Working Paper No. 2015008

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Product Market Competition and Value of Innovation: Evidence from US Patent Data

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October 13, 2015

Abstract

This study investigates the relationship between product market competition and the market value of innovation using firm-level patent data of US firms over the period 1977-2005. We find that there is an inverted U-shaped relationship between competition and the value of innovation. Furthermore, we show that there is an "*asymmetric*" causal effect of intensifying product market competition on the market value of innovation, using a quasi-natural experiment based on tariff-cut events for US manufacturing firms between 1977 and 2006: a firm's incentive to innovate tends to get stronger in response to a tariff cut when product market competition is very mild, while it tends to get weaker when very severe.

JEL classification: L10, O31, O34, G30

Keywords: Innovation, Product Market Competition, Value of Innovation, Tariff Cuts

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1 Introduction

Innovation is one of the most important determinants of the prosperity and sustainable growth of corporations. An innovative firm can have a significant competitive advantage over its competitors by possessing exclusive technologies and providing profitable products to the market. Thus, it is evident that innovation increases firm value, but how much is it worth? This market value of innovation is the key concept—higher value indicates stronger motivation for firms to innovate. In this paper, we investigate the relationship between product market competition and the value of innovation by examining how the market value of innovation varies with competition circumstances.

The relationship between product market competition and innovation has been widely studied in the past several decades[1]. The theoretical predictions and empirical findings, however, have not yet reached consensus. Figure 1 summarizes four possible depictions of the relationship between product market competition and innovation. Each model, using different sets of assumptions, predicts various scenarios contradicting each other. Such sharp contrast calls for further investigation on this topic. Our work differs from most existing studies on the relationship between product market competition and innovation in that we directly measure the market value of innovation. By using the market value of innovation, we can directly judge how a firm's incentive to innovate changes through different levels of product market competition.

[Insert Figure 1 Here]

There are several notable studies that investigate the relationship between the market value of firms and their innovation (e.g., Blundell *et al.*, 1999; Hall *et al.*, 2005). Among them, Greenhalgh and Rogers'(2006) is the first (and, to our knowledge, the only) study that examines the relationship between the market value of innovation and product market competition. Using data on UK companies' research and development (R&D) and intellectual property activities from 1989 to 2002 and comparing valuations of R&D among 6 Pavitt sectors, they find that firms in the most competitive sector have the lowest market valuation of R&D. They further show that, within the most competitive sector, firms with higher market shares, which are likely to face less competitive pressure, have higher valuation for R&D. Their findings generally support Schumpeter's (1943) view that returns to innovation are higher in less than perfectly competitive markets.

In this study, we revisit the question by utilizing firm-level patent data of US firms in periods between

[1] See Gilbert (2006).

1977 and 2005. We measure innovation using the number of total non-self citations of patents that a firm has applied for in a specific year, which is suggested to be a better measure by recent studies such as Fang *et al.* (2014), and product market competition with price-cost margin following Nickell (1996) and Aghion *et al.* (2005). To estimate the market value of innovation, we apply the methodology used by Faulkender and Wang (2006) and Dittmar and Mahrt-Smith (2007). Specifically, we investigate the impact of a competition measure on the coefficient of an innovation measure in a regression model in which the dependent variable is excess or raw stock returns of firms.

2 Data and methodology

We use Center for Research in Security Prices (CRSP) data to calculate annual stock returns of a firm and total market value of a firm's equity. As benchmark returns, we use returns to the 2×3 Fama and French portfolio provided in Kenneth French's data library. In addition, we use data from COMPUSTAT North America to construct variables based on the information contained in financial statements. We go through a series of data-cleaning procedures, such as excluding firms in utilities and financial services industries, dropping observations with a missing or negative book value of total assets, dropping observations with raw or excess returns that are greater than +100% or smaller than -100%, and restricting the sample to common shares traded in three major stock exchanges in the US (NYSE, NASDAQ, and AMEX). We then winsorize all variables at the 1st and 99th percentiles. After all these procedures, we have an unbalanced panel of 11,035 firms among 247 industries based on three-digit Standard Industrial Classification (SIC) codes over the period 1978-2006, which contains 81,463 firm-year observations with returns as well as lagged innovation and competition measures as defined below.

As a measure of industry-level product market competition, we use price-cost margin (also known as Lerner Index) closely following Aghion *et al.* (2005). This measure has an advantage over Herfindahl concentration index or other market-share-based measures because it is not affected by geographic considerations. To measure how active a firm's innovation activities are, we use the latest version of the National Bureau of Economic Research (NBER) US Patent Citations Data File. After handling truncation issues following Hall *et al.* (2001, 2005), we use the number of patents, the number of total citations, and the number of total non-self citations as innovation measures. One common concern for these measures is that their distributions are severely skewed to the right. To minimize this concern, our innovation measures, $INN_{i,t}$, are defined as the natural logarithms of one plus original measures.

To examine how the market value of innovation varies with the intensity of product market competition, we modify an empirical framework suggested by Faulkender and Wang (2006) and Dittmar and Mahrt-Smith (2007). Specifically, we investigate the effect of a competition measure on the coefficient of an innovation measure in a regression model in which the dependent variable is excess or raw stock returns of firms. Our baseline model with excess stock returns is specified as follows:

$$
\begin{aligned}
r_{i,t} - R_{p,t} &= \beta_0 + (\gamma_0 + \gamma_1 COM_{j,t-1} + \gamma_2 COM^2_{j,t-1}) INN_{i,t-1} \\
&+ \beta_{CONTROLS} CONTROLS + INDUSTRY\ DUMMIES + YEAR\ DUMMIES + \varepsilon_{i,t}, \qquad (1)
\end{aligned}
$$

where $r_{i,t}$ is the stock return of a firm from year $t-1$ to t, $R_{p,t}$ is the annual return of the matched portfolio of a firm in year t, $COM_{j,t-1}$ is the lagged competition level for the j-th industry, measured as $(1 - \text{Lerner Index}_{j,t-1})$, $INN_{i,t-1}$ is the natural logarithm of 1 plus the number of total non-self citations of the patents that the firm has applied for in year $t-1$ (i.e., $ln(1+\text{the number of total non-self citations})$), and *CONTROLS* includes changes in profitability, investment (including R&D), and financing. The control variables are the same as in Faulkender and Wang (2006) and Dittmar and Mahrt-Smith (2007). Note that industry dummies based on Fama and French's 12 industries and year dummies are included to control for industry and year fixed effects. In Equation (1), the market value of innovation is measured by the regression coefficient for $INN_{i,t-1}$, which is modeled as a quadratic function of a competition measure: $\beta_1 = \gamma_0 + \gamma_1 COM_{j,t-1} + \gamma_2 COM^2_{j,t-1}$. This specification allows us to evaluate which theoretical prediction is best supported by our data among four possible explanations: *i)* a positive linear relationship (Arrow, 1962); *ii)* a negative linear relationship (Schumpeter, 1943); *iii)* a U-shaped relationship (Boone, 2001); and *iv)* an inverted U-shaped relationship (Aghion *et al.*, 2005).

3 Results

3.1 Main regression results

Before we present main results, we first estimate a semi-parametric smooth coefficient model (SPSCM) proposed by Li *et al.* (2002) and used by Stengos and Zacharias (2006) and Sun and Kumbhakar (2013) among others. Our model with excess stock returns is specified as follows:

$$r_{i,t} - R_{p,t} = X'_{i,t-1}\beta(COM_{j,t-1}) + \varepsilon_{i,t}, \tag{2}$$

where $\beta(\cdot)$ is a vector of smooth but unknown functions of $COM_{j,t-1}$, and $X_{i,t-1}$ includes 1, $INN_{i,t-1}$, *CONTROLS*, *INDUSTRY DUMMIES*, and *YEAR DUMMIES*. In this model, the coefficients of an innovation measure and control variables depend on $COM_{j,t-1}$, allowing us to examine if our baseline specification (i.e., $\beta_1 = \gamma_0 + \gamma_1 COM_{j,t-1} + \gamma_2 COM^2_{j,t-1}$) is appropriate to model the relationship between competition and the value of innovation. Figure 2 depicts the empirical results for the semi-parametric smooth coefficient model. Panels (a) and (b) show empirical relationships between the value of innovation (β_1) and $COM_{j,t-1}$ when excess returns and raw returns are used as dependent variables, respectively. Both panels show that the market value of innovation and product market competition have a quadratic, specifically an inverted-U shaped, relationship. Thus, we conclude that the quadratic form in Equation (1) is an appropriate specification.

[Insert Figure 2 Here]

Table 1 shows main regression results for the model specified in Equation (1). Columns (1) and (2) are the results for the excess returns as the dependent variable, and Columns (3) and (4) show the results using raw returns instead. Our results show that there exists a significant non-linear relationship between the value of innovation and competition. The value of γ_2 or the coefficient of $INN_{i,t-1} \times COM^2_{j,t-1}$ is significantly negative in all cases. With the significantly positive γ_1 or the coefficient of $INN_{i,t-1} \times COM_{j,t-1}$, the market value of innovation and competition have an inverted-U shaped relationship as Aghion *et al.* (2005) hinted. The coefficients of control variables are reported similarly to Faulkender and Wang (2006) and Dittmar and Mahrt-Smith (2007): while earnings growth, assets growth, R&D expenditures growth and dividend growth have positive impacts on firm value, interest expense growth and new financing have negative effects on firm value.

Our results reported in Columns (2) and (4) suggest that the value of innovation has a peak when $COM_{j,t-1}$ has a value of 0.8974 for excess returns and 0.9106 for raw returns, respectively. Given our sample mean and median for $COM_{j,t-1}$ are 0.9483 and 0.9473, the peaks are located slightly to the left of the sample median and mean of the competition measure.

[Insert Table 1 Here]

Overall, our results are consistent with Aghion *et al.*'s (2005) prediction that there is a significant inverted-U shaped relationship between product market competition and innovation, and contradict the other three studies (Arrow, 1962; Schumpeter, 1943; Boone, 2001). Our results are different from those of Greenhalgh and Rogers (2006), who have found that firms in the most competitive sector have the lowest market valuation of R&D, by using data on UK companies' R&D and intellectual property activities from 1989 to 2002 and comparing valuations of R&D among 6 Pavitt sectors.

3.2 A quasi-natural experiment using tariff cuts

There are three potential concerns for our main regression model. The first is the reverse causality. A higher value of innovation would eventually end up with more innovation carried out by firms, thus changing the industry's competition circumstances. The second issue is a simultaneity bias. If a third factor, e.g. growth opportunities, is correlated with our variables of interest (returns, innovation, and product market competition), our main results are likely to be biased. Third, one might argue that our competition measure, price-cost margin, is not the best measure. To mitigate these concerns, we design a quasi-natural experiment to examine the impact of an exogenous shock to competition on the value of innovation. Specifically, we use tariff-cut events as a quasi-natural experiment to further examine the impact of the events on the value of innovation[2]. In our design, a tariff cut is considered a positive shock to the competition of the corresponding industry because it lowers foreign firms' entry barriers, intensifying product market competition.

To examine whether there is a causal effect of intensifying competition due to a tariff cut on the market value of innovation, we replace $COM_{j,t}$ with $D\_Cut_{j,t}$, a dummy variable which has a value of one when industry j experiences a tariff cut in year t, and zero otherwise. To capture nonlinearity in the relationship, we also add $D\_Cut_{j,t} \times D\_COM1_{j,t}$, $D\_Cut_{j,t} \times D\_COM2_{j,t}$, $D\_Cut_{j,t} \times D\_COM4_{j,t}$, and $D\_Cut_{j,t} \times D\_COM5_{j,t}$[3]. Note that we do not include $D\_Cut \times D\_COM3_{j,t}$, as medium-competition industries are considered a refer-

[2] To implement the quasi-natural experiment, we closely follow Fresard's (2010) research design.

[3] All industries are grouped into 5, based on the intensity of competition. For example, $D\_COM1_{j,t} = 1$ if a specific industry has the competition measure below the first quintile both before and after a tariff cut, while $D\_COM5_{j,t} = 1$ if it is above the 4th quintile both before and after a tariff cut. A variable interacting the #-th dummy ($D\_COM\#_{j,t}$) with the tariff cut dummy ($D\_Cut_{j,t}$) is denoted as $D\_Cut_{j,t} \times D\_COM\#_{j,t}$.

ence group. Our regression model with excess returns is shown as follows:

$$\begin{aligned} r_{i,t} - R_{p,t} &= \beta_0 + (\delta_0 + \delta_1 D\_Cut_{j,t} + \delta_2 D\_Cut_{j,t} \times D\_COM1_{j,t} + \delta_3 D\_Cut_{j,t} \times D\_COM2_{j,t} \\ &+ \delta_4 D\_Cut_{j,t} \times D\_COM4_{j,t} + \delta_5 D\_Cut_{j,t} \times D\_COM5_{j,t}) INN_{i,t-1} + \delta_6 D\_Cut_{j,t} \\ &+ \beta_{CONTROLS} CONTROLS + INDUSTRY\ DUMMIES + YEAR\ DUMMIES + \varepsilon_{i,t}, \end{aligned} \tag{3}$$

Table 2 presents regression results for the model specified in Equation (3). The table shows that there is an inverted U-shaped relationship between product market competition and the market value of innovation, supported by significantly positive δ_2 and significantly negative δ_5. These findings suggest that there is an "*asymmetric*" causal effect of intensifying product market competition on the market value of innovation. A firm's incentive to innovate tends to get enhanced in response to a tariff-cut shock in a less competitive market, while it tends to get much weakened when product market is highly competitive. This means that the value of innovation for firms facing the lowest level of competition is increased by the positive competition shock, and the value of innovation for firms in the most competitive industry is decreased by the positive shock in competition. These results suggest that the value of innovation could drop to below zero if an extremely competitive industry gets a tariff-cut shock. The value of innovation should be equal to its net present value (NPV), or the present value of cash flows generated by innovation less the cost of innovation. A tariff cut can severely affect additional future cash flows generated by innovation. The entry of competitive foreign firms might damage the expected sales growth or profit margin of innovative domestic firms. Therefore, foreign firms' entry could make the NPV of innovation be negative, meaning that the benefits of innovation cannot cover the costs. Thus, the market revalues innovation, reducing firm value.

These analyses also show that the market value of innovation changes very sensitively to an exogenous "entry" shock such as a tariff cut. When an industry with the lowest degree of competition faces a tariff cut, the market value of one unit of innovation is increased by 3.0% in terms of excess returns and 3.5% in terms of raw returns, while it drops for the most competitive industry by 3.4% and 3.0%, respectively. This difference is quite high, and much greater than that found in Table 1. This might be due to the absence of measurement problems: instead of using a direct competition measure, we used tariff-cut events as exogenous shocks to product market competition in Table 2.

[Insert Table 2 Here]

3.3 Robustness tests

Our major findings are robust to: *i)* using the number of patents as an innovation measure, *ii)* using the number of total citations of patents as an innovation measure, *iii)* measuring the Lerner Index without considering financial costs, and *iv)* using industry mean returns as reference returns in Equation (1).

4 Conclusions

Using US firm-level patent data from 1977 to 2005, we find evidence for an inverted U-shaped relationship between product market competition and the market value of innovation. In addition, using a quasi-natural experiment based on tariff-cut events, we also show that there is an "*asymmetric*" causal effect of intensifying product market competition on the market value of innovation. A firm's incentive to innovate tends to get stronger in response to a tariff-cut shock when the product market is not very competitive, while it tends to get much weaker when the product market is too competitive.

The rationale behind the results can be found in two classical theories of innovation. Schumpeter (1943) predicted that a highly competitive industry would not be suitable for innovation because the companies in such industry would not have excess resources to innovate. This view can be extended to explain the lower value of innovation for a highly competitive industry. Arrow (1962) suggested that companies that are currently enjoying a monopolistic rent in the market would have lower incentives to innovate because the innovation may undermine their existing market share. That is, since such companies are already enjoying high mark-ups in the existing product market, they will have smaller gains by innovating. This observation could be developed as a theory to explain the lower value of innovation when the competition is very low. The combination of these two theories would be a possible explanation of the inverted U-shaped relationship we have found.

Our results are different from those of Greenhalgh and Rogers (2006), who find that firms in the most competitive sector have the lowest market valuation of R&D, by using data on UK companies' R&D and intellectual property activities from 1989 to 2002 and comparing valuations of R&D among 6 Pavitt sectors. This difference may arise from different degrees of maturity of industries in the two countries. If companies in the UK are facing more severe competition in general, the different results can be well explained. That is, Greenhalgh and Rogers' (2006) results could be highlighting one part of our results. However, it is difficult to consistently compare the competition levels between two countries using a single measure. In addition, innovation measures for UK and US are not directly comparable. Therefore, we leave reconciliation of two different results to future research.

Despite the fundamental difference in the measurement of innovation, our findings of an inverted U-shaped relationship between competition and the value of innovation are consistent with those of Aghion *et al.* (2005). Our findings, however, can be interpreted differently from those of Aghion *et al.* (2005), as we directly measure the market value of innovation while they measure the magnitude of innovation. The theory presented in Aghion *et al.* (2005) does not provide a clear distinction between the two. It would be natural to assume that the increased market value of innovation would lead to increased innovation, *ceteris paribus*. However, it cannot be concluded that the increased innovation is necessarily due to the increased market value of innovation, rather than other aspects such as market size, firm heterogeneity between industries, and the ease of imitation of innovation. Our findings provide a piece of new evidence that the inverted U-shaped relationship between competition and innovation is driven by a similar relationship between competition and the market value of innovation.

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Figure 1: Theoretical predictions of the relationship between product market competition and innovation

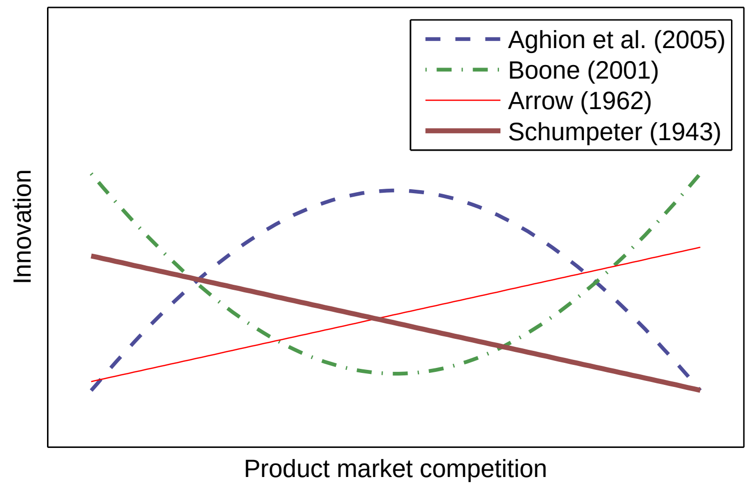
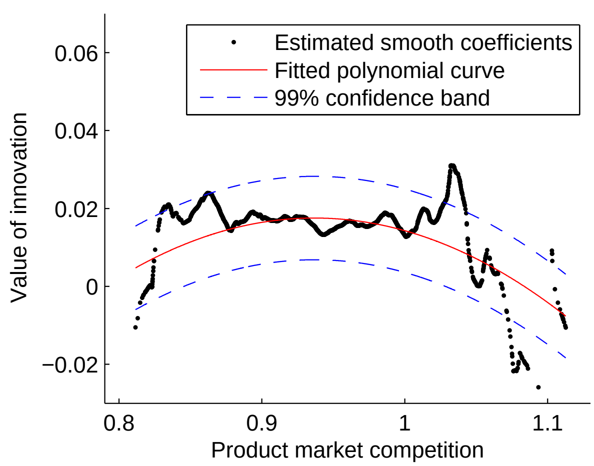
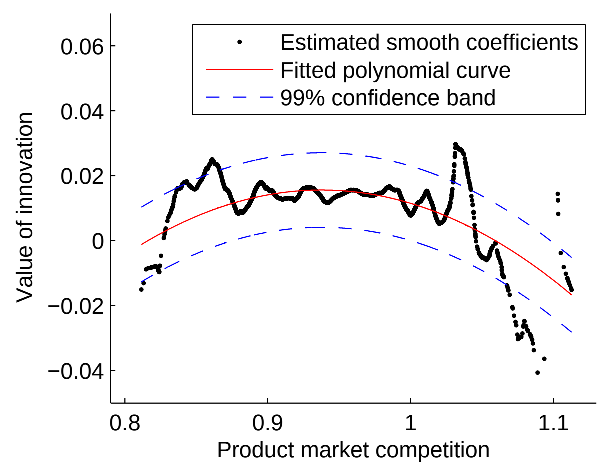


Figure 2: Semi-parametric estimation of the relationship between competition and the value of innovation



(a) Excess returns



(b) Raw returns

Note: Least-squares cross-validation method is used to select smoothing parameters. Epanechnikov kernel function is used. 10 outliers among 6,691 industry-year observations are dropped.

Table 1: The impact of product market competition on the market value of innovation

VARIABLES	(1) $r_{i,t} - R_{p,t}$	(2) $r_{i,t} - R_{p,t}$	(3) $r_{i,t}$	(4) $r_{i,t}$
$INN_{i,t-1}$	-0.714***	-0.589***	-0.911***	-0.790***
	(0.152)	(0.151)	(0.148)	(0.147)
$COM_{j,t-1} \times INN_{i,t-1}$	1.628***	1.355***	2.032***	1.772***
	(0.323)	(0.320)	(0.314)	(0.311)
$COM^2_{j,t-1} \times INN_{i,t-1}$	-0.902***	-0.755***	-1.112***	-0.973***
	(0.171)	(0.170)	(0.166)	(0.165)
$\Delta E_{i,t}/ME_{i,t-1}$		0.311***		0.306***
		(0.009)		(0.009)
$\Delta TA_{i,t}/ME_{i,t-1}$		0.139***		0.146***
		(0.004)		(0.004)
$\Delta RD_{i,t}/ME_{i,t-1}$		0.696***		0.640***
		(0.065)		(0.064)
$\Delta DIV_{i,t}/ME_{i,t-1}$		1.255***		1.142***
		(0.120)		(0.117)
$D_{i,t-1}/ME_{i,t-1}$		0.001		0.005***
		(0.001)		(0.001)
$\Delta XINT_{i,t}/ME_{i,t-1}$		-0.852***		-0.874***
		(0.047)		(0.047)
$NF_{i,t}/ME_{i,t-1}$		-0.082***		-0.094***
		(0.007)		(0.007)
Constant	-0.043***	-0.028***	0.255***	0.148***
	(0.009)	(0.008)	(0.009)	(0.008)
Observations	81,463	80,249	81,463	80,249
Adjusted R-squared	0.049	0.125	0.108	0.185

Note: Industry and year dummies are included in all regression models. The robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 2: A quasi-natural experiment using tariff-cut events

VARIABLES	(1) $r_{i,t} - R_{p,t}$	(2) $r_{i,t} - R_{p,t}$	(3) $r_{i,t}$	(4) $r_{i,t}$
$INN_{i,t-1}$	0.017***	0.016***	0.015***	0.013***
	(0.001)	(0.001)	(0.001)	(0.001)
$D\_Cut_{j,t} \times INN_{i,t-1}$	-0.000	-0.002	0.002	0.001
	(0.007)	(0.007)	(0.007)	(0.007)
$D\_Cut_{j,t} \times D\_COM1_{j,t} \times INN_{i,t-1}$	0.027***	0.030***	0.033***	0.035***
	(0.010)	(0.010)	(0.010)	(0.009)
$D\_Cut_{j,t} \times D\_COM2_{j,t} \times INN_{i,t-1}$	0.010	0.008	0.013	0.011
	(0.012)	(0.012)	(0.011)	(0.011)
$D\_Cut_{j,t} \times D\_COM4_{j,t} \times INN_{i,t-1}$	0.006	0.005	0.010	0.009
	(0.010)	(0.009)	(0.009)	(0.009)
$D\_Cut_{j,t} \times D\_COM5_{j,t} \times INN_{i,t-1}$	-0.042***	-0.034***	-0.038***	-0.030***
	(0.011)	(0.011)	(0.011)	(0.011)
$D\_Cut_{j,t}$	-0.009	-0.007	-0.019	-0.017
	(0.015)	(0.014)	(0.015)	(0.014)
$\Delta E_{i,t}/ME_{i,t-1}$		0.360***		0.355***
		(0.013)		(0.013)
$\Delta TA_{i,t}/ME_{i,t-1}$		0.163***		0.170***
		(0.006)		(0.006)
$\Delta RD_{i,t}/ME_{i,t-1}$		0.739***		0.671***
		(0.078)		(0.077)
$\Delta DIV_{i,t}/ME_{i,t-1}$		1.511***		1.344***
		(0.170)		(0.166)
$D_{i,t-1}/ME_{i,t-1}$		0.002		0.006**
		(0.003)		(0.003)
$\Delta XINT_{i,t}/ME_{i,t-1}$		-1.014***		-1.040***
		(0.078)		(0.077)
$NF_{i,t}/ME_{i,t-1}$		-0.107***		-0.124***
		(0.010)		(0.010)
Constant	-0.150***	-0.044***	0.339***	0.131***
	(0.011)	(0.011)	(0.010)	(0.011)
Observations	43,191	42,678	43,191	42,678
Adjusted R-squared	0.051	0.139	0.120	0.207

Note: Industry and year dummies are included in all regression models. The robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.