Product-market competition, corporate governance and innovation: evidence on US-listed firms

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Abstract

The debate on competition and innovation has produced a wide range of theoretical and empirical findings. Recently, corporate governance quality has emerged as an additional factor that may complement or substitute for competition's effect on innovation. We aim to contribute to the debate by investigating whether product-market competition and corporate governance quality affect firm-level innovation, utilising a dataset for 1,400 non-financial US-listed companies. Using two-way cluster-robust estimation, we report several findings. First, the relationship between industry-level competition and *input* as well as *output* measures of innovation is non-linear. Secondly, the non-linear relationship is of an inverted-U shape with respect to input measures of innovation, but the relationship has a U-shape when output measure of innovation is estimated. Third, corporate governance indicators such as anti-takeover defences and insider control tend to have a negative effect on input measures of innovation but their effect is positive with respect to the output measure. Finally, when interacted with market concentration, anti-takeover defences and insider control emerge as substitutes, leading to sign reversals in the relationship between competition and innovation. The results are obtained by using two-way cluster-robust estimation that controls for dependence within company/year and industry/year clusters, but they are robust to different estimation methods including fixed-effect and Fama-Macbeth procedure.

Keywords: Innovation, competition, corporate governance, two-way cluster-robust estimation

JEL Codes: O310; G300; L100; D210; D220

1. Introduction

The debate concerning the effect of competition on innovation dates back to Schumpeter (1934, 1942), who put forward two hypotheses: (i) competition may lead to higher levels of innovation by firms trying to maintain market shares or profit levels; and (ii) competition may deter innovation because large firms and firms in concentrated industries are better able to capture the benefits of and/or to finance innovation. Gilbert (2006) reviews the extensive theoretical and empirical literature and provides evidence that supports both hypotheses. On the one hand, process innovations tend to be associated with market concentration (rather than competition) because the benefits of process innovation are proportional to the level of production by (hence the size of) the firm. In the case of product innovation, however, the evidence does not support the Schumpeterian view that monopoly or highly concentrated market structures promote innovation. Furthermore, the relationship between competition and innovation is complicated by other factors – for example, the dynamics of discovery, the characteristics of innovation, the intellectual property regime, and the probability with which innovation investments are converted into patents.

This paper aims to contribute to the debate in a number of ways. First, we provide evidence on the relationship between product-market competition and both 'input' and 'output' measures of innovation. The evidence indicates that higher competition (and less market concentration) is associated with higher research and development (R&D) expenditures. However, the relationship between competition and the output measure of innovation - the net book value of the patents and trademarks per unit of R&D expenditures - is negative. This finding suggests that we must expect variation in the competition-innovation relationship depending not only on the innovation type (i.e., on product *versus* process innovation), but also depending on the measure of innovation (i.e., input *versus* output measures).

Secondly, we report that the relationship between competition and innovation is non-linear in both types of innovation. Our estimation results indicate that the relationship is of an inverted-U shape in the case of competition's effect on R&D expenditures; and of a U-shape in the case of the net book value of patents/trademarks per unit of R&D expenditures.

The paper also addresses the issue of whether or not corporate governance quality affects the level of innovation, measured in terms of input or output. To do this, we estimate the effect of corporate governance on innovation independently and in interaction with the level of product-market competition. This is to take account of the theoretical debate on whether product-market competition and corporate governance rules are complementary or substitutes in affecting the innovation incentives faced by managers. We report that corporate governance indicators such as anti-takeover defences and insider control tend to have a negative effect on input measures of innovation but their effect is positive with respect to the output measure. When interacted with market concentration, anti-takeover defences and insider control emerge as complements, leading to sign reversals in the relationship between competition and innovation. In contrast to the competition-innovation relationship, however, the effect of corporate governance quality on innovation (whether independently or jointly with competition) is not robust to all model specifications or innovation measures.

The data for this paper consists of an unbalanced panel for 1,400 US-listed firms over the period 2004-2010. Given that the data generating process consists of repeated observations on the same set of firms over time, panel data tend to contain variables that are both cross-sectionally and serially correlated. Therefore, the common assumption of independence in regression errors may not be valid. In this paper, we address the issue of cross-sectional and serial dependence within the variables by using a relatively new method that is robust to both forms of dependence. This two-way cluster-robust method reduces the risk of biased estimates by producing well-specified test statistics (see for example Gow et al, 2007: Thompson, 2006).

The rest of this paper is organised as follows. Section 2 provides a brief review of the related literature. Section 3 describes the data and explains the method of estimation. Section 4 reports the findings, whilst the last section summarizes the main findings and conclusions.

2. Related literature

The incentive to innovate depends on the difference in the profit that a firm can earn with and without innovation. Examined from this perspective, the problem is a fairly straightforward one. Yet the determinants of innovation have been a subject of intense debate since Schumpeter (1934, 1942) advanced the argument that 'large firms and concentrated market structures promote innovation' (Gilbert, 2006: 159). This is due to the fact that the difference in the profits that a firm can earn with and without innovation depends on a complex set of factors – including market structure, the level of competition before and after innovation, the dynamics of innovation and discovery, the intellectual property regime, and whether innovation consists of product or process innovation.

Following Schumpeter, Arrow (1962) is one of the earliest attempts at theorising the relationship between market structure and innovation. This work demonstrates that a monopoly shielded against competition has less incentive to innovate because it can earn positive profits even before innovation. Hence the net profit after innovation is equal to the difference between pre- and post-innovation profits. However, the firm does not earn positive profits if it were competitive. Yet the same firm can earn positive profits if it innovates and innovations are protected through exclusive intellectual property rights. Therefore, a competitive firm will have greater incentives to innovate compared to a monopolist. Arrow (1962) is a reflection of the first Schumpeterian hypothesis in that it accords competition a positive role in driving innovation – albeit innovation is in turn conducive to increased market power (i.e., positive profits) and less competition *ex post*.

What if the existing monopoly is not shielded against competition? Gilbert and Newey (1982) analyse the case of a monopolist with an existing technology and a new-comer investing in new technology. They demonstrate that innovation can be analysed as a 'bid for patents' and that the successful bidder (i.e., the innovator) earn higher post-innovation profits. In this scenario, there is support for Schumpeter's second hypothesis because the incumbent monopolist will always earn higher levels of total profits over the pre- and post-innovation periods. A monopolist will earn monopoly profits before innovation + duopoly profits after innovation if its bid for patent is *unsuccessful* (i.e., if the new-comer is successful in the bid for patent). The same monopolist will earn monopoly profits in both periods if its own bid for patent is *successful*. Comparing this with a new-comer, we can see that it may have to satisfice with zero profits/rents if its bid for patent is unsuccessful and can earn only duopoly profits if it is successful. Therefore, the large firm with significant market power can be expected to invest more in innovation compared to a new-comer.

The neat result obtained by Gilbert and Newey (1982) depends on the assumption that the patent is obtained by the highest bidder – i.e., by the firms that invests more in R&D. This assumption is challenged by Reinganum (1983, 1985) who demonstrate that the end result of the innovation process is uncertain – i.e., innovation expenditures increase the probability of obtaining the patent but does not guarantee success. As a result, the pre-emptive innovation by Gilbert and Newey's (1982) monopolist is replaced by innovation by the new-comer. Because of the uncertainty involved in the innovation process, the incumbent monopolist will decide to invest in innovation depending on the nature of innovation (drastic *versus* incremental innovation) and on the probability of innovation by the new-comer. Reinganum (1983, 1985) show that, the expected profits for the monopolist that invests in innovation are less than the expected profits for a competitor when the invention is drastic. In fact, this result holds even if innovation becomes less drastic on a drastic/non-drastic scale.

The large volume of empirical literature reviewed by Gilbert (2006) yields conflicting results. On the one hand, the findings suggest that R&D expenditures increase as the firm size increases – albeit the firm size varies across industries. On the other hand, the reasons as to why large firms tend to spend more on R&D remain unclear. The evidence does not support the arguments that large firms invest more in R&D because they have larger cash flows or can engage in risk diversification. However, both theoretical and empirical work indicates that the effect of competition on innovation is not uniform – it differs across industries and types of innovation.

The non-uniformity of the competition-innovation relationship is central to the theoretical and empirical work by Philippe Aghion and his co-researchers – even though their earlier work within the endogenous growth theory demonstrates that the effect of product-market competition on innovation is negative. The work by Aghion and his colleagues deserve special mention here because not only do they provide a framework that captures the diverse findings in the empirical literature, but also because they address the interaction between competition and corporate governance explicitly.

Aghion et al (2002a, 2005) explain the non-linear relationship between product-market competition and innovation through a formal model where both incumbent technological leaders and their followers can innovate, and all innovations occur step-by-step. This model predicts that competition leads to higher levels of innovation when incumbent firms operate with similar technologies – i.e., when technological competition is neck-and-neck. In addition, neck-and-neck competition in technology is more likely to occur when product-market competition is low. Hence, at low levels of product-market competition, innovation is expected to increase as product-market competition increases. However, when product-market competition is already high, innovation is more likely to be undertaken by new-comers with low-profits. New-comers in competitive markets engage in innovation because the latter improves their post-innovation profits. In this case, further increases in product-market competition will be associated with lower levels of innovation because the innovative firms have low initial profits. The main mechanism that drives the inverted-U relationship between competition and innovation is that the fraction of sectors with neck-and-neck or new-comer competitors is an endogenous outcome of the equilibrium innovation intensities in different sectors. This theoretical perspective implies that the relationship between product-market competition and innovation should be modelled and estimated as a non-linear relationship –

whereby innovation tends to increase with competition at low levels of competition and to decline with competition at high levels of competition.

The limitation of Aghion et al (2002a, 2005) is that their theoretical results depend on the assumption that innovation takes place in a step-by-step manner and the laggard firms (the new-comers) never overtake the incumbents. Therefore, the non-linear relationship they predict can be questioned. Yet, other work by Aghion and his colleagues point out a different mechanism that can also generate a non-linear relationship between product-market competition and innovation. This is the managers' innovation incentives that are determined not only by competition in the product market but also by the nature of the corporate governance rules they are bound with.

Aghion et al (1999 and 2002b) examine the ways in which innovation efforts can be affected by the interaction between product-market competition and corporate governance – paying attention to their disciplining effects on managers. According to Aghion et al (1999) managers face conflicting incentives with respect to innovation. On the one hand, they are prone to minimise not only the direct cost of innovation but also the adjustment cost associated with implementation of the new technology. On the other hand, they are motivated to innovate as a means of reducing the risk of bankruptcy. On balance – and irrespective of the kind of corporate governance rules and/or debt pressure they face – increased product-market competition leads managers to undertake higher levels of innovations. However, if corporate governance rules and/or debt pressure are already strict enough to reduce managerial slack and thereby induce innovation, product-market innovation becomes less significant as a driver of innovation. In this analysis, corporate governance (or financial discipline) AND product-market competition are substitutes rather than complements.

A wider set of theoretical results and empirical findings are reported in Aghion et al (2002b), which examines the interplay between corporate governance, product-market competition and financial discipline. Aghion et al (2002b) extends the model of Aghion et al (1999) by introducing step-by-step innovation (already discussed above) and Hart's (1983) idea of 'competition as an incentive scheme'. This extension enables Aghion et al (2002b) to demonstrate that competition and corporate governance as well as competition and financial discipline can be complementary in their effects on innovation. This is because step-by-step innovation enables managers to use innovation as a route for 'escaping' competition when the managers are already faced with strict governance rules and high risk of bankruptcy. The theoretical and empirical findings of Aghion et al (2002b) confirm the non-linear relationship between competition and innovation reported in Aghion (2002a and 2005); and relate the non-linear nature of the relationship to interplay between product-market competition, corporate governance and financial discipline. Stated explicitly, corporate governance and financial discipline can be either complementary or substitute to product-market competition as a driver of innovation.

We aim to contribute to this debate in a number of ways. First, we provide evidence based on a unique dataset for 1,400 non-financial US-listed companies from 2004-10. To our knowledge, this is the largest dataset used in the empirical literature on the interplay between product-market competition, corporate governance and innovation.[1] Secondly, we use both 'input' and 'output' measures of competition, consisting of R&D expenditures and net book value of patents and trademarks respectively. Although the input measure is the same as other empirical studies, the output measure is unique and may be a better proxy of the quality of the innovation compared to un-weighted patent counts or those weighted by the number of citations. This is because our output measure indicates the value of the innovation output as an intangible asset. Third, the empirical novelty in the paper extends to the measures of product-market competition too. Unlike previous studies that tend to utilise either a market concentration measure or a proxy for the Lerner Index, our paper utilises both measures of competition – the Herfindahl-Hirschman Index of concentration and the Lerner Index of market power calculated on the basis of 4-digit ISIC codes. Finally, we use a relatively new method of estimation (two-way cluster-robust standard errors) that takes account of within-firm (time-series) *and* within-year (cross-sectional) dependence of the regressors and the residuals. Using this method, we estimate coefficients with cluster-robust standard errors via two-way clustering on the basis of firm-year and industry-year.

3. Estimation method and data

The empirical work on determinants of firm innovation tends to use panel data sets, which may contain variables that are correlated serially and cross-sectionally. These types of correlations violate the assumption that the regression residuals are distributed independently. If serial and/or cross-sectional dependence exists, the standard OLS estimation leads to underestimated standard errors – and therefore higher rates of rejection of the null hypothesis. Empirical studies in finance and accounting have tried to address this problem by controlling for one type of dependence at a time. For example, Newey and West (1987) propose an estimation method that yields standard errors that are robust to time-series dependence. On the other hand, Fama and MacBeth (1973) develops a method that produces standard errors that are robust to cross-sectional dependence. Although Newey-West and Fama-Macbeth standard errors are less biased downwards, the former

[1] Aghion et al (2005) have an unbalanced panel of 311 of UK-listed firms, distributed along seventeen two-digit SIC codes over the period 1973–1994. Grosfeld and Tressel (2002) examine 200 non-financial firms listed on Warsaw Stock Exchange over the period 1991-98.

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assumes that the data is cross-sectionally independent while the latter assumes time-series independence.

In the last few years, a number of studies in accounting and finance have developed and used a method that would allow for two-way clustering and produce standard errors that are robust to two-way clusters such as time-firm or time-industry clusters. The work by Cameron et al.(2006b); Thompson (2006); Petersen (2007); and Gow et al (2010), etc. is based on the observation that most of the micro-econometric variables (e.g., R&D expenditures, accounting items, executive salaries, corporate governance quality, firm characteristics such as size or leverage, etc.) are likely to be correlated both serially and cross-sectionally. If this is the case, controlling for one-type of dependence would lead to biased standard errors and inefficient estimates.

To address this shortcoming, we use two-way clustering that controls for the possibility that the observation for firm *i* in year *t* can be correlated with another observation for the same firm in year *t+1* and with an observation for firm *j* in year *t*. The method involves calculating cluster-robust standard errors along 2 clusters in accordance with the following expression:

$$\hat{V}(\hat{\beta}) = (X'X)^{-1}\hat{\beta}(X'X)^{-1}, \text{ where } \hat{\beta} = \sum_{h=1}^{H} X'_h u_h u'_h X_h$$

Here X_h is the $N_h \times K$ matrix of regressors; u_h is the N_h-vector of residuals for cluster *h*. The one-way cluster-robust regression estimates unbiased standard errors if the errors are correlated within clusters, but uncorrelated across clusters. Two-way cluster-robust regression, however, evaluates the expression above twice: First it calculates one-way cluster-robust standard errors for each cluster – say V1 for year and V2 for firm. Then it calculates a cluster-robust standard error using an intersection cluster – say V3 for observations within a firm/year. Finally, the two-way cluster-robust estimator *V* is calculated as $V = V1 + V2 - V3$.[2]

Simulations by Petersen (2007) and Gow et al (2010) provide similar results about the robustness of the standard errors estimated by one-way and two-way clustering. The results can be summarised as follows:

[2] We have used the Stata procedure produced by Mitchell Petersen to run two-way cluster-robust regressions with panel data. The package is at http://www.kellogg.northwestern.edu/faculty/petersen/htm/.

Fixed-effect estimations with firm dummies:

Standard errors are un-biased, but this is true only if the firm effect is fixed. If the firm-effect declines over time, firm dummies do not capture fully the within-cluster dependence and OLS standard errors remain biased downward.

Random-effect estimations, using GLS:

GLS estimates are more efficient than the OLS estimates - both with or without firm dummies. However, GLS standard errors are unbiased only when the firm effect is permanent. If the firm effect is temporary, GLS estimates are still more efficient than OLS estimates but the standard errors remain biased downwards.

Fama-MacBeth procedure:

The standard errors produced by Fama-MacBeth are unbiased when there is only time effect. With time effect only, the slope coefficients across years are zero. However, if there were both time and firm effects, Fama-MacBeth standard errors would be biased downwards.

Two-way clustering:

Clustering by two dimensions (say year and firm) produces less biased standard errors compared to any method of one-way clustering. However, two-way clustering does not eliminate the risk of biased estimates altogether. When the number of the clusters along one dimension (e.g., number of firms) is large but the number of clusters along the second dimension (e.g., number of years) is small, the method of two-way clustering produces similar results to one-way clustering based on the large number of clusters (e.g., firms). However, this is not true for results obtained from clustering along the less frequent cluster (e.g., time). In other words, two-way clustering produces at least similar or less-biased standard errors compared to one-way clustering under all conditions.

Our estimation strategy is informed by these results. We first run fixed- and random-effect regressions, using Hausman test to decide about the appropriate method. The test favours the use of fixed-effect method for all model specifications. The fixed-effect estimates can be expected to have lower standard errors and hence higher chance of being statistically significant. Then, we use Fama-MacBeth procedure to control for cross-sectional dependence. Finally, we use the two-way clustering method of Petersen (2007). This strategy enables to control for both types of dependence first one at a time and then at the same time. In addition, it enables to establish whether our model specifications remain robust to estimation methods.

In its general form, the model we estimate can be stated as:
$INV = F(CG, MS, FC)$, where

INV = 3x1 vector of innovation measures, consisting of:

1. Log of R&D expenditures
2. Log of R&D to total asset ratio
3. Log of book value of patents and brands to R&D expenditures

CG = 3x1 vector of corporate governance indicators, consisting of:

1. CGDummy1 – dummy for board independence
2. CGDummy2 – dummy for anti take-over defences
3. CGDummy3 – dummy for insider control through share ownership

MS = 2x1 vector of market structure/competition indicators, consisting of:

1. HHI – Herfindahl-Hirschman index based on net sales
2. PMC – product-market competition, measures as 1-Lerner Index

FC = 5x1 vector of firms characteristics, consisting of:

1. Size1 – log of number of employees
2. Size2 – log of market capitalisation
3. Leverage1 - total debt as a percentage of total equity
4. Leverage2 – long-term debt as percentage of total equity
5. Age – company age

We estimate the model with different model specifications and with different estimation methods – as indicated above. The results are similar, with the exception of higher standard errors yielded by the two-way cluster-robust estimation. Therefore, we report the results only from the two-way cluster-robust procedure. To check for robustness, we have clustered the data along two sets of clusters: (a) firm and year clusters; and (b) industry and year clusters. We have also checked the sensitivity of our estimates to: (i) different measures of innovation (market concentration and product-market competition); (ii) different measures of firm size (number of employees and market capitalization); and (iii) different measures of leverage (total debt as percentage of equity and long-term debt as percentage of equity).

Finally, we also investigate if product-market competition and corporate governance quality are complement or substitutes in their effects on innovation. For this purpose, we use the two-way cluster-robust method to estimate the innovation models with interaction terms added. The interaction terms represent the interaction between 3 corporate governance measures (board independence, anti-takeover defence measures, and insider control) and two measures of competition (the Herfindahl-Hirschman Index and the Product-Market Competition index).[3]

The sample used in this paper is an unbalanced panel consisting of 1,400 non-financial US-listed companies from the NASDAQ, NYSE, and AMEX stock exchanges for the period 2004-2010. The choice of the period is determined by the availability of corporate governance data, obtained from the *Corporate Library*. The corporate governance data is matched with annual accounting and financial data from Thomson Reuters' *Datastream*. Consistent with prior studies, we exclude financial firms (banks, investment trusts, insurance companies, and properties companies). To calculate the measure of concentration and product-market competition, we use four-digit industry classification code utilized by the Securities and Exchange Commission (SEC).

For each company in each year, we collect information on the following corporate governance indicators and financial variables:

Board_Indep: Dummy variable that measures board independence and indicates whether the "Outside" directors of a board constitute a majority over "Inside" and "Outside Related" directors. The dummy provides information about the scope for shareholder control over management. It takes the value of one if the company board is independent, zero otherwise.

Antitakeover_Def: A takeover defence measure that indicates whether the company has both a staggered board and business combination provision – both of which reduces the risk of acquisition and hostile bids. This indicator provides information about the extent to which the management is shielded against competition for corporate control. It takes the value of one if the company has both staggered board and business combination provision, and zero otherwise.

Insider_Control: An insider control measures and indicates whether or not a majority of outstanding shares are held by top management and/or directors. It indicates the extent to which

[3] As it was the case above, we have used fixed-effect panel and Fama-MacBeth methods to estimate the models with interaction terms. The results remain robust across estimation methods, albeit with larger standard errors as we move form fixed-effect to Fama-MacBeth and from the latter to the method of two-way cluster-robust estimation. The results can be provided on request.

shareholder and management interests are aligned and takes the value of one if the majority of outstanding shares are held by top management and/or directors, zero otherwise.

R&D: Research and development expenditures, defined as all direct and indirect costs related to the creation and development of new processes, techniques, applications and products with commercial possibilities. This is our 'input' measure of innovation.

Assets (A)*:* Total assets of the company, representing the sum of total current assets, long term receivables, investment in unconsolidated subsidiaries, other investments, net property plant and equipment and other assets.

R&D/A: The ratio of *R&D* to total assets – a scaled measure of innovation input.

R&D_Conversion**:** Ratio of the net book value of patents and brands to research and development (R&D) expenditures. This is our 'output' measure of innovation, which indicates the extent to which firms convert R&D expenditures into valuable patents and brands.

Employees: The number of employees of the company as a measure of firm size

Market_ca)*:* Market capitalisation as an alternative proxy of firm size.

Total_Debt_to_Equity: Total (short- and long-term) debt as a percentage of total equity.

Longterm_Debt_to_Equity: Long-term debt as percentage of total equity:

Age**:** Company age in years.

Net_Sales*:* The net sales or revenue of the company, defined as gross sales and other operating revenue minus discounts, returns and allowances. It excludes items such as non-operating income, interest income, rental income, dividend income, etc.

Profit_Margin*:* Operating profit margin of the company defined as operating income as a percentage of net sales.

To construct the measure of industry concentration, we calculate the ***Herfindahl-Hirschman index (HHI)*** for each industry and year as follows:

$$HHI_{jt} = \sum S_{ijt}^2$$

S_{ijt} represents the market share of firm *i* in industry *j* for a given year *t*. We calculate S_{ijt} as firm's share in industry net sales as defined above. The HHI ranges between 0 and 1, and indicates higher levels of concentration (hence lower levels of competition) as it approaches 1.

To calculate ***product market competition (PMC)***, we use the operating profit margin of the company as a proxy for Lerner Index (Li). The Lerner Index is based on the price-cost margin *[(P – MC)/P]*, where P is price and MC is marginal cost. Given that the marginal cost cannot be observed, the literature uses average cost (AC) as a proxy (Aghion et al,1999; 2002b and 2005). Hence Li_{it} is approximately equal to [(P – AC) / P]. This, in turn, can be converted into operating profit margin that is equal to *[(P*Q – AC*Q) / P*Q]*. Having calculated the Lerner Index for each company, we then calculate the industry-level product-market competition in accordance with:

$$PMC_{jt} = 1 - \frac{1}{N} \sum LI_{it}$$

LI_{it} represents the Lerner Index of firm *i* in industry *j* for year *t*, and *N* is the number of firms in industry *j*. The product market competition measure (PMC) ranges between (0) to (1), and indicates higher levels of competition as it approaches 1.

Table 1: Descriptive statistics for pooled sample

Variable	***Obs.***	***Mean***	***Std. Dev.***	***Min***	***Max***
Ln(R&D)	8138	10.18669	1.842873	0	16.05622
Ln(R&D /A)	8092	-9.98089	1.476379	-18.522	-2.59429
Ln(R&D_Conversion)	4045	-1.3136	2.235679	-10.141	6.030546
Board_Indep	10684	0.898914	0.301456	0	1
Antitakeover_Def	12185	0.240542	0.42743	0	1
Insider_Control	12815	0.088178	0.283565	0	1
HHI	16982	0.327549	0.234844	0	1
PMC	13395	0.86648	0.069463	0.0506	0.9994
Ln(Employees)	16406	7.660588	2.005971	0	14.55745
Ln(Market_cap)	12762	20.88635	1.697241	-0.6165	26.88236
Age	11420	38.40657	36.70195	0	234

3. Estimation results

We estimate a general, with 3 different measures of innovation as dependent variables: (1) R&D expenditures, (2) R&D expenditures relative to total assets, and (3) net book value of patents and brands scaled by R&D expenditures. The model can be stated as follows:

$$ln(INV)_{it} = \alpha_0 + \sum \beta_k C_{kit} + \sum \gamma_l CG_{lit} + \sum \theta_m FC_{mit} + \varepsilon_{it}$$

Here *INV* is one of the innovation measures listed above; *C* is two measures of competition (HHI or PMC); and *FC* are firm characteristics used as control variables, including two different measures of size (number of employees and market-cap) and two measures of leverage (long-term and total debt over equity).

We use the lagged values of the independent variables to reduce the risk of endogeneity. We also use the two-way cluster-robust method to estimate each of the models above. Estimation results for model 1 (where R&D expenditures are the dependent variable) are reported in Table 2.

Table 2: Estimation with Firm and Year clusters ***Dependent variable: Ln(R&D) as input measure of innovation***				
	1	***2***	***3***	***4***
Board_Indep_1	0.271	0.279	0.278	0.279
	(0.172)	*(0.178)*	*(0.178)*	*(0.183)*
Antitakeover_Def_1	-0.493***	-0.441***	-0.474***	-0.438***
	(0.114)	*(0.108)*	*(0.113)*	*(0.108)*
Insider_Control_1	-0.485**	-0.498*	-0.515**	-0.533*
	(0.226)	*(0.275)*	*(0.236)*	*(0.280)*
HHI_1	-4.348***		-4.442***	
	(0.693)		*(0.691)*	
HHISQ_1	3.141***		3.209***	
	(0.696)		*(0.703)*	
PMC_1		37.554***		38.354***
		(11.507)		*(10.882)*
PMCSQ_1		-26.353***		-26.795***
		(7.120)		*(6.777)*
Ln(Employees)_1	0.677***	0.745***		
	(0.029)	*(0.040)*		
Ln(Market_cap)_1			0.678***	0.749***
			(0.032)	*(0.041)*
Total_Debt_to_Equity_1	-0.00000417***	0.000		
	(0.000)	*(0.000)*		
Longterm_Debt_to-Equity_1			0.000	0.000
			(0.000)	*(0.000)*
Age_1	-0.002	-0.001	-0.001	-0.001
	(0.002)	*(0.002)*	*(0.002)*	*(0.002)*
R-Square	0.429	0.448	0.430	0.450
Number of Observations	2365	1640	2347	1628
Number of Firms	950	735	945	731

*, **, and *** denote statistically significant at the 10%, 5% and 1% level, respectively.
Standard errors in brackets.

As indicated above, the two-way cluster-robust controls for both cross-section and serial dependence, yielding standard errors that are robust to two types of dependence. Results reported in Table 2 remain stable to inclusion and exclusion of the independent variables and can be summarised as follows:

1. Board independence has a positive effect on R&D expenditures, but the effect is statistically insignificant across model specifications;
2. Anti-takeover defences has a negative effect on R&D expenditures and the effect is significant across model specification. On average, firms with staggered board and business combination provisions spend 35 – 39% less on R&D compared to firms that do not have staggered boards and business combination provision.[4]

[4] Business combination is defined as ‘A union of two or more entities, either by merging one or more of the entities into another of the entities or by consolidating the entities into a new entity.’ Business combination provision

3. Insider control (a majority of outstanding shares held by top management and/or directors) has a negative effect on R&D expenditures and the effect is statistically significant across model specifications. On average, firms with insider control spend 38 – 41% less on R&D compared to firms that do not have insider control.
4. The relationship between market concentration (HHI) and R&D expenditures is negative and non-linear (U-shaped), and remains significant across model specifications. A one-unit increase in market concentration index of 0 - 1 is associated with 4.3 – 4.4 percent decrease in R&D expenditures at low levels of concentration, but the relationship changes sign at high levels of concentration.
5. The relationship between product-market competition (PMC) and R&D expenditures is positive and non-linear (inverted-U shape), and remains significant across model specifications. A one-unit increase in the PMC index of 0 - 1 is associated with 37 – 38 percent increase in R&D expenditures at low levels of competition, but the association changes sign at high levels of competition.
6. The findings summarised in (4) and (5) above indicate that lower market concentration and higher product-market competition induce higher levels of innovation effort at lower levels of competition, but the innovation effort declines and becomes negative as competition increases beyond a critical value. Hence, we can infer that, up to a critical level, competition is conducive to higher levels of R&D expenditures as an *input* measure innovation. This finding is in line with Aghion et al (2005), who report an inverted-U relationship between competition and the *output* measure of innovation (citations-weighted patent count).
7. Of firm characteristics, only size is significant and has a positive effect on R&D expenditures. A one-percent increase in number of employees or market value is associated with an increase of 0.67 – 0.75 percent in R&D expenditures. AGE is negatively associated with R&D expenditures, but the estimates are small and statistically insignificant.

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refers to provisions that prohibit or place restrictions on mergers or acquisitions. The percentage change is calculated using the following formula for log-transformed dependent variable: $100*(e^{\beta} - 1)$, where β is the estimated parameter.

Table 3: Estimation with Firm and Year clusters

Dependent variable: Ln(R&D/A) as input measure of innovation

	1	*2*	*3*	*4*
Board_Indep_1	0.140	0.082	0.147	0.090
	(0.130)	*(0.121)*	*(0.128)*	*(0.118)*
Antitakeover_Def_1	-0.215**	-0.199*	-0.198**	-0.196*
	(0.101)	*(0.108)*	*(0.101)*	*(0.109)*
Insider_Control_1	-0.179	-0.222	-0.170	-0.218
	(0.214)	*(0.217)*	*(0.216)*	*(0.221)*
HHI_1	-3.113***		-3.214***	
	(0.584)		*(0.599)*	
HHISQ_1	2.136***		2.201***	
	(0.603)		*(0.620)*	
PMC_1		55.183***		55.528***
		(8.771)		*(9.034)*
PMCSQ_1		-34.263***		-34.457***
		(5.256)		*(5.415)*
Ln(Employees)_1	-0.222***	-0.193***		
	(0.027)	*(0.034)*		
Ln(Market_cap)_1			-0.221***	-0.188***
			(0.027)	*(0.035)*
Total_Debt_to_Equity_1	-0.0000042***	0.000		
	(0.000)	*(0.000)*		
Lterm_Debt_to-Equity_1			0.0000135**	0.000
			(0.000)	*(0.000)*
Age_1	-0.0027125***	-0.002	-0.0025309**	-0.002
	(0.001)	*(0.001)*	*(0.001)*	*(0.001)*
R-Square	0.227	0.136	0.227	0.131
Number of Obervations	2360	1638	2342	1626
Number of Firms	945	733	940	729

*, **, and *** denote statistically significant at the 10%, 5% and 1% level, respectively.
Standard errors in brackets.

Table 3 presents the two-way cluster-robust estimates for model 2 above – i.e, for R&D/Assets as the dependent variable. Compared to Table 2, the estimated parameters have similar signs and significance levels; and the results remain robust to inclusion of different measures for size and leverage. The two differences are: (i) insider control is now insignificant; and (2) company age has a negative effect on innovation effort when the model is estimated with concentration measure (HHI). Results in Table 3 can be summarised as follows:

1. Of the corporate governance indicators, only anti-takeover defences has a negative and statistically significant effect on R&D expenditures as proportion of total assets across different model specifications. On average, firms with staggered board and business

combination provisions have and R&D/Asset ratio that is 18 – 19 percent smaller compared to firms that do not have staggered boards and business combination provision.[5]

2. The relationship between market concentration (HHI) and R&D expenditures as proportion of total assets is non-linear (U-shaped) and remains significant across model specifications. A one-percent increase in market concentration index of 0 - 1 is associated with 3.11 – 3.21 percent decrease in R&D expenditures as proportion of total assets at low levels of concentration, but the association changes sign at high levels of concentration.
3. The relationship between product-market competition (PMC) and R&D expenditures as proportion of total assets is also non-linear (inverted-U shape) and remains significant across model specifications. A one-percent increase in the PMC index of 0 - 1 is associated with about 55% increase in R&D expenditures as proportion of total assets at low levels of competition, but the association changes sign at high levels of competition.
4. The findings summarised in (2) and (3) above indicate that higher product-market competition and lower market concentration induce higher levels of innovation effort at lower levels of competition, but the innovation effort declines and becomes negative as competition increases beyond a critical value. Hence, we can infer that, up to a critical level, competition is conducive to higher levels of R&D expenditures relative to assets as an *input* measure innovation. This finding is in line with Aghion et al (2005), who report an inverted-U relationship between competition and the *output* measure of innovation (citations-weighted patent count).
5. Of firm characteristics, size is significant and has a negative effect on R&D expenditures as proportion of total assets. A one-percent increase in number of employees or market value is associated with a decrease of 0.18 – 0.20 percent in R&D expenditures as proportion of total assets. This is in contrast to effect of size on un-scaled R&D expenditures.
6. Leverage is significant only in one model, but its effect is too small to be of practical significance.
7. AGE has a negative effect on R&D expenditures as proportion of total assets in some models, but its effect is small - about 0.2% .

[5] Business combination is defined as 'A union of two or more entities, either by merging one or more of the entities into another of the entities or by consolidating the entities into a new entity.' Business combination provision refers to provisions that prohibit or place restrictions on combination. The percentage change is calculated using the following formula for log-transformed dependent variable: $100*(e^{\beta} - 1)$, where β is the estimated parameter.

Table 4: Estimation with Firm and Year clusters				
Dependent variable: R&D_CONVERSION as output measure of innovation				
	1	***2***	***3***	***4***
Board_Indep_1	-0.187	-0.260	-0.230	-0.337
	(0.439)	*(0.444)*	*(0.444)*	*(0.445)*
Antitakeover_Def_1	0.166	0.117	0.162	0.125
	(0.169)	*(0.190)*	*(0.172)*	*(0.189)*
Insider_Control_1	0.720**	0.588**	0.697**	0.569**
	(0.309)	*(0.285)*	*(0.314)*	*(0.289)*
HHI_1	6.680***		6.541***	
	1.256		*1.256*	
HHISQ_1	-4.881***		-4.763***	
	(1.297)		*(1.300)*	
PMC_1		-82.850***		-83.017***
		(22.200)		*(20.416)*
PMCSQ_1		49.528***		49.483***
		(13.366)		*(12.281)*
Ln(Employees)_1	0.102	0.1658*		
	(0.066)	*(0.097)*		
Ln(Market_cap)_1			0.101	0.169*
			(0.067)	*(0.100)*
Total_Debt_to_Equity_1	0.0000122***	0.000		
	(0.000)	*(0.000)*		
Lterm_Debt_to-Equity_1			-0.0000351**	-0.000044***
			(0.000)	*(0.000)*
Age_1	0.00577**	0.00539**	0.00562**	0.00508**
	(0.003)	*(0.003)*	*(0.003)*	*(0.003)*
R-Square	0.121	0.055	0.117	0.055
Number of Obervations	1311	978	1302	969
Number of Firms	568	468	567	467

*, **, and *** denote statistically significant at the 10%, 5% and 1% level, respectively.
Standard errors in brackets.

The measure of innovation in Table 4 is the net book value of patents and brands as a proportion of R&D expenditures. As such, cross-sectional and time-series variations in this measure indicate firms' ability to convert R&D expenditures into innovation outputs with market value.

Table 4 provides opposite findings to Tables 2 and 3 in the sense that estimated parameters for corporate governance indicators, measures of concentration and competition, and measures of size have all switched signs. Hence, insider control now has a positive effect on R&D conversion (the output measure of innovation). In addition, the non-linear relationship between competition and innovation now has a U-shape instead of an inverted-U shape. Findings concerning R&D conversion can be summarised as follows:

1. Board independence now has a negative effect on the output measure of innovation (net book value of patents and brands as a proportion of R&D expenditures). This is opposite to findings in Table 2 and 3, where the dependent variable consists of input measures of innovation. However, the estimated parameters are statistically insignificant across model specifications;
2. Anti-takeover defences has also switched signs (has become positive), but remains insignificant across model specifications.
3. Insider control now has a positive effect on R&D conversion, and the effect is statistically significant across model specifications.
4. The relationship between market concentration (HHI) and R&D conversion is positive but non-linear (inverted-U shape) and remains significant across model specifications. A one-percent increase in market concentration index of 0 - 1 is associated with approximately 6.5 percent increase in R&D conversion at low levels of concentration, but the relationship becomes negative at higher levels of concentration.
5. The relationship between product-market competition (PMC) and R&D conversion is negative and non-linear (U-shaped), and remains significant across model specifications. A one-percent increase in the PMC index of 0 - 1 is associated with about 83 percent decrease in R&D conversion at low levels of competition, but the relationship becomes positive at higher levels of competition.
6. The findings summarised in (4) and (5) above indicate that higher product-market competition and lower market concentration induce lower levels of innovation output at lower levels of competition, but the innovation output increases as competition increases beyond a critical value. Hence, we can infer that, up to a critical level, firms in competitive markets are less able to convert R&D expenditures into patents and brands with value for the firm. This finding is in contrast to Aghion et al (2005), who report an inverted-U relationship between competition and the *output* measure of innovation (citations-weighted patent count).
7. Of firm characteristics, size and AGE have positive effects on R&D conversion. A one-percent increase in number of employees or market value is associated with an increase of about 0.16 – 0.17 percent in R&D conversion. On the other hand, a one-unit increase in age has a positive effect of approximately 0.5% on R&D conversion.

8. Leverage is significant in 3 out of 4 models, but its effect is too small to be of practical significance.

Recall that these findings are obtained by clustering along the firm (*i*) and year (*t*) dimensions. In what follows we establish whether the results remain robust to clustering along industries (*j*) and years (*t*), using 4-digit ISIC codes for industries. To test for this, we re-estimate models 1-3 using year and industry clusters. Estimations results are given below in Table 5a (with HHI as measure of market concentration) and 5b (with PMC as measure of product-market competition).

Comparing the results in Table 5a with results in column (1) of Tables 2, 3 and 4; and the results in Table 5b with the results in column 2 of Tables 2, 3 and 4 we can report the following:

1. There is 100% sign consistency between the results based on year-firm and year-industry clusters.
2. Estimated coefficients obtained from clustering along industry and year (Tables 5a and 5b) are similar or slightly smaller than the estimates obtained through clustering along year-firm dimensions (Tables 2, 3 and 4).
3. In majority of the cases, the cluster-robust standard errors associated with estimates from year-industry clusters (in Table 5A and 5B) are larger than the cluster-robust standard errors obtained by clustering along the year-firm dimensions.[6]

The findings so far (Tables 2 to 5) suggest that our estimates for the effect of market structure and corporate governance on firm innovation are:

1. Robust to model specification (different measures of innovation and inclusion/exclusion of independent variables)
2. Robust to estimation method (including fixed-effect panel, Fama-MacBeth and two-way cluster-robust estimations)
3. Robust to dimensions along which clustering is performed.

[6] We have re-estimated models 3 and 4 with the two-way cluster-robust method and the results are very much similar. We do not report these results here, but they are available upon request.

Table 5a: Estimation with Industry and Year clusters
(Using HHI)

	Ln(R&D)	*Ln(RD/A)*	*R&D_CONVERSION*
Board_Indep_1	0.271*	0.140	-0.187
	(0.157)(-)	*(0.128)(-)*	*(0.428)(-)*
Antitakeover_Def_1	-0.492***	-0.215**	0.166
	(0.117)(+)	*(0.105)(+)*	*(0.178)(+)*
Insider_Control_1	-0.485***	-0.179	0.719**
	(0.166)(-)	*(0.197)(-)*	*(0.319)(+)*
HHI_1	-4.348***	-3.113***	6.680***
	(1.471)(+)	*(1.091)(+)*	*(1.858)(+)*
HHISQ_1	3.141**	2.136**	-4.882***
	(1.245)(+)	*(0.964)(+)*	*(1.696)(+)*
Ln(Employees)_1	0.677***	-0.222***	0.102
	(0.038)(+)	*(0.033)(+)*	*(0.070)(+)*
Total_Debt_to_Equity_1	-0.00000417***	-0.0000042***	0.0000122***
	(0.000)	*(0.000)*	*(0.000)*
Age_1	-0.002	-0.0027125***	0.0057654*
	(0.002)	*(0.001)*	*(0.003)*
R-Square	0.429	0.227	0.121
Number of Obervations	2365	2360	1311
Number of Industires	215	215	177

Table 5a: Estimation with Industry and Year clusters
(Using PMC)

	Ln(R&D)	*Ln(RD/TA)*	*R&D_CONVERSION*
Board_Indep_1	0.279	0.082	-0.260
	0.174(+)	*0.123(+)*	*0.430(-)*
Antitakeover_Def_1	-0.441***	-0.199*	0.117
	0.117(+)	*0.119(+)*	*0.183(-)*
Insider_Control_1	-0.498***	-0.222	0.588**
	0.147(-)	*0.191(-)*	*0.298(+)*
PMC_1	37.554**	55.183***	-82.849***
	17.547(+)	*15.165(+)*	*30.368(+)*
PMCSQ_1	-26.353**	-34.263***	49.528***
	10.729(+)	*9.207(-)*	*18.450(+)*
Ln(Employees)_1	0.745***	-0.193V	0.166*
	0.041(+)	*0.037(+)*	*0.097*
Total_Debt_to_Equity_1	0.000	0.000	0.000
	0.000	*0.000*	*0.000*
Age_1	-0.001	-0.002	0.00539*
	0.002	*0.002*	*0.003*
R-Square	0.448	0.136	0.055
Number of Obervations	1640	1638	978
Number of Industires	201	201	161

*, **, and *** denote statistically significant at the 1%, 5% and 10% level, respectively.
Standard errors in brackets.
(-) Standard error less than firm-year clustering; (+) standard error greater than firm-year clustering

In terms of substantive conclusions, the following can be stated:

1. Of the CG indicators, board independence tends to have a positive effect on input measures of innovation and negative effect on output measure of innovation. However, the effect is only partly significant.
2. Anti-takeover measures tend to have a negative effect on input measures of innovation, but positive effect on the output measure of innovation. The effect is significant when the dependent variable is the input measure of innovation, but insignificant with the output measure.
3. Insider control tends to have a negative effect on input measures of innovation, but a positive effect on the output measure. The negative effect on input measures of innovation is significant with respect to R&D expenditures only. The effect with respect to the output effect (R&D conversion) is positive and significant.
4. Market concentration and product-market competition tend to have significant and non-linear effects on both input and output measures of innovation. Market concentration (HHI) has a negative and significant effect on both input measures of innovation, and positive effect on the output measure. This finding is reinforced by the estimates of the PMC coefficients. Product-market competition tends to have a positive effect on input measures of innovation, but negative effect on the output measure.
5. Firm SIZE and AGE also tend to have opposite effects on innovation – depending on the measure. Size tends to have a negative effect on input measures of innovation, but positive effect on output measure of innovation. Similarly, age tends to have a negative effect on input measures of innovation, but positive effect on the output measure.

The final set of results we will present below are aimed at addressing the question of whether or not competition and corporate governance are substitutes or complements in their effects on innovation. To address this question, we re-estimate the models in Table 5 by adding interaction terms for corporate governance and market structure indicators. Hence, we have 3 interaction terms for market concentration and 3 for product-market competition:

Board_Indep_1 * HHI_1**; **Antitakeover_Def_1 * HHI_1**; and **Insider_Control_1 * HHI_1

Board_Indep_1 * PMC_1**; **Antitakeover_Def_1 * PMC_1**; and **Insider_Control_1 * PMC_1

The results are reported in Table 6A and 6B below.

Table 6a: Estimation with Industry and Year clusters
(Interacting HHI with CG Dummies)

Dependent variable →	*Ln(R&D)*	*Ln(RD/TA)*	*R&D_CONVERSION*
Board_Indep_1	0.203	0.079	0.197
	(0.159)	*(0.140)*	*(0.373)*
Antitakeover_Def_1	-0.873***	-0.561***	0.902***
	(0.213)	*(0.188)*	*(0.332)*
Insider_Control_1	-0.218	0.059	0.706
	(0.309)	*(0.429)*	*(0.555)*
HHI_1	-4.592***	-3.334***	7.811***
	(1.400)	*(1.071)*	*(2.256)*
HHISQ_1	2.913**	1.930**	-4.313***
	(1.277)	*(0.987)*	*(1.615)*
Board_Indep_1 * HHI_1	0.238	0.215	-1.184
	(0.379)	*(0.301)*	*(0.894)*
Antitakeover_Def_1 * HHI_1	0.941**	0.856**	-1.799**
	(0.393)	*(0.369)*	*(0.780)*
Insider_Control_1 * HHI_1	-0.643	-0.578	-0.157
	(0.565)	*(0.611)*	*(1.221)*
Ln(Employees)_1	0.677***	-0.223***	0.105
	(0.038)	*(0.033)*	*(0.069)*
Total_Debt_to_Equity_1	-0.00000458***	-0.00000457***	0.0000128***
	(0.000)	*(0.000)*	*(0.000)*
Age_1	-0.002	-0.0028*	0.00605**
	(0.002)	*(0.002)*	*(0.003)*
R-Square	43.22%	23.31%	13.01%
Number of Obervations	2365	2360	1311
Number of Industires	215	215	177

Table 6b: Estimation with Industry and Year clusters
(Interacting PMC with CG Dummies)

Dependent variable →	*Ln(R&D)*	*Ln(RD/TA)*	*R&D_CONVERSION*
Board_Indep_1	-0.252	2.060	-3.757
	(3.220)	*1.984*	*5.573*
Antitakeover_Def_1	-2.062	-0.363	-5.389
	(2.506)	*2.564*	*4.307*
Insider_Control_1	1.804	0.698	-6.659
	(5.441)	*2.933*	*6.176*
HHI_1	38.421**	57.972***	-81.260**
	(19.838)	*16.345*	*32.779*
HHISQ_1	-27.442**	-34.646***	45.082**
	(11.539)	*9.836*	*18.577*
Board_Indep_1 * PMC_1	0.609	-2.284	4.027
	(3.777)	*2.279*	*6.532*
Antitakeover_Def_1 * PMC_1	1.839	0.187	6.259
	(2.801)	*2.839*	*4.830*
Insider_Control_1 * PMC_1	-2.610	-1.055	8.200
	(6.225)	*3.487*	*7.033*
Ln(Employees)_1	0.747***	-0.193***	0.170*
	(0.039)	*0.036*	*0.096*
Total_Debt_to_Equity_1	0.000	0.000	0.000
	(0.000)	*0.000*	*0.000*
Age_1	-0.001	-0.002	0.00533*
	(0.002)	*0.002*	*0.003*
R-Square	44.84%	13.63%	5.92%
Number of Obervations	1640	1638	978
Number of Industires	201	201	161

*, **, and *** denote statistically significant at the 10%, 5% and 1% level, respectively.
Standard errors in brackets.

The estimates for the interaction terms in Table 6a and 6b are not consistent between measures of competition and/or between measures of innovation. In addition, only a few of the estimates are statistically significant – mainly those for the interaction between anti-takeover defences and HHI. These estimates indicate that firms in highly concentrated industries spend more on R&D when they have anti-takeover defences. Stated differently, the presence of anti-takeover defences reverses the relationship between concentration and R&D expenditures, implying that anti-takeover defences cause firms to behave as if they are on the upward-sloping section of the U-shape relationship between concentration and R&D expenditures. As such, the presence of anti-takeover defences complements the level of concentration and makes the positive relationship between concentration and R&D expenditures dominant. Given that this finding remains robust to two input measures of innovation (R&D and R&D/A), we can infer that concentration and anti-takeover defences are complement. The complementarity between the two variables is conformed with respect to the output measure of innovation (R&D Conversion) too. Here, the presence of anti-takeover defences causes firms to behave as if they are on the downward-sloping section of the inverted-U shape relationship between concentration and R&D conversion. A similar conclusion cannot be derived with respect to interaction with product-market innovation as the results are insignificant.

Conclusions

We have provided evidence on the relationship between corporate governance, competition/concentration and innovation for 1,400 non-financial US-listed companies from 2004-10. The sample constitutes an un-balanced panel due to missing values, but it remains the largest sample used so far in the empirical literature.

The evidence - which is robust to model specification, cross-sectional and serial correlation, and definition of innovation indicators - enable us to derive a number of conclusions:

1. The impact of board independence on R&D expenditures is positive but insignificant. Its effect on R&D conversion is negative but insignificant. Hence, it is not possible to make any inference about the effect of board independence on innovation.
2. The effect of anti-takeover defences on R&D expenditures is negative and significant in the large majority of the results. The effect on R&D conversion, however, is positive but insignificant. Hence, we can conclude that anti-takeover defences tend to be associated with lower innovation effort – as measured by R&D expenditures.

3. The effect of insider control on R&D expenditures is negative in all model specifications, but it is significant only in models with R&D expenditures. The effect on R&D conversion is the opposite: insider control is associated with higher levels of R&D conversion across different models. Hence, we can conclude that firms with insider control tend to spend less on R&D but are better able to convert R&D spending into patents and brands with market value.
4. The effect of market structure on innovation is consistent across all model specifications and estimation methods. Hence we can conclude that firms in *less concentrated* and *competitive* markets tend to spend more on R&D; but they are less able to convert R&D expenditures into patents and brands with market value.
5. Another consistency in the estimated effects of market structure concerns its non-linear nature. We can report that the effect of market concentration on R&D expenditures follows a U-shape and its effect on R&D conversion follows and inverted-U shape. The effect of product-market competition reinforces the relevance of this finding: it is inverted-U shape with respect to R&D expenditures and follows a U-shape with respect to R&D conversion.
6. Therefore, the overall conclusion about the relationship between market structure and innovation can be stated as follows: less concentrated and more competitive firms tend to invest more in R&D expenditures, but they are not necessarily successful in converting R&D expenditures into patents and brands with market value.
7. The impact of leverage on innovation is very small and mostly insignificant across models and estimation methods.
8. The effect of age and size concur with the effect of competition: larger and older firms tend to spend less on R&D expenditures, but they are more successful in converting R&D expenditures into patents and brands with market value.
9. The implications of these findings for the competition - innovation debate can be stated as follows:
    (a) Competition (i.e., the fall in pre-innovation profits) drives firms to invest in innovation; but already large and profitable companies are better able to benefit from that investment in terms of patents and brands with value for the firm.
    (b) However, the effect of competition on both R&D expenditures and R&D conversion is non-linear. This non-linearity indicates that the effect of competition on R&D expenditures is subject to diminishing returns to the level of competition; but its effect on R&D conversion is subject to increasing returns to the level of competition.
    (c) These findings are supported by the findings concerning age and size.

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