# Innovation, Corporate Governance and Firm Age: Evidence from the ISS risk metrics database

Stefano Bianchini[a,b], Jackie Krafft[c], Francesco Quatraro[c,d]

a) Sant'Anna School of Advanced Studies

b) BETA, Université de Strasbourg

c) GREDEG, CNRS et Université de Nice Sophia Antipolis

d) BRICK, Collegio Carlo Alberto

ABSTRACT. This paper investigates the relationship between corporate governance, age and innovation. By combining insights from the corporate governance (CG) lifecycle literature with the recent strand of contributions analyzing CG and innovation, we propose that the predicted negative relationship is stronger for young than for mature firms. The empirical analysis is carried out on a sample of firms drawn from the ISS risk metrics database, and observed over the period 2003-2005. The parametric methodology provides results that are consistent with the literature, and supports the idea that mature firms are better off than the young ones. The nonparametric analysis allows us to check for possible nonlinearities, suggesting that the negative relationship between CG and innovation is mostly driven by higher values of CG.

JEL Classification Codes : G30, L20, L10, O33

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# 1 Introduction

The issue of corporate governance (CG) has received increasing attention for the last decades. As practitioners already acknowledged the importance of CG in the early 1990s, soon policymakers started to diffuse the rules for a 'good CG' . For example, the OECD (2004) *Principles of Corporate Governance* acknowledge that an effective corporate governance system can lower the cost of capital and encourage firms to use resources more efficiently, thereby promoting growth.

From a theoretical viewpoint, the seeds of this strand literature date back to Jensen and Meckling (1976) who showed that better governed firms may have more efficient operations, resulting in higher expected future cash-flow streams. Principal-agent theory is the starting point of most discussions of CG (Shleifer and Vishny, 1997). Agency problems can affect firm value and performance via expected cash flows for investors, and the cost of capital. Good CG means that 'more of the firm's profit would come back to (the investors) as interest or dividends as opposed to being expropriated by the entrepreneur who controls the firm' (La Porta et al. 2002, p. 1147). Risk and expected return are negatively related and thus investors perceive well-governed firms as less risky and better monitored and tend to apply lower expected rates of return, which leads to a higher firm valuation.

In this direction, the bulk of theoretical and empirical studies have focused on the impact of CG on firms' performances, and in particular on firms' value (La Porta et al., 2002; Gompers et al., 2003; Drobetz et al. 2004; Lombardo and Pagano, 2000; Errunza and Miller, 2000). Somewhat less attention has been devoted to the impact of CG practices on firms' innovative performances. Actually, innovation like CG has been found to positively affect firms' growth, both in terms of productivity and of market value (Griliches, 1994). It seems interesting in this respect to wonder whether good governance and high innovation performances are positively related, or rather if they are at odds. The literature on the issue is not conclusive, although some empirical evidence suggests for a negative relationship between the two dimensions.

This paper contributes this stream of analysis by investigating the impact of CG on innovation and stressing the importance of firms' age in moderating such relationship. In so doing, we gather together the theoretical considerations grounded on agency theory, which provide expectations on the effects of good governance practices on innovation efforts, and the literature about corporate governance and firm's lifecycle. The contribution to the extant literature is manifold. First, there are neither empirical nor theoretical analyses focused on the interplay between CG, age and innovation. This is all the more surprising, given on the one hand the importance of firms' lifecycle in the strategic decisions concerning the commitment of resources to innovative projects (Abernathy and Utterback, 1978); and on the other hand the recent interest in the impact of firms' age on their performances (Haltiwanger et al., 2013). Second, we implement both parametric and non-parametric methodologies to estimate such relationships. Non-parametric estimations allow for the detection of nonlinearities, which often are not detected in parametric settings even when explicitly included in the model to be estimated. Third, we compare results obtained by using both input and output measures of innovation, i.e. R&D expenditures and patent applications. Finally, we use a pretty original dataset of listed firms drawn from the ISS Risk Metrics database and merged with the Bureau van Dijk ORBIS database.

The results of the analyses suggest that actually CG is likely to be negatively related to innovation performances. Such negative relationship is even stronger for younger firms, which may be hindered by narrower resource bases, insufficient knowledge and underdeveloped capacity to successfully manage innovation projects. Non-parametric analyses also suggest that strong nonlinearities are at stake. In particular, the average negative relationship observed through parametric estimations seems to be driven mostly by innovation performances of firms with extremely high CG scores.

The rest of the paper is organized as it follows. Section 2 discusses the theoretical underpinnings of the investigation. Section 3 presents the data and the variables, while Section 4 describes in detail the employed methodologies. In Section 5 we show and discuss the empirical results, while some conclusions are provided in Section 6.

## 2 Corporate governance, age and innovation: the importance of the lifecycle

In the theoretical literature on corporate governance there is a major shift from a "normative" view of the separation ownership-control and its supposedly bad consequences on the system as a whole, to a more "predictive" approach trying to elaborate on the causal relations between agency problems, governance practices, and corporate performance. At the origins, the issue of corporate governance is first related to firms' internal efficiency (Berle and Means, 1932; Chandler, 1977). In the 1980s, most of the early contributions in agency theory (Jensen and Meckling, 1976; Fama, 1980; Fama and Jensen, 1983) consider that managers' private information create managerial discretion and self-serving leading to agency problems and costs. These difficulties, they argue, can be reduced by the definition of an optimal contract between managers and shareholders, able to restore efficiency in decision making by facilitating the monitoring from shareholders, securing their right to a better reward and the full benefit of their investment, and thus improving corporate performance.

The mid 1990s bring new theoretical explanations into the scene, and soon results into an explosion of empirical work (Schleifer and Vishny, 1997). New developments tend to exhibit a direct relation between agency problems, corporate performance, and the implementation of good governance practices. Agency models demonstrate that corporate governance affects firm value and performance through two basic channels: the expected cash flow for investors, and the cost of capital.

Despite the increasing body of empirical literature analyzing the effects of CG and firm performance, the link between CG and innovation has only recently begun to attract the interest of scholars in the field. The mechanism through which CG likely affects innovation performances is indeed at least twofold. On the one hand, because good governance involves better monitoring, greater transparency and public disclosure, increase in investor trust, decrease in manager discretion and rent expropriation, less risk, more efficient operations, etc…, it should be beneficial to all investments, especially innovative ones. On the other hand, because good governance puts a large emphasis on the interests of the shareholders as a primary goal, it should be detrimental to innovative investments as a) shareholders and investors are mostly interested by dividends and returns on investments, not about R&D strategy, b) it introduces a short-term perspective while innovation is long-term.

Driver and Guedes (2012) contribute the debate by testing the possibility of a perverse effect of "good governance" on uncertain, long term investments. The data comes from the Manifest global proxy governance and voting service database, a UK Investor data. They consider 91 UK manufacturing and service (excluding financial) firms, with the highest averaged R&D expenditure in the period 2000–2005. They end up with the following results. The governance variable in levels is significantly negative in all specifications (FE and GMM), suggesting that there is a long-run negative effect of governance on R&D which is consistent with the views arguing that the adoption of the best practice may have contradictory or perverse effects when innovation is taken into account.

Lhuillery (2011) uses the Vigéo Data regrouping 5528 firms belonging to 110 large French listed business groups. He notes that there is no significant influence of good governance on R&D decisions (GMM and FE), resulting into possible doubts regarding the "Anglo-Americanization" of (some) European firms.

Finally, there is also a focus on the impact of antitakeover provisions on firm innovation. Here, the issue is to know whether the managerial myopia hypothesis (Stein, 1988) or the quite life hypothesis (Bertrand and Mullainathan, 2003) prevail. According to the first hypothesis, the threat of hostile acquisition can lead managers to avoid undertaking long-term, risky investments because such projects can lead to a wide divergence between market and intrinsic values. Takeover provisions may shield managers from concerns related to short-term performance and permit more long-term, value-maximizing investment strategy that encourages greater innovation. Alternatively, according to the second assumption, if the presence of takeover protection reduces the effectiveness of the external disciplinary market then the manager may exploit the opportunity to avoid difficult and risky investments, especially if these could reveal managers to be lower quality.

Becker-Blease (2011) uses the IRRC, and merges the data with Financial accounting standards and NBER patent database. The study covers the period 1984-1997, and the sample is composed of 600 US firms. The results show that higher levels of 23 takeover provisions are associated with innovation efforts (R&D expenditures, awarded patents, quality of patents, number of patents awarded per $ of R&D), suggesting that innovation is positively correlated with antitakeover provisions. Indeed, some provisions appear more important than others in this positive correlation, and firm-level provisions are significant in this positive correlation, while state-level provisions are not significant.

O'Connor and Rafferty (2012) also use IRRC together with Compustat, and construct a sample of 1719 firms (1990-2005). With static models (OLS), they obtain a negative, but non robust relationship between corporate governance index and R&D activity, but not robust. With dynamic models (GMM), there is no relation anymore, or only a slightly positive.

Krafft, Qu, and Ravix (2008) use Risk Metrics / International Shareholder Services, with 2500 firms from 25 Industries in 24 Countries (non US), over the period Oct 2003 to Dec. 2008. They show that good governance principles have a stronger impact on stock market performance in innovative industries compared to more traditional ones. Also, variations of CGQ are much more important in innovative industries than in more traditional ones, suggesting that the adoption of the best practice is amplifying the ups and downs of industrial development, especially of innovative industries.

>>> INSERT TABLE 1 ABOUT HERE <<<

Table 1 provides a synthesis of the main conclusions achieved in the literature for what concerns the link between corporate governance and innovation. What comes out of the empirical work is that corporate governance is not neutral to innovation, suggesting that short-term oriented models of corporate governance like the shareholder value model is probably interacting with the long-term perspective of innovation leading to potential mismatch.

Time matters in the relationship between corporate governance and innovation, also as far as firms' age is concerned. Recent contributions indeed stress the importance of corporate lifecycle in the implementation of good governance dynamics. Actually, the weight of the different dimensions affecting corporate governance is likely to change across the stages of the evolution of the firm. O'Connor and Byrne (2006) suggest that individual governance provisions, like independence, accountability and transparency can have differential importance at different moments. On average, they show that governance quality increases when firms are mature, and greater resources are devoted to value preservation than to value creation. This would imply that mature firms would be less prone to invest in innovative projects. A completely different conclusion is reached by Saravia (2013), according to whom mature firms are likely to be characterized by increasing cash flows and decreasing investment opportunities. This would stimulate overinvestments also in risky projects with uncertain paybacks (like innovation projects).

Filatochev et al. (2006) provides an interesting framework to understand the link between firms' strategic decision and corporate governance lifecycle, which gathers together agency issues with a resource based view of the firm. In such context mature listed firms are characterized by extensive resource base, i.e. tacit knowledge that has been accumulated over time as well as production facilities, trade secrets, engineering experience and human capital assets. In this direction, mature listed firms seem to possess the all the resources that are needed to manage successful innovative projects. On the contrary, young listed firms, are characterized by narrow resource base, and are mostly depended on external knowledge sources. However, the ability to manage external knowledge inputs is linked to the development of internal capabilities, i.e. absorptive capacity (Cohen and Levinthal, 1990). This once more suggests that mature listed firms are likely to be featured by higher likelihood to manage successful innovative projects than young firms.

In sum, the literature is not conclusive, at least from a theoretical viewpoint, as far as the relationship between corporate governance is concerned. However, recent empirical estimations seem to suggest that good corporate governance is associated to lower levels of innovation, due to the shareholders value maximization target, which leads manager to prefer value preservation instead that value creation. In such a context, young listed firms are worse off than mature firms, as these latter can draw upon a mix of internal resources and competences accumulated over, which make the management of innovative projects more effective.

# 3 Data, variables, and descriptive analysis

In this Section we present our sample along with the main variables. We then provide some basic statistics to a deeper comprehension of the data we have at hand.

## 3.1 The Dataset

The Investor Responsibility Research Center (IRRC) publishes detailed listings of corporate governance provisions for individual firms in corporate takeover defences. Data are derived from a variety of public sources (corporate bylaws and charters, proxy statements, annual reports, 10K, and 10Q documents). All sample firms are drawn from Standard & Poor's 500 and the annual lists of Fortune, Forbes, and Business Week. The IRRC reports (published in 1990, 1993, 1995, 1998) include several hundred firms.

In this paper we use the CGQ index (Corporate Governance Quotient) from *RiskMetrics / Institutional Shareholder Services*[1]. We focus on overall (aggregate) corporate governance ratings for a large range of international firms. Our sample is constructed using information on 2205 firms in 24 countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong (China), Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, South Korea, Spain, Sweden, Switzerland, UK) and 21 industries. The CGQ is calculated on the basis of a rating system that incorporates 8 categories of corporate governance, leading to an improved qualitative measure of 55 governance factors. The study period covered is 2003-2008, which includes the largest number of reporting firms with complete and consistent data.

[1] It is generally acknowledged that studies using IRRC data can only examine the effects of external mechanisms of corporate governance because the G-index is more similar to a takeover defence index than a measure of overall corporate governance. Also, since the IRRC reports are based on the largest US firms, there may be variations in the list of firms included from volume to volume, leading to a potential sample bias problem. Reports are not published annually, but studies assume that the governance provisions reported in a given IRRC volume were in place during the period immediately following the publication of the volume until publication of the subsequent volume. This means that some important changes in corporate governance may not be reported adequately. Finally, the way that corporate governance develops outside the US is beyond the scope of IRRC data.

## 3.2 Variables and descriptive statistics

### 3.2.1 Corporate Governance Quotient

Prior to being acquired by *RiskMetrics* in 2007, *Institutional Shareholder Services* operated independently as the world's largest corporate governance data provider. *Institutional Shareholder Services* developed its corporate governance rating system to assist institutional investors to evaluate the impact that a firm's corporate governance structure and practices might have on performance. The rating is aimed at providing objective and complete information on firm's governance practices. Importantly, these ratings are not tied to any other service provided by *RiskMetrics / Institutional Shareholder Services* and firms do not pay to be rated, although they are invited to check the accuracy of the ratings. The only way a firm can improve its rating is to publicly disclose changes to its governance structure and / or practices.

The CGQ is the output of a corporate governance scoring system that evaluates the strengths, deficiencies, and overall quality of a company's corporate governance practices. It is updated daily for over 7,500 companies worldwide. The ratings are based on a single set of policy standards inspired by OECD principles.

Each company's CGQ rating is generated from detailed analysis of its public disclosure documents (i.e. Proxy Statement, 10K, 8K, Guidelines…), press releases and company web site. CGQ is calculated by adding 1 point if the firm under scrutiny meets the minimum accepted governance standard. The score for each topic reflects a set of key governance variables. Most variables are evaluated on a standalone basis. Some variables are analysed in combination on the premise that corporate governance is improved by the presence of selected combinations of favourable governance provisions. For example, a company whose board includes a majority of independent directors, and independent board committees (audit, etc.) receives higher ratings for these attributes in combination than it would have received for each separately. Next, each company's CGQ is compared with other companies in the same index (here the index is MSCI EAFE index).[2] For example, Company

[2] This is a stock market index of foreign stocks, from the perspective of North American investors. The index is market capitalization weighted (meaning that the weight of securities is determined based on their respective market capitalizations.) The index aims to cover 85% of the market capitalization of the equity

A scores 24% (or 0.24) for its CGQ index, this means that Company A is performing better (outperforming) in relation to corporate governance practices and policies than 24% of the companies in the MSCI EAFE index.

Table 2 presents the corporate governance variables. A detailed description of governance standards using the eight categories (board of directors, audit committee, charter/bylaws, antitakeover provisions, compensation, progressive practices, ownership, and director education) is provided in Krafft et al. (2014).

>>> INSERT TABLE 2 ABOUT HERE <<<

Our sample is composed of 2,205 non-US firms operating in 24 countries and 21 industries. Table 3 reports information on the composition of our sample according to NACE classification. Almost half of the sample is composed of firm operating in manufacturing, followed by financial and insurance activities. Despite few exceptions, we have data on firms that are active in almost all sectors. As in the original database, CGQ refers to 55 governance factors spanning the 8 categories of corporate governance. Thus the data are firm-level; all our scores are relative (percentiles), allowing for within-country as well as cross-country differences (the data explicitly consider anti takeover provisions under national (local) law).

INSERT TABLE 3 ABOUT HERE

### 3.2.2 Innovation and other firm-level variables

Our main focus is to study the effect of corporate governance on innovation performance, and moderating effect that age might play on such relationship.

In performing this task we merge the *RiskMetrics / Institutional Shareholder Services* with micro-level accounting data coming from the Bureau van Dijk ORBIS dataset, which also provides information on firms’ patent applications.

Innovation performance are measured with two traditional (and widely used) input and output indicators, namely R&D-to-sales intensity (i.e. total R&D expenditure over total turnover) and number of patent applications. Despite sharing the obvious idea that corporate

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markets of all countries that are a part of the index. It is maintained by Morgan Stanley Capital International. EAFE is Europe, Australia, Asia and Far East.

governance perhaps affects many other dimensions of the firm's innovation behaviour, we wish to partially control for the multidimensionality of the innovation process.

Beside demographic characteristics such as age and size (proxied by total turnover), we introduce in our analysis some control variables to capture firm operating performance and financial constraints, which are both likely to affect firm's innovative initiatives. The former is measured by using Return on Assets index (ROA) whereas the latter by the cash flow.

Table 4 contains a summary of all the variables along with some basic descriptive statistics. To have a deeper picture, in Figures 1 we also plot the kernel densities of the main variables under investigation, meaning corporate governance, R&D-to-sales intensity, patent applications, and age[3].

INSERT TABLE 4 ABOUT HERE

INSERT FIGURE 1 ABOUT HERE

CGQ ranges from 0 to 1, with mean and median respectively equal to 0.47 and 0.45. By looking at the kernel density (Figure 1) it is possible to notice the wide support of the distribution, consistent with the huge heterogeneity underlying corporate governance practices. This evidence motivates us to explicitly account for idiosyncratic firm fixed-effects when setting our econometric strategy. Beside the CGQ in level, we account also for changes in governance practice by calculating the growth rates of CGQ. Its high standard deviation suggests that corporate governance index is indeed a quite volatile variable.

Firms in our sample are also quite heterogeneous in terms of age. The latter ranges in fact from 0 (newborn companies) to 536 years old (old established enterprises), with mean and median 54.38 and 44. To compress the scale we will apply a log-transformation. Basic statistics suggest that, although we have information on new nascent firms, our sample is primarily composed of incumbent established units. This evidence will drive us, when selecting a cut-off point to distinguish young/mid-age vs. mature firms, to look for an age threshold which is a reasonably good compromise between sample size and coherence.

Turning to innovation variables, R&D-to-sales intensity is on average equal to 6%. Although the statistic is on pooled data, this value is roughly constant along the time span we

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[3] Kernel densities are computed by pooling all the observations. We estimate the density by using an adaptive kernel as in Silverman (1986).

cover. As expected, a considerable proportion of our sample (almost 10%) do not perform R&D activities (or at least they do not report any information), whilst only few firms invest more than their actual turnover (see Figure xxx). We account also for variation in R&D intensity by computing the log-difference for each subsequent year.

On the output side, patent applications per year has a mean value of 4.46 and a median equal to 7. This difference is certainly due to the positive skewness characterising the statistical distribution of such variable (see Figure xxx). Not only the mass of the density is concentrated on the left tail but, to notice, almost two-third of the total number of observations has value equal to zero (no patent applications). In studying our corporate governance shapes firm’s innovative outcome, we will explicitly take into account this phenomenon by adopting econometric tools designed for the presence of many zeros.

For what concerns the control variables, we proxy the size of the firm by using total turnover (or alternatively the total number of employees). Mean value for ROA index is 0.06 (0.11 for the median), with the extreme values (-0.97 for its minimum and 0.94 for its maximum) indicating the coexistence of many good and bad performers. As cash flow (here measured in millions) is essential to solvency, its range of values depicts a robust stylised fact, meaning the existence of many financially constrained companies.

To appreciate a first screenshot of the contemporaneous relationship between the entire set of our variables, Table 5 reports the pair-wise correlation matrix (significance at 5% level are indicated by asterisks). Interestingly there is a negative association between corporate governance index GGQ and age, so as with the size of the firm. Beyond some obvious relationships (see for instance age and size), it may be noticed that CGQ and patent applications are negatively and significantly correlated. R&D-to-sales intensity and CGQ appear, on the contrary, characterised by a positive association. However, when we look at the correlation between age and innovation variables (R&D intensity and patent applications), we detect negative relations. All in all we can conclude that the relationships at work seem to be very complex.

INSERT TABLE 5 ABOUT HERE

# 4 Methodology

Two types of statistical analysis are performed in our study. First, both R&D-to-sales intensity and patent applications are used as response variable in a standard parametric setting. Secondly, in order to explore potential nonlinearities in the relationships between corporate governance and innovation, we exploit nonparametric regression technique.

### 4.1.1 Parametric setting

We set different specifications. We first model (Fixed Effects - within transformation) the variation in R&D-to-sales intensity as a function of corporate governance, age, and a set of key controls. The baseline model is the following:

$$\Delta\, ln(RDI)_{i,t} = \alpha + \beta_1 RDI_{i,t-1} + \beta_2 CGQ_{i,t-1} + \beta_3 ln(\Delta CGQ)_{i,t} + \beta_4\, ln(Age)_{i,t} + \qquad (1)$$

$$\beta_5 CGQ_{i,t-1} \times \left(Age_{i,t} < 20\right) + \boldsymbol{\beta} \times \boldsymbol{X}_{i,t-1} + u_i + \varepsilon_{i,t}$$

for each firm *i* at time *t*. $\boldsymbol{X}$ is a vector of control variables such as size, cash flow, etc.. All the non-time varying determinants (e.g. technological opportunities) which are likely to influence R&D activities are subsumed in the fixed-effect term $u_i$. The lagged variables partially reduces the potential endogeneity between the set of covariates and the innovation proxy, but yet we refrain to give any causal interpretation.

We start by regressing CGQ index on the variation in R&D-to-sales intensity. Step-by-step we augment the model with several explanatory variables to verify whether our estimations are robust across different configurations. Although the time window we span is quite short, we include time dummies to account for potential macro-economic changes.

We build a dummy variable that explicitly controls for young/middle-aged firms. The cut-off point that we impose corresponds to 20 years old [4]. Afterward, this dummy is interacted with the index of corporate governance so to account for the effect of the latter on

4 We have tried different thresholds, say 15 and 25 years old, to check whether our results remained robust. In both cases the estimations are consistent with the picture with present in the article. However, when 15 is imposed the sample size sharply decreases, leading to potential inaccuracy.

different layers of age (young/middle-age vs. mature firms) [5]. By mean of this new variable we can capture the ‘moderating effect’ of age.

Subsequently, we model the innovative effort in level by implementing the Arellano and Bond (1991) two-step robust GMM estimators. The implementation of the dynamic model is derived from equation (1), by considering that $\Delta\, ln(RDI)_{i,t} = ln(RDI)_{i,t} - ln(RDI)_{i,t-1}$.

This leads us to the following specification:

$$ln(RDI)_{i,t} = \alpha + \gamma_1 RDI_{i,t-1} + \beta_2 CGQ_{i,t-1} + \beta_3 ln(\Delta CGQ)_{i,t} + \beta_4\, ln(Age)_{i,t} + \beta_5 CGQ_{i,t-1} \times \left(Age_{i,t} < 20\right) + \boldsymbol{\beta} \times \boldsymbol{X}_{i,t-1} + u_i + \varepsilon_{i,t} \qquad (2)$$

Where $\gamma_1 = \beta_1 + 1$.

Turning to the innovation outcome, as highlighted in Section 4.2.2 patent applications variable presents a very skewed distribution with the presence of many zeros. Moreover the conditional variance exceeds to large extent the conditional mean. Thus, to analyze the effect of corporate governance on patent applications it seems appropriate to abandon OLS setting and to adopt a zero-inflated negative binomial model (henceforth, ZINB), explicitly designed for the nature of our response variable. Indeed zero-inflated models estimates two equations simultaneously, one to describe the relationship between the response variable and the set of covariates and one to model the excess of zeros. We substantially re-estimate model in eq.(1), substituting patent application as response variable. The computation burden (i.e. convergence is not achieved) of the ZINB model does not allow us to introduce firm-level fixed effects; to this end we re-estimate a negative binomial (with no zero-inflation) accounting for the unobserved heterogeneity. Results are consistent with the ones we present along the article and are available on request. As for the zero-inflation, we use R&D intensity as inflator (we expect firms will lower R&D investment to exhibit lower propensity to patent).

5 Alternatively we have interacted the index of corporate governance with age but the coefficient for this new variable never turned out to be significant, regardless the proxy of innovation. More on this in Section Main results

### 4.1.2 Nonparametric modelling

We turn to Generalized Additive Model (henceforth, GAM) to incorporate clear nonlinear forms of the covariates and to achieve the best prediction of the response variables. In particular we wish to explore more in depth the relation between corporate governance and innovation.

A more intuitive generalization of the multiple regression model is to maintain the additive nature of our model, but to replace at least some (possibly all) terms of the linear equation $\beta_i x_i$ with $f_i(x_i)$ where $f_i$ is a nonparametric function of the covariate $x_i$. The family distribution of the response variable $y$ (e.g. R&D-to-sales intensity or alternatively patent applications) is specified along with a link function $g$ that relates the predicted values of $y$ to the set of covariates $\boldsymbol{X}$. Formally:

$$g\big(E(y)\big) = \beta_0 + f_1(x_1) + f_2(x_2) + \cdots + f_k(x_k)$$

Instead of single coefficients, GAM provides a nonparametric function for each predictor. The shape of the function describes how the relationship between the covariate $x_i$ and the response variable $y$ varies along the whole spectrum of $x_i$. There exist different alternatives to choose the smoothing function *f(x)*. We follow the approach proposed by Wood (2006) by implementing a cubic spline, essentially a connection of multiple cubic polynomial regression, that is:

$$f(x) = \sum_{j=1}^{4} b_j(x)\beta_j$$

where for basis we have: $b_1(x) = 1,\ b_2(x) = x,\ b_3(x) = x^2,\ b_4(x) = x^3$

As for the link function, in modeling patent applications we set negative binomial family distribution [6]. Briefly, GAM proceeds as follows: (i) points of an explanatory variable, also known as knots, are used to generate sections (knots are placed evenly throughout the covariate values to which the term refers); (ii) separate cubic polynomials are fit at each section according to equation xxx; (iii) polynomials are joined at the knots to build a continuous curve. The estimation is conducted via penalized likelihood approach and is then

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6 To note that our results are not sensible to the choice of the link function. The outcome of the GAM modeling remains indeed almost unchanged.

separated into parametric and smooth, or nonparametric parts. In our setting the only parametric component is the intercept.

# 5 Econometric results and discussion

## 5.1 Main findings

Results of the estimation (R&D-to-sales intensity as response variable) are shown in Table 6 and Table 7. In what follows we comment our findings by referring to both tables.

INSERT TABLE 6 ABOUT HERE

INSERT TABLE 7 ABOUT HERE

Let us focus first on the effect of corporate governance. The overall picture we derive is that good governance variable exerts on average a negative and significant effect on R&D spending. In Table xxx (FE estimation), both level and growth rate measures, are slightly significant when time dummies are omitted from the specification [7]. In Table xxx (GMM estimation) the coefficient for the variation in governance practices is no longer significant. Interestingly when we add the interaction term between CGQ and young/middle-aged dummy, the estimated coefficient for the governance variable in level switches to insignificant, whereas the coefficient for the interaction is negative and significant, also when we control for time dummies. Our results support (see Section xxx) theoretical arguments according to which good governance inhibits innovation. As large emphasis is put on the interests of the shareholders, long-run innovation opportunities appear to be hindered. However, in addition to the current state of the art, we do also find a 'moderating effect' of age, such that corporate governance influences R&D decision mainly young/middle-aged firms.

On the other side, the effect of age is always not significant. In light of this we conclude that both young and more mature firms display the same propensity in allocating their money in risky activities.

Some broad comments on the sign and significance of the control variables are in order. First, size of the firm plays a negative effect on R&D spending. This evidence

[7] The vanishing effect of corporate governance on innovation once controlling for time dummies mimics results in Drivers and Guedes (2012). Their interpretation is that the fall of significance probably reflects co-movement of corporate governance across firms due to the compliance pressure exerted by investors over the period considered.

contradicts the primordial conjecture advanced by Schumpeter (1943) according to which large firms should have at their disposal greater economies of scale and scope, together with an easier access to capital. Our result is more in accordance with the literature pointing to a negative relation. The central argument resides in the potential loss of managerial control in research allocation, typical of large companies (Cohen, 1995). As argued in Acs and Audretsch (1987), size may be also interpreted as a proxy for market concentration and product market competition, thus leading to different effects depending on the sector in which firms operate. We cannot exclude a-priori such hypothesis on our data but its testing goes largely beyond the purpose of the paper.

Operating performance (ROA) and financial constraints (cash flow) have not significant effect on R&D investments. Literature relating cash flow and R&D provides indeed mixed results. Among the many, Hall et al. (1990) and Mairesse et al. (1999) point to a positive link. By the same token Bond et al. (2003) find that cash flow and operating performance appear to be much more significant in UK than in Belgium, France, and Germany, where the effect is almost nil. Brown et al. (2009), focusing on high-tech companies, find that financial constraints are particularly pronounced for younger firms, whereas no effect is detected on large companies.

Results of the estimation (patent applications as response variable) are reported in Table 8. The relationships we identify in this second part of the analysis appear more strong and stable along different specifications and therefore have to be regarded as more reliable.

INSERT TABLE 8 ABOUT HERE

First and foremost, the negative and strongly significant ($p$-value$<0.001$) effect of corporate governance is clearly evident everywhere. This evidence holds both for the corporate variable in level and in growth rate. Despite being aware that patent applications only captures some aspects of firm innovation, our results suggest that good governance severely inhibits the innovative outcome of a firm.

Age plays a positive and significant effect on patenting, although as long as we do not introduce the interaction term. This result is consistent with ??? reference ???

Once again, however, the more interesting finding emerges when we interact the governance measure with the dummy for young/middle-aged firms. The estimated coefficient for such interaction is very large in terms of magnitude (almost half of the one for CGQ), negative and statistically significant. This supports our conjecture on ‘moderating effect’ of age on the relationship between governance and innovation implying that, although always negative, the effect of governance on non-mature firm is much stronger [8].

The estimated coefficients for the set of control variables have the expected sign. Larger and more R&D intensive firms tend to patent more, superior operating performance does not necessarily influence innovation outcome.

## 5.2 Exploring nonlinearities in the CGQ

We switch to nonparametric setting to explore whether the relationship between corporate governance and innovation is dominated by nonlinearities. Some notes of caution: in performing this exercise we do not account for firm-level fixed effects as the computation burden would be too high, and secondly we exclude the interaction term as we are interested on the effect of CGQ on the entire sample.

INSERT FIGURE 2 ABOUT HERE

In what follows we focus specifically only on corporate governance measures, plots for the entire set of control variables are reported in Appendix xxx.

Figure xxx shows the results of the GAM estimation on R&D-to-sales intensity. We can promptly note that nonparametric modeling does not help in providing additional information on the nature of the relationship between governance and R&D investment. Indeed, both corporate governance measures (level and growth) display slightly decreasing curves which however lie close to zero. This evidence supports the overall null effect we have reported in Table 6.

INSERT FIGURE 3 ABOUT HERE

Turing to patent applications as response variable, very interesting findings emerge when we embark in the nonparametric setting. Although in the parametric exercise we find an

[8] As stated in the Methodology section we have also interacted the governance measure with age. The estimated coefficient was positive in sign and close to the threshold of significance at 10% level. Whilst we claim that corporate governance exerts different effect on two layers of age, we refrain from arguing that such effect constantly decreases as the age of the firm increases.

overall negative effect of governance, in Figure 3 it may be noticed that such effect is mainly driven by extreme values of CGQ. Curiously we do find that very poor governance turns out to have a positive effect on innovation[9]. The governance variable in growth rate is characterized by very strong nonlinearities which lead any interpretation to be implausible.

In its simplicity, the evidence we propose casts some doubts on the somehow simplistic ‘yes/no effect’ view of corporate governance on innovation that most of the theories depict.

[9] To notice that we could not capture this effect by simply adding a quadratic term of the corporate governance measure.

# 6 Conclusions

Empirical analyses of the relationships between CG and firm performances have mostly focused on the impact on financial performances and on market value. Only recently some contributions have begun to investigate the impact of CG on innovation performances, by showing in most of the cases that good governance practices are associated with low levels of innovation. No attention has been devoted in this framework to the differential impact of CG on innovation across the different stages of firms' lifecycle. This paper aims at filling this gap by investigating whether firms' age moderates the relationship between CG and innovation and, if so, in which direction.

We carried out empirical analyses on a sample of listed firms extracted by the ISS Risk Metrics database, observed in the time period 2003-2008. The results of the parametric estimations provide support to the idea that high CG scores are associated to low levels of innovation, due to the fact that good managers are likely to maximize shareholders' utility, by privileging value preservation rather than value creation. In this framework, the effect of age is such that young firms are featured by an even stronger negative relationship between CG and innovation. The impact of good governance practices is augmented by the lack of the necessary competences in younger firms to ensure effective management of successful innovation projects. The non-parametric analysis allows us to appreciate the nonlinearities in these relationships, by showing that actually the negative impact of CG on innovation is driven by firms characterized by extremely high CG scores.

## Table 1: Evidence on the impact of good governance on innovation

| | **Multiple attributes** | **Takeover defenses** | **Country** | **Firms** | **Results CG on Innovation** |
|---|---|---|---|---|---|
| Driver and Guedes (2012) | X | | UK | 91 | Negative |
| Lhuillery (2011) | X | | F | 110 | Not significant |
| Becker-Blease (2011) | | X | US | 600 | Positive |
| O'Connor and Rafferty (2012) | | X | US | 1719 | No relation: slightly positive with GMM, negative but not robust with OLS |
| Krafft and Ravix (2008) | X | | Non US | 2500 | Positive, potentially amplifying ups and downs |

### Table 2. Corporate Governance Quotient criteria

| | |
|---|---|
| Board Structure | Audit |
| Board Composition | Audit Committee |
| Nominating Committee | Audit Fees |
| Compensation Committee | Auditor Rotation |
| Governance Committee | Auditor Ratification |
| Board Structure | Executive and Director Compensation |
| Board Size | Cost of Option Plans |
| Changes in Board Size | Option Re-Pricing |
| Cumulative Voting | Shareholder Approval of Option Plans |
| Boards Served On - CEO | Compensation Committee Interlocks |
| Boards Served On - Other than CEO | Director Compensation |
| Former CEO's | Pension Plans for Non-Employee Directors |
| Chairman / CEOs Separation | Option Expensing |
| Board Guidelines | Option Burn Rate |
| Response To Shareholder Proposals | Corporate Loans |
| Boards Attendance | Progressive Practices |
| Board Vacancies | Retirement Age for Directors |
| Related Party Transactions | Board Performance Reviews |
| Charter/Bylaws | Meetings of Outside Directors |
| Features of Poison Pills | CEO Succession Plan |
| Vote Requirements | Outside Advisors Available to Board |
| Written Consent | Directors Resign upon Job Change |
| Special Meetings | Ownership |
| Board Amendments | Director Ownership |
| Capital Structure | Executive Stock Ownership Guidelines |
| Anti-Takeover Provisions | Director Stock Ownership Guidelines |
| Anti-Takeover Provisions Applicable | Officer and Director Stock Ownership |
| Under Country(local)Laws | Director Education |
| | Director Education |

### Table 3. Sectoral Distribution of Sampled Firms

| Industry | N. firms | |
|---|---|---|
| A – Agriculture, forestry and fishing | 7 | 0.317 |
| B – Mining and quarrying | 62 | 2.812 |
| C – Manufacturing | 813 | 36.871 |
| D – Electricity, gas, stream and air conditioning supply | 56 | 2.540 |
| E – Water supply; sewerage, waste management and remediation activities | 9 | 0.408 |
| F – Construction | 71 | 3.220 |
| G – Wholesale and retail trade; repair of motor vehicles and motorcycles | 165 | 7.483 |
| H – Transportation and storage | 105 | 4.762 |
| I – Accommodation and food service activities | 39 | 1.769 |
| J – Information and communication | 214 | 9.705 |
| K – Financial and insurance activities | 346 | 15.692 |
| L – Real estate activities | 88 | 3.991 |
| M – Professional, scientific and technical activities | 118 | 5.351 |
| N – Administrative support service activities | 48 | 2.177 |
| O – Public administration and defence; compulsory social security | 0 | 0.000 |
| P – Education | 2 | 0.091 |
| Q – Human health and social work activities | 11 | 0.499 |
| R – Arts, entertainment and recreation | 20 | 0.907 |
| S – Other service activities | 16 | 0.726 |
| T – Activities of households as employers | 0 | 0.000 |
| U – Activities of extraterritorial organisations and bodies | 0 | 0.000 |
| Missing information | 15 | 0.680 |
| Total | 2205 | |

## Table 4. Descriptive Statistics

| Variables | Mean (std) | Min | 1st quartile | Median | 3rd quartile | Max |
|---|---|---|---|---|---|---|
| CGQ | 0.47 (0.26) | 0 | 0.26 | 0.45 | 0.69 | 1 |
| ΔCGQ | 0.17 (2.57) | -1 | -0.16 | -0.02 | 0.12 | 3.41 |
| Age | 54.38 (47.90) | 0 | 17 | 44 | 81 | 536 |
| ln(SZ) | 14.76 (1.86) | 4.23 | 13.85 | 14.87 | 15.93 | 19.97 |
| RDI | 0.06 (0.37) | 0 | 0.001 | 0.01 | 0.04 | 9.74 |
| Δln(RDI) | -0.01 (0.61) | -4.81 | -0.05 | 0 | 0.04 | 6.27 |
| Patents | 4.46 (6.63) | 0 | 0 | 1 | 7 | 47 |
| ROA | 0.06 (0.11) | -0.97 | 0.02 | 0.05 | 0.09 | 0.94 |
| CF | 0.80 (2.39) | -7.30 | 0.04 | 0.16 | 0.55 | 44.51 |

Note : Cash flow in million of €

### Table 5. Correlation Matrix

| Variables | CGQ | ΔCGQ | Age | ln(SZ) | RDI | Δln(RDI) | Patents | ROA | CF |
|---|---|---|---|---|---|---|---|---|---|
| CGQ | 1 | | | | | | | | |
| ΔCGQ | -0.0042 | 1 | | | | | | | |
| Age | -0.1278* | 0.0068 | 1 | | | | | | |
| ln(SZ) | -0.0509* | 0.0065 | 0.2654* | 1 | | | | | |
| RDI | 0.0635* | -0.0159 | -0.0494* | -0.3843* | 1 | | | | |
| Δln(RDI) | -0.0122 | -0.0214 | 0.0128 | -0.0743* | 0.2703* | 1 | | | |
| Patents | -0.1519* | -0.0206 | 0.1312* | 0.1550* | 0.1471* | 0.0214 | 1 | | |
| ROA | 0.0738 | 0.0110 | -0.0222* | 0.1211* | -0.2549* | -0.0051 | -0.0364* | 1 | |
| CF | 0.0964* | 0.0118 | 0.0360 | 0.4387* | -0.0309* | 0.0018 | 0.0798* | 0.1255* | 1 |

Note : *, p-value < 0.05

## Table 6. CGQ effect on Δln(RDI) – Fixed-effects

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| CGQ $_{t-1}$ | -0.1188$^{*}$ | -0.1178$^{*}$ | -0.1105 | -0.0585 |
| | (0.0671) | (0.0683) | (0.0674) | (0.0618) |
| ΔCGQ $_{t}$ | -0.0072$^{*}$ | -0.0072$^{*}$ | -0.0073$^{*}$ | -0.0079$^{***}$ |
| | (0.0040) | (0.0040) | (0.0040) | (0.0025) |
| ln(age) $_{t}$ | | -0.0390 | -0.0446 | 0.0655 |
| | | (0.1589) | (0.1579) | (0.2026) |
| CGQ $_{t-1}$ (age<20) | | | -0.0652 | -0.0679 |
| | | | (0.1485) | (0.1265) |
| ln(RDI) $_{t-1}$ | | | | -1.0668$^{***}$ |
| | | | | (0.0313) |
| ln(SZ) $_{t-1}$ | | | | -0.5688$^{***}$ |
| | | | | (0.0739) |
| ROA $_{t-1}$ | | | | 0.0158 |
| | | | | (0.2091) |
| CF $_{t-1}$ | | | | -0.0021 |
| | | | | (0.0112) |
| Industry dummies | - | - | - | - |
| Time dummies | no | no | no | yes |
| *N* | 3754 | 3712 | 3712 | 3667 |
| $R^2$ | 0.0008 | 0.0008 | 0.0009 | 0.7021 |
| Log likelihood | -3259.03 | -3213.63 | -3213.53 | -941.85 |

Notes: Robust standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

## Table 7. CGQ effect on ln(RDI) – GMM

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| CGQ $_{t-1}$ | -0.3015$^{**}$ | -0.3769$^{**}$ | -0.1602 | -0.1333 |
| | (0.1393) | (0.1497) | (0.1151) | (0.1738) |
| ΔCGQ $_{t}$ | -0.0236 | -0.0201 | -0.0126 | -0.0058 |
| | (0.0325) | (0.0286) | (0.0239) | (0.0328) |
| ln(age) $_{t}$ | | -0.1907 | -0.2661 | 0.0298 |
| | | (0.1639) | (0.1774) | (0.1905) |
| CGQ $_{t-1}$ (age<20) | | | -0.9663$^{**}$ | -0.8196$^{*}$ |
| | | | (0.4453) | (0.4414) |
| ln(RDI) $_{t-1}$ | | | | -0.1772 |
| | | | | (0.1407) |
| ln(SZ) $_{t-1}$ | | | | -0.4136$^{**}$ |
| | | | | (0.1884) |
| ROA $_{t-1}$ | | | | -0.3717 |
| | | | | (0.6972) |
| CF $_{t-1}$ | | | | 0.0031 |
| | | | | (0.0095) |
| Industry dummies | - | - | - | - |
| Time dummies | no | no | no | yes |
| *N* | 3007 | 2971 | 2971 | 2704 |
| AR(1) | 0.000 | 0.000 | 0.000 | 0.076 |
| AR(2) | 0.432 | 0.355 | 0.289 | 0.127 |
| Sargan | 0.483 | 0.368 | 0.225 | 0.446 |
| Hensen | 0.455 | 0.472 | 0.557 | 0.490 |

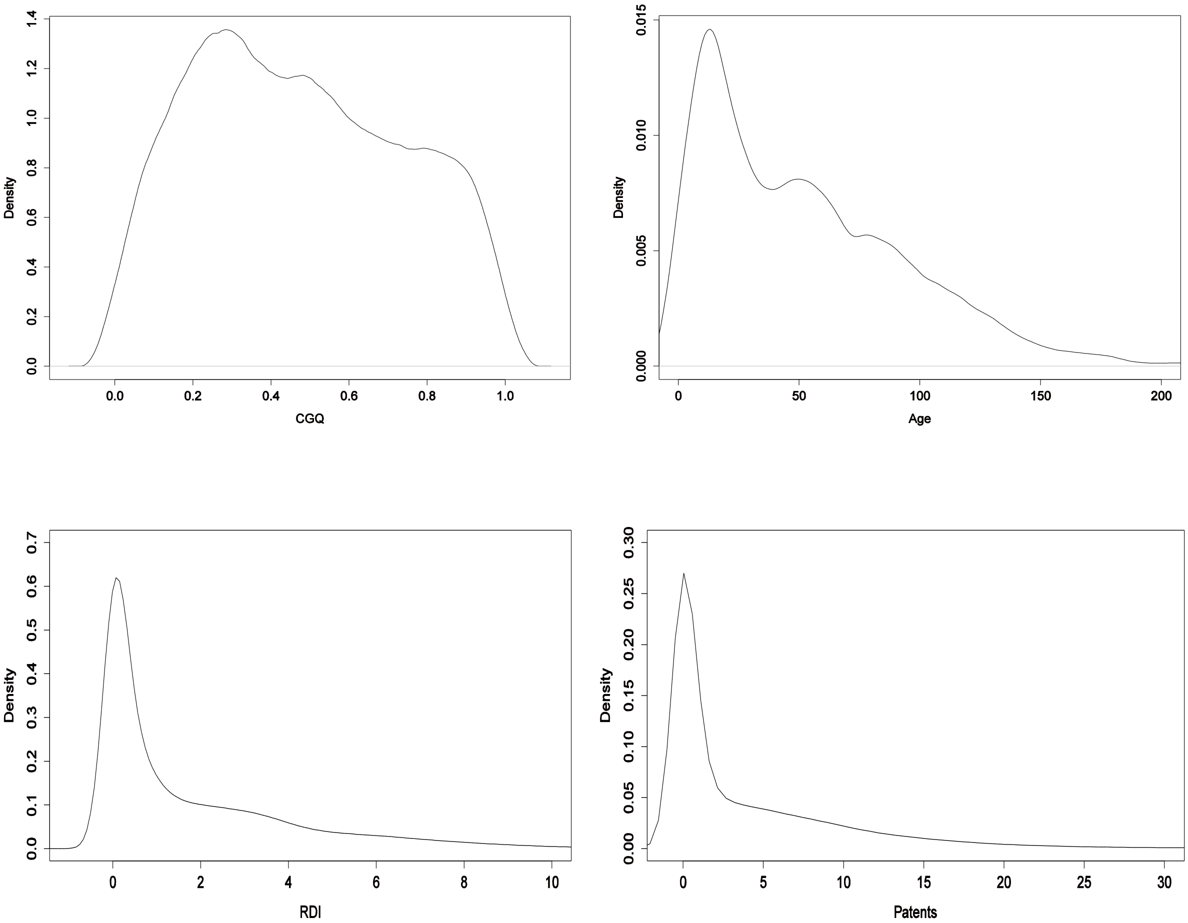
Note: Robust standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

### Table 8. CGQ effect on patent applications – ZINB

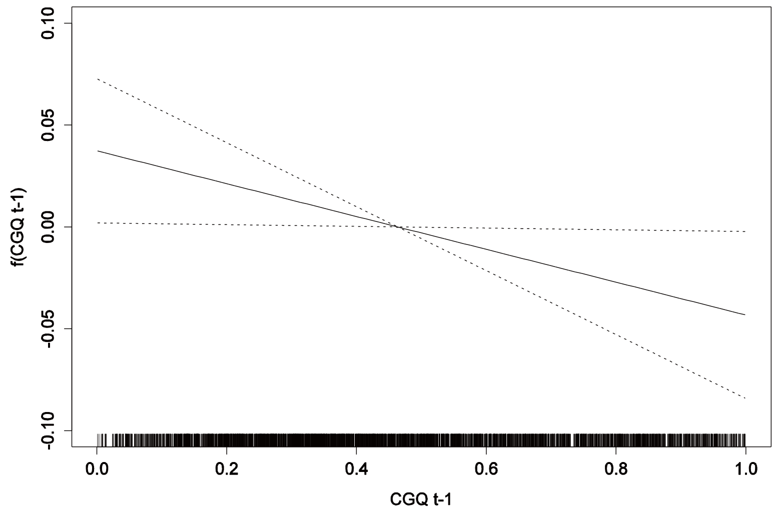
| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| CGQ $_{t-1}$ | -1.0112$^{***}$ | -0.9546$^{***}$ | -0.8887$^{***}$ | -0.8767$^{***}$ |
| | (0.0998) | (0.1022) | (0.1056) | (0.1083) |
| ΔCGQ $_{t}$ | -0.0315$^{***}$ | -0.0280$^{***}$ | -0.0278$^{***}$ | -0.0256$^{***}$ |
| | (0.0079) | (0.0065) | (0.0065) | (0.0070) |
| ln(age) $_{t}$ | | 0.1162$^{***}$ | 0.0597 | 0.0406 |
| | | (0.0298) | (0.0407) | (0.0429) |
| CGQ $_{t-1}$ (age<20) | | | -0.3123$^{*}$ | -0.3871$^{**}$ |
| | | | (0.1806) | (0.1904) |
| ln(RDI) $_{t-1}$ | | | | 0.0479$^{*}$ |
| | | | | (0.0266) |
| ln(SZ) $_{t-1}$ | | | | 0.0749$^{***}$ |
| | | | | (0.0184) |
| ROA $_{t-1}$ | | | | 0.3323 |
| | | | | (0.3752) |
| CF $_{t-1}$ | | | | 0.0070 |
| | | | | (0.0083) |
| Industry dummies | yes | yes | yes | yes |
| Time dummies | yes | yes | yes | yes |
| Inflation (logit-type) | | | | |
| ln(RDI)$_{t}$ | -7.0155$^{***}$ | -7.4068$^{***}$ | -7.2221$^{***}$ | -7.8875$^{***}$ |
| | (1.4787) | (1.4952) | (1.5089) | (1.5680) |
| *N* | 4023 | 3975 | 3975 | 3667 |
| Vuong | 12.71$^{***}$ | 12.55$^{***}$ | 12.45$^{***}$ | 10.71$^{***}$ |
| Log Pseudolik. | -9646.25 | -9539.09 | -9534.47 | -9037.23 |

Notes: Standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

## Figure 1. Kernel density for the main variables



### Figure 2. GAM regression on Δln(RDI)



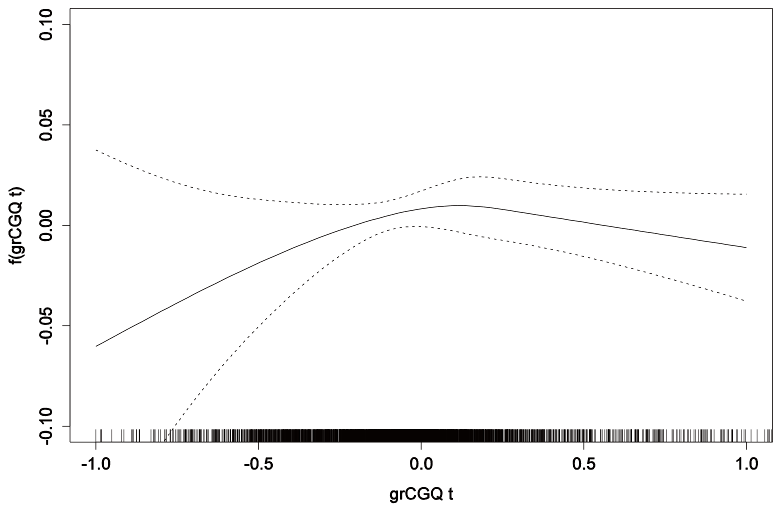
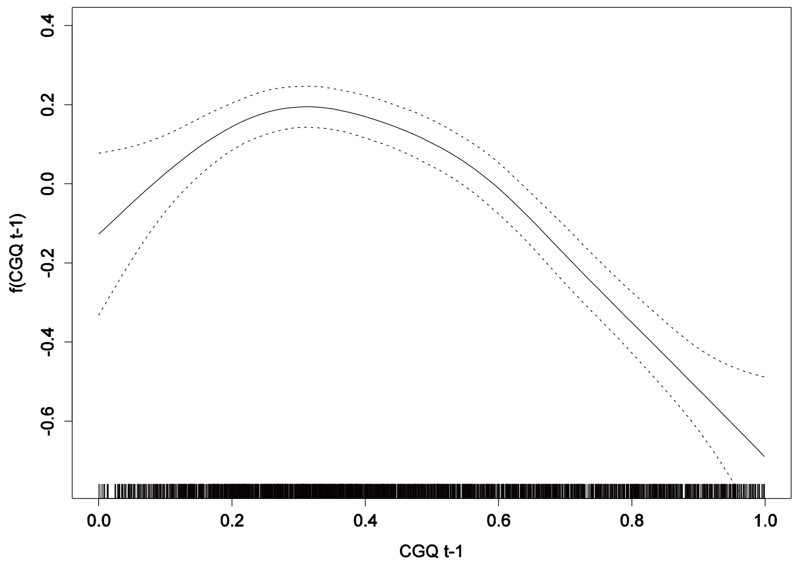
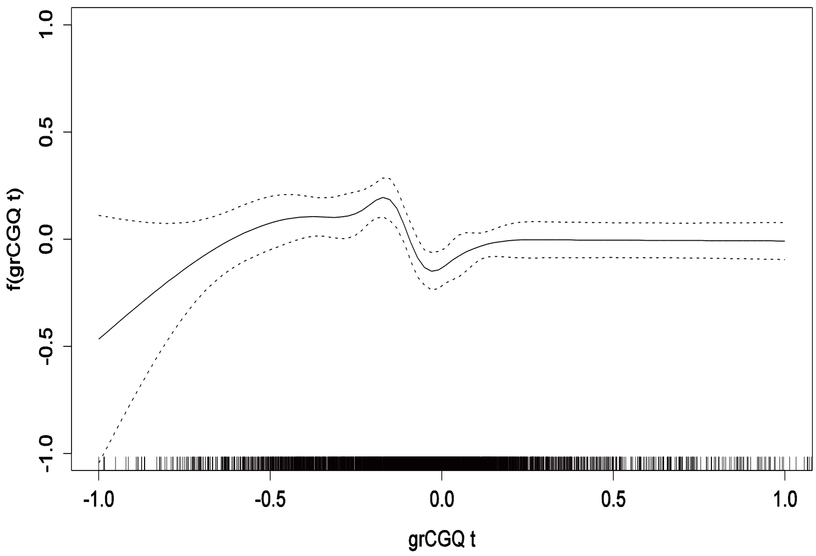
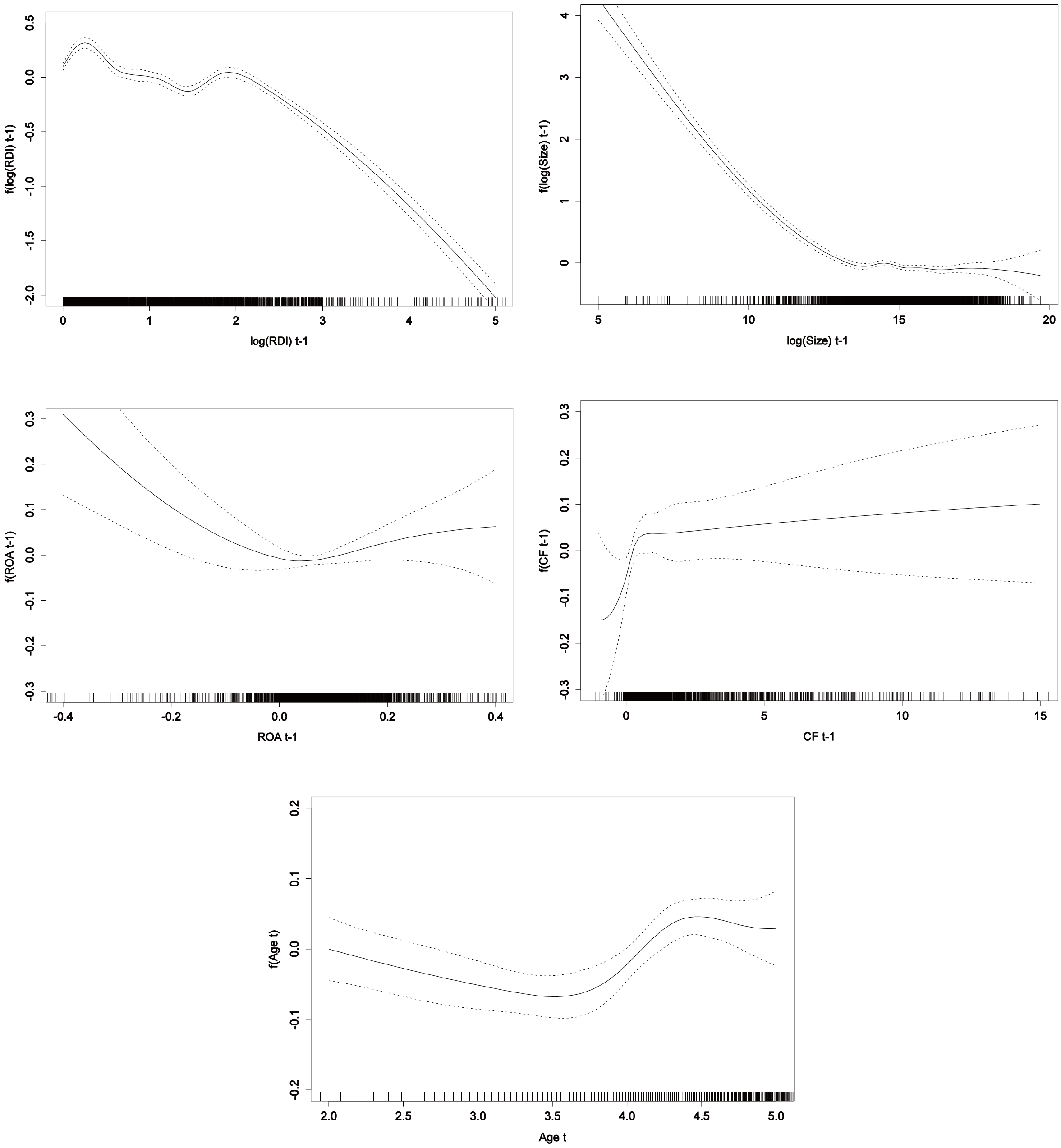



**Figure 3. GAM regression on patent applications (CGQ and ΔCGQ)**



## Figure 4. GAM regression on patent applications (control variables)



## Figure 5. GAM regression on patent applications (control variables)