Market Concentration, Corporate Governance and Innovation: Partial and Combined Effects in US-Listed Firms

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Abstract

Existing research on the relationship between market concentration and innovation has produced conflicting findings. In addition, the emerging literature on the relationship between corporate governance and innovation tends to focus only on *partial* effects of corporate governance on innovation. We aim to contribute to the debate by investigating both *partial* and *combined* effects of corporate governance and market concentration on innovation. Utilising a dataset for 1,400 non-financial US-listed companies and two-way cluster-robust estimation methodology, we report several findings. First, the relationship between market concentration and innovation is non-linear. Secondly, the relationship has a *U-shape* in the case of input measure of innovation (research and development - R&D – expenditures); but it has an *inverted-U shape* when net book-value of brands and patents is used as output measure of innovation. Third, corporate governance indicators such as anti-takeover defences and insider control tend to have a *negative partial effect* on R&D expenditures but a *positive partial effect* on net book-value of brands and patents. Finally, when interacted with market concentration, anti-takeover defences and insider control act as *complements* to market concentration. Hence, firms with strong anti-take-over defences and under insider control tend to spend more on R&D but are less able to generate valuable brands and patents as market concentration increases. These results are based on two-way cluster-robust estimation, which takes account of both serial and cross-sectional dependence in the error terms.

Keywords: Innovation, competition, corporate governance, two-way cluster-robust estimation
JEL Codes: O310; G300; L100; D210; D220

1. Introduction

The debate on the relationship between market structure and innovation dates back to Schumpeter (1934, 1942), who posited that firms' innovation effort is likely to be higher when markets are concentrated and/or firm size is large. The Schumpeterian hypothesis is based on the assumption that market power enables firms to generate excess profits, which can be used to hire highly qualified personnel and respond to competition quickly by utilising internal finance instead of relying on costly external finance. In addition, market concentration and large size enable firms to enjoy the benefits of innovation by erecting new barriers against future entry.

Nevertheless, the theoretical and empirical work that follows does not provide unequivocal support to the Schumpeterian hypothesis. In a recent survey, Gilbert (2006) indicates that the jury is still out and that the Schumpeterian hypothesis may not hold because of the way in which monopoly power affects manager attitudes. As Hicks (1935) had observed, monopolies may be slow to innovate because monopoly power enables managers to enjoy "quite life". When such agency problems are taken into account, corporate governance quality emerges as an additional determinant of innovation effort. Therefore, it is necessary to investigate not only the partial effects of corporate governance and market concentration on innovation, but also their combined effects. The combined effects have been investigated only by Aghion et al (1999 and 2002), who demonstrate that corporate governance may be either a substitute for or a complement to competition – depending on whether managers are profit-maximizers or satisficers.

However, despite Agion et al's (1999, 2002) contribution and the significant increase in the volume of work that examines the relationship between corporate governance and firm performance in general, the number of studies that investigate the relationship between corporate governance and innovation has remained limited. In addition, existing studies tend to focus on the relationship between innovation and corporate governance only and as such they overlook the combined effects of corporate governance and market structure on innovation incentives and outcomes.

The aim of this article is to contribute to the existing literature by analysing the relationship between corporate governance, market concentration and input and output measures of firm-level innovation. We demonstrate that both corporate governance and market concentration are related to R&D expenditures and net book-value of patents and brands in a sample of US-listed non-financial firms. The theoretical explanation for the relationship can be summarised as follows: given a firm's corporate governance regime, the level of market concentration affects the managers' R&D effort because it determines the level of expected profits before and after innovation. However, investment in innovation is costly and associated with uncertain returns for shareholders and uncertain private benefits for managers. Hence corporate governance rules, which reflect the time horizon of the shareholders and the extent to which managers are profit-maximizers or satisificers, emerge as additional factors that determine the firm's R&D effort at each level of market concentration. The aim of this article is to investigate how market concentration and corporate governance characteristics affect R&D effort separately and in interaction with each other.

The data for this investigation 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 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 empirical findings, whilst the last section summarizes the main findings and distils some policy- and practice-relevant conclusions.

2. Related literature

Firm's innovation effort must be analysed by taking into account two factors that affect the incentives of firm managers: the extent of product-market competition they face and the nature of the corporate governance rules they are bound with. Yet, so far and with the exception of Aghion et al (1999 and 2002), the relationship between these factors and innovation has been analysed separately. As a result, we observe a detachment between a well-developed body of work on the relationship between market structure and innovation and an emerging literature on the relationship between corporate governance and innovation. In order to set the stage for joint analysis, we will first summarise the main findings of the theoretical work on the competition-innovation relationship. This will be followed by a similar exercise on the relationship between corporate governance and innovation. At the end of this section, we will draw on Aghion et al (1999 and 2002) to develop the case for joint analysis, whereby research and development (R&D)

expenditures are estimated by controlling for market concentration, corporate governance indicators and the interaction between the two.

2.1 Market concentration and innovation

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). Arrow (1962) is the earliest attempt that takes issue with the Schumpeterian hypothesis. Arrow work demonstrates that a monopoly shielded against competition has less incentive to innovate because it can earn positive profits with or without innovation. However, a firm in a perfectly competitive market does not earn positive unless it innovates and its innovation is protected by exclusive intellectual property rights. Given that the incentive for innovation depends on the sum of pre- and post-innovation profits, a competitive firm tends to have greater incentives to innovate compared to a monopolist.

However, Arrow (1962) examines the case of a pure monopolist and a perfectly-competitive firm. Gilbert and Newey (1982) derives opposite conclusions – i.e., find support for the Schumpeterian hypothesis - by analysing the case of imperfect competition. They examine the case of a monopolist with existing technology and a new-comer investing in new technology. In their analysis, innovation is a 'bid for patents' and the successful bidder (i.e., the innovator) earns higher post-innovation profits. In this scenario, there is support for Schumpeter's 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*. Compared to the incumbent monopolist, the new-comer face zero profits/rents if its bid for patent is unsuccessful and can earn only duopoly profits if it is successful. Therefore, the incumbent 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. Given this uncertainty, 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 drastic innovation are less than the expected profits for a competitor; and this result holds even if innovation becomes less drastic on a drastic/non-drastic scale.

The large volume of the empirical literature reviewed by Gilbert (2006) yields similar conflicting results. It is evident that the debate has been dominated by antagonism between a positive 'Schumpeter effect' and a negative 'Arrow effect' from market concentration on to innovation. As Peneder (2012) observes, however, it is simplistic to assume that the effects postulated either by Schumpeter or Arrow are linear or independent of the degree of initial competition assumed. In Schumpeter, the argument concerning the impossibility of endogenous innovation under perfect competition is valid only at low levels of initial market concentration. In Arrow, on the other hand, the positive effect of competition on innovation is derived from contrasting a legally protected monopoly with a competitive duopoly. This scenario clearly implies high levels of market concentration. Therefore the incentives analysed by Schumpeter and Arrow unfold exactly at the opposite ends of the market concentration spectrum.

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.

2.2 Corporate governance and innovation

The limitation of Aghion et al (2002a, 2005) is that their 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.

In this setting, satisficing managers face conflicting incentives with respect to innovation. On the one hand, they are motivated to minimise the innovation effort in order to avoid the direct cost of innovation and the adjustment cost associated with implementing the new technology. On the other hand, they are motivated to innovate in order to reduce the risk of bankruptcy. Given this optimisation strategy, how would an increase in product market competition affect the manager's innovation effort? According to Aghion et al (1999), product market competition would tilt the balance in favour of higher innovation effort and higher growth. This is because higher levels of product market competition lead to lower flow of rents to firms that have just innovated. Therefore, these firms must innovate sooner rather than later in order to remain solvent and/or to compete with advanced firms for skilled labour requiring higher wages. The result is that product-market competition stimulates innovation especially when managers satisfice – i.e., when they do not respond to monetary incentives under dispersed ownership structures. In other words, corporate governance and product market competition emerge as *substitutes* when firm managers satisfice rather than maximize profits.

This prediction has been challenged by evidence in Grosfeld and Tressel (2001), who utilize a panel-data set for 200 firms listed on the Warsaw Stock Market during the period 1990-1998. The authors report that higher levels of product market competition increases total factor productivity (TFP) growth in firms with both concentrated and dispersed ownership. The positive relationship between competition and innovation in firms with concentrated ownership (i.e., in firms where managers are expected to be profit-maximizers rather than satisficers) suggests *complementarity* between corporate governance and product market competition.

To address this contradiction, Aghion et al (2002) draw on earlier models where innovation occur step-by-step' – i.e, a laggard firm must first innovate to catch up with the technological leader, before it can become a leader in the future. In this setting, the incentive to innovate is equal to the difference between the effects of innovation on post-innovation and pre-innovation rents. Competition encourages innovation because, as competition increases, the firm's post-innovation rents would fall by less than the fall in pre-innovation rents. In other words, innovation is a means of escaping the harmful effects of competition on excess profits. Introducing corporate governance into the analysis, Aghion et al (2002) demonstrate that the positive effect of competition on innovation will be stronger in firms where corporate governance provides better alignment between the interests of managers and shareholders - i.e., under concentrated ownership. This is just the opposite of the finding in Aghion et al (1999) and can be stated as follows: product market competition stimulates innovation especially when managers act like profit-maximizers – i.e., when they do respond to monetary incentives under a concentrated ownership structure. In other words, corporate governance and product market competition emerge as *complements*.

Full-scale investigations of the relationship between corporate governance and innovation are relatively recent. Nonetheless, there is an evident increase in the volume of work in this area and the theories it draws upon (the principal-agent theory and the theory of contracting) are well established in corporate finance. Two recent work (Belloc, 2012; Sapra et al, 2009) provide excellent reviews of this emergent literature. In what follows, we will first provide an overview of the theoretical findings on the relationship between innovation and corporate governance. Then, we will elaborate on why it is necessary to investigate innovation effort not only in the light of market structures or corporate governance separately, but by paying attention to the way in which the two dimensions interact and affect innovation.

The principal-agent framework tends to affirm that concentrated ownership is conducive to more effective monitoring over management strategies and hence reduces the agency costs associated with innovation. The argument can be summarised as follows: small and dispersed shareholders are less able to monitor managers because monitoring costs may be higher than the benefits (which are proportional to their small shareholdings) and this leads to collective action failures generally encountered within diffused groups. This view finds support in work by Hill and Snell (1988) and Baysinger et al. (1991), who provide theoretical justification and empirical evidence in support of the principal-agent framework. Their findings indicate a positive relationship between ownership concentration and R&D expenditures.

However, this relationship holds only if large shareholders have long time horizons – i.e., if they do not prefer to maximise short-term returns at the expense of long-term returns. However, this assumption may not hold. This is evident in Hill et al (1988), who argue that one category of large shareholders – i.e., institutional investors - are risk-averse and, when they are major shareholders, they wield pressure on the management to secure high short-term profits at the expense of long-term projects such as investment in innovation. Similar findings have been reported by Graves (1988), who conclude that institutional shareholders tend to have short-time horizons and that their knowledge of the firms or industries in which they operate is limited. Therefore, the higher the level of institutional ownership, the lower is the level of innovation investment.

It is clear that the assumption about the time horizon of the large shareholders drives the predictions of the principal-agent approach to the relationship between corporate governance and innovation. Therefore, the contract theory is called upon to investigate the extent to which ownership structures can address the short-time-horizon problem by facilitating contracting between various stakeholders. According to Battaggion and Tajoli (2001), ownership structure shapes the *ex-post* bargaining power of the stakeholders and therefore the final allocation of the quasi-rents generated by the firm. If the ownership structure facilitates contracting and reduces the asymmetry in the distribution of power between small and large shareholders (block-holders), it encourages innovation. Otherwise, greater bargaining power enjoyed by the large block-holders reduces their commitments to small outside investors and this causes difficulties for the firm in raising funds for financing innovative investment projects.

Hence either the principal-agent perspective alone or in combination with contracting theory leads to conflicting predictions about the relationship between ownership structures and innovation. Similar results are obtained with respect to the relationship between take-over pressure and innovation. In Sapra et al (2009), the manager faces a trade-off when they choose the level of innovation effort in the face of takeover pressure. On the one hand, investment in innovative projects increases take-over pressure as innovation investment is costly and its returns are uncertain. On the other hand, higher takeover pressure that may follow investment in innovation results in a larger takeover premium to be expected. The manager trades off the benefits of this higher expected takeover premium after innovation against the loss of control benefits that may result from innovation-induced takeover.

Shleifer and Summers (1988) demonstrate that takeover pressure reduces managers' willingness to invest in firm-specific technological innovation as they anticipate a higher probability of *ex-post* expropriation by 'raiders'. In other words, higher probability of *ex-post* takeover leads to suboptimal levels of firm-specific investments *ex-ante*. Maher and Andersson (2002) and Stein (1988) also report a negative relationship between takeover pressure and innovation. However, these findings are challenged by the 'quite life' approach, which argues that anti-takeover defences (either through legislation or thorough firm-specific measures such as staggered boards, business combination procedures or poison pill provisions) hinder the market for corporate control and encourage managerial slack. As managers opt for 'quite life', they are less likely to commit to investment in costly innovative projects with uncertain outcomes (Jensen, 1988). With a more nuanced approach, Sapra et al (2009) demonstrate that the relationship between takeover pressure and innovation is non-monotonic: firms are more likely to invest in innovative projects either when the market for corporate control is well-developed and takeover pressure is high; or when anti-takeover laws and provisions are strict enough to deter takeovers.

2.3 Market structure, corporate governance and innovation: towards a synthesis

The overview presented above indicates that the relationship between market structure, corporate governance and innovation can be positive, negative or non-linear – depending on the assumptions about the initial level of competition, the incentive structures faced by managers and shareholders, and the kind of innovation strategies involved (neck-and-neck *versus* step-by-step innovation). Despite differences in modelling and findings, however, it is possible to detect a degree of convergence towards the affirmation of a non-linear relationship between competition and innovation. This tendency is confirmed in recent work published in a special issue of the *Journal of Industry, Competition and Trade*. In an introductory article to the special issue, Peneder (2012) states that the nonlinear model is technically sophisticated and has intuitive appeal - not the least because it can reconcile the Schumpeterian and Arrow-like arguments. Three empirical papers in the special issue test explicitly for non-linear relationship between competition and innovation. While Berubé et al (2012) and Polder and Veldhuizen (2012) confirm the existence of an inverted-U relationship in Canadian and Dutch microdata, Peroni and Gomes Ferreira (2012) report a U-shaped relationship in Luxembourg firm-level data.

Another conclusion that can be derived from the review above is that both market structure and corporate governance rules shape the cost-incentive structure that managers face when they choose the level of innovation effort. Therefore, it is necessary to take account of both factors and their interaction when we investigate the determinants of innovation. Like the move towards investigating the *inverted-U* relationship between market structure and innovation, the move towards joint examination of market structure and corporate governance is informed by Aghion et al 1999 and 2002).

In this article, we aim to contribute to the existing literature by extending the evidence base on the relationship between innovation, market structure and corporate governance. Our contribution consists of three components. First, we investigate the relationship between three corporate governance indicators and innovation. The corporate governance indicators include board independence, anti-takeover defences, and share of insiders in equity. Secondly, we investigate whether market concentration and corporate governance are complements or substitutes for the three indicators of corporate governance by interacting each indicator with market concentration. This exercise enables us to extend the evidence base on compelementarity or substitution between corporate governance and competition. The existing evidence on this issue is limited to Aghion (1999 and 2002), who investigate the interaction between product market competition and one corporate governance dimension – namely ownership structure only. Third, we establish whether the results remain robust to inclusion of different firm characteristics such as size and leverage; and to use of different clusters consisting of firms and industries.

3. Data and estimations

We estimate models (3) and (4) below, using 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* of *GovernanceMetrics International.* The corporate governance data is matched with annual accounting and financial data from Thomson Reuters' *Datastream*.[1] Consistent with prior studies, we exclude financial firms (banks, investment trusts, insurance companies, and properties companies). To calculate the measure of concentration, we use four-digit industry classification code utilized by the Securities and Exchange Commission (SEC). For each company in each year, we have collected data 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 extent to which the board can steer the company to achieve long-term sustainable growth in shareholder value. Independent boards are expected to achieve this objective by discouraging excessive risk-taking for the sake of short-term returns and by encouraging long-term investment in areas such as innovation. It takes the value of one if the company board is independent, zero otherwise.

[1] The Corporate Library has merged with Governance Metrics International in 2010. Information on corporate governance metrics provided by GMI can be obtained from http://www3.gmiratings.com/solutions/methodology/ . For information on Datastream, see http://online.thomsonreuters.com/datastream/.

Antitakeover_Def: A takeover defence measure that indicates whether the company has both a staggered board and business combination provision in the same year. In publicly-held companies, staggered boards have the effect of making hostile takeover attempts more difficult. When a board is staggered, hostile bidders must win more than one proxy fight at successive shareholder meetings in order to exercise control of the target firm. On the other hand, business combination prohibits the company from engaging in a merger or other extraordinary transaction with a person or entity that owns a specified percentage of the company's stock for some period of time after the shareholder acquires the threshold amount. It may also require a higher shareholder vote for approval of transactions with the interested or related shareholder, even after the waiting period has expired. Both provisions reduce the risk of acquisition and hostile bids. The dummy variable takes the value of one if the company has both staggered board and business combination provision, and zero otherwise.

Insider_Control: Insider control indicates whether or not a majority of outstanding shares are held by top management and/or directors. It indicates the extent to which 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: Natural logarithm of the number of employees as a measure of firm size

Market_cap*:* Natural logarithm of market capitalisation as an alternative proxy for firm size. Market capitalization is equal to the total number of shares outstanding multiplied by the most recent quarter-end market price.

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

Total_Debt_to_Capital: Total (short- and long-term) debt as a multiple of capital

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.

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

$$HHI_{jt} = \sum S_{ijt}^2 \qquad (1)$$

S_{ijt} represents the share of firm *i* in the total sales of industry *j* for a given year *t*. The industry is defined on the basis of four-digit standard industry classification (SIC) code used by the Securities and Exchange Commission (SEC). The HHI ranges between 0 and 1, and indicates higher levels of concentration (hence lower levels of competition) as it approaches 1.

The summary statistics of the variables are in Table 1 below.

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
Total_Debt_to_Equity	15970	187.878	3931.938	0	356937
Total_Debt_to_Capital	14337	454.9726	21746.5	0	1500000
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

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 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:

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

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]

Petersen (2007) and Gow et al (2010) provide simulation results that compare the two-way cluster-robust estimations with results obtained from fixed- and random-effect effect panel-data estimators and the estimator proposed by Fama-Macbeth (1973). Their findings can be summarised as follows:

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 (increases) over time, firm dummies do not capture fully the within-cluster dependence and OLS standard errors remain biased downward (upward).

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:

[2] We have used the Stata procedure produced by Mitchell Petersen to run two-way cluster-robust regressions with panel data. See: http://www.kellogg.northwestern.edu/faculty/petersen/htm/papers/se/cluster2.ado .

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, which indicate that the two-way cluster-robust method of Petersen (2007) is either superior to or at least as good as other methods. This method allows for taking account of both serial and cross-sectional dependence in the error terms.

In its general form, the model we estimate can be stated as:

$$INV_j = F[CG_k, (CG_k * HHI), HHI, FC_l] \qquad (2)$$

Where:

$\boldsymbol{INV_j}$ is a 3x1 vector of **innovation** measures, consisting of:

1. Log of R&D expenditures
2. Log of R&D expenditures as proportion of total assets
3. Log of net book-value of patents and brands as a proportion of R&D expenditures

$\boldsymbol{CG_k}$ is a 3x1 vector of **corporate governance indicators**, consisting of:

1. Board independence – a dummy variable that takes the value of 1 if "outside" directors of a board constitute a majority over "inside" and "related-outside" directors; and zero otherwise.
2. Anti-takeover defences – a dummy variable that takes the value of 1 if the firm has both a staggered board and business combination provision; and zero otherwise.

3. Insider control – a dummy variable that takes the value of 1 if majority of outstanding shares are held by top management and/or directors; and zero otherwise.

CG_k*HHI is a 3x1 vector of interaction terms between 3 CG indicators and the Herfindhal-Hirschman index as the measure of market concentration.

HHI is the **Herfindahl-Hirschman concentration index**, based on firm shares of net sales within each industry defined by four-digit standard industry classification (SIC) codes.

FC_l = is a 5x1 vector of **firm characteristics**, consisting of:

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

We estimate model (1) in two stages. In stage 1, we estimate only the partial effects of corporate governance and market concentration (model 2 below). In stage 2, we estimate the partial and combined effects of corporate governance and market concentration at the same time (model 3 below). Stated formally, the models for estimation are as follows:

$$ln(INV_j)_{it} = \alpha_i + \sum_1^3 \beta_k \, CG_{kit-1} + \theta HHI_{it-1} + \sum_1^5 \gamma_l \, FC_{lit-1} + \omega_i + \varepsilon_{it} \qquad (3)$$

And

$$ln(INV_j)_{it} = \alpha_i + \sum_1^3 \beta_k \, CG_{kit-1} + \sum_1^3 \varphi_k \, (CG_{kit-1} * HHI_{it-1}) + \theta HHI_{it-1} + \sum_1^5 \gamma_l \, FC_{lit-1} + \mu_i + \epsilon_{it} \qquad (4)$$

In both models, the variables are as defined above. Of the error terms, ω_i and μ_i represent industry-specific fixed effects; ε_{it} and ϵ_{it} represent the residuals that have a mean zero but may be correlated over time or across firms within a given year. We estimate both models with two-way cluster-robust standard errors, which take account of within-firm correlation over time and between-firm correlation in the same year (Petersen, 2007; Gow et al, 2010). We also use the four-digit SIC codes as industry dummies to take account of the fixed industry effects.

We have clustered the data along two dimensions: (i) firm and year clusters; and (ii) industry and year clusters. We have also checked the sensitivity of our estimates to: (i) different measures of innovation (natural log of R&D expenditures, R&D expenditures as percentage of total assets, and net-book value of patents and brands as proportion of R&D expenditures); (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 total debt as percentage of capital). Finally, we have used lagged values of the regressors in order to reduce the risk of reverse causality from innovation into corporate governance and market concentration.

We estimate model 3 three times to establish the partial effects of corporate governance and market concentration on two input and one output measures of innovation. We repeat the same exercise for model 4, which enables us to estimate the partial effects and combined effects at the same time. Estimating model 4 will enable us to establish whether the partial effects remain significant in the presence of interaction terms and whether market concentration and corporate governance are complement or substitutes in their effects on innovation.

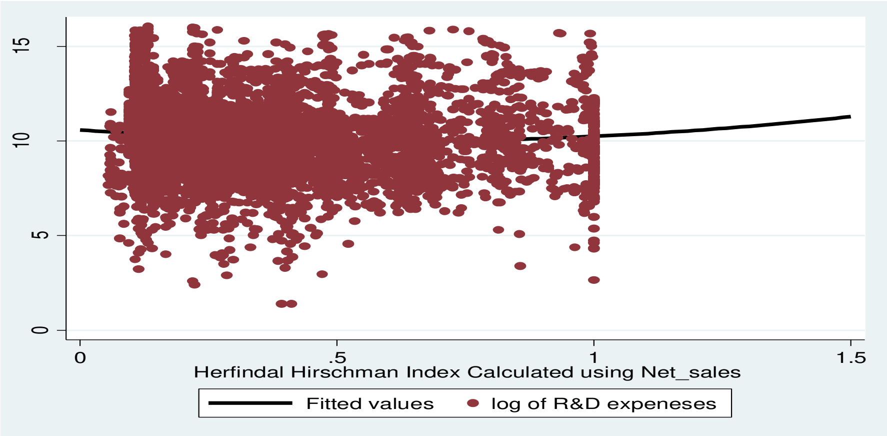
The existence of complementarity or substitution effects depends on the sign and significance of the interaction terms' coefficients. If the coefficients on the interaction terms are significant and of the *same sign* produced by the multiplication of the coefficients on corporate governance and market concentration individually, concentration and innovation interact as *complements*. Otherwise, they are *substitutes*. On the other hand, the magnitude of the interaction effects can be compared with the magnitude of the partial effects in order to establish whether corporate governance and market concentration combined have larger or smaller effects on innovation compared to the partial effects of corporate governance indicators only.

4. Estimation results

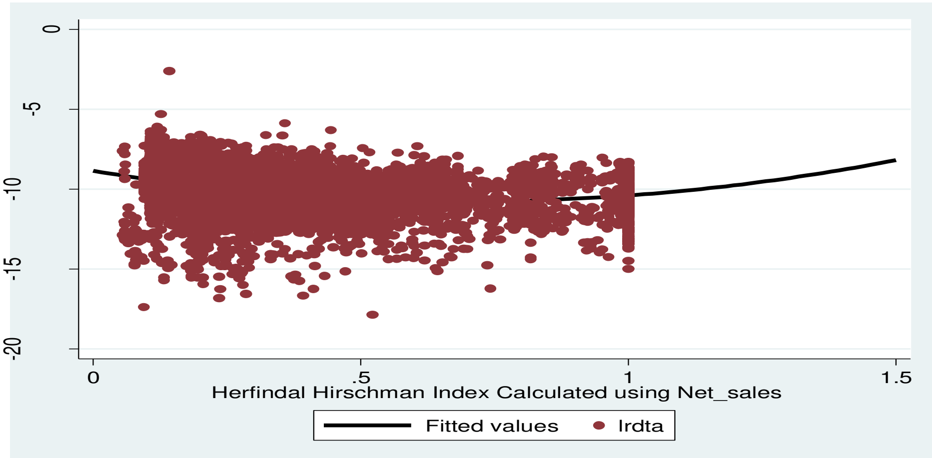
First, we have estimated model 3 with three different measures of innovation as dependent variables: (i) R&D expenditures; (ii) R&D expenditures relative to total assets; and (iii) net book-value of patents and brands as a ratio of R&D expenditures. For three measures, the relationship between market concentration and innovation is non-linear. This can be seen in Figure 1 below. In the case of R&D expenditures in levels and relative to total assets (panels A and B), the relationship has a *U-shape*. At lower levels of concentration, R&D effort tends to decrease as concentration increases; but at higher levels of concentration, R&D effort tends to increase as concentration increases. In the case of innovation outcomes (i.e., net book-value of patents and brands), the relationship has an *inverted-U* shape. At lower levels of concentration, innovation output tends to decrease as concentration increases but it tends to decrease at higher levels of concentration. These findings are in contrast to Aghion et al (2005), who report an *inverted-U* shape between *competition* (as opposed to concentration) and number of patents. In what follows, we will test whether the non-linear relationship between concentration and innovation measures is statistically significant and whether it remains robust to inclusion of corporate governance indicators and other firm characteristics.

Figure 1: Quadratic relationship between market concentration and innovation

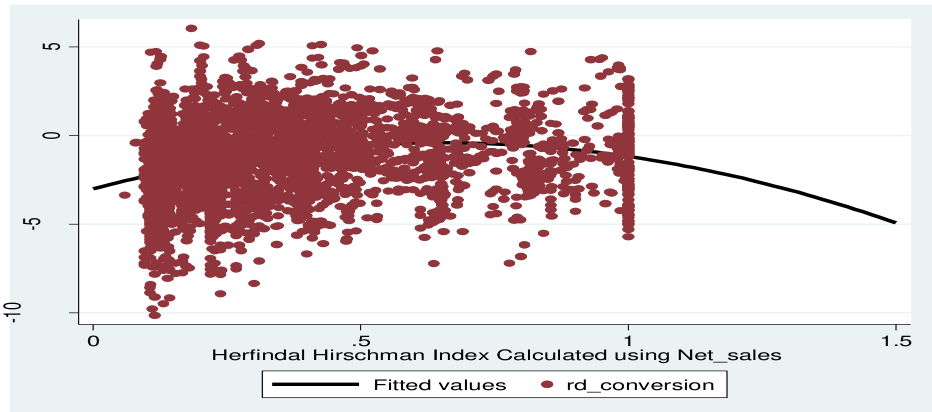
A- Market concentration and log of R&D expenditures



B- Market concentration and log R&D expenditures relative to total assets



C- Market concentration and net book-value of patents and brands as ratio of R&D expenditures



Panel A of Table 2 below presents the estimation results based on firm and year clusters, with firm age, number of employees and total-debt-to-equity as firm characteristics (control variables). Panel B presents the results with firm/year clusters as panel A, but with market value and total-debt-to-capital as alternative control variables. Results reported in Table 2 remain robust to change in control variables and can be summarised as follows:

1. Board independence has a positive effect on R&D expenditures and R&D expenditures as a ratio of total assets, but the effect is negative with respect to the net book-value of brands and patents as a ratio of R&D expenditures. However, the effect is statistically insignificant across model specifications.

2. The effect of anti-takeover defences (staggered boards and business combination provisions) is positive but statistically insignificant with respect to net book-value of brands and patents. However, firms with staggered boards and business combination provisions tend to spend less on R&D in level terms and relative to total assets; and the negative effect is statistically significant. Given that the anti-takeover defences is a dummy variable, this finding indicates that staggered board and business combination provisions cause the *U-shape* curve in Figure 1 to shift downward by 0.474 - 0.493 logarithmic units in the case of R&D expenditures and by 0.198 - 0.215 logarithmic units in the case of R&D expenditures relative to total assets. In the case of net book-value of patents and brands, anti-takeover defences causes the *inverted-U* curve to ship upward but this shift is not statistically significant.

3. The negative effect of anti-takeover defences on R&D expenditures is in line with the theoretical prediction of the 'quite life' approach in managerial economics and corporate finance which dates back to Hicks (1935). In this approach, anti-takeover defences (either through legislation or thorough firm-specific measures such as staggered boards, business combination procedures or poison pill provisions) hinder the market for corporate control and encourage managerial slack. As managers opt for 'quite life', they are less likely to commit to investment in costly innovative projects with uncertain outcomes (Jensen, 1988). A similar finding has been reported by Atanassov (2012), who demonstrates that state-level antitakeover laws in the US has led to decline in innovation by firms incorporated in states that pass antitakeover laws relative to firms incorporated in states that do not.

Table 2: Partial effects of corporate governance and market concentration on innovation

Panel A: Firm/year clusters, number of employees, and total-debt-to-equity

Dependent variable	*Ln(R&D Exp.)*	*Ln(R&D Exp. as ratio of Total Assets)*	*Ln(Brands and Patents as ratio of R&D Exp.)*
Board_Indep_1	0.271	0.140	-0.187
	(0.172)	*(0.130)*	*(0.439)*
Antitakeover_Def_1	-0.493***	-0.215**	0.166
	(0.114)	*(0.101)*	*(0.169)*
Insider_Control_1	-0.485**	-0.179	0.720**
	(0.226)	*(0.214)*	*(0.309)*
HHI_1	-4.348***	-3.113***	6.680***
	(0.693)	*(0.584)*	*1.256*
HHISQ_1	3.141***	2.136***	-4.881***
	(0.696)	*(0.603)*	*(1.297)*
Ln(Employees)_1	0.677***	-0.222***	0.102
	(0.029)	*(0.027)*	*(0.066)*
Total_Debt_to_Equity_1	-0.00000417***	-0.0000042***	0.0000122***
	(0.000)	*(0.000)*	*(0.000)*
Age_1	-0.002	-0.0027125***	0.00577**
	(0.002)	*(0.001)*	*(0.003)*
Constant	-5.530***	-8.173***	-2.526***
	(0.364)	*(0.264)*	*(0.821)*
R-Squared	0.429	0.227	0.121
Number of Observations	2365	2360	1311
Number of Firms	950	945	568

Panel B: Firm/year clusters, market value, and total-debt-to-capital

Dependent variable	*Ln(R&D Exp.)*	*Ln(R&D Exp. as ratio of Total Assets)*	*Ln(Brands and Patents as ratio of R&D Exp.)*
Board_Indep_1	0.278	0.147	-0.230
	(0.178)	*(0.128)*	*(0.444)*
Antitakeover_Def_1	-0.474***	-0.198**	0.162
	(0.113)	*(0.101)*	*(0.172)*
Insider_Control_1	-0.515**	-0.170	0.697**
	(0.236)	*(0.216)*	*(0.314)*
HHI_1	-4.442***	-3.214***	6.541***
	(0.691)	*(0.599)*	*1.256*
HHISQ_1	3.209***	2.201***	-4.763***
	(0.703)	*(0.620)*	*(1.300)*
Ln(Market_cap)_1	0.678***	-0.221***	0.101
	(0.032)	*(0.027)*	*(0.067)*
Total_Debt_to_Capital_1	0.000	0.0000135**	-0.0000351**
	(0.000)	*(0.000)*	*(0.000)*
Age_1	-0.001	-0.0025309**	0.00562**
	(0.002)	*(0.001)*	*(0.003)*
Constant	-5.706***	-7.928***	-2.726***
	(0.750)	*(0.262)*	*(0.742)*
R-Square	0.430	0.227	0.117
Number of Observations	2347	2342	1302
Number of Firms	945	940	567

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

4. Insider control (a majority of outstanding shares held by top management and/or directors) has a negative effect and the effect is statistically significant with respect to the level of R&D expenditures. Given that the insider control is a dummy variable, this finding indicates that insider control causes the *U-shape* curve in Figure 1 to shift downward by 0.485 - 0.515 logarithmic units in the case of R&D expenditures. However, in the case of net book-value of brands and patents, the effect of insider control is positive and ranges between 0.69 – 0.72. This indicates that insider control causes the *inverted-U* curve in Figure 1 to shift downward by 0.69 - 0.72 logarithmic units.

5. 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-tenth increase in the Herfindahl-Hirschman index of 0 - 1 is associated with 31.1 to 44.4 per cent decrease in R&D expenditures at low levels of concentration, but the relationship changes sign at high levels of concentration. Furthermore, the relationship between market concentration and output measure of innovation (net book-value of patents and brands) has an *inverted-U* shape. Net book-value of brands and patents tend to increase at low levels of concentration but declines after a certain threshold of concentration. Our findings are in contrast to the results obtained by Aghion et al (2005), who report an *inverted-U* relationship between the level of *competition* (i.e., lower concentration) and innovation – which is measured as citations-weighted patents count for UK firms. However, they are in line with Peroni and Gomes Ferreira (2012) who report a U-shaped relationship between competition and innovation in firm-level data in Luxemburg.

6. Of firm characteristics, size in terms of the number of employees and market capitalization has a significant and positive effect on R&D expenditures. A one-percent increase in number of employees or market capitalization is associated with an increase of about 0.67% in R&D expenditures. However, the effect is negative and equal to about 0.22% when R&D expenditures are scaled by total assets. Both measures of size are insignificant with respect to net book-values of brands and patents. Both company age and leverage tend to have a negative effect on input as well as output measures of innovation – with the exception of one positive relationship between total debt relative to capital and R&D expenditures as a ratio of total assets.

We have re-estimated model (3) by clustering the observations within industries and years. Table 3 below reports the results obtained with number of employees and total debt relative to equity.[3] Estimated coefficients remain the same – as expected. The only change concerns the cluster-robust standard errors. The positive (+) and negative (-) markers next to each standard error indicates whether the industry/year clustering has led to larger or smaller standard errors. It can be seen that clustering by industry and year has led to larger standard errors for 13 parameters and smaller standard errors for 5 parameters. The change in standard errors, however, has not led to any change in the statistical significance of the parameters. Therefore, we can conclude that the results derived from Table 2 remains robust to different levels of clustering.

Table 3: Results of estimation with industry and year clusters
(Using number of employees and total-debt-to-equity as control variables)

Dependent variable	*Ln(R&D Exp.)*	*Ln(R&D Exp. as ratio of Total Assets)*	*Ln(Brands and Patents as ratio of R&D Exp.)*
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)*
Constant	-5.530***	-8.173***	-2.526***
	(0.507)	*(0.348)*	*(0.913)*
R-Squared	0.429	0.227	0.121
Number of Obervations	2365	2360	1311
Number of Industires	215	215	177

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

Comparing the results in Tables 2 and 3, we can derive the following conclusions:

1. There is 100% sign consistency between the results based on firm-year and industry-year clusters.

[3] We have also estimated model 3 with market capitalization as a measure of size and total debt relative to capital as a measure of leverage. The results remain similar. We do not report these results here, but they are available upon request.

2. In majority of the cases, the cluster-robust standard errors associated with estimates from industry-year clusters (in Table 3) are larger than the cluster-robust standard errors obtained by clustering along the firm-year dimensions.

3. The findings in Tables 2 and 3 indicate that our estimates for the relationship between market concentration, corporate governance and innovation are robust to change in control variables and to different levels of clustering.

4. The results so far can be summarised as follows:

i. Board independence tend to be positively related to innovation inputs but it is insignificant with the exception of one estimation based on industry-year cluster;

ii. Firms with anti-takeover defences tend to spend less on R&D in level terms and relative to total assets at each level of market concentration. However, the relationship between anti-takeover defences and output measure of innovation (net book-value of patents and brands) is insignificant.

iii. Firms controlled by insiders tend to spend less on R&D in level terms at each level of concentration, but are able to generate more valuable brands and patents compared to firms owned by external shareholders.

iv. the relationship between market concentration and innovation has a *U-shape* in the case of R&D expenditures in levels or relative to total assets; and (v) the relationship between market concentration and innovation has an *inverted-U* shape in the case of innovation output measured as net book-value of patents and brands.

The results summarised above are estimates for *partial effects* of corporate governance indicators and market concentration. Such partial-effect estimation is the usual practice in the literature on the relationship between corporate governance, market structure and innovation. However, they may be biased upward or downward if there is interaction between corporate governance and market concentration. In addition, given that both market concentration and corporate governance rules shape the incentives faced by managers, it is necessary to estimate how both sets of factors interact in their effects on incentives for investment in R&D and on the ability of the firms to convert R&D investment into valuable patents and brands. In what follows, we address these issues by incorporating interaction terms and estimating model (4), which enable us to establish whether: (i) the partial effects of corporate governance and market concentration on innovation remains robust to inclusion of interaction terms; and (ii) corporate governance and market concentration are substitutes or complements in their effects on innovation.

Recall that the corporate governance indicators are all dummy variables. Hence the interaction terms are zero when the firm does not have the relevant corporate governance feature and they are equal to the Herfindhal-Hirschman index when the firm possesses the relevant corporate governance feature in a given year. As such, the interaction terms enable us to determine substitution/complementarity between corporate governance and market concentration and to establish whether the firms with a given corporate governance characteristic are located on the upward- or downward-sloping segments of the *U-shape* or *inverted-U* shape curves in Figure 1 above. As indicated above, corporate governance and market concentration will be *complements* if the sign of the parameter on the interaction term is the *same* as the sign of the multiplied partial-effect parameters on corporate governance indicators and market concentration. Otherwise, corporate governance and market concentration will be substitutes. The results of estimating model (4) are presented in Table 4 below.

Table 4: Partial and combined effects of corporate governance on innovation

Dependent variable	***Ln(R&D Exp.)***	***Ln(R&D Exp. as ratio of Total Assets)***	***Ln(Brands and Patents as ratio of R&D Exp.)***
Board_Indep_1	0.052	-0.046	0.197
	(0.225)	(0.175)	(0.453)
Antitakeover_Def_1	-0.957***	-0.615**	0.714**
	(0.254)	(0.239)	(0.348)
Insider_Control_1	-0.076	0.184	0.396
	(0.339)	(0.342)	(0.712)
*Board_Indep_1 * HHI_1*	1.140**	0.745	-2.122***
	(0.473)	(0.461)	(0.770)
*Antitakeover_Def_1 * HHI_1*	1.005**	0.884**	-1.508**
	(0.457)	(0.405)	(0.732)
*Insider_Control_1 * HHI_1*	-0.940	-0.838	0.459
	(0.699)	(0.544)	(1.261)
HHI_1	-5.219***	-3.434***	7.922***
	(1.516)	(1.271)	(2.370)
HHISQ_1	2.706*	1.689	-3.894**
	(1.379)	(1.078)	(1.911)
Ln(Employees)_1	0.716***	-0.212***	0.128*
	(0.031)	(0.034)	(0.067)
Total_Debt_to_Equity_1	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Age_1	-0.003	-0.003	0.007**
	(0.002)	(0.002)	(0.003)
Constant	6.086***	-7.583***	-4.355***
	(0.357)	(0.224)	(0.855)
R-Square	43%	20.8%	12.4%
Number of Obervations	2365	2360	1311
Number of Industires	215	215	177

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

The results in Table 4 indicate that only the *partial effect* of anti-takeover defences on R&D expenditures and net book-value of patents and brands remains significant. Neither board independence nor insider control are significant on their own. In the extended model (model 4), the sign and significance of anti-takeover defences remains the same as the base model (model 3). However, the magnitudes of the parameters for anti-takeover defences in model (4) are larger than the parameters estimated for model (3), which does not include interaction terms. This finding indicates that partial-effect parameters estimated without including interaction terms in model (3) may be underestimating the effects of anti-takeover defences on innovation.

The second conclusion that can be derived from Table 4 is that the sign of the market concentration variable remains consistent with model (3), but the magnitude is larger in model (4). This result also indicates that failure to take account of interaction between corporate governance and market concentration may be leading to downward bias in the estimates of the partial effect from market concentration to innovation.

The third finding in Table 4 is that the sign of the coefficients on the *interaction term* is positive in the case of R&D expenditures (in levels and relative to total assets), but negative in the case of net book-value of patents and brands. The positive sign in the former is consistent with the multiplication of the partial-effect parameters on corporate governance and concentration, which are both negative. This sign inconsistency indicates that the innovation effects of corporate governance are reversed when the latter is interacted with market concentration. According to the results in Table 4, firms with an independent board would invest more in R&D expenditures as market concentration increases. This is in contrast to the partial-effect parameters in Tables 2 and 3, which were statistically insignificant. Similarly, firms with anti-takeover defences would spend more on R&D as market concentration increases. This is in contrast to the partial-effect parameters for anti-takeover defences in Tables 2 and 3, which was consistently negative and significant. A similar sign consistency is observed with respect to partial and combined effects of anti-takeover defences on net book-value of patents and brands: firms with anti-takeover defences are less able to generate patent and brand value per unit of R&D expenditures as concentration increases. This sign consistency indicates that anti-takeover defences and market concentration are *complements* in their effects on innovation. A similar but partial conclusion can be derived with respect to board independence. Overall, we can sate that interaction between market concentration and corporate governance leads firms to be located at the upward-sloping segment of the U-shape curve between market concentration and R&D expenditures; and at the downward-sloping segment of the inverted-U shape curve between market concentration and net book-value of patents and brands as outcome measures of innovation.

Finally, we can also observe that the magnitudes of the market concentration (HHI) parameters in Table 4 are larger than the magnitudes of the market concentration parameters in Tables 2 and 3. This is the case for the three variants of the dependent variable – i.e, for R&D expenditures in level, R&D expenditures relative to total assets, and the net book-value of patents and brands relative to R&D expenditures. The larger magnitude of the market concentration parameter in Table 4 indicates that the *U-shape* and *inverted-U* shape relationship between market concentration and innovation becomes steeper when we estimate the partial and combined effects at the same time. This finding reinforces the finding reported in conclusion two above: exclusion of interaction terms may lead to downward bias in the estimates of the partial effects from both corporate governance and market concentration.

5. 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 on corporate governance, market concentration and innovation.

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 partial effect of board independence on R&D expenditures is positive but insignificant. Its effect on net book-value of patents and brands is negative but insignificant. Hence, it is not possible to establish any relationship between board independence and innovation.
2. The partial effect of anti-takeover defences on R&D expenditures is negative and significant in the majority of the results. The effect on net book-value of patents and brands, however, is positive and significant. Hence, we can conclude that anti-takeover defences tend to be associated with lower innovation effort – as measured by R&D expenditures. However, firms with anti-takeover defences are better able to generate valuable patents and brands per unit of R&D expenditures.
3. The effect of insider control on R&D expenditures is negative and significant with respect to R&D expenditures only. The effect on net book-value of brands and patents is the opposite:

firms under insider control tend to generate more valuable patents and brands compared to firms owned external shareholders.

4. The relationship between market concentration and innovation is consistent across all model specifications and method of clustering. The relationship is of a *U-shape* in the case of R&D expenditures in levels or relative to total assets; but it has an *inverted-U* shape in the case of net book-value of patents and brands. Hence we can derive two conclusions with respect to innovation at two end of the market concentration spectrum: (i) firms in *less concentrated* markets tend to *spend more* on R&D as concentration increases, but they are *less able* to convert R&D expenditures into patents and brands with market value; (ii) firms in *more concentrated* markets tend to *spend less* on R&D as concentration increases, but they are *better able* to convert R&D expenditures into patents and brands with market value.
5. We also derive two conclusions with respect to interaction between corporate governance and market concentration. First, inclusion of interaction terms in models to be estimated is likely to correct the downward bias in the partial-effect estimates for both corporate governance indicators and market concentration index. Secondly, there is evidence to suggest that corporate governance and market concentration are *complements* in their effects on input as well as output measures of innovation.

The implications of these findings for the debate on market concentration, corporate governance and innovation can be stated as follows:

(a) At low levels of market concentration (i.e., when firms are less likely to extract rents), further concentration reduces the R&D effort. However, when concentration is high (i.e., when firms are more likely to extract rents), further concentration tend to increase the R&D effort. The relationship between market concentration and innovation outcomes is the opposite: at low levels of concentration firms are better able to convert R&D expenditures into valuable patents and brands as concentration increases; but they are less able to do so when the initial level of concentration is already high. These trends suggest that firms in highly concentrated markets are more likely to utilise excess profits for financing R&D investment and as such they are more likely to engage in risky innovation projects which may not always lead to successful outcomes. However, firms in less concentrated markets are less able to rely on excess profits as a source of finance for innovation. Hence, such firms are under stricter constraints and therefore they are more likely to invest in R&D projects that are more likely to generate valuable patents and brands.

(b) There is partial evidence that firms with independent boards are more likely to invest in R&D at each level of market concentration and their levels of R&D expenditures continue to increase as market concentration increases. There is stronger evidence to suggest that firms with anti-take-over defences (i.e., firms with staggered boards and business combination provisions) also spend more on R&D as concentration increases. These results are in contrast to the partial effects of anti-takeover defences and market concentration on R&D expenditures. Hence we can conclude that firms with independent boards and anti-takeover defences tend to be located at the upward-sloping segment of the *U-shape* relationship between concentration and R&D expenditures. However, these firms tend to be located at the downward-sloping segment of the *inverted-U* relationship between concentration and net book-value of patents and brands.

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