpricing and suggests greater information asymmetry.

This research also contributes to our understanding of why entrepreneurial firms patent – a question of interest in the innovation literature. While a number of reasons have been identified

for patenting, such as protecting a new technology, precluding entry into a related technology area by a competing firm, and generating a patent portfolio for cross-licensing purposes, we provide another factor to take into account when firms decide whether or not to patent. When patents serve as a signal of the firm's value in the IPO market and thus help the firm get a better price, it is a clear benefit in the form of a lower cost of issuing equity.

The paper is organized as follows. We first discuss the role of innovation in creating firm value and present our model relating firm patent stock to the first-day returns of the stock when the firm goes public. We then describe the data used to test the model and define the variables used in the model. Next we present the results of our multivariate regression analysis. Finally we conclude with a discussion of our findings and make some suggestions for future research.

INNOVATION STOCKS AND INITIAL PUBLIC OFFERINGS

The role of innovation in creating firm value has long been recognized. Firms undertake investment in research and development in hopes of developing innovative products and services that lead to increased performance. Prior research has found a positive correlation between innovation and firm value (Griliches, 1981; Pakes, 1985). However, the role of innovation in the IPO process is not as clear. Given the number of technology-oriented firms that enter the market through IPOs, an increased understanding of the role of innovation in this process offers the potential for firms and underwriters to maximize returns from the offering.

Signals about firm innovation have the potential to inform investors about the value of the IPO. An accurate signal of the value of the firm’s innovation stock will reduce information asymmetry (between informed and uninformed investors) about the value of the firm. This reduction in information asymmetry will be associated with a commensurate reduction in underpricing – in other words the money firms leave on the table. Due to the unique and

uncertain nature of most research efforts, information asymmetries are likely to be particularly severe for innovative firms. This problem is exacerbated by the fact that a research project's value often depends on confidentiality (Bah & Dumontier, 2001). Aboody and Lev (2000), for example, find that insider gains are substantially larger in R&D-intensive firms than in firms without R&D. Accordingly when a signal reflects the level of R&D effort, awareness about the degree of information asymmetries between individuals who have knowledge of the value of the innovation and uninformed investors will be contained in the signal, rather than information about the resultant value. Under this perspective, the signal of firm innovation informs potential investors about higher ex-ante uncertainty, leading to greater underpricing to compensate investors for the increased risk.

While both effects will in all likelihood be present in any signal of the firm's innovation efforts, the extent to which one dominates depends upon the signal used and context in which it is evaluated. Together these jointly determine the quality of the signal of firm innovation value. Historically the primary measure used to evaluate firm innovation has been R&D expenditures. While past research has found a positive relationship between research and development expenditures and measures of firm value, the estimated effect of R&D has been surprisingly large. For example, Griliches (1981), reports that "the long-run effect of a dollar of R&D spending is to add about $2 to the market value of the firm." Pakes (1985) finds that a $100 unexpected increase in R&D is, on average, associated with a $1,870 increase in the value of the firm. The range of these observations raises questions about the quality of R&D as a signal of firm innovation value.

Part of the problem with R&D expenditures is they are an input to the innovation process and do not necessarily reflect the differential innovation ability of firms. Consequently R&D may

provide more information about the magnitude of the ex-ante uncertainty rather than the value of the innovative output. Consistent with the view that increased R&D increases the information uncertainty about the quality of firm innovation in the initial public offering, Guo, Lev, and Shi (2002) find that increased R&D intensity is correlated with increased underpricing.

Because of the limitations of R&D expenditures as a measure of firm innovation, researchers often choose to examine patent statistics. Patents represent an output from the research process. Technological variables, such as patents, have received some attention in the entrepreneurial finance literature recently. Wang, Chua and Megginson (2001) analyze the relative strength of the number of patents, R&D expenditures, and alliances, as signals of information about the value of a firm five days after the IPO. While results from this study indicate that the technology variables are dominated by financial variables such as underwriter reputation in explaining firm value after the IPO, unaddressed is the question of what role patents play in predicting underpricing.

Part of the lack of information in patent counts in prior research may stem from heterogeneity in the value of individual patents or uncertainty as to the rationale for securing the patent. We propose that the signal quality of patents in the IPO market will vary depending on the context in which it is evaluated. The effectiveness of patents in protecting new technologies varies by industry (Bettis & Hitt, 1995) suggesting that the information content of the patent signal may depend on the industry in which the firm is operating. In a study investigating the importance of patent protection, Mansfield (1986) found that the effects are heterogeneous across industries. In five industries (pharmaceuticals, chemicals, petroleum, machinery, and fabricated metal products) patent protection is viewed as important for the development and introduction of innovations. A theoretical explanation for the difference in patenting across

industries is due to the nature of the technologies underlying the new innovations. Technologies have been classified as discrete or complex in nature (Cohen, Nelson, & Walsh, 2000; Levin, Klevoric, Nelson, & Winter, 1987). Product technologies characterized as complex are comprised of a large number of patentable elements, while discrete product technologies consist of relatively few patentable elements (Cohen et al., 2000).

We hypothesize that the information contained in the patent signal will vary depending on whether the firm is in an industry where products tend to be comprised of a large number of patentable elements (complex) versus an industry where products consist of a relatively small number of patentable elements (discrete). In discrete product technology industries, such as pharmaceuticals and chemicals, the link between patents and innovation value is much clearer. New drugs and chemicals typically contain a small set of patentable elements (Cohen et al., 2000). One implication is that relatively clear standards can be used to assess a patent's validity and defend against infringement (Levin et al., 1987). Levin (1986) notes that patents are regarded as most effective in industries with chemical-based technologies. As an example of the importance of patenting in these industries, Mansfield (1986) found seventy-five percent of inventions in the pharmaceutical and chemical industries would not have been introduced without patent protection. Accordingly we argue that patents in these industries will convey information of the value of the firm's innovation stock, reducing information asymmetry about the value of the firm. Which leads to the following hypothesis:

Hypothesis 1. In industries characterized by discrete technologies there will be a negative relationship between patents and underpricing.

In contrast, in industries characterized by complex technologies, the uncertainty about the relationship between patents and innovation value will be higher. Due to the large number of components underlying products in these industries, it is not uncommon for firms to lack

ownership of all the essential elements of the technologies they are developing (Cohen et al., 2000). Successful innovation often entails creating a condition of mutual dependence that fosters cross-licensing of component technologies. Consequently, in complex-product technology industries information disclosed as part of securing a patent will not provide information about the value of the firm's innovation, but rather provide information about the magnitude of the R&D investments. This will increase the information asymmetry between insiders who are knowledgeable about the expected value of any patent and uninformed investors. Which leads to the following hypothesis:

Hypothesis 2. In industries characterized by complex technologies there will be a positive relationship between patents and underpricing.

In conclusion we argue that patent counts offer potential information about a firm's innovation at the time of the IPO, however, the quality of the signal will depend on the context in which the signal is made, i.e. the nature of the technology underlying innovation in the industry in which the IPO is being conducted.

MODEL

To test the hypothesized relationships we start by estimating with the following equation:

$$FDret_i = \beta_0 + \beta_1 Pat_i + \beta_2 CV + \varepsilon_i \quad (1)$$

where *FDret* is the percentage change in the stock price during the first-day of trading; *Pat* is the stock of firm patents at the time of the IPO and *CV* is a vector of control variables. To allow for a differential effect of patenting on underpricing we allow β_1 to vary systematically by including a dummy variable (discrete_dum) which equals 1 if the firm is in an industry characterized by discrete technologies, 0 otherwise. That is:

$$\beta_1 = \beta_{11} + \beta_{12}\ discrete\_dum$$

which when substituted into equation (1) results in the following equation:

$$FDret_i = \beta_0 + \beta_{11} Pat_i + \beta_{12} Pat_i * discrete\_dum + \beta_2 CV + \varepsilon_i \quad (2)$$

The null hypothesis of our analysis is that the coefficient estimates β_{11} and β_{12} equal zero which would indicate that a firm's patent stock has no effect on IPO underpricing. The alternative hypothesis is that some or all of the coefficients are not equal to zero, which implies that there is information in the patent stock signal. The hypothesis that patents signal greater ex-ante innovation uncertainty in industries characterized by complex technologies implies $\beta_{11} > 0$. The hypothesis that patents will be a signal of innovation value and reduce information asymmetry leading to less underpricing in industries characterized by discrete technologies implies that $\beta_{11} + \beta_{12} < 0$.

DATA SOURCES AND VARIABLE DEFINITIONS

To estimate the above models we obtained data from a number of sources. The Securities Data Corporation (SDC) New Issues database was used to identify manufacturing firms (SIC 20-39) conducting initial public offerings in the period 1981-1998. First-day trading information for the sample of IPOs was obtained from the Center for Research in Security Prices (CRSP) tapes. Patent data from 1981 to 1998 were obtained from the 1998 USPTO patsic/coname database which provides the date and assignee information for each utility patent. Firm assets in the year prior to the IPO were obtained from Standard and Poors Compustat data tapes. Underwriter quality was measured using the update by Lourange and Ritter (2001) of the underwriter reputation rank developed by Carter and Manaster (1990). After deleting firms with (i) an offer price below 5.00 dollars, (ii) total proceeds from the IPO of less than 5.00 million dollars, or (iii) incomplete data, the final sample consists of 1488 firms of which 765 had filed for at least one

patent in the five years prior to their initial public offering. One benefit of the time period of our study is that we avoid any effect of the internet bubble in 1999 and 2000.

Variable Definitions

First-day stock return is measured as the percentage change in stock price during the first-day of trading for the IPO, i.e. $\left(closing\ \ price - offer\ \ price\right) / offer\ \ price$.

Patent stock is measured by summing the number of patents that the firm has filed for in the five-year period prior to the initial public offering. Following common practice (e.g. Griliches, 1981) firm patents are dated according to the application (as opposed to granting) date. We focus on recent patents, i.e. filed in the five years prior to the IPO for two reasons. First, recent patents will provide the most current information about the firm inventive capabilities at the time of the IPO. Second, while in theory patent protection lasts for 20 years from the date of filing, it has been shown that patents provide a relatively short protection period. For example, Mansfield, Schwartz, and Wagner (1981) found that 60% of the patents in their study were invented around in less than four years. As such current information about the value of firm innovation will only be contained in recent patents. To account for the skewness in the data we use a *log(pat+1)* transformation.

To identify whether the IPO is in a discrete or complex product industry we follow the classification scheme developed by Cohen et al. (2000) and coded industries with an ISIC code less that 2900 (e.g. chemicals, pharmaceuticals, and metals) as discrete and those with an ISIC code of 2900 or higher as complex (e.g. machinery, computers, and electrical equipment).[1] Kusonki, Nonaka, and Nagata (1998) use a similar coding scheme except for labeling the categories material and system instead of discrete and complex.

Control Variables

To account for the effect of other signals that might contain information about the value of the firm's innovation at the IPO we include information about venture capital backing and prestigious underwriting backing in our model. In addition we also include firm size and controls to account for the macro economic conditions at the time of the IPO. We could not control for R&D intensity because R&D data is only available for 60% of our sample. We do, however, conduct a sensitivity analysis (page 16) using this smaller sample.

Venture capital backed. We include a dummy variable to indicate whether the firm has received venture capital financing or not. Early research suggests that the certification and monitoring role of venture capitalists will lead to less underpricing (Barry et al., 1990; Megginson & Weiss, 1991). However, more recent work indicates that the relationship between venture capitalists and IPO underpricing is more complex. For example, Lerner (1994) suggests that venture capitalists try to time IPOs to benefit from market conditions. Brav and Gompers (2003) find that VC-backed offerings are more underpriced while Bradley and Jordan (2002) find that after controlling for the market exchange and the effect of underwriter there is no difference in underpricing between VC- and non-VC backed IPOs.

Prestigious underwriter backed. To account for the effect of utilizing a highly reputed underwriter we use Loughran and Ritter's (2001) version of the underwriter reputation measure developed by Carter and Manaster (1990) and updated by Carter, Dark and Singh (1998). Following Loughran and Ritter (2001) we construct a dummy variable that equals 1 if the underwriter rank is equal or greater than 8.0. Initial research into the relationship between underwriters and underpricing argued that the certification role played by prestigious underwriters would lead to less underpricing. Empirical work such as Carter and Manaster

(1990) study found support for this contention examining IPOs between 1979 and 1983. However, more recent work by Loughran and Ritter (2001) argues that there is an inherent agency problem between underwriters and IPO firms which in the 1990s led prestigious underwriters to underprice new issues. To account for the potential differential effect of underwriter reputation in the 1980s and 1990s, we include an interaction term created by multiplying the prestigious underwriter term by a decade dummy (*dum90* equals 1 if the firm conducted its IPO in the 1990s, 0 otherwise).

Firm size. To control for the effect of firm size we include a measure of log firm assets in the year prior to the IPO. It is important to account for firm size to insure that our patent stock measure is reflecting the innovation output of the firm and not firm size as larger firms in general will have more patents. Increase in firm size will reduce underpricing due to the reduction in information asymmetry about the viability of the firm. Larger firms will in general be older and thus have less uncertainty about their value.

Hot markets. We include a count of the number of IPOs in the same industry as the IPO firm in the preceding year to account for the effect of hot markets. IPO markets are characterized by rotating periods of significant activity, i.e. hot periods and periods of low activity, i.e. cold periods. Research had shown that hot markets are associated with higher underpricing than cold markets (Ritter, 1984).

Lagged market return. To account for the effect of recent market conditions that are not included in the final offer price we include a measure of the market value-weighted return for the twenty-day pre-IPO period. Logue (1973) contends that underwriters may price IPOs independently of market conditions and finds a positive relationship between pre-IPO market

returns and IPO first-day returns. More recent work (e.g. Beard, Neuhauser, Mantecon, & Ryan, 2002; Loughran & Ritter, 2002) finds similar results.

To account for macro-economic factors that are not controlled for by the preceding measures, all regressions include annual dummy variables.

DESCRIPTIVE STATISTICS

Table 1 presents the descriptive statistics for the sample of IPO firms. The mean first-day stock return of 11.38 % for the full sample is consistent with studies utilizing data from similar time periods. For example, Guo, Lev, and Shi (2002) report a mean first-day stock return of 10.14% for a sample of 2696 IPOs during the period of 1980 to 1995. Of the 1488 firms in our sample, 51% had filed for patents at the time of the IPO with an average of 5.85 per firm, 46.64% of firms are venture backed, and 45.70% are underwritten by prestigious underwriters. The average size is 228 million dollars, however this figure is skewed by the large firms and median firm size is 20.33 million dollars.

Insert Table 1 about here

In comparing the firms in the two industry groups, we observe some important differences. First, the average number of patents per firm (7.87) and the percentage of firms who patent (59.97%) are highest in the industry group characterized by complex technologies. This underscores the prominence of patents in this group because complex products are comprised of many patentable elements. Second, while there is no discernable pattern to prestigious underwriter backing across the groups, the percentage of firms backed by venture capitalists is highest in the complex technology group. Third, there is an increase in the hot markets measure in the complex technology group which may in part be driven by the fact that venture capitalists

will often try to time the IPO to take advantage of favorable market conditions (Lerner, 1994). Finally, we see a sizeable difference in the mean first-day stock return between the discrete complex industry groups (8.62% versus 13.77%).

To further explore the relationships between the variables in our study we computed bivariate correlations (Table 2). Firm size is negatively correlated with first-day stock returns suggesting that larger firms experience less underpricing. In contrast being backed by a prestigious underwriter leads to more underpricing, however, this result may be driven in part by the behavior of prestigious underwriters in the 1990s. We also observe a positive correlation between patenting and first-day stock returns which suggests that as the number of patents increases there will be greater information asymmetry concerning the value of the firm. As hypothesized this relationship will likely vary depending on whether the firm is operating in an industry characterized by discrete or complex product technologies.

Insert Table 2 about here

Finally, in examining the correlations between patents, prestigious underwriter and VC backing, we observe significant and positive bivariate correlations. This suggests that some information about firm innovation is contained in the other indirect signals (VC backing and prestigious underwriting backing). However, as discussed earlier, both the VC and prestigious underwriter signal can be confounded by other factors leading to questions about their reliability as a signal of innovation quality.

While the prior analysis suggests there is information in the patent signal, the significant correlation between patent stocks, venture backing and prestigious underwriter backing indicates a multivariate approach is necessary in order to isolate the different signal effects. In the next

section, we present and discuss the results of estimating our two multivariate models, i.e. Equations 1 and 2.

EMPIRICAL ANALYSIS

The results from our regression analysis are shown in Table 3. We start by estimating a model (Equation 1) that relates the patent stock measure and the control variables to first-day stock returns. This model is significant and explains 5 % of the variance. While we find no evidence of a significant effect for patents, a number of the control variables are significant. The effect of firm size is negative and significant ($p<0.001$) suggesting that information asymmetry about the firm's value or viability decreases as firm size increases. The effect of venture capital backing is negative but not significant. Thus the current results provide no support for the afore mentioned certification and monitoring hypothesis (see Barry et al., 1990; Megginson & Weiss, 1991). The effect of prestigious underwriter backing is non-significant in the 1980s, but positive and significant ($p<0.05$) in the 1990s. Consistent with Loughran and Ritter's (2001) agency hypothesis, we find evidence that prestigious underwriters underpriced new issues in the 1990s. The hot market measure is positive but non-significant. While the lack of a hot market effect is surprising, (especially given the positive and significant bivariate correlation between hot markets and first-day stock returns), to some extent the effect of hot markets will be encapsulated in the annual dummy terms. Finally, consistent with prior research the effect of lagged market returns is positive and highly significant ($p<0.001$), suggesting that recent market conditions are not fully incorporated into the offer price.

Insert Table 3 about here

In our next model (Equation 2), we allow the patent term to vary according to whether the firm is in an industry group characterized by discrete or complex product technologies. The results indicate that the effect of patents on underpricing varies according to the industry group. The null hypothesis that the effect of patents is the same in both groups can be rejected at the $p<0.01$ level. In looking at the individual coefficient estimates, the negative and significant ($p<0.01$) interaction term indicates that firms in industries characterized by discrete technologies with increased patents experience less underpricing than firms in industries characterized by complex technologies. To compute the direct effect of patenting on first-day stock returns in the discrete technology group, we add the two patent coefficients together. Consistent with Hypothesis 1 the direct effect is negative ($0.015 + -0.030 = -0.015$) and significantly different from zero ($p<0.05$), suggesting that in discrete product industries the value signal dominates the ex-ante uncertainty signal. In contrast, consistent with Hypothesis 2 that increased patenting in industries characterized by complex technologies will lead to increased information asymmetry, we observe a positive and significant effect ($p<0.01$) of patenting on first-day stock returns.

In conclusion, we find that there is information in the patent signal. However, consistent with our hypotheses, the information content depends on the context in which the signal is made. In industries characterized by complex technologies, we find a positive association between patents and underpricing suggesting greater information asymmetry (between informed and uninformed investors) concerning the value of the firm. In contrast, in industries characterized by discrete technologies we find a negative association between patents and underpricing, suggesting a lower degree of information asymmetry.

SENSITIVITY ANALYSIS

As noted earlier increased R&D expenditures may increase uncertainty about the quality of firm innovation in the IPO and lead to increased underpricing (Guo et al., 2002). This raises the question of whether the information in the patent signal in the initial public offering is associated with information contained in firm R&D expenditures. To investigate this consideration we re-estimated Equation 2 and include a measure of R&D intensity (R&D / Assets) prior to the IPO. R&D data is only available for 904 firms (61% of our sample) in Compustat. While the results of the patent measures are in close correspondence to those reported in Table 3, the effect of R&D intensity is positive but not significant.

To see if patents reduce the information asymmetry associated with R&D expenditures by providing additional information about the firm innovation, we also tested to see if there was any interaction effect between R&D and patents. While the interaction effect is in the expected direction (negative) the coefficient estimate is not significant. In conclusion, the results of our sensitivity analysis indicate that patents provide information about the quality of firm innovation independent of any information contained in R&D expenditures.

DISCUSSION AND CONCLUSIONS

An extensive literature documents that, on average, initial public offerings are underpriced. Rock (1986) argues that one cause of underpricing is the information asymmetry between uninformed and informed investors about the value of the firm. In order to compensate uniformed investors the issuing firm provides a premium in the form of a discounted price. Firms (and underwriters) underprice IPOs to induce investors without full information about the value of the firm to participate in the market.

One source of the information asymmetry between informed and uninformed investors is lack of information about the value of the firm's innovation stock. In this paper we developed and tested a model that provides a theoretical foundation to examine whether information in the patent signal in the initial public offering is associated with the value of the firm's innovation or the information asymmetry due to uncertainty about the value of the underlying R&D. We find that a firm's patent stock can act as a quality signal of firm innovation value, but only in industries where product technologies consist of discrete patentable components. In such industries, the presence of patents reduces information asymmetry and leads to less underpricing. In contrast, in industries characterized by complex technologies, patents signal more about the uncertain process of innovation leading to higher underpricing in order to compensate investors for the increased risk. In these industries the relationship between patents and inventive value is not as clear due to factors such as uncertainty as to the rational for securing the patent, leading to increased information asymmetry between informed and uninformed investors about the value of the firm

Our results provide additional support for information asymmetry as a primary cause of underpricing. By developing a model that identifies a potential signal of firm quality and conditions under which the signal will differentially impact the first-day stock returns, we are able to isolate conditions when the level of information asymmetry will be different between informed and uninformed investors. Additionally our results have important implications for when firms decide to patent or not. While prior research has identified a number of reasons for patenting, such as protecting a new technology, we provide another factor to take into account when deciding to patent or not. In industries characterized by discrete technologies patents help the firm reduce the cost of issuing equity. In industries characterized by complex technologies,

however, patents actually increase the costs of issuing equity, a factor that needs to be taken into account when evaluating the benefits of securing a patent.

While our results indicate that information is contained in the patent signal, one direction for future research would be to see if information about the differing value of individual patents is contained within patent-based signals. One option would be to use patent renewal information, which Schankerman (1998) has linked to patent value. Alternatively, recent work has highlighted that information contained in citations from future patents can account for the some of the variance in patent values (Hall, Jaffe, & Trajtenberg, 1998; Shane & Klock, 1997).

ENDNOTES

[1] Following Cohen et al. (2000) we excluded firms assigned to industry ISIC3600 (other manufacturing) from the analysis.

TABLE 1
Descriptive Statistics

Variable	Full Sample		Industries Characterized by Discrete Technologies		Industries Characterized by Complex Technologies	
	Mean	Median	Mean	Median	Mean	Median
First-day returns (%)	11.38	5.00	8.62	3.57	13.77	7.14
Patent Stock	5.85	0	3.52	0	7.87	2
Firms with patent(s) (%)	51.41		41.53		59.97	
Assets (millions of dollars)	288.60	20.33	319.09	25.56	150.15	17.14
Venture backed (%)	46.64		40.81		51.69	
Prestigious underwriter backed (%)	45.70		45.15		46.17	
Hot Market	21.28	20.00	15.77	9.00	26.05	25.00
Lagged market return (%)	1.39	1.50	1.32	1.45	1.40	1.53
Number of observations	1488		691		797	

TABLE 2
Bivariate Correlations

Variable		1	2	3	4	5	6	7
1	First-day stock returns	1.00						
2	Log (Patents + 1)	0.07**	1.00					
3	Log (Assets)	-0.09***	-0.01	1.00				
4	Venture backed	0.02	0.25***	-0.21***	1.00			
5	Prestigious underwriter backed	0.07**	0.20***	0.34***	0.14***	1.00		
6	Hot market	0.07**	0.27***	-0.26***	0.20***	0.11***	1.00	
7	Lagged market return	0.14***	0.07**	0.01	-0.01	-0.01	0.00	1.00

*p< .05, **p< .01,***p< .001

TABLE 3
Results of Regression Analysis of The First-day Stock Returns[a]

	Equation 1	Equation 2
Variable	β	β
Intercept	0.189*** (0.056	0.195*** (0.056)
Log (Assets)	-0.019*** (0.004	-0.018*** (0.003)
VC backed	-0.014 (0.012)	-0.013 (0.012)
Prestigious underwriter backed	-0.008 (0.024)	-0.010 (0.024)
Prestigious underwriter backed * dum90s	0.069* (0.028)	0.070* (0.028)
Hot market	0.0002 (0.0004)	0.0002 (0.0004)
Lagged market returns	0.879*** (0.182)	0.899*** (0.181)
Log (Patents + 1)	0.004 (0.005)	0.015* (0.007)
Log (Patents + 1)* discrete_dum		-0.030** (0.010)
discrete_dum		-0.015 (0.015)
Adjusted R-Square	0.05	0.07
F Value	4.25***	4.83***

[a] Values are regression coefficients with standard errors are in parentheses; number of observations equals 1488, all regressions include annual dummies. Note we do not include the decade dummy (dum90s) as a main effect as its effect is encapsulated in the annual dummy terms.

* $p < .05$, ** $p < .01$, *** $p < .001$

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