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Do Managerial Practices Matter in Innovation and Firm Performance Relations? New Evidence from the UK

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Abstract

The innovation and firm performance relationship remains a puzzle, as all types of innovation are not equally beneficial. Besides, better-managed firms can perform better. Integrating these two strands of literature, we examine whether managerial practices explain this relationship using data from UK firms during 1992–2014. We find that firms which focus on R&D activities jointly with better managerial practices benefit favourably. During the post-crisis period, higher intangibles are only beneficial when combined with R&D activity. Also firms with better managerial practices and innovative activities exhibit a positive effect of higher leverage. Finally, an inverse U-shaped result supports the Schumpeterian theory of creative destruction.

Keywords: *firm performance, firm profitability, financial crisis, leverage, intangible assets, R&D intensity, innovation, managerial practices, panel data models*

JEL classification: *C33*, *G01*, *G1*, *G3*, *O3*, *O32*, *O34*

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1. Introduction

While investigating the relationship between innovation and firm performance, the key unresolved question is whether higher intellectual capital is beneficial or unfavourable to firm performance, as not all types of innovation positively influence firm performance. Existing research in this regard remains unclear on the effects of intangibles and does not provide a consensus on how to measure intellectual capital, given the decline in valuation of intangibles following the global financial crisis. Evidence from studies such as Hall and Oriani (2006) and Bloom and Van Reenen (2010) shows that productivity differences have been the focus of researchers for decades and, traditionally, those differences were attributed to R&D investments. In other words, the residual in production that is not accounted for by the usual inputs (such as labour, capital and intermediate inputs) is assumed to be the product of R&D that produces technical change.[1] For that reason, it is vital to observe the impact of R&D on firm performance. On the other hand, Bloom and Van Reenen (2007, 2010) and Bloom *et al.* (2012) argue that the literature fails to consider the differences in managerial practices among firms that contribute to better firm performance. In this paper, we try to integrate these two strands of literature, whilst also considering the role of intangibles on firm performance – in terms of profitability – in the pre-and post-crisis periods.

One strand advocates the idea that performance differences across firms are the result of different management practices (see Bloom and Van Reenen (2007, 2010), Bloom *et al.* (2012), Keller (2009, 2011)), while the second strand of literature centres its arguments upon innovation activities by using R&D investment, R&D intensity and related company intangibles as a proxy to explain differences in firm performance. However, as the studies that focus on managerial practices do not consider innovative activities such as R&D, patents, intangible assets, the R&D arguments (see studies such as Hall (2010, 2011), Hall and Oriani (2006) and Hall *et al.* (2007, 2009, 2010 and 2013)) become important since R&D activities explain performance differences across firms.

Another aspect emphasised by Hall (2010), Hall and Lerner (2010), Borisova and Brown (2013) and Brown *et al*. (2012) relates to the role of financial constraints in R&D activities by firms. The question then arises whether firms that are R&D and innovation-based display differences in performance, after controlling for financial leverage. In other words, we examine whether financial constraints impede innovation. Firms with higher leverage ratios could have difficulties in financing innovation activities because investors, banks or other finance providers usually seek tangible assets. When a company does not have tangible assets, it is perceived as riskier, and investors are wary of investing in them. Companies who are considered to be good performers are expected to use their intangible assets (such as patents, brands, trademarks and trade secrets)

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[1] According to Hall (2011), even though some of the ideas discussed were estimated in his 1973 survey, Griliches (1979) is the first and pioneering analytic survey on this topic. In that article, Griliches laid out the structure of the problem in the production function context and discussed two major measurement difficulties: the measurement of output when a great deal of R&D is devoted to quality improvement and non-market goods, and the measurement of input, specifically, of the stock of R&D capital. Also, Griliches (1998) summarises all his writings on this topic.

and create tangibles out of them. Successful companies may have higher levels of intangible assets, but they are successful due to their ability to turn those innovative activities into assets. On the other hand, start-up companies may have good ideas, but if those intangible efforts are not transformed into assets, they are perceived as non-performers.

While the literature on managerial practices lacks a focus on R&D, intangibles and firm financial constraints, the R&D-focused literature ignores differences in managerial practices when comparing firm performance. Therefore, this paper combines both aspects to examine differences in firm performance. Besides, there is a gap in both strands of literature in examining what happens to R&D and innovative activities during a crisis, and whether firms that are highly innovative and those that are better managed outperform others during the post-crisis period. From the full sample, we can see that the leverage ratios appear dispersed but they vary differently during pre- and post-crisis periods. As shown in the descriptive statistics, firms' leverage ratios were higher in the pre-crisis, but in the post-crisis period, leverage started to decline. Moreover, previous literature has not explored whether these differences (pre- and post-crisis) change the relationship between R&D, managerial practices, and their impact on firm performance.

This paper uses UK firm-level data over the period 1992–2014 to investigate the impact of managerial practices and innovation on firm's profitability. The paper is motivated by four key questions. The first one examines the impact of intangible assets and R&D activity on firm performance. The second question examines whether better managerial practices matter for firm performance. Additionally, the third question elaborates how better managerial practices and innovation impact firms that are financially constrained. Finally, the fourth question examines how managerial practices, R&D activity and intangible assets have impacted performance before and following the recent financial crisis. We find that intangible assets together with R&D activity have a positive impact on firm performance, as firms with only higher levels of intangible assets do not always benefit. Additionally, following the crisis, firms with high R&D activity experienced a positive effect of intangibles on performance, as total assets became more important in improving firm performance rather than intangibles that did not reflect their true valuation in the pre-crisis period. This paper suggests that firms with better managerial practices tend to outperform, even when we consider the impact of the financial crisis, distinguishing firms with higher innovation activities and better managerial practices. Finally, the paper finds an inverse U-shaped relationship between intangible assets and firm performance. In the remainder of the paper, section 2 presents the literature review and hypotheses development. Section 3 examines the data and methodology, section 4 presents empirical results and the robustness checks. Finally, section 5 concludes the paper.

2. Literature Review and Hypotheses Development

2.1. *Impact of intangible assets on firm performance*

Various empirical studies show the impact of intangible assets on firm performance. The best-documented and most widely researched area is research and development (R&D) (see Marr *et al.* (2003, 2004)). The key approach in the majority of the early studies such as Hall and Vopel (1997) and Hall *et al.* (2005, 2007) was to relate the market value of a

company to the value of its knowledge assets with indicators such as R&D and patent citations, indicating a positive relationship. Lin *et al.* (2016) use R&D, intangible assets, leverage and firm size as a benchmark, including R&D in five lags to show the dynamics of R&D. They used Tobin's Q as a firm performance measure, suggesting that intangibles have a positive impact on firm performance, with leverage affecting firm performance negatively.

According to Hall (2011), due to data availability, the most used measures of innovative activities are patent counts and R&D spending. Hall et al. (2013) present an analysis of a firm's patenting decisions and its impact on performance measures. Some of the variables that they analysed were product innovation, process innovation, formal IP and informal IP[2], and R&D per employee. The results suggest that among the firms conducting R&D or focusing on innovation, only 4% of them apply for patents. There are four reasons for this: 'If [the] innovation is process innovation [rather than product innovation]'; 'if this application or innovation is new to the company but not to the market'; 'if the [c]ost and (the time) and patent yield no additional benefits'; and that '[s]ome innovations are inventions that are non-patentable'. These reasons foster the idea that some parts of the intellectual properties of firms are embedded within managerial practices instead of being formally protected. That also, to some extent, reflects the argument of Bloom and Van Reenen on managerial practices and firm performance (see Bloom and Van Reenen (2007, 2010), Bloom *et al*. (2012)).

As seen in the literature, intangibles are generally expected to have a positive impact on firm performance. However, in this paper we suggest that intangible assets can have a negative impact if the recent crisis period is considered when the valuation perception of intangible assets changed. Before the recent financial crisis, intangibles were expected to have a positive impact on firm performance, and following the crisis, this impact is expected to become negative. The reason being that, in the pre-crisis period the greater amount of intangible assets can be supportive for a company which does not have enough tangible assets. So, even with lack of collateral and tangible assets, a higher amount of intangible assets can cause those companies to get overvalued as happened before the financial crisis. In the post-crisis period, investors became very cautious when a company's tangible assets became crucial in investment decisions rather than intangible assets. Companies need tangible assets as collateral. Thus, it can be said that total assets matter more after the crisis. Companies that had better performance before the crisis with higher intangibles no longer benefit from those intangible assets. Therefore, they tend to see a decline in their performance. That leads to Hypothesis 1.

H1: *Intangible assets have a positive impact on firm performance before the crisis due to the overvaluation of firms; and their effect is negative after the crisis due to the change of valuation perception of intangible assets*.

2.2. *R&D and firm performance*

The contribution of R&D to firm performance can be estimated by relating a performance measure such as sales or profit to R&D expenditures in the current and

[2] Formal IP means the intangible assets that are legally protected by intellectual property such as patents, trademarks or copyrights and informal IP is the one that is not legally protected.

previous periods to allow the delayed effect of R&D on business performance and by controlling for the influence of other investments such as investment on physical assets. Studies by Hall and Ziedonis (2001) and Hall *et al.* (2005, 2007) analysed the effect of R&D on the market value of companies and also returns to R&D.

O'Mahony and Vecchi (2009) analysed the relationship between R&D and productivity by using Dynamic GMM estimation with data from five OECD countries (US, UK, Japan, France and Germany). Their main contribution is that they integrated standard analysis by using company accounts data with industry measures of knowledge-generating factors such as R&D and human capital. To undertake this study at the industry level, they introduced two taxonomies: factor intensity taxonomy and skill intensive taxonomy. This provides an alternative to the traditional classification of high-tech and low-tech industries. The results suggest that firms within an R&D/skill intensive industry benefit from 2–5% higher productivity growth.

As we discussed earlier, according to Hall (2011), the most used measures of innovative activities are patent counts and R&D spending. Hall (2011) argues that the product innovation has a positive impact on revenue productivity, and the impact of process innovation is less observable. We argue that the product and process innovation distinction can be attributed to the fact that the less observable aspects of process innovation can be dealt with by adding organisational capital into the analysis via incorporating managerial practices. Parallel to the previous literature, the direct effect of R&D on firm performance is expected to be positive in the overall sample. However, we also examine the indirect effects of R&D activity on firm performance by using interaction terms. R&D and non-R&D firms differ because R&D-based firms can generate better performance from having intangible assets. The aim is to see whether firms that invest heavily in R&D tend to have higher intangible assets and thus perform better in terms of profitability.

Another dimension that is worth noting is the recent global financial crisis when firms made substantial cuts in capital expenses to reduce their vulnerability. Therefore, it can be suggested that firms which chose to maintain their R&D investment would benefit, or at least, would be less prone to crisis. We perform an analysis before and following the financial crisis to examine the relationship for the crisis period starting 2008 and also to see how R&D-based firms are affected by the crisis in comparison to non-R&D and non-intangible based firms. This aspect has not been addressed in the literature. We suggest that the firms with higher R&D tend to benefit more from having higher intangibles, captured by the interaction term of R&D and intangible assets. This leads to the following hypothesis:

H2: *R&D investments have a positive influence on firm performance over the sample period; and following the recent financial crisis, firms with greater investments in R&D tend to benefit more from having higher intangible assets, thus they perform better*.

2.3. *The impact of organisational capital and managerial practices on firm performance*

Managerial practices play a significant role in firm-level performance and in explaining productivity differences when measured across countries (Bloom and Reenen (2010), Bloom *et al*. (2014)). Bloom and van Reenen (2010) extended their 2007 study by

including 16 countries, and concluded that the differences in productivity at the firm and the national levels largely reflects variations in management practices. Bloom and Van Reenen (2007) proposed 18 measures of managerial practices in a survey format, and then analysed the impact of those managerial practices on firm performance in several countries namely the United States, France, Germany, and the United Kingdom.

Camisón and Villar-López (2014) assessed the relationship between organisational innovation and technological innovation capabilities, and analysed the effect on the performance of 144 Spanish firms. The authors focused on the OECD's definition of organisational innovation (OI) which was as follows: 'Organisational innovation is the introduction of new organisational methods for business management in the workplace and in the relationship between a company and external agents' (OECD, 2005). As Mol and Birkinshaw (2009) state, 'The literature offers little evidence of the empirical relationship between the introduction of new management practices and financial performance'. Consequently, the debate on the impact of managerial practices on firm performance is on-going, with one side maintaining that managerial practices have a positive effect on firms as an indispensable source of competitive advantage (see Armbruster *et al.* (2008), Mol and Birkinshaw (2009)). Furthermore, unlike previous research, this study specifically considers how product and process intellectual capital (IC) separately impact financial performance and how they correlate to achieve a positive effect. Their argument is important as it provides a better understanding of how firms benefit from these two types of technological IC. The results confirm that organisational innovation favours the development of technological capabilities for products and processes to provide better firm performance.

The effects of social, financial and human capital are valuable for firms. Doong *et al.* (2011), Du *et al.* (2009) and Fung *et al.* (2007) argued that the traditional production function of labour and capital omits the skilled human capital factor. Early studies show that employees with economically valuable skills, experience and knowledge are valuable to firms. An enterprise with extensive human capital can innovate more and resolve customers' problems more promptly, leading to better performance (see Abeysekera and Guthrie (2004), Striukova *et al.* (2008)). A firm with more high-quality human resources, which are not easily reproduced by competitors, can produce more profit, competitive advantages, and core capabilities.

Doong *et al*. (2011) investigate the impact of social capital, financial capital and human capital on firm performance. They define social capital as total lending and borrowing among related-party transactions and find a positive effect on firm value. Based on the relationships outside of, and within the firm, they compute the total amount of intangible assets and goodwill as a ratio of assets for firm-related activities for social capital. For human capital, they add R&D, education and other variables, such as product and process development, which also have positive and significant effects on financial performance. Our analysis is similar in the sense that we include intangibles and R&D in our analyses. However, in our paper, we address product and process development and human capital elements within the index for managerial practices. A detailed explanation of the construction of the managerial practices variable will be discussed in the data description section.

Matemilola *et al*. (2013) include managerial skill factors in their analysis showing that leverage and managerial skills have a positive relationship with the return. They develop a measure of managerial skills and use the management literature to explain how managerial skills impact shareholders' return. Matemilola *et al.* (2013) investigate

whether managerial practices and financial leverage have an impact on investors' return. Before the financial crisis, firms' leverage ratios were very high. Similarly, it is also observed in our dataset that if a pre-crisis period is considered, leverage ratios are substantially high. The global increase in risk premium and shareholders' return during the recent financial crisis is partly attributed to the use of excessive leverage by top management. Since the use of high leverage increases financial risk, shareholders' demand a higher return to compensate them for the added financial risk. Nonetheless, managerial skill has frequently been omitted because its measurement is relatively less straightforward, and failure to account for unobservable firm-specific factors in a return model leads to omitted variable bias. Specifically, the role of unobservable firm-specific factors such as managerial skills has been ignored in the literature, but managerial skills could have a strong influence on shareholder return. Crummenerl *et al.* (2015) also looked at the subject from managers' perspective and investigated the decisions of managers and their optimal stock-based compensation from the perspective of shareholder value.

Furthermore, the results of Archibugi *et al.* (2013) are similar to the previous literature, in that size, economic performance, and an exploitation strategy predict increased innovation investment before the crisis. Strategy performs a central role in the understanding of intellectual capital, allowing a complete and critical interpretation of intangible assets. For instance, earlier studies such as Edvinsson and Sullivan (1996) and Edvinsson (1997) categorise 'strategy' within the organisational capital, whereas Bontis (1998) focuses on managing intellectual capital strategically and uses the term 'strategic innovation'. García-meca et al. (2005) and García-Meca and Martínez (2007) use strategy as an IC (intellectual capital) element in their study. Kaplan and Norton (1996, 2001, 2004) place 'the strategy' in the centre of their Balance Scorecard.[3] Verschoor (1999) finds a positive relationship between a strong ethical commitment (which becomes a key part of firms' strategies in the current decade) and firm performance. Some authors argue the corporate social responsibility to be positively related to a firm's profitability (Stanwick and Stanwick (1998), Simpson and Kohers (2002)). Hillman and Keim (2001) note that the shareholder value increases when a firm invests in socially responsible activities. More recently, Capelle-Blancard and Monjon (2014) investigate the impact of socially responsible firms in terms of the environment, sustainability and governance on the financial performance of funds. We also adopt a similar approach in order to incorporate the environment, sustainability and governance indicators for calculation of our managerial practices variable. Based on a sample of French SRI Funds, Capelle-Blancard and Monjon (2014) find non-linear evidence that a greater screening intensity slightly reduces financial performance, and this moves in the opposite direction when screening gets tougher. Additionally, García-Meca and Martínez (2007) use five classifications for IC: Human Capital; Customers; Organizational Innovation; Research

[3] Kaplan and Norton's Balance Scorecard (1992,1996) where firm's strategy and vision is in the centre of the model and four perspectives – Financial perspective, Internal Business Process perspective, Customer perspective, Learning & Growth perspective – that firms should look to ensure firm's vision and strategy, can be provided as one of the key studies in the area of firms' organisational practice. A company can monitor short-term results from the customers, internal business processes, and learning and growth perspectives and evaluate strategy in the light of recent performance. The scorecard thus enables companies to modify strategies to reflect real-time learning.

and Development; and Strategy. Our hypothesis is parallel with García-Meca and Martínez's classification. They include the variable for strategy – a firm's most critical process to create IC and thus firm value.

To sum up, we argue that the better managed firms tend to have better financial performance and that is where our study diverges from the traditional R&D literature and aims to contribute. In this paper, we include managerial practices of each firm, leading to the next hypothesis.

H3: *Better managerial practices have a positive impact on firm performance.*

2.4. *Impact of financial constraints and the recent financial crisis on R&D decisions and firm performance*

The literature often has contrasting views on whether financial constraints impede innovation and firm performance. Some scholars argue that innovation activities are curtailed during bad times, and when a firm has a higher leverage ratio, it uses borrowing to expand or sustain business activities. When a firm has a high leverage ratio, the first decision the management team takes is to cut extra costs. As R&D activities are considered as an expense, R&D investment can be the first thing to be reduced. Some scholars find that firms prefer to maintain R&D activities in bad times because they were locked into these activities due to an initial investment (see Archibugi *et al.,* 2013).

Lin *et al.* (2016) use financial constraint in their analysis as an explanatory variable in their estimation and find a negative relationship with firm performance (also see Mallick and Yang, (2011)). Additionally, Lin *et al.* include intangible assets, goodwill and research and development to capture innovative activities. On the other hand, there are various studies on financial constraints, suggesting that financially constrained firms tend to invest in R&D due to being locked in to R&D activities as a result of previous commitments and agreements (see Archibugi *et al.* (2013)). In addition, Li (2011) provides new perspectives by investigating these aspects via the interaction between financial constraints and R&D investment. As opposed to capital investment, R&D investment is inflexible. A financially constrained R&D-intensive firm is more likely to withdraw its R&D projects. Therefore, the risk for the R&D-intensive firms increases with their financial constraints position and vice versa, meaning that financially constrained firms' risks increase with the growth of their R&D intensity. The relationship of financial limits and return are more robust in R&D-intensive firms and are positive only among financially constrained firms. These findings suggest that financial constraints have a significant impact on the risk and return of R&D-intensive firms and potentially drive the positive R&D-return relationship. So, with the above evidence, it can be said that the literature on the relationship between financial constraints and stock returns suggests mixed evidence. To capture this, we investigate the joint impact of financial leverage with R&D and managerial practices via adding interactions, as this aspect has not been investigated in previous studies.

There is a strong positive link between cash inflows and corporate R&D investment, but only among firms that are most likely facing binding financing constraints, as supported by evidence in Borisova and Brown (2013). The evidence that financing frictions impact the increasingly important, yet understudied, intangible corporate investments can drive innovative activity. Sales have a positive impact on R&D

spending in constrained firms, as they use their sales revenue to finance R&D activities rather than to increase their leverage. Overall, evidence supports that financing frictions have economically significant effects on major corporate investment decisions. The study of Borisova and Brown (2013) is one of the few studies to test for financing constraints on intangible corporate investment activities. Although fixed investment has received much more attention, there are several reasons to expect that intangible investments like R&D were particularly sensitive to financing difficulties due to information asymmetries and limited collateral value. However, according to Hall and Lerner (2010), prior studies that examine R&D offer mixed and inconclusive evidence, and they show that financing frictions influence firm-level R&D.

The results of Borisova and Brown (2013) clearly indicate that financing constraints impact R&D investment in smaller, younger and low pay-out firms. R&D is an increasingly critical decision and a key input for innovation and productivity growth in modern economies. The results indicate that financial market developments that ease financing constraints increase R&D investment in growing firms, which in turn, should incentivise innovation and lead to higher overall economic growth.[4]

Several studies advance a 'financing hypothesis' to explain corporate divestitures, but this literature has not considered whether firms use asset sale proceeds to support intangible investments that are particularly sensitive to funding difficulties. The use of cash inflows from asset sales for intangible investment can be valuable because asset sales tend to be negatively correlated with other financing sources. This suggests that a fixed asset may be especially valuable to innovative firms during recessions and other periods when liquidity concerns are particularly pronounced. Borisova and Brown (2013) show that funds from the sale of fixed assets can support a key intangible investment in firms facing binding financing constraints. R&D investment by its nature is intangible, as it does not fulfill the criteria of collateral. Judge (2006) assesses disclosures in the annual reports of 400 UK companies with data collected via a survey, and finds unlike many previous US studies strong evidence linking the decision to hedge and the expected costs of financial distress. Additionally, Cosci *et al.* (2015) find that firms with credit constraints may choose to lease instead of borrowing from a bank for buying the fixed assets and therefore they will be able to allocate more resources to their projects which require investment. They used total company assets, firm size and other firm-specific variables and find a negative relationship with credit constraints. Xu *et al.* (2013) analyse the Chinese listed firms with credit constraints and interestingly find that firms that face under-investment problems can mitigate this issue if the firm has stronger political connections; the mitigation effect was found to be even stronger in financially more constrained firms.

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[4] Their findings also suggest that public policy efforts to foster financial market access by liberalising capital markets and providing stronger legal protections for outside suppliers of capital can have an especially pronounced effect on innovation and intangible investment. In addition, their findings suggest policies that increase the funds available for intangible investment – such as lower effective corporate tax rates for R&D intensive firms or government loan guarantees to finance innovative projects – can be growth-enhancing. Such efforts could be especially important for countries with less developed capital markets where financing constraints on R&D are likely to be especially severe.

Brown *et al.* (2012) study a large sample of European firms and also find little evidence of binding financing constraints when estimating standard investment-cash flow regressions. However, they find substantial evidence that the availability of finance matters for R&D, controlling for firm efforts to smooth R&D with cash reserves and a firm's use of external equity finance. Brown *et al.* (2012) also evaluate the impact of financing constraints when firms rely extensively on external funding and endogenously manage cash flows. Results indicate an important role for external equity in financing R&D and promoting firm-level innovative activity. An important aspect of R&D is the susceptibility to financing constraints. For several reasons, including lack of collateral value and asymmetric information problems, R&D may face significant adverse selection and moral hazard problems, particularly in younger and smaller firms. For such firms, financing constraints can drive R&D investment below the privately optimal level in a world of no financing frictions. If funding constraints are binding for many firms, national and global R&D levels will be depressed, leading to lower levels of innovation and growth than in a world without financing frictions.

Despite R&D's critical role in economic growth and its susceptibility to financing difficulties, relatively few studies evaluate how financing frictions affect R&D, and the results of these studies are mixed. Furthermore, evidence supporting economically vital funding constraints on R&D is much stronger for US firms compared to European firms, which is puzzling, as capital markets in the US are at least as developed as those in Europe. For example, recent studies by Brown *et al.* (2009) and Brown and Petersen (2009) find a strong link between R&D and internal and external equity finance for young publicly-traded US firms. On the other hand, Bond and Van Reenen (2003) find that neither German firms nor UK firms display a correlation between the level of R&D and cash flow. Hall and Lerner (2010) provide a comprehensive summary of the literature and conclude that it remains an open question whether financing constraints matter for R&D.

According to Brown *et al.* (2012), determining whether financing constraints matter for R&D is important for identifying the causal connections between finance and economic growth. Yet, prior studies focusing on European firms tend to find weak evidence (at most) that financing constraints have a quantitatively important impact on R&D. Utilising a broad sample of European enterprises, Brown *et al.* (2012) find little or no evidence that finance matters for R&D if only the R&D-cash flow sensitivity is examined, consistent with the approach in nearly all studies of financing R&D.

However, findings of Brown *et al.* (2012) show that access to internal and external equity finance matters a great deal for R&D, particularly in firms most likely to face binding financing constraints. The main reason for this reversal of results appears to be that firms facing financing frictions have strong incentives to build and utilise costly stocks of liquidity to keep the flow of R&D spending relatively smooth compared to transitory finance shocks, avoiding massive adjustment costs associated with R&D. Their results also indicate that better access to equity financing can substantially increase R&D investment, which has long been a key public policy goal in the EU and many other countries. Brown *et al.* (2012) show that stock markets are much more than a 'sideshow' when it comes to financing R&D. That helps explain the very high R&D-intensities of young publicly traded firms in countries such as the UK and Sweden.

Because this paper is based on the analysis of firm performance at the micro level, another question is to what extent financing of innovative firms is different from other firms. According to Hall (2010), owing to the intangible nature of their investment, asymmetric information and moral hazard, these firms are more likely to be financed by equity than debt, especially if they are small. Hall points out differences between the US and the UK on the one hand, and continental European countries on the other, in estimates of the cash-flow sensitivity for established firms. The former is more sensitive than the latter; so, in principle, the US and UK firms should be more subject to financing constraints. However, there is little evidence that this leads to less innovative activity. The largest of these firms in all countries and the ones that undertake the greatest amount of R&D, tend to compete in international markets; so, it is not likely that the behaviour of firms from different countries can diverge too far. Some policy implications can be derived from the results of Hall (2010).[5]

Early studies by Hall (2002), Hall *et al.* (2009) and Hall and Lerner (2010) agree that although leverage may seem a useful tool for reducing agency costs in the firm, it is of limited value for R&D-intensive firms. Because knowledge assets that are created within the firm by R&D investments are intangible and embedded in human capital and managerial practices, the capital structure of R&D-intensive firms customarily exhibits less leverage than others. Banks and other debt holders prefer to use physical assets to secure loans and are reluctant to lend for projects that involve substantial R&D investment rather than plant and equipment.

To sum up, financial constraints impact the decision of innovative activities. More importantly, during times of financial crisis, more constraints are added, and innovative activities are affected even more. One of the best explanations for the differences in arguments regarding the behaviour of financially constrained firms was presented by Filippetti and Archibugi (2011), Archibugi and Filippetti (2011) and Archibugi *et al.* (2013). Filippetti and Archibugi (2011) investigate the impact of the current economic downturn on innovation across Europe using micro-level and macro-level data. Evidence suggests that while some firms exhibit persistence in investing in innovation during recessions, others do not. This persistence can be a result of several factors including firm-specific characteristics – such as strategies, managerial differences, stage of development, advertisement profits – and technological changes, scientific research and the nature of innovation. Firms across Europe that performed well in these factors were found to be able to offset the effect of the economic downturn on innovation investments.

Archibugi *et al.* (2012, 2013) find that size, economic performance, and an exploitation strategy predicted increased innovation investment before the crisis. However, during the crisis, they found interesting differences. Both size and economic performance played a less important role. By contrast, the presence of in-house R&D activity became a major predictor of increases in innovation expenditure during the crisis. As for the firm's strategy, pursuing an explorative strategy (including considering new markets), became relatively more important. This evidence suggests that there are

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[5] This paper was published as: Hall, B., 'The financing of innovative firms', *European Investment Bank Papers,* Vol. 14, 2009, pp. 8–28. It was then reprinted in the *Review of Economics and Institutions* and the recommended citation is Hall, B. (2010), 'The Financing of Innovative Firms', *Review of Economics and Institutions*, 1 (1), Article 4.

two sources that can create persistence in innovation in a crisis period. First, the existence of an R&D department suggests the firm has made a medium or long-term commitment to innovation. Secondly, the contribution of R&D into a firm's strategy is vital, if the strategy is based on exploration of new markets and development of new products.

According to the results of Archibugi *et al.* (2012, 2013), the 2008 economic crisis has severely reduced the short-term willingness of firms to invest in innovation. However, this reduction has not occurred uniformly, and a few firms even increased their investment, despite the adverse macroeconomic environment. When the drivers of innovation investment before and during the crisis were examined, it was found that the crisis led to a concentration of innovative activities within a small group of fast-growing new firms and those firms were already highly innovative before the crisis. Companies pursuing more explorative strategies towards new product and market developments are better able to cope with the crisis.

After an extensive review of the literature on leverage and financial constraints, we find that the direct and indirect effects of leverage can be different during the pre- and post-crisis periods. In this paper, we aim to address that by dividing our sample into pre- and post-crisis and by incorporating the joint impact of R&D with intangibles and managerial practices into our analyses. By doing this, we suggest that the impact of leverage on firm performance will vary if the firms have better managerial practices, higher intangible assets and higher R&D ratios. Therefore, the next hypothesis can be structured as follows:

H4: *The direct impact of leverage tends to be negative on a firm's performance, both before and during crisis; while the indirect impact of leverage will be positive for the firms with intangibles, more R&D investment, and better managerial practices.*

3. Data and Methodology

3.1. *Data description*

This paper investigates the impact of R&D activities and managerial practices on firm performance using firm-level data from the UK (i.e., FTSE ALLSHARE) over the period 1992–2014. Firm performance is examined in terms of profitability and we use profit margins as dependent variable in our analyses, denoted as '*PM*'. Profit margins can be calculated as total profit over total sales. Baseline estimations are done by using OLS with time and firm fixed effects, and further estimations are done using Dynamic GMM. Besides, marginal effects analysis is conducted to elaborate the joint impact of R&D intensity, managerial practices and intangible assets further.

The data are collected from Thomson Reuters DataStream. Our analysis started with FTSE100 companies and then, to improve our analysis further, we expanded the dataset to FTSEALLSHARE. However, we have data limitations due to missing observations, resulting in fewer firms and lowering the number of observations in our sample. Table 1a lists the names and a short description of the variables used in the analysis. Each variable is taken as a ratio of sales to overcome the scaling problem. For that reason, each variable is divided by sales. Additionally, each variable is represented on a logarithmic scale.

Table 1a

Descriptions of variables

This table describes the variables. All variables are represented as a ratio of sales and are in logarithms.

Variable	Description
PM	Net Profit Margin (Net Profit /Sales)
Int	Intangible ratio (Total Intangible Assets/Total Sales)
R&D	R&D intensity
Mngprc	Managerial Practices
DtoC	Leverage ratio: (Total Debt/Total Capital)
TotA	Total Assets ratio (Total Assets/Total Sales)
int_sq	Squared Intangible Assets
mngprc_sq	Squared Managerial Practices
TotA_sq	Squared Total Assets

Intangible Ratio is the amount of intangible assets over sales and is calculated as the amount of Intangible Assets in £ millions divided by Total Sales in £ millions and denoted as '*Int*'. Instead of R&D investment as an expense, we are interested in R&D intensity, which shows the contribution of R&D per unit of output: *R&D* is calculated by the total amount of investment towards R&D, divided by total sales in £ millions. Another variable is Total Asset ratio which is calculated as Total Assets to Sales ratio, and can also be called Total Assets Turnover. That compares assets relative to the amount of sales that a company can generate using their assets. Total assets to Total Sales ratio is a measure of a company's efficiency in managing its assets in relation to the revenue generated. When this ratio is higher, it indicates the required investment is smaller. It is denoted as '*TotA'*. Sources of the variables denoting Intangible Assets, Total Assets and Total Sales are explained in Table 1b below in detail.

The question that motivates the choice of explanatory variables is whether besides the traditional form of innovation (i.e., R&D activities), modern innovative practices such as improving managerial practices drive company performance and whether this relationship is influenced by financial crisis or high leverage. In fact, instead of focusing only on R&D for measuring firm productivity, managerial practices are integrated to solve firm performance-innovation puzzle. Human and organisational capital can be considered as the main attributes of managerial practices. Therefore, we used data addressing those attributes. For further details regarding the data sources and explanations, please see Table 1b below. The Managerial Practice variable is based on score variables on a scale of 0–100 for each firm and denoted as '*MngPrc*'. This dataset is from a survey called ASSET4, which is obtained from Thomson Reuters DataStream. The variable is a score-based system that attributes scores between 0–100 in each period across firms. We have six different measures which we use in building up the Managerial Practice variable (listed in Table 1c). To form our measure, we sum all these variables which makes our maximum score 600 and minimum score 0. Following that, we then construct our managerial practice variable by dividing the scores by the total sales of each firm within a particular time period. It can be justified that Managerial Practices over Sales indicate managerial practices per unit of output. Firms are not identical in size. Some firms are larger while some are smaller. Those

Table 1b

Data description

This table shows the data code and DataStream source for Intangible Assets, Total Assets and Total Salesdata, along with a description. Then these three variables are used to construct 'Intangible to Sales' and 'Total Asset to Sales' ratios which were described previously in Table 1a.

Data Code	DataStream Source	Name	Explanations
WC02649	Worldscope (Balance Sheet/ Annual / Assets)	*Total Intangible Assets Net (total)*	It represents other assets not having a physical existence. The value of these assets lies in their expected future return.
WC02999	Worldscope (Balance Sheet/ Annual / Assets)	*Total Assets*	All Industries: Total assets in this category represent the sum of total current assets, long-term receivables, investment in unconsolidated subsidiaries, other investments, net property, plant and equipment and other assets. Banks: Total assets here represent the sum of cash and due from banks, total investments, net loans, customer liability on acceptances (if included in total assets), investment in unconsolidated subsidiaries, real estate assets, net property, plant & equipment and other assets. Insurance Companies: Total assets here represent the sum of cash, total investments, premium balance receivables, investments in unconsolidated subsidiaries, net property, plant & equipment and other assets. Other Financial Companies: Total assets here represent the sum of cash & equivalents, receivables, securities inventory, custody securities, total investments, net loans, net property, plant and equipment, investments in unconsolidated subsidiaries and other assets.
WC01001	Worldscope (Income Statement/Annual)	*Net Sales*	Net sales represent gross sales and other operating revenue less discounts, returns and allowances. Franchise sales when corresponding costs are available are included in expenses.

Table 1b
Continued

Data Code	DataStream Source	Name	Explanations
WC01201	Worldscope (Income Statement /Annual/ Supplementary)	*Research & Development*	Research and development expense represents all direct and indirect costs related to the creation and development of new processes, techniques, applications and products with commercial possibilities. These costs can be categorised as 1. Basic research 2. Applied research 3. Development costs of new products
DWNM	Worldscope (Time Series/Fundamentals)	*Net (Profit) Margin*	(Ratio %). (DWNP / DWSL) Net profit is divided by net sales (unavailable before 1998). DWNM represented by '.' when net sales equal to zero.
WC08221	Worldscope (Ratios/ Annual / Leverage	*Total Debt % Total Capital*	Leverage ratio of the company. It is calculated by: (Long Term Debt + Short Term Debt & Current Portion of Long Term Debt) / (Total Capital + Short Term Debt & Current Portion of Long Term Debt) * 100

Notes:

1) *'Total Intangible Assets'* includes but is not restricted to: Goodwill, patents, copyrights, trademarks, formulae, franchises of no specific duration, capitalised software development costs/computer programs, organisational costs, customer lists, licences of no specific duration, capitalised advertising cost, mastheads (newspapers), capitalised servicing rights, purchased servicing rights.

2) *'Total Assets'* excludes contra items (contingent liabilities), it is adjusted to exclude deferred taxes, includes trust business assets. It is adjusted to exclude foreign currency translation gains/losses, to exclude provision for bad debt/loan losses, to exclude treasury stock, to exclude investment in own bonds, to exclude foreign currency translation losses and provision for bad debts, to excluded treasury stock and investment in own bonds, to excluded unappropriated net loss; increased by payments on work in progress that has been treated as a current liability.

3) *'Total Sales'* includes but is not restricted to: Consulting fees, service income, royalty income when included in revenues by the company, contracts-in-progress income, licensing and franchise fees, income derived from equipment lease or rental when considered part of operating revenue, commissions earned (not gross billings) for advertising companies, income from leased departments. It excludes: Non-operating income, interest income, interest capitalized, equity in earnings of unconsolidated subsidiaries, rental income, dividend income, foreign exchange adjustment, gain on debt retired, sale of land or natural resources, sale of plant and equipment, sale of investment, sales from discontinued operations, security transactions, income on reserve fund securities when shown separately, operating differential subsidies for shipping companies, net mutual aid assistance for airlines companies, general and service taxes, value-added taxes, excise taxes, windfall profit taxes.

4) *'Research & Development'* includes but is not restricted to: Software expense, design and development expense, engineering expense; contributions from government, customers, partnerships or other corporations, science or technology expense, includes market testing & research, exploration expense. It excludes customer or government sponsored research amortisation, for oil, gas, coal, drilling and mining companies, and purchase of mineral rights. It excludes cost of plant R&D, contributions by government, customers, partnerships or other corporations to the company's R&D expense.

Table 1c

Description of Managerial Practice Index data

This table reports the elements that are used in constructing managerial practices variables and explains their DataStream Codes with their sources. It also presents the specific questions that were used in the surveys while constructing the scoring for the managerial specific measures.

DataStream Code	DataStream Source	Name	Representation in tables	Explanations
ENPI	ESG-ASSET4 (Environmental/ Product Innovation)	Product Innovation	*prodinnov*	Does the company have an environmental product innovation policy (eco-design, life cycle assessment, and dematerialisation)?
CGVS	ESG – ASSET4 (Corporate Governance/Vision and Strategy)	Integration/ Vision and Strategy	*cgvs*	Does the company integrate vision and strategies on economic (financial), social and environmental dimensions into its day-to-day decision-making processes?
SOTDD04S	ESG-ASSET4 (Social/ Training and Development)	Training and Development/ Improvements	*tdimprov*	Does the company set specific objectives to be achieved on the employee training and career development?
SOTDO03S	ESG-ASSET4 (Social/ Training and Development)	Training and Development/ Internal Promotion	*intpromot*	Does the company claim to favour promotion from within?
SOTDO05S	ESG-ASSET4 (Social / Training and Development)	Training and Development/ University Partnerships	*univpart*	Does the company claim to cooperate with schools or universities?
SOTD	ESG – ASSET4 (Social/ Training and Development	Workforce /Training and Development	*sotd*	Does the company claim to provide and/or monitor regular skill and business management training for its employees/ managers?

Notes:

1) ESG stands for Environmental, Sustainability and Governance.

2) The product innovation category measures a company's management commitment and effectiveness towards supporting the research and development of eco-efficient products or services. It reflects a company's capacity to reduce the environmental costs and burdens for its customers, and thereby creating new market opportunities through new environmental technologies and processes or eco-designed, dematerialised products with extended durability.

3) The integration/vision and strategy category measures a company's management commitment and effectiveness towards the creation of an overarching vision and strategy, integrating financial and extra-financial aspects. It reflects a company's capacity to convincingly show and communicate that it integrates the economic (financial), social and environmental dimensions into its day-to-day decision-making processes.

4) The workforce/training and development category measures a company's management commitment and effectiveness towards providing training and development (education) for its workforce. It reflects a company's capacity to increase its intellectual capital, workforce loyalty and productivity by developing the workforce skills, competence, employability and careers in an entrepreneurial environment.

differences in firm sizes may cause biases in examining the value of managerial scores, as a considerably smaller firm might have the same level of managerial practices as a larger firm due to its small size. Therefore, we are looking for the quality of managerial practices per unit of output. This consideration will eliminate potential bias.

Alternatively, bias related to firm size could be dealt with by using total assets instead of total sales. However, this would be an inaccurate method for our estimations, because the amount of intangible assets is used as an explanatory variable, and it would cause a multi-collinearity problem if intangible assets and total assets were used in the same regression because total assets cover tangible plus intangible assets. Here, the idea behind using ratios of sales is that sales will capture the activity type within a firm. The bigger activity could be a sign of bigger firms; those firms produce more and they will be more complex regarding their managerial structures. Therefore, it will reveal whether firms can improve managerial practice if they are producing more. The impact of intangibles, managerial practices and R&D investments on firm performance is plotted as scatterplots in Figure 1 below. The results suggest that when R&D investments increase, firm performance increases as well. The same relationship holds for intangible assets and managerial practices. We test whether the data satisfy normality and we plot histograms before and after the crisis and for the whole sample (see Figure 2). Figure 2 shows that before the crisis, the performance of intangibles was higher. Therefore, the before crisis graph is skewed to the right, while the after-crisis graph is more skewed to the left. We see that after the crisis, firms' intangible performances were reduced. That is why our after-crisis curve becomes left skewed.

Descriptive statistics are presented in Table 2, and the correlation matrix is shown in Table 3. Table 2 constructs a classification of firms as: high managerial-practice intensive and low managerial-practice intensive, and also describes the data for the pre-crisis, post-crisis and overall sample. Also, in Table 2, the summary of the elements constructing managerial practices is presented for both pre- and post-crisis, as well as low and high managerial practice intensive firm categories. Low managerial practice intensive firms have managerial practices values below mean, while high managerial practice intensive firms take values above the mean.

In Table 3, correlation matrix has been constructed with significance levels reported with '*', and all of them are significant at least at the 10% significance level. That means the results of the correlation matrix indicate weak correlations between variables which are robust at the 10% level at least. There is a low correlation among the covariates and significant correlation between dependent variable and explanatory variables.

3.2. *Methodology*

Baseline regressions are conducted by using the OLS estimation method by adding time and firm fixed effects. The Haussmann test and Lagrange Multiplier tests have been conducted to choose between FE, RE and OLS. However, the panel data have a long-time period, and the FE and Dynamic FE do not give robust results, both theoretically from the test results, and practically, from the insignificance of the coefficients of regression – which has not been reported here for brevity. Typically, in a panel dataset, the unobserved heterogeneity could be dealt with by first difference or individual fixed effects transformations.

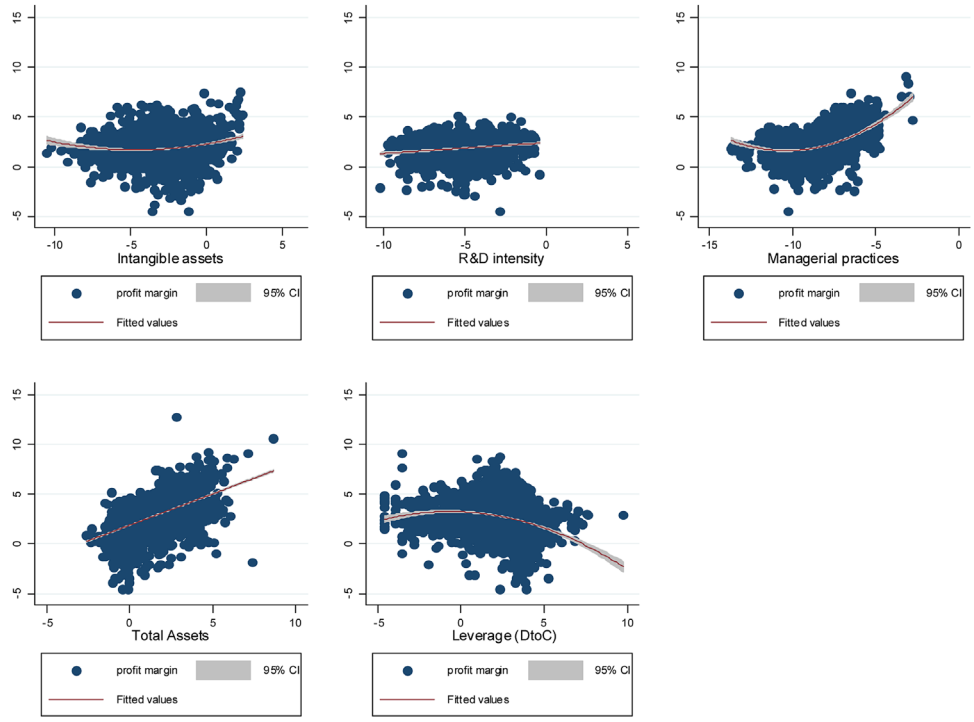


Fig. 1. Scatter plots

Each figure represents the relationship between an explanatory variable and the dependent variable – profit margin. Fitted values are shown within 95% confidence intervals. The figure suggests that higher R&D intensity, intangibles, managerial practices and total assets increase profit margin, while higher leverage increases profit margin initially and then reduces it.

Given that our estimates could be subject to endogeneity bias, we use the Dynamic System GMM approach, where lagged levels are used as instruments for the equations in first differences, and lagged first differences are used as instruments for the equations in levels. In this case, System GMM tends to give more robust results in the context of production function estimation than Difference GMM (Blundell and Bond (2000)). In our estimations, GMM instruments are drawn from lagged and differenced variables for $y_{i,t-1}$ and $y_{i,t-2}$ and the data are transformed by differencing as $\Delta y_{i,t-1}$, $\Delta y_{i,t-2}$. In our estimations, these were created by lagged variables.

Some diagnostic tests are conducted to ensure the validity of Dynamic GMM estimates. The Sargan test, the Arellano-Bond test and the Wald test are used. For a valid instrument set, the orthogonality between the instrument and the error term is tested using the Sargan test of over identifying restrictions. This test can be applied in the case where more than one instrumental variable is available for each endogenous variable. Under the null hypothesis that the instrumental variables are valid, the Sargan test is distributed as a Chi-square with degrees of freedom equal to the number of over identifying restrictions. Sargan test results suggest that the instruments are valid.

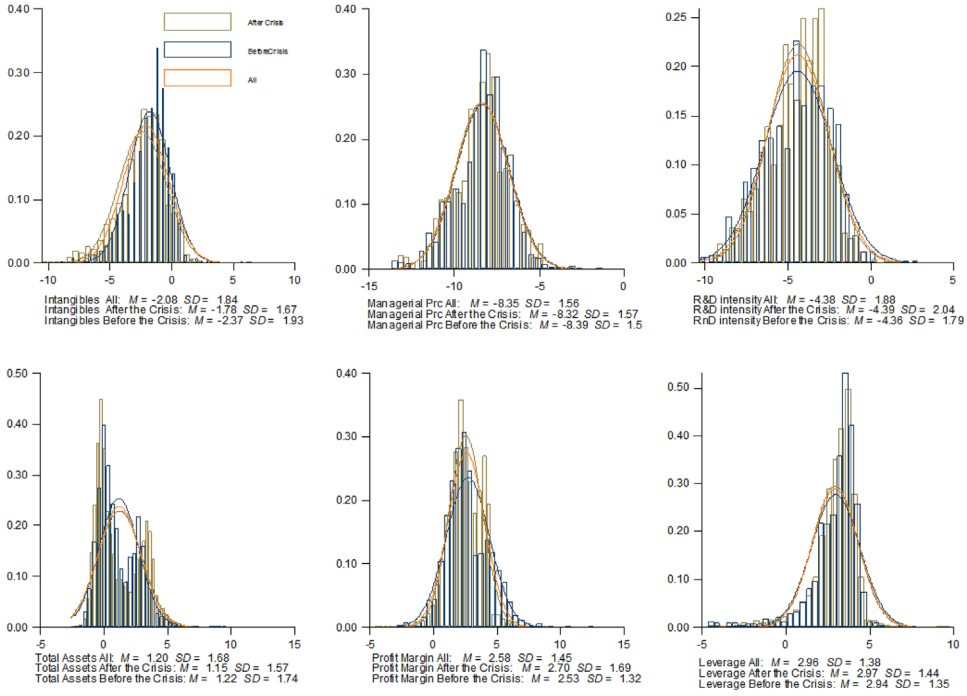


Fig. 2. Histograms

These figures represent the distribution of the data and plot histograms for all the variables in pre- & post-crisis periods and in overall sample. From these figures, it is seen that standard deviation of post crisis profit margins increases showing a higher volatility of profit margins across all firms in the after-crisis sample. The same is also true for the leverage and R&D intensity as these two are both highly volatile. However interestingly, the volatility of total assets declines post-crisis, unlike the intangibles in pre-crisis which had higher volatility.

We conducted the Arellano-Bond test that was developed by Arellano and Bond (1991) to test for autocorrelation in the idiosyncratic disturbance term. The instrument set is restricted to 3 lags, as in all of the models only order-1 serial correlation (AR (1)) is found. The test for AR (1) and AR (2) validates the existence of first order autocorrelation. A longer set of lags would be needed if the order-2 serial correlation was observed, which is not found in our estimated models. Because we have only level 1 serial correlation and we test AR (1) and AR (2), we limited our maximum lagged variables to be instrumented to lag 3.

The Wald test works by testing the null hypothesis that the two coefficients of interest are simultaneously equal to zero. The rejection of the null hypothesis indicates that the coefficients are not simultaneously equal to zero. The result indicates that the model and selected variables are valid.

4. Empirical Results

As our primary empirical analysis, we estimate the impact of R&D investments, intangible assets and managerial practices on firm performance using net profit margin

Table 2

Descriptive statistics

This table presents descriptive statistics of our main variables and elaborates the managerial practices index in detail along with summary statistics for the variables used in constructing managerial practice index in our estimations. The detailed explanations of the Managerial Practice index can be found in Table 1c. The descriptive statistics were presented further for the full sample, pre-crisis and post-crisis sub-samples. Pre-crisis period covers 1992 to 2008 and post-crisis period covers 2009 till 2014. High MPI firms indicate high managerial practice intensive firms and low MPI indicates low managerial practice intensive firms. High MPI firms are firms with managerial practices above the mean, and low MPI firm is the one below mean (Mean MP=332.01).

Pre- Crisis Period (1992–2008)						Post-Crisis Period (After 2009–2014)						Full Sample (1992–2014)					
Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Obs	Mean	Std.Dev.	Min	Max	Variable	Obs	Mean	Std.Dev.	Min	Max
PM	6354	0.19	1.66	−41.70	78.21	*PM*	3364	0.68	11.48	−91.15	376.10	*PM*	10225	0.31	6.82	−91.15	376.10
R&D	6342	0.01	0.09	0	4.57	*R&D*	3214	0.02	0.40	0	18.96	*R&D*	10103	0.02	0.24	0	18.96
Int	6467	0.15	0.64	0	29.04	*Int*	3210	0.45	6.78	0	376.29	*Int*	10224	0.26	3.87	0	376.29
DtoC	6545	0.12	9.17	−550.44	175.49	*DtoC*	3203	0.29	0.64	−5.27	23.94	*DtoC*	10302	0.18	7.32	−550.44	175.49
Mngprc Index Details						***Mngprc Index Details***						***Mngprc Index Details***					
Cgvs	1101	59.72	30.86	12.62	98.64	*cgvs*	1502	65.15	27.23	9.09	94.54	*cgvs*	2862	62.80	29.04	9.09	98.64
intpromot	1101	48.84	27.46	26.84	99.75	*intpromot*	1502	60.14	33.95	22.20	91.92	*intpromot*	2862	55.64	32.07	22.20	99.75
tdimprov	1101	47.39	8.37	44.98	100.00	*tdimprov*	1502	47.01	13.95	42.45	100.00	*tdimprov*	2862	47.19	12.02	42.45	100.00
univpart	1101	49.28	32.25	16.80	96.59	*univpart*	1502	58.33	31.51	9.77	81.16	*univpart*	2862	54.47	32.25	9.77	96.59
Sotd	1101	59.47	28.47	6.52	96.78	*sotd*	1502	65.96	24.54	5.17	95.27	*sotd*	2862	63.37	26.33	5.17	96.78
prodinnov	1101	45.94	28.26	8.35	99.68	*prodinnov*	1502	50.27	29.86	10.89	97.65	*prodinnov*	2862	48.54	29.32	8.35	99.68
Total						***Total***						***Total***					
Mngprc	1101	310.65	104.07	125.50	580.76	*Mngprc*	1502	346.87	108.14	103.04	555.52	*Mngprc*	2862	332.01	107.87	103.04	580.76

Notes: Sample is separated before and after crisis period to observe how innovation and managerial practices vary following the crisis.

Table 2

Continued

High MPI firms						Low MPI firms					
Variable	Obs	Mean	Std.Dev	Min	Max	Variable	Obs	Mean	Std.Dev.	Min	Max
PM	8866	0.32	7.24	−91.15	376.10	*PM*	1359	0.23	2.95	−36.17	85.00
R&D	8725	0.02	0.25	0	18.96	*R&D*	1378	0.01	0.04	0	0.55
Int	8847	0.24	4.12	0	376.29	*Int*	1377	0.37	1.58	0	54.85
DtoC	8926	−0.04	3.28	−296.61	1.75	*DtoC*	1376	0.00	0.01	−0.07	0.24
Mngprc Index Details						***Mngprc Index Details***					
Cgvs	1471	80.97	18.57	11.12	98.64	*Cgvs*	1391	43.58	25.53	9.09	98.61
Intpromot	1471	71.08	30.55	22.20	99.75	*Intpromot*	1391	39.31	24.72	22.20	99.75
Tdimprov	1471	49.40	16.15	42.45	100.00	*Tdimprov*	1391	44.85	3.33	42.45	100.00
Univpart	1471	74.39	22.51	9.77	96.59	*Univpart*	1391	33.41	27.23	9.77	96.59
Sotd	1471	81.76	11.81	31.06	96.78	*Sotd*	1391	43.92	23.29	5.17	95.49
Prodinnov	1471	63.68	28.28	8.90	99.68	*Prodinnov*	1391	32.54	20.60	8.35	99.58
Total						***Total***					
Mngprc	1471	421.28	55.23	332.04	580.76	***Mngprc***	1391	237.60	58.07	103.04	331.94

Table 3

Correlation matrix

This table presents correlation matrix providing information on the correlation between innovation, managerial practices and leverage variables. It contains pairwise correlation coefficients and the level of significance of the correlation. * indicates 10% significance level.

		1	2	3	4	5	6	7	8	9	10	11	12
1	*PM*	1											
2	*Int*	0.1497*	1										
3	*R&D*	0.2022*	0.2504*	1									
4	*Mngprc*	0.4023*	0.0413*	0.3466*	1								
5	*R&D*mngprc*	−0.1968*	−0.4068*	−0.9310*	−0.6410*	1							
6	*Int*mngprc*	−0.1616*	−0.9492*	−0.4171*	−0.2817*	0.5172*	1						
7	*Int*R&D*	−0.1823*	−0.8641*	−0.5613*	−0.2554*	0.5989*	0.8915*	1					
8	*DtoC*	−0.2258*	0.0095	−0.2906*	−0.1924*	0.3171*	0.0261	0.0974*	1				
9	*TotA*	0.1882*	0.1603*	0.1122*	0.1466*	0.1115*	−0.0548*	−0.0565*	−0.0032	1			
10	*Int_sq*	−0.0862*	−0.8809*	−0.1795*	0.0340*	0.3515*	0.8365*	0.8156*	−0.0095	0.0349*	1		
11	*Mngprc_sq*	−0.3584*	−0.0558*	−0.3203*	−0.9898*	0.6252*	0.3015*	0.2652*	0.1824*	−0.0929*	−0.0118	1	
12	*TotA_sq*	0.593*	0.138*	0.0467*	0.2114*	0.2348*	−0.0154	−0.0225	−0.2254*	0.2634*	0.022*	−0.1465*	1

Table 4

Baseline estimations: Impact of R&D and intangible assets on firm performance

This table presents baseline estimations by using OLS from 1992–2014. Standard errors are shown in parentheses. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented Total assets. Additionally, the last column estimates dynamic OLS. So in column (8) the lagged dependent variable is added as a regressor to the equation, to control for the dynamic relationship between innovation and firm performance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D	0.108***	0.0955***	0.101***	0.128***	0.138***	0.484***	0.470***	0.186**
	[0.0115]	[0.0133]	[0.0182]	[0.0250]	[0.0257]	[0.111]	[0.112]	[0.0880]
Int		0.0588***	0.0584**	0.163**	0.00269	−0.176	−0.190	−0.166
		[0.0153]	[0.0262]	[0.0712]	[0.123]	[0.135]	[0.135]	[0.105]
Mngprc			−0.0198	−0.0207	−0.0652*	0.0796	0.0708	0.0162
			[0.0211]	[0.0210]	[0.0350]	[0.0572]	[0.0575]	[0.0446]
Intellectual Capital Interactions								
*R&D*Int*				0.0181	0.0220*	0.0219*	0.0210*	0.00846
				[0.0115]	[0.0117]	[0.0117]	[0.0117]	[0.00906]
*Int*mngprc*					−0.0201	−0.0410***	−0.0422***	−0.0250**
					[0.0127]	[0.0142]	[0.0142]	[0.0112]
*R&D*mngprc*						0.0404***	0.0392***	0.0146
						[0.0126]	[0.0127]	[0.00989]
DtoC							−0.0811	−0.0299
							[0.0553]	[0.0421]
PM $_{(t-1)}$								0.580***
								[0.0285]
Constant	2.405***	2.459***	2.437***	2.567***	2.228***	3.435***	3.372***	1.330***
	[0.0556]	[0.0647]	[0.175]	[0.193]	[0.288]	[0.475]	[0.477]	[0.382]
Observations	2,064	1,611	813	813	813	813	811	761
Company Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
r^2	0.0409	0.0493	0.0612	0.0641	0.0670	0.0787	0.0813	0.408
Adjusted R-square	0.0404	0.0481	0.0577	0.0595	0.0612	0.0718	0.0733	0.402
F	87.86	41.72	17.59	13.8	11.59	11.47	10.15	64.82

as a performance measure. The results are reported in Table 4. All the variables are used in a logarithmic scale, to prevent scaling differences in our estimation and to provide consistency in units. Additionally, all the variables are represented as a ratio of sales to observe the impact of the variable on firm performance for each additional unit of output. To keep our results consistent, we used these representations throughout all the tables. The results from Table 4 suggest that incorporating time and company fixed effects along with the first lag of profit margin does not give very robust results. This is due to the potential endogeneity and heterogeneity in our dataset which is addressed by using Dynamic System GMM in the rest of the tables. Our benchmark estimations are conducted using Dynamic GMM estimates, and the results are shown in Table 5a. The model we estimate is given in equation (1). The result that can be inferred is that neither solely intangible assets nor managerial practices alone are enough for optimal firm performance. Therefore, the firm performance can be improved only if those two are combined within a firm. Equation (1) is based on model (8) from Table 5a:

$$\begin{aligned} PM_{i,t} = {} & \beta_0 + \beta_1 PM_{i,t-1} - \beta_2 (Int)_{i,t} + \beta_3 logR\&D_{i,t} + \beta_5 (Mngprc)_{i,t} \\ & + \beta_4 (Int)_{i,t} * R\&D_{i,t} + \beta_5 (MngPrc)_{i,t} * logR\&D_{i,t} \\ & - \beta_6 (MngPrc)_{i,t} * (Int)_{i,t} - \beta_7 (DtoC)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{1}$$

where,
i: denotes each company listed in FTSE; *t:* time periods;
$PM_{i,t}$: Profit margin of company i in time t (our dependent variable);
$PM_{i,t-1}$: Profit margin of company i in time t–1 (lagged dependent variable);
$(Int)_{i,t}$: Intangible ratio of company i in time *t;*
$logR\&D_{i,t}$: R&D intensity of company i in time *t;*
$(Mngprc)_{i,t}$: Managerial practices of company i in time *t;*
$(DtoC)_{i,t}$: Leverage ratio of company i in time *t.*

Throughout the estimations in the Table 5a, R&D is positive. However, intangible assets appear to be negative, which may seem unexpected. To analyse further, we introduce interaction terms that will help us understand the complex relationship of R&D, managerial practices, and intangibles in the model. Furthermore, there is an optimal level of the joint impact of intangibles and R&D or intangibles and managerial practices for each company, beyond which firm performance can decline because any additional R&D spending can become sunk cost.

4.1. *Marginal effects*

After the OLS estimations in Table 4, in Table 5a we present the benchmark model using Dynamic System GMM regression to overcome the endogeneity problems. Following the estimations in Table 5a model (8) in column (8), we then estimated the marginal effects shown in Figure 3. The estimation of marginal effects on profit margins is carried out at different percentiles (10^{th}, 25^{th}, mean, 50^{th}, 75^{th}, 90^{th}, 95^{th} and 99^{th}). Marginal effects estimations assist us in determining at what level, profit margin is affected, and we check whether the interactions are correctly specified and justify the marginal effects of R&D, intangibles and managerial practice on firm performance at different levels. Figure 3 shows the marginal effects of intangible

Table 5a

Benchmark estimations: Impact of managerial practice and innovation on firm performance using dynamic GMM

This table presents benchmark estimations using dynamic GMM from 1992–2014, using variables' own lags as GMM type instruments. Standard errors are shown in parentheses. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We conducted Wald Chi-square test, Sargan test and AB test for AR (1) and AR(2).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$PM_{(t-1)}$	0.154***	0.154***	0.164***	0.163***	0.168***	0.200***	0.203***	0.194***
	[0.00519]	[0.00365]	[0.00163]	[0.00219]	[0.00596]	[0.00329]	[0.00372]	[0.00565]
R&D	0.0441***	0.0153***	0.00765**	0.0943***	0.217***	0.0491***	0.290***	0.295***
	[0.00496]	[0.00331]	[0.00377]	[0.0253]	[0.0399]	[0.00578]	[0.0363]	[0.0290]
Int		−0.0158***	−0.0983***	−0.0601***	−0.155***	0.105***	−0.0715**	−0.0412
		[0.00210]	[0.00468]	[0.00335]	[0.0348]	[0.0393]	[0.0314]	[0.0364]
Mngprc			0.0184***	0.145***	0.0650**	−0.0259**	0.0686***	0.0789***
			[0.00451]	[0.0138]	[0.0274]	[0.0113]	[0.0163]	[0.00918]
Intellectual Capital Interactions								
*R&D*mngprc*				0.0136***	0.0250***		0.0294***	0.0306***
				[0.00283]	[0.00419]		[0.00375]	[0.00248]
*Int*mngprc*					−0.0136***	0.00181	−0.0192***	−0.0182***
					[0.00336]	[0.00447]	[0.00454]	[0.00399]
*Int*R&D*						0.0221***	0.0215***	0.0243***
						[0.00257]	[0.00320]	[0.00293]
DtoC								−0.0533***
								[0.00361]
Constant	1.875***	1.725***	1.793***	2.790***	2.225***	1.638***	2.365***	2.460***
	[0.0305]	[0.0152]	[0.0365]	[0.109]	[0.258]	[0.0782]	[0.159]	[0.0999]
Observations	1,815	1,451	763	763	763	763	763	761
chi2 (Wald test)	1,028.7	2,793.5	55,341.6	34,677.3	2,067.2	9,671.0	16,023.5	8,643.6
Adjusted R-square	0.310	0.294	0.191	0.169	0.159	0.193	0.178	0.147
Sargan	126.5	128.1	105.1	101.0	102.6	101.7	102.6	101.6
AR (1)	−5.734	−5.322	−3.802	−3.806	−3.790	−3.807	−3.791	−3.773
AR (2)	0.967	1.030	1.244	1.266	1.318	1.320	1.381	1.389

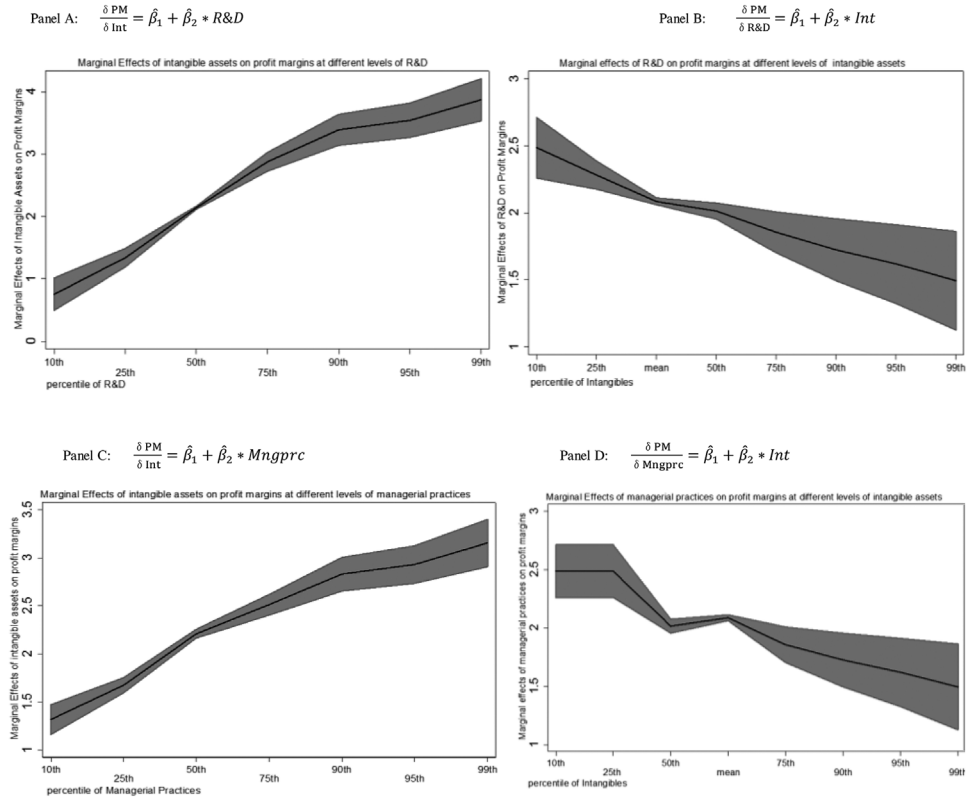


Fig. 3. Marginal effects

The figures show the marginal effects plots based on marginal effect estimations from Table 5a.

assets at different levels of R&D, the marginal effects of R&D intensity at different levels of intangible assets, the marginal effects of intangibles at different levels of managerial practices, and the marginal effects of managerial practices at different levels of intangible assets.

First, in Figure 3 (Panel A), we show the marginal effect of intangible assets on firm performance at different levels of R&D to justify the significance and direction of the joint relationship between R&D and intangibles and whether this interaction has an impact on profit margins. It is observed that marginal effects of intangible assets are higher at a higher percentile of R&D. Clearly, the figure shows that companies with R&D intensity at higher percentiles benefit more from intangible assets in achieving better firm performance. An increasing pattern is observed with a significant positive coefficient of the interaction term of R&D and intangible assets; the joint impact of those two positively influences firm performance. The intangible assets have a higher impact on profitability with higher levels of R&D. Furthermore, we also investigated the marginal effects of R&D on profit margins at different levels of intangible assets and found a declining pattern, reported in Panel B. This indicates that the marginal effects of R&D on profit margins decline but remain positive with higher levels of intangible assets. This can be due to the direct negative

impact of intangibles on profit margins during the pre-crisis period which dominates the whole sample.

Also, we investigate the marginal effect of intangibles on firm performance at different levels of managerial practices shown in Panel C of Figure 3. It is observed that marginal effects of intangible assets are higher with higher levels of managerial practices, meaning that the impact of intangible assets is greater when the company has better managerial practices. Furthermore, we also examined the marginal effects of managerial practices on profit margins at different levels of intangibles in Panel D showing a declining pattern, which suggests that the marginal effects of managerial practices on profit margin decline with higher levels of intangible assets. The interaction term from this estimation is negative and significant throughout, justifying the opposite relationship between managerial practices and intangibles.

4.2. *U-test and the application of Schumpeterian Theory of Innovation: Creative destruction and creative accumulation*

According to Schumpeter (1942), innovation results in *creative destruction*, or the situation when the recent innovation replaces or destroys previous innovation, showing an inverse U-shaped relationship . As stated by Gallini (1992), Horowitz and Lai (1996) and later shown by Qian (2007), innovation has an *'inverted U-shaped curve'*, meaning that there is an optimal level of innovation above which further patent protection actually has an adverse effect on innovation.

By examining the relationships between indicators of Schumpeterian patterns of innovation and indicators of the variables defining technological regimes empirically, Breschi *et al.* (2000) suggest that different technological regimes lead the industry to two patterns of innovations in Schumpeterian thought. The first pattern is where *deepening,* or *creative accumulation* takes place, where innovator firms continue to innovate and accumulate knowledge. The second pattern is *creative destruction* where innovations are made by innovators that did not innovate before, causing *widening.* The two patterns are best explained by the suitability of conditions and technological opportunities available plus the existence of relevant knowledge base in the industry. It has been shown by Breschi *et al.* (2000) that fewer technological opportunities, better suitability of conditions and more cumulative knowledge carry a system towards (*deepening) creative accumulation* pattern. However, more technological opportunities, suitable conditions, and a relevant knowledge base will move towards a *(widening) creative destruction* pattern.

According to Gilbert (2006), 'the incentive to innovate is the difference in profit that a firm can earn if it invests in research and development compared to what it would earn if it did not invest'. Differences in market structure, the characteristics of innovations, the feature discovery, and whether exclusive or non-exclusive rights protect the innovations, can impact the innovation–firm performance relationship. In fact, whether a new technology can be sold or licensed is usually determined by exclusive rights, such as patents. Those rights allow for independent invention and the ability to adapt new processes ahead of rivals. Consequently, an increase in the number of competing firms decreases the value of each discovery, because the use of a 'new technology' by many firms reduces each firm's stake in the entire output created by that new technology. So, in general, Gilbert's suggestions are consistent with

Schumpeter's concept of 'creative destruction' that accepts monopolies as temporary and new competition can arise.

Following the regressions in Table 5b, we conducted a U-test for our main explanatory variables: managerial practices, intangibles and R&D intensity reported in Table 5c. The test results suggest that intangible assets and managerial practices have inverse U shapes, while R&D intensity is not U-shaped or inverse U-shaped. Then, throughout the estimations, we added squared terms of intangibles and managerial practices. The results also support our hypotheses for intangible assets before and after a crisis. The interpretation of the inverse U-shape relationship in intangible assets is that there is a threshold for intangible assets. Up to certain level, intangibles have a positive impact on firm performance, meaning that each additional unit of intangibles has a positive contribution to firm performance. However, beyond that threshold, the effect tends to decline. That is also true for managerial practices. Indeed, this result is consistent with the Schumpeterian theory of creative destruction discussed above. In addition to the models in Table 5a, we added a squared term of intangibles and squared term of managerial practices in model (10) of Table 5b. The model we obtained is shown in equation (2).

$$PM_{i,t} = \beta_0 + \beta_1 PM_{i,t-1} - \beta_2 (Int)_{i,t} + \beta_3 logR\&D_{i,t} + \beta_5 (Mngprc)_{i,t}$$

$$+\beta_4 (Int)_{i,t} * R\&D_{i,t} + \beta_5 (MngPrc)_{i,t} * logR\&D_{i,t} - \beta_6 (MngPrc)_{i,t} * (Int)_{i,t}$$

$$-\beta_7 (DtoC)_{i,t} + \beta_8 (Int)^2_{i,t} - \beta_9 (Mngprc)^2_{i,t} + \varepsilon_{i,t} \quad (2)$$

The relationships shown in the benchmark equation (Table 5a in the last column) are again maintained in the last column of Table 5b where all of the explanatory variables, interaction terms, and squared terms are included in the estimation model. R&D intensity and managerial practices have positive impacts on firm performance while intangible assets still seem to have a negative impact. The interaction terms, however, have positive coefficients, apart from intangibles with managerial practices. The squared term of intangibles, however, has a positive coefficient, which confirms the inverse U-shaped nature of intangible assets.

4.3. *The role of financial leverage in the innovation and firm performance relationship*

Firms with high financial leverage or financial constraints are expected to behave differently than others, and therefore, they need to be analysed in detail. The joint impact of managerial practices, R&D and intangible assets should differ with financial constraints; a firm with higher financial constraints will cut R&D investments or operational expenses such as salaries, wages and skills training. To examine the impact of financial leverage, starting from Table 6, we introduced leverage, and interaction terms with leverage to show how managerial practices and innovation impact firm performance in financially constrained firms. When leverage alone is added to estimation, it has a negative impact; this is in line with the previous literature. However, we argue that this may change for a firm with better managerial practices and a greater focus on innovation.

Table 5b

Nonlinearity of managerial practice and innovation

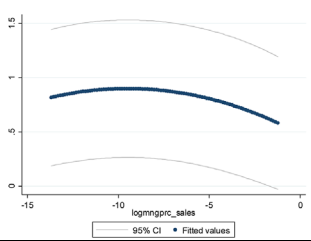
This table presents dynamic GMM estimations from 1992–2014, using lagged variables as GMM type instruments. Standard errors are shown in brackets. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We conducted Wald Chi-square test, Sargan test and Arellano-Bond test for AR (1) and AR (2).

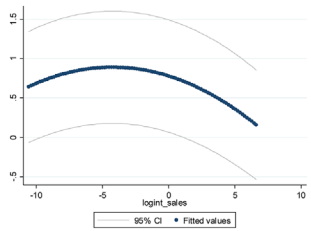
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PM $_{(t-1)}$	0.154***	0.154***	0.164***	0.163***	0.168***	0.200***	0.203***	0.194***	0.209***	0.210***
	[0.00519]	[0.00365]	[0.00163]	[0.00219]	[0.00596]	[0.00329]	[0.00372]	[0.00565]	[0.00580]	[0.00770]
R&D	0.0441***	0.0153***	0.00765**	0.0943***	0.217***	0.0491***	0.290***	0.295***	0.273***	0.358***
	[0.00496]	[0.00331]	[0.00377]	[0.0253]	[0.0399]	[0.00578]	[0.0363]	[0.0290]	[0.0415]	[0.0385]
Int		−0.0158***	−0.0983***	−0.0601***	−0.155***	0.105***	−0.0715**	−0.0412	−0.0770	−0.0656
		[0.00210]	[0.00468]	[0.00335]	[0.0348]	[0.0393]	[0.0314]	[0.0364]	[0.0524]	[0.0669]
Mngprc			0.0184***	0.145***	0.0650**	−0.0259**	0.0686***	0.0789***	0.0477***	0.141**
			[0.00451]	[0.0138]	[0.0274]	[0.0113]	[0.0163]	[0.00918]	[0.0157]	[0.0568]
Intellectual Capital Interactions										
*R&D*mngprc*				0.0136***	0.0250***		0.0294***	0.0306***	0.0278***	0.0334***
				[0.00283]	[0.00419]		[0.00375]	[0.00248]	[0.00466]	[0.00426]
*Int*mngprc*					−0.0136***	0.00181	−0.0192***	−0.0182***	−0.0206***	−0.0235***
					[0.00336]	[0.00447]	[0.00454]	[0.00399]	[0.00620]	[0.00619]
*Int*R&D*						0.0221***	0.0215***	0.0243***	0.0145***	0.0212***
						[0.00257]	[0.00320]	[0.00293]	[0.00225]	[0.00364]
DtoC								−0.0533***	−0.0590***	−0.0563***
								[0.00361]	[0.00538]	[0.00905]
Squared Terms										
int_sq									0.00849***	0.00864***
									[0.00147]	[0.00106]
mngprc_sq										0.000553
										[0.00294]
Constant	1.875***	1.725***	1.793***	2.790***	2.225***	1.638***	2.365***	2.460***	2.221***	3.257***
	[0.0305]	[0.0152]	[0.0365]	[0.109]	[0.258]	[0.0782]	[0.159]	[0.0999]	[0.138]	[0.324]
Observations	1,815	1,451	763	763	763	763	763	761	761	
chi^2 (Wald test)	1,028.7	2,793.5	55,341.6	34,677.3	2,067.2	9,671.0	16,023.5	8,643.6	10,096.6	761
Adjusted R-square	0.310	0.294	0.191	0.169	0.159	0.193	0.178	0.147	0.197	0.200
Sargan	126.5	128.1	105.1	101.0	102.6	101.7	102.6	101.6	101.5	462.4
AR (1)	−5.734	−5.322	−3.802	−3.806	−3.790	−3.807	−3.791	−3.773	−3.810	100.0
AR (2)	0.967	1.030	1.244	1.266	1.318	1.320	1.381	1.389	1.460	−3.846

Table 5c

U-tests for testing non-linearity

Variable	*t* value	P>|*t*|	Decision
Mngprc	10.88	2.81e-27	We reject the H_0 with 0.05 (5%) significance level, H_0 = Inverse U-shaped or monotone H_1 = U-shaped
Int	6.23	2.59e-10	We reject H_0 with 0.05 (5%) significance level H_0 = U-shaped or monotone H_1 = Inverse U-shaped
R&D	0.85	0.197	We cannot reject Ho. H_0 = Inverse U-shaped or monotone H_1 = U-shaped





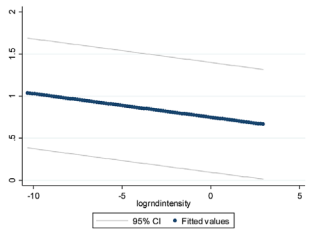


Table 6

Impact of leverage and U-shaped relationship of innovation on firm performance

This table presents dynamic GMM estimations from 1992–2014, using lagged variables as GMM type instruments. Standard errors are shown in brackets. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We conducted Wald Chi-square test, Sargan test and Arellano-Bond tests for AR (1) and AR (2).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
PM $_{(t-1)}$	0.154***	0.154***	0.164***	0.163***	0.168***	0.200***	0.203***	0.194***	0.188***	0.192***	0.209***	0.226***	0.230***	0.230***	0.234***
	[0.0052]	[0.0037]	[0.0016]	[0.0022]	[0.0060]	[0.0033]	[0.0037]	[0.0057]	[0.0052]	[0.0046]	[0.0043]	[0.0075]	[0.0075]	[0.0065]	[0.0064]
R&D	0.044***	0.015***	0.0076**	0.094***	0.217***	0.049***	0.290***	0.295***	0.289***	0.577***	0.468***	0.590***	0.433***	0.612***	0.421***
	[0.005]	[0.003]	[0.0037]	[0.025]	[0.040]	[0.0058]	[0.0363]	[0.0290]	[0.0309]	[0.0404]	[0.0271]	[0.0305]	[0.0245]	[0.0429]	[0.0489]
Int		−0.016***	−0.098***	−0.060***	−0.155***	0.105***	−0.0715**	−0.0412	−0.0604	−0.132***	−0.132***	−0.221***	−0.229***	−0.229***	−0.271***
		[0.0021]	[0.00468]	[0.00335]	[0.0348]	[0.0393]	[0.0314]	[0.0364]	[0.0578]	[0.0508]	[0.0258]	[0.0457]	[0.0541]	[0.0506]	[0.0680]
Mngprc			0.018***	0.145***	0.0650**	−0.0259**	0.069***	0.079***	0.093***	0.266***	0.198***	0.215***	0.154***	0.372***	0.365***
			[0.00451]	[0.0138]	[0.0274]	[0.0113]	[0.0163]	[0.0092]	[0.0114]	[0.0331]	[0.0116]	[0.0143]	[0.0224]	[0.0720]	[0.0763]
Int. Capital Interactions															
R&D mngprc*				0.014***	0.025***		0.029***	0.031***	0.027***	0.061***	0.049***	0.060***	0.049***	0.059***	0.043***
				[0.0028]	[0.0041]		[0.0038]	[0.00248]	[0.0031]	[0.00441]	[0.0027]	[0.0025]	[0.0024]	[0.0042]	[0.0042]
Int mngprc*					−0.014***	0.0018	−0.019***	−0.018***	−0.021***	−0.022***	−0.029***	−0.029***	−0.025***	−0.035***	−0.036***
					[0.0033]	[0.0045]	[0.0045]	[0.004]	[0.0069]	[0.0054]	[0.0035]	[0.0066]	[0.0048]	[0.0040]	[0.0069]
int R&D*						0.022***	0.022***	0.024***	0.027***	0.036***	0.036***	0.016***	−0.017***	0.026***	−0.00368
						[0.0026]	[0.0032]	[0.003]	[0.002]	[0.0023]	[0.0032]	[0.0054]	[0.0049]	[0.0057]	[0.0069]
DtoC								−0.053***	−0.194***	0.820***	0.244***	0.335**	0.450***	0.507***	0.599***
								[0.0036]	[0.020]	[0.0413]	[0.0319]	[0.150]	[0.081]	[0.0719]	[0.0932]
Leverage Interactions															
Mngprcs* *rnd* lrev*									0.005***			−0.00172	−0.007***	−0.00161	−0.007***
									[0.0006]			[0.003]	[0.0022]	[0.002]	[0.00274]

Table 6
Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
*Int*mngprcs*lev*										−0.038***		−0.0264**	−0.047***	−0.039***	−0.061***
										[0.0019]		[0.0126]	[0.00791]	[0.00771]	[0.0106]
*Int*rnd*lev*											−0.025***	0.022	0.065***	0.034**	0.08***
											[0.00259]	[0.018]	[0.0138]	[0.014]	[0.019]
Squared Terms															
Int_sq													0.02***		0.019***
													[0.003]		[0.0027]
Mngprc_sq														0.0066*	0.0124**
														[0.004]	[0.005]
Constant	1.875***	1.725***	1.793***	2.790***	2.225***	1.638***	2.365***	2.460***	2.691***	3.837***	3.376***	3.654***	2.953***	4.594***	4.015***
	[0.0305]	[0.0152]	[0.0365]	[0.109]	[0.258]	[0.0782]	[0.159]	[0.0999]	[0.0585]	[0.281]	[0.0840]	[0.148]	[0.220]	[0.348]	[0.300]
Observations	1,815	1,451	763	763	763	763	763	761	761	761	761	761	761	761	761
chi^2 (Wald test)	1,028.7	2,793.5	5,5341.6	34,677.3	2,067.2	9,671.0	16,023.5	8,643.6	6,922.2	14,813.7	100,503.3	60,134.2	1,075,7830	1,176,4250	1,548,7410
Adjusted R-square	0.310	0.294	0.191	0.169	0.159	0.193	0.178	0.147	0.162	0.176	0.133	0.186	0.225	0.150	0.201
Sargan	126.5	128.1	105.1	101.0	102.6	101.7	102.6	101.6	102.9	103.0	96.06	100.1	97.19	99.84	95.91
AR (1)	−5.734	−5.322	−3.802	−3.806	−3.790	−3.807	−3.791	−3.773	−3.764	−3.782	−3.781	−3.825	−3.840	−3.802	−3.811
AR (2)	0.967	1.030	1.244	1.266	1.318	1.320	1.381	1.389	1.383	1.432	1.467	1.566	1.614	1.575	1.605

In Table 6 column (8), leverage on its own has a negative impact on firm performance. However, in columns (9) through (11), the impacts turn positive when leverage is interacted with managerial practices and R&D; intangibles and managerial practice; and finally, intangibles and R&D, one by one and together in column (12). The positive impact of managerial practices and R&D jointly means firms with better managerial practices and R&D performance, in general, can overcome the negative impact of leverage. The following equation (3) is estimated and shown in the last column of Table 6.

$$PM_{i,t} = \beta_0 + \beta_1 PM_{i,t-1} - \beta_2 (Int)_{i,t} + \beta_3 logR\&D_{i,t} + \beta_5 (Mngprc)_{i,t}$$

$$-\beta_4 (Int)_{i,t} * R\&D_{i,t} + \beta_5 (MngPrc)_{i,t} * logR\&D_{i,t} \quad \beta_6 (MngPrc)_{i,t} * (Int)_{i,t}$$

$$+\beta_7 (DtoC)_{i,t} + \beta_8 (Int)^2_{i,,t} + \beta_9 (Mngprc)^2_{i,,t} + \beta_{10} (DtoC)_{i,t} * (Int)_{i,t} * R\&D_{i,t}$$

$$-\beta_{11} (DtoC)_{i,t}. * (Mngprc)_{i,t} * logRnD_{i,t} - \beta_{12} (DtoC)_{i,t} * (Mngprc)_{i,t} * (Int)_{i,t}$$

$$+\beta_8 (Int)^2_{i,,t} + \beta_9 (Mngprc)^2_{i,,t} + \varepsilon_{i,t} \tag{3}$$

In Table 6, we use leverage, and interactions with leverage to analyse situations with financial constraints. In columns (9) to (12), we added leverage interactions. In columns (13) to (15), however, we added squared terms of intangibles and managerial practices separately and together in the estimation to show the impact of leverage on innovation performance in the presence of nonlinearity. Results suggest that the joint impact of R&D, managerial practices and intangibles are positive for firms without leverage; however, when we look at firms with financial leverage, the relationship changes. While firms that combine R&D and intangibles tend to be impacted positively from leverage, leverage otherwise still has a negative impact on firms.

4.4. *The impact of the recent financial crisis on the innovation–firm performance relationship*

When we conducted our estimation with the full sample, we found that intangible assets had a negative impact on firm performance. However, these hypotheses as in the existing literature suggested that intangibles have a positive impact on firm performance. Because our full sample covers the periods before crisis and post-crisis, we, therefore, want to observe the relationship of managerial practices, innovation and firm performance both before and after the crisis, as well as to look at the puzzle on the effect of intangible assets. Therefore, in Table 7, we divide our analysis into two parts: before the crisis (before 2008) and after the crisis (2008 and later). The estimations in Table 7 show the impact of intangibles on firm performance is both positive and negative in two sub-periods (i.e., before and after the crisis).

Before the crisis, intangibles have a positive impact on firm performance. After the crisis period, this turns negative. Having a higher amount of intangible assets probably helped these companies before the crisis. However, they may not have had enough tangible assets and were overvalued before the crisis. With the change in perception

Table 7

Assessing the impact of crisis on firm performance by estimating the benchmark model for two sub-periods

This table presents dynamic GMM estimations from 1992–2014, using lagged variables as GMM type instruments. Standard errors are shown in brackets. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We conducted Wald Chi-square test, Sargan test and Arellano-Bond tests for AR (1) and AR (2).

	Pre-Crisis				Post-Crisis				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PM $_{(t-1)}$	0.148***	0.136***	0.126***	0.133***	0.0652***	0.0515***	0.0833***	0.0623***	0.0630***
	[0.0054]	[0.0064]	[0.0085]	[0.0088]	[0.0022]	[0.0031]	[0.0034]	[0.0037]	[0.0041]
R&D	0.148*	0.173***	0.163**	−0.0123	0.353***	0.420***	0.189***	0.335***	0.276***
	[0.0787]	[0.0542]	[0.0722]	[0.0561]	[0.0253]	[0.0309]	[0.0530]	[0.0487]	[0.0356]
Int	0.448***	0.455***	0.182***	0.0768	−0.374***	−0.346***	0.0234	−0.0705	−0.0691
	[0.0204]	[0.0500]	[0.0602]	[0.0873]	[0.0360]	[0.0347]	[0.0646]	[0.0597]	[0.0614]
Mngprc	0.153***	0.144***	0.103***	0.355***	0.0853***	0.136***	−0.0264	0.0359*	−0.0296
	[0.0552]	[0.0293]	[0.0381]	[0.131]	[0.0262]	[0.0211]	[0.0267]	[0.0215]	[0.148]
Intellectual Capital Interactions									
*R&D*mngprc*	0.0149	0.0159***	0.0232***	−0.000598	0.0412***	0.0491***	0.0195***	0.0342***	0.0234***
	[0.0091]	[0.0046]	[0.0065]	[0.0073]	[0.0029]	[0.0042]	[0.0049]	[0.0042]	[0.0045]
*Int*R&D*	0.0288***	0.0348***	0.00269	0.0164	−0.00594**	−0.00392	0.00829*	0.0102**	0.0202***
	[0.0030]	[0.0029]	[0.0076]	[0.0118]	[0.0024]	[0.0028]	[0.0050]	[0.0047]	[0.0046]
*Int*mngprc*	0.0296***	0.0257***	−0.0107	−0.0282**	−0.0400***	−0.0396***	−0.0117*	−0.0225***	−0.0311***
	[0.0025]	[0.0049]	[0.0099]	[0.0136]	[0.0036]	[0.0033]	[0.0063]	[0.0067]	[0.0078]
DtoC		−0.290***	−0.285***	−0.262***		−0.119***		−0.116***	−0.115***
		[0.0298]	[0.0198]	[0.0186]		[0.0020]		[0.0043]	[0.0037]
Squared Terms									
Int_sq			0.0505***	0.0479***			0.0047*	0.00323	0.00439**
			[0.0049]	[0.0050]			[0.0025]	[0.0027]	[0.0017]
Mngprc_sq				0.0216**					−0.0041
				[0.0104]					[0.0089]
Constant	3.272***	3.415***	2.874***	3.523***	2.613***	3.121***	1.823***	2.530***	2.469***
	[0.469]	[0.293]	[0.330]	[0.434]	[0.230]	[0.138]	[0.225]	[0.185]	[0.627]
Observations	281	281	281	281	408	406	408	406	406
chi^2 (Wald test)	9,120,317.5	358,078.0	31,054.3	214,534.5	7,208.4	36,645.1	58,032.3	155,825.8	17,117.8
Adjusted R-square	0.186	0.180	0.164	0.190	0.136	0.101	0.114	0.117	0.189
Sargan	69.37	67.06	69.28	69.63	95.17	94.93	94.34	93.74	87.85
AR(1)	−2.523	−2.501	−2.550	−2.561	−2.965	−3.028	−2.962	−3.012	−3.026
AR(2)	0.554	0.497	0.559	0.520	0.256	0.363	0.286	0.382	0.353

regarding company valuation after the crisis, investors pay more attention to the amount of tangible assets companies hold, not just intangible assets. In other words, total assets matter more after the crisis, with a change in perception. Therefore, companies that had better performance before the crisis no longer sustain the same performance after the crisis, as they no longer benefit from their over-valued intangible assets, and this causes a decline in their performance.

Additionally, the results in Table 7 are consistent with Table 5b, meaning that apart from intangible assets, the remaining variables, including managerial practices, R&D and leverage have the same effect before and after the crisis. Also, squared terms of intangible assets and managerial practices are positive and significant before the crisis, whereas the squared term of intangible assets is still positive and the managerial practices squared term turns insignificant after the crisis. In the pre-crisis period in Table 7 (column (1) to (4)), even after introducing the interaction terms of intangible assets, R&D and managerial practices, the intangible assets and their joint impact remain positive.

However, in the post-crisis period, as shown in Table 7 (columns (5) to (9)), intangible assets have a negative impact. This creates a motivation for us to further focus on intangibles before and after the crisis, as the valuation perception of intangible assets changed following the crisis. This paper justifies why one should look at this relationship separately for the pre-crisis and post-crisis sub-periods. Firms that are R&D-intensive tend to perform well, regardless of crisis conditions. Nevertheless, for firms with only intangibles, the impact is negative. This is because intangibles are only valued higher during good times and tend to be valued lower in bad times when investors want to ensure that the company has enough tangible assets. Should a company not have tangible assets, it is perceived as more risky which hinders investment.

In Table 8, we estimate our model from Table 6 for pre- and post-crisis periods. R&D and managerial practices are consistently positive in both pre- and post-crisis periods. However, intangibles are positive again before the crisis and turn negative post-crisis. In Table 8, all the interaction terms, the joint impact of all three – managerial practices, R&D and intangibles – are negative before the crisis. Additionally, leverage has an adverse effect throughout the pre-crisis period, with a negative coefficient. As firms' leverage ratio was high before the crisis, it had an enormous negative impact on firm performance during the pre-crisis period. However, this varies after the crisis, as firms' leverage ratios began to decline. Additionally, the joint impact of intangibles and R&D is positive when interacting with leverage, both before and after the crisis. This indicates that firms that focus jointly on R&D and intangibles perform better, regardless of the financial constraints, both pre- and post-crisis. Nevertheless, the same is not valid for managerial practices and R&D, because they have a positive joint impact before the crisis and a negative joint impact post-crisis, while their joint impact with leverage is negative, in both pre- and post-crisis periods.

Also, the joint impact of managerial practices and R&D is positive on firm performance (pre-crisis and post-crisis), while their interaction with leverage had an adverse impact on firm performance in both periods. This result indicates that even in a financial crisis, firms that combine R&D with better management practices always perform better than other firms. Also, before the crisis, firms with or without financial leverage do not exhibit any differences regarding R&D and managerial practices,

Table 8

Impact of leverage and squared innovation on pre- and post-crisis firm performance

This table presents dynamic GMM estimations from 1992–2014, using variables' own lags as GMM type instruments. Standard errors are shown in brackets. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We conducted Wald Chi-square test, Sargan test and Arellano-Bond test for AR (1) and AR (2).

	Pre-Crisis								Post-Crisis							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
PM $_{(t-1)}$	0.321***	0.312***	0.318***	0.348***	0.351***	0.345***	0.350***	0.327***	0.150***	0.117***	0.156***	0.159***	0.153***	0.167***	0.150***	0.169***
	[0.00826]	[0.0136]	[0.00814]	[0.00229]	[0.0203]	[0.0164]	[0.0219]	[0.0226]	[0.00907]	[0.00498]	[0.00463]	[0.00548]	[0.00350]	[0.00394]	[0.00284]	[0.00430]
Int	0.438***	0.505***	0.444***	0.500***	0.438***	0.0301	0.155**	−0.193***	−0.482***	−0.686***	−0.533***	−0.586***	−0.956***	−0.787***	−0.580***	−0.510***
	[0.0651]	[0.0590]	[0.0348]	[0.0418]	[0.0374]	[0.0334]	[0.0657]	[0.0609]	[0.0605]	[0.0358]	[0.0389]	[0.0543]	[0.0353]	[0.0407]	[0.0326]	[0.0460]
R&D	0.111***	0.104***	0.287***	0.185***	0.290***	0.376***	0.0915	0.0335	0.539***	0.919***	0.762***	0.726***	0.979***	0.833***	0.999***	0.698***
	[0.0272]	[0.0212]	[0.0381]	[0.0341]	[0.0401]	[0.0750]	[0.0690]	[0.0475]	[0.0823]	[0.0418]	[0.0556]	[0.0536]	[0.0485]	[0.0327]	[0.0362]	[0.0272]
Mngprc	0.0694***	0.120***	0.228***	0.161***	0.184***	0.110***	0.580***	0.703***	0.124***	0.366***	0.284***	0.218***	0.290***	0.217***	0.416***	0.582***
	[0.0229]	[0.0202]	[0.0208]	[0.0253]	[0.0334]	[0.0367]	[0.0966]	[0.0999]	[0.0408]	[0.0249]	[0.0329]	[0.0347]	[0.0262]	[0.0223]	[0.0850]	[0.0611]
Intellectual Capital Interactions																
R&D mngprc*	0.0116***	0.00728***	0.0343***	0.0223***	0.0256***	0.0412***	−0.00341	−0.00472	0.0574***	0.118***	0.0828***	0.0768***	0.118***	0.106***	0.111***	0.0790***
	[0.00257]	[0.00140]	[0.00369]	[0.00347]	[0.00459]	[0.00835]	[0.00732]	[0.00429]	[0.00923]	[0.00387]	[0.00586]	[0.00542]	[0.00535]	[0.00366]	[0.00429]	[0.00388]
Int mngprc*	0.0207***	0.0353***	0.0201***	0.0272***	0.0314***	−0.00323	−0.0164*	−0.0579***	−0.0591***	−0.0871***	−0.0609***	−0.0703***	−0.100***	−0.0869***	−0.0632***	−0.0597***
	[0.00699]	[0.00625]	[0.00316]	[0.00494]	[0.00640]	[0.00528]	[0.00916]	[0.00975]	[0.00798]	[0.00470]	[0.00506]	[0.00622]	[0.00340]	[0.00418]	[0.00312]	[0.00406]
Int R&D*	0.0363***	0.0209***	0.0374***	0.0230***	0.0275***	−0.0284***	0.0502***	0.0142	0.00509	0.00866**	0.0169***	0.0172***	−0.0148***	−0.0403***	0.00400*	−0.0249***
	[0.00267]	[0.00553]	[0.00296]	[0.00368]	[0.00599]	[0.00731]	[0.00655]	[0.0103]	[0.00560]	[0.00347]	[0.00408]	[0.00430]	[0.00174]	[0.00223]	[0.00220]	[0.00337]
DtoC	−0.249***	−0.864***	−0.124***	−0.460***	−0.416***	−0.191***	−0.697***	−0.519***	−0.0649***	1.003***	0.409***	0.0744	1.253***	1.084***	1.527***	1.485***
	[0.0397]	[0.125]	[0.01000]	[0.0265]	[0.0731]	[0.0426]	[0.0543]	[0.144]	[0.00528]	[0.0765]	[0.0885]	[0.0498]	[0.116]	[0.0674]	[0.137]	[0.138]

Table 8
Continued

	Pre-Crisis						Post-Crisis									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Leverage Interactions																
Mngprcs rnd* lrev*		0.0195***			0.0143***	0.00292*	0.0206***	0.0141***		−0.0359***			−0.0364***	−0.0371***	−0.0284***	−0.0306***
		[0.00238]			[0.00117]	[0.00176]	[0.00163]	[0.00324]		[0.00259]			[0.00206]	[0.00142]	[0.00236]	[0.00231]
Int mngprcs* lev*			−0.00625***		−0.0508***	−0.111***	−0.0236**	−0.0646***			−0.0200***		−0.0549***	−0.0624***	−0.0799***	−0.103***
			[0.00140]		[0.00653]	[0.0112]	[0.00981]	[0.0136]			[0.00380]		[0.00703]	[0.00409]	[0.00957]	[0.0110]
Int rnd* lev*				0.0242***	0.0415***	0.151***	0.00791	0.0803***				−0.0107***	0.0858***	0.115***	0.0919***	0.145***
				[0.00277]	[0.00814]	[0.0195]	[0.0145]	[0.0214]				[0.00398]	[0.00836]	[0.00550]	[0.0123]	[0.0146]
Squared Terms																
Int_sq						0.0387***		0.0409***						0.0263***		0.0260***
						[0.00277]		[0.00429]						[0.00137]		[0.00200]
Mngprc_sq							0.0348***	0.0500***							0.000882	0.0197***
							[0.00557]	[0.00524]							[0.00390]	[0.00351]
Constant	2.299***	2.850***	3.559***	3.071***	3.372***	2.713***	4.400***	4.304***	3.048***	4.685***	4.168***	3.757***	4.085***	3.444***	5.317***	5.350***
	[0.182]	[0.154]	[0.194]	[0.207]	[0.269]	[0.337]	[0.434]	[0.555]	[0.312]	[0.209]	[0.251]	[0.287]	[0.219]	[0.171]	[0.434]	[0.253]
Observations	281	281	281	281	281	281	281	281	406	406	406	406	406	406	406	406
chi^2 (Wald test)	254,340.1	92,746.7	68,816.3	1,589,761.2	5,115,585.0	396,122.6	156,454.5	343617.6	650.5	9129.8	5,177.3	3,545.3	628,816.7	255,502.6	174,511.3	395,538.0
Adjusted R-square	0.305	0.282	0.269	0.297	0.321	0.328	0.370	0.327	0.255	0.139	0.178	0.199	0.189	0.224	0.204	0.272
Sargan	66.69	65.31	65.53	68.18	68.96	58.26	62.86	64.83	71.85	89.35	86.33	89.10	91.04	90.61	89.88	87.55
AR (1)	−2.695	−2.725	−2.704	−2.740	−2.680	−2.761	−2.721	−2.748	−3.017	−2.921	−3.010	−3.015	−3.002	−2.993	−2.996	−3.015
AR (2)	0.527	0.610	0.566	0.566	0.553	0.521	0.543	0.493	0.639	0.603	0.670	0.672	0.726	0.693	0.699	0.665

because both the interaction of R&D and managerial practices, with or without leverage, shows a positive coefficient before the crisis. While the pre-crisis leverage ratio is negative, the post-crisis leverage ratio declines overall, and therefore the overall impact of leverage on firm performance is no longer negative.

However, signs of the breakdown of leverage interactions appear after the crisis, shifting towards the point where the interaction of R&D and managerial practices with leverage is no longer positive and the interaction of R&D and intangibles with leverage is still positive. Lastly, in Table 8, the final point we analysed was the impact of squared terms of intangibles and managerial practices on firm performance. We looked at whether the inverse U-shaped relationship found in our data is maintained in both pre- and post-crisis periods. We found that the squared terms of both intangible assets and managerial practices are positive and significant during pre- and post-crisis sub-periods.

4.5. *Robustness checks*

Our results remain insensitive to various robustness tests. To provide unbiased effects of intellectual capital on firm performance, we confirm our results using two alternative controls. In Table 9, for a robustness check, we replaced intangible assets with total assets and re-estimated the models from Table 6. So, instead of using intangible assets as an explanatory variable, we use total assets and check each interaction term accordingly, by replacing intangible assets with total assets within these interactions. All the relationships found in Table 6 remain insensitive to the robustness check we conducted in Table 9. Investigating the impact of total assets on firm performance, we find that greater total assets have a positive influence on firm performance. It also reveals that, although intangible assets have a negative impact on firm performance, total assets have a positive impact, because total assets matter more to firm performance after the crisis, due to a change in the valuation of intangibles. We know that intangibles were overvalued during the pre-crisis period and the valuation changed in the post-crisis period. To justify that point we conduct further tests.

As a second robustness, we replaced intangibles with total assets and re-estimated our models in Table 10. These results validate that total assets are positive after the crisis, meaning that instead of intangibles, firms started to focus more on total assets. In Table 10, we estimate the impact of leverage, while replacing intangibles with total assets in both the pre- and post-crisis parts of the table. Results are consistent with our expectations on total assets having a positive impact on firm performance in the post-crisis period. Total assets, therefore tangible assets, matter more following a crisis. We found that managerial practices and R&D have a positive impact on firm performance both before and after the crisis, while intangible assets were important in the pre-crisis period, and total assets became more important in the post-crisis period. The interaction terms are also replaced with interactions with total assets. Thus, before the crisis, firms that combined total assets with high R&D intensity had a better performance, while the same impact jointly with leverage is negative before the crisis and positive after the crisis. This indicates that firms focusing on total assets and R&D perform better following a crisis. In the post-crisis, financially constrained firms benefit jointly from total assets and R&D rather than the positive joint impact of total asset and managerial practices in financially constrained firms in the pre-crisis period. Therefore, the positive joint impact for the firms with financial constraints shifts towards benefiting from total assets and R&D stocks following the crisis. Our findings

Table 9

Robustness check 1: The role of total assets in explaining the leverage, innovation and firm performance relationship

This table presents dynamic GMM estimations from 1992-2014, using variables' own lags as GMM type instruments. Standard errors are shown in brackets. Here ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We conducted Wald Chi-square test, Sargan test and Arellano-Bond test for AR (1) and AR (2) which are reported in the table.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
PM $_{(t-1)}$	0.319***	0.163***	0.0872***	0.119***	0.121***	0.147***	0.144***	0.115***	0.148***	0.162***	0.148***	0.131***	0.133***	0.122***
	[0.0191]	[0.0004]	[0.0043]	[0.00310]	[0.003]	[0.0049]	[0.0043]	[0.00799]	[0.00835]	[0.00544]	[0.0104]	[0.0147]	[0.00877]	[0.00864]
TotA	0.319***	0.366***	0.745***	0.680***	1.029***	1.034***	0.943***	0.724***	1.117***	0.719***	0.871***	1.250***	0.654***	1.231***
	[0.0248]	[0.00194]	[0.0145]	[0.0111]	[0.0913]	[0.0922]	[0.135]	[0.0965]	[0.117]	[0.108]	[0.139]	[0.110]	[0.119]	[0.141]
R&D		0.0506***	0.0316***	0.235***	0.0717***	0.132***	0.125***	0.253***	0.192***	0.351***	0.409***	0.447***	0.466***	0.597***
		[0.000222]	[0.00107]	[0.0222]	[0.0276]	[0.0423]	[0.0443]	[0.0646]	[0.0444]	[0.0474]	[0.0442]	[0.0561]	[0.0885]	[0.0829]
Mngprc			0.0659***	0.114***	0.0206	0.0114	0.000219	0.136***	0.0431**	0.181***	0.254***	0.293***	0.0629	−0.146
			[0.00538]	[0.0165]	[0.0156]	[0.0239]	[0.0307]	[0.0374]	[0.0208]	[0.0272]	[0.0274]	[0.0334]	[0.0963]	[0.118]
IC Interactions														
*R&D*mngprc*				0.0283***	0.00934***	0.0163***	0.0150***	0.0380***	0.0230***	0.0398***	0.0572***	0.0641***	0.0604***	0.0768***
				[0.00251]	[0.00291]	[0.00490]	[0.00538]	[0.00755]	[0.00463]	[0.00511]	[0.00471]	[0.00624]	[0.00967]	[0.00882]
*TotA*mngprc*					0.0426***	0.0716***	0.0714***	0.0174***	0.0858***	0.0340**	0.0570***	0.0708***	0.0600***	0.0769***
					[0.0106]	[0.0158]	[0.0164]	[0.00652]	[0.0152]	[0.0145]	[0.0147]	[0.00777]	[0.0178]	[0.0203]
*TotA*R&D*						−0.0375***	−0.0507***	−0.0203	−0.0316**	−0.00618	−0.0102	0.00897	−0.0393	0.00869
						[0.0125]	[0.0138]	[0.0147]	[0.0145]	[0.0169]	[0.0205]	[0.0118]	[0.0244]	[0.0322]
DtoC							−0.0378***	0.491***	0.0142	0.0152	0.975***	0.935***	1.024***	0.972***
							[0.00291]	[0.0405]	[0.0123]	[0.0118]	[0.0544]	[0.0510]	[0.0516]	[0.0539]
Leverage Interactions														
*Mngprc*R&D*DtoC*								−0.0180***			−0.0275***	−0.0257***	−0.0275***	−0.0262***
								[0.00145]			[0.00152]	[0.00145]	[0.00130]	[0.00141]
*TotA*mngprcs*DtoC*									−0.0181***		−0.0944***	−0.0433**	−0.133***	−0.0329
									[0.00433]		[0.0184]	[0.0220]	[0.0238]	[0.0323]
*TotA*R&D*DtoC*										−0.0462***	0.0363	−0.0742**	0.0708*	−0.107*
										[0.00723]	[0.0385]	[0.0363]	[0.0427]	[0.0577]
Squared Terms														
logtotA_sales2												−0.361***		−0.347***
												[0.0218]		[0.0263]
logmngprc_sales2													−0.0133**	−0.0285***
													[0.00538]	[0.00636]
Constant	1.388***	1.868***	1.055***	2.636***	1.497***	1.726***	1.670***	2.623***	1.994***	3.213***	3.490***	3.792***	3.052***	2.425***
	[0.0467]	[0.00118]	[0.0508]	[0.138]	[0.145]	[0.190]	[0.230]	[0.303]	[0.190]	[0.227]	[0.238]	[0.280]	[0.485]	[0.554]
Observations	7,329	1,815	768	768	768	768	766	766	766	766	766	766	766	766
chi2 (Wald test)	789.1	147,156.9	24,206.2	20,989.7	77,924.1	16,989.3	18,244.4	7,309.5	16,139.4	13,982.8	8,957.2	17,631.6	26,238.9	4,774.2
Adjusted R-square	0.665	0.344	0.222	0.195	0.159	0.163	0.163	0.185	0.160	0.230	0.210	0.184	0.213	0.190
Sargan	236.8	144.9	103.5	101.3	102.6	99.75	99.36	99.21	100.7	101.3	99.05	98.44	96.32	97.43
AR (1)	−11.01	−5.721	−3.727	−3.723	−3.734	−3.760	−3.767	−3.684	−3.770	−3.768	−3.698	−3.695	−3.673	−3.650
AR (2)	2.883	1.012	1.090	1.245	1.198	1.284	1.314	1.238	1.329	1.438	1.398	1.257	1.406	1.253

Table 10

Robustness check 2: Impact of total assets on explaining the leverage, innovation and firm performance relationship pre- and post-crisis

This table presents dynamic GMM estimations from 1992–2014, using lagged variables as GMM type instruments. Standard errors are shown in brackets. Here ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Dependent variable is profit margin (in logs). All the estimations are presented in a stepwise format to show the impact of each variable on company performance. We have reported several diagnostic tests namely Wald Chi-square test, Sargan test and Arellano-Bond test for AR (1) and AR (2).

	Pre-Crisis								Post-Crisis							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
PM $_{(t-1)}$	0.200***	0.165***	0.227***	0.239***	0.241***	0.256***	0.243***	0.286***	0.111***	0.0809***	0.117***	0.114***	0.116***	0.110***	0.101***	0.0880***
	[0.00790]	[0.00709]	[0.0106]	[0.00570]	[0.00361]	[0.00826]	[0.0233]	[0.0171]	[0.0123]	[0.00890]	[0.00744]	[0.00630]	[0.00564]	[0.00815]	[0.00725]	[0.00614]
TotA	−0.249***	−0.663***	1.527***	0.466***	−0.118	−0.150	−0.788***	−1.049***	3.499***	3.083***	2.776***	2.775***	2.707***	2.888***	2.993***	3.559***
	[0.0905]	[0.107]	[0.129]	[0.119]	[0.130]	[0.140]	[0.100]	[0.163]	[0.217]	[0.188]	[0.219]	[0.194]	[0.119]	[0.0872]	[0.164]	[0.143]
R&D	−0.0547	0.107**	0.0933	0.301***	0.399***	0.465***	0.0647	0.103**	0.307***	0.333***	0.155***	0.213***	0.336***	0.296***	0.694***	0.770***
	[0.0372]	[0.0497]	[0.0632]	[0.0222]	[0.0178]	[0.0352]	[0.0460]	[0.0488]	[0.0793]	[0.0562]	[0.0431]	[0.0388]	[0.0350]	[0.0454]	[0.0705]	[0.0675]
Mngprc	−0.137***	−0.00162	0.0368	0.223***	0.260***	0.272***	0.928***	0.879***	0.130***	0.171***	−0.00278	0.0387	0.143***	0.144***	−0.373***	−0.501***
	[0.0258]	[0.0309]	[0.0392]	[0.0231]	[0.0146]	[0.0194]	[0.107]	[0.142]	[0.0498]	[0.0320]	[0.0290]	[0.0284]	[0.0228]	[0.0322]	[0.0647]	[0.0842]
IC Interactions																
*R&D*mngprc*	−0.00305	0.0177***	0.0132*	0.0338***	0.0501***	0.0574***	0.00938*	0.0114**	0.0331***	0.0384***	0.0129**	0.0191***	0.0347***	0.0346***	0.0781***	0.0901***
	[0.00382]	[0.00546]	[0.00678]	[0.00281]	[0.00224]	[0.00379]	[0.00557]	[0.00534]	[0.00937]	[0.00632]	[0.00516]	[0.00460]	[0.00411]	[0.00590]	[0.00874]	[0.00804]
*TotA*mngprc*	−0.0978***	−0.171***	0.222***	0.0211*	−0.0850***	−0.133***	−0.197***	−0.287***	0.301***	0.267***	0.169***	0.212***	0.274***	0.275***	0.362***	0.402***
	[0.0114]	[0.0109]	[0.0147]	[0.0113]	[0.0243]	[0.0184]	[0.0191]	[0.0174]	[0.0229]	[0.0194]	[0.0198]	[0.0156]	[0.0163]	[0.0173]	[0.0175]	[0.0171]
*TotA*R&D*	0.00132	0.0400***	0.00524	0.152***	0.138***	0.172***	0.188***	0.255***	−0.0597*	−0.0912***	−0.0121	−0.0960***	−0.222***	−0.210***	−0.260***	−0.231***
	[0.0101]	[0.00803]	[0.00673]	[0.00519]	[0.0178]	[0.0232]	[0.0255]	[0.0192]	[0.0311]	[0.0128]	[0.0157]	[0.0147]	[0.0118]	[0.0167]	[0.0181]	[0.0147]
DtoC	−0.484***	−0.317***	−0.107***	−0.252***	−0.102***	−0.142***	−0.169***	−0.198***	−0.00382	0.321***	−0.174***	−0.171***	0.258***	0.300***	0.825***	0.930***
	[0.0196]	[0.0317]	[0.0188]	[0.0310]	[0.0320]	[0.0406]	[0.0378]	[0.0457]	[0.00380]	[0.0414]	[0.0170]	[0.0130]	[0.0419]	[0.0603]	[0.0494]	[0.0491]
Leverage Interactions																
Mngprc R&D* DtoC*		−0.00427***			−0.00676***	−0.00877***	−0.00299*	−0.00455***		−0.0110***			−0.00821***	−0.00866***	−0.0249***	−0.0255***
		[0.00120]			[0.000900]	[0.00129]	[0.00168]	[0.00168]		[0.00140]			[0.00117]	[0.00172]	[0.00162]	[0.00144]
*TotA*mngprc* DtoC*			−0.206***		−0.0218	0.0907***	0.0640**	0.193***			0.0666***		−0.266***	−0.215***	−0.281***	−0.231***
			[0.00559]		[0.0194]	[0.0301]	[0.0272]	[0.0192]			[0.00595]		[0.0191]	[0.0305]	[0.0235]	[0.0313]
*TotA*R&D*DtoC*				−0.340***	−0.197***	−0.331***	−0.319***	−0.502***				0.125***	0.508***	0.392***	0.472***	0.315***
				[0.00775]	[0.0237]	[0.0395]	[0.0460]	[0.0374]				[0.00866]	[0.0291]	[0.0480]	[0.0415]	[0.0522]
Squared Terms																
TotA_sq						−0.100***		−0.0857**						−0.476***		−0.519***
						[0.0332]		[0.0338]						[0.0164]		[0.0285]

Table 10
Continued

	Pre-Crisis						Post-Crisis									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Mngprc_sq							0.0474***	0.0465***							−0.0403***	−0.0498***
							[0.00660]	[0.00800]							[0.00508]	[0.00585]
Constant	0.494**	1.648***	1.820***	3.598***	3.764***	3.939***	5.943***	5.663***	2.848***	3.187***	1.858***	2.226***	3.005***	2.966***	1.684***	1.290***
	[0.245]	[0.284]	[0.370]	[0.200]	[0.123]	[0.177]	[0.444]	[0.630]	[0.398]	[0.263]	[0.231]	[0.232]	[0.195]	[0.245]	[0.224]	[0.325]
Observations	285	285	285	285	285	285	285	285	407	407	407	407	407	407	407	407
chi2 (Wald test)	272,616.3	7,936.3	122,758.8	338,105.8	84,497.1	35,750.7	97,525.7	156,248.0	1,677.6	5,424.2	6,551.1	9,216.5	300,040.9	183,730.2	68,948.0	21,911.3
Adjusted R-square	0.304	0.335	0.220	0.278	0.353	0.374	0.397	0.425	0.269	0.286	0.320	0.322	0.339	0.323	0.327	0.301
Sargan	66.71	66.06	68.12	64.06	55.26	48.79	58.62	56.46	78.64	84.67	84.89	86.55	94.73	90.85	88.94	87.15
AR (1)	−2.703	−2.656	−2.577	−2.525	−2.606	−2.638	−2.693	−2.801	−2.881	−2.826	−2.903	−2.885	−2.904	−2.919	−2.882	−2.875
AR (2)	0.680	0.728	0.782	0.913	0.915	0.936	0.909	0.945	0.265	0.143	0.274	0.259	0.296	0.345	0.293	0.343

are in line with Hall (2010) and Hall and Lerner (2010) which explain why we have a negative coefficient for intangibles.

5. Conclusion

This paper focuses on estimating the relationship between innovation and firm performance. While the traditional view of innovation is on R&D, modern innovation focuses on better managerial practices. Solely focusing on traditional innovation is less effective in firm performance than improving managerial practices. If firms concentrate more on better managerial practices through organisational capital enhancements such as new strategies, new targets and process development, and through human capital such as improving employee's expertise and knowledge, additional training and measurement of skills, and incentives to increase their skills, the contribution of innovation to firm performance will be higher. We, therefore, integrated these two strands of literature to examine whether managerial practices make a difference in the relationship between innovation and performance, using firm-level data from the UK over the period 1992–2014, applying dynamic system GMM that helps overcome the problem of heterogeneity and endogeneity in the dataset.

Our analyses show that firms that are R&D intensive tend to perform well, regardless of the crisis. However, for firms that have only intangibles, the impact is negative because intangibles are only valued higher during good times. During bad times, the valuation of intangibles declines. That is because, during bad times, investors seek tangible assets. As Hall (2010) stated, intangibles are not counted as collateral. A company that does not possess tangible assets is perceived as riskier and investors avoid this risk. Companies who are considered good performers are expected to use intangible assets (such as patents, brand, trademark and trade secrets) and create tangibles out of them. For instance, the technology company Apple has higher intangible assets; however, it is successful because it can turn innovative activities into assets. In contrast, some start-up companies may have good ideas (intangibles), but if those intangible efforts are not turned into real assets, they are perceived as non-performers.

One of the key contributions of the paper is on intangible assets and their impact on firm's performance in the pre- and the post-crisis periods. More specifically, intangible assets were over-valued before the crisis and the valuation perception changed in the post-crisis period. Thus, intangibles have a negative impact in the post-crisis period (and the negative impact dominates the full sample) and therefore total assets are critical to firm's performance following the crisis. Intangible assets are then replaced with total assets, as good performing firms may have higher tangible assets than intangibles. Following the crisis, total assets did matter more in improving firm performance along with R&D activity, rather than intangibles that did not reflect their true valuation in the pre-crisis period. Moreover, we found an inverse U-shaped relationship between the firms' profitability with managerial practices and intangible assets. An inverse U-shaped curve of intangibles indicates that there is a threshold level for intangible assets, up to which intangible assets tend to have a positive impact on firm performance and above which the effect starts declining.

Not all firms benefit equally from intellectual capital. As suggested by Bloom and Van Reenen (2007, 2009 and 2010), better-managed firms perform better. Firms that focus on strategies and modern innovation tend to outperform others that focus solely on traditional innovation. The ability to perform better is therefore limited without changing

managerial practices or making process or product innovation. However, firms that focus on both traditional innovation via R&D, and modern innovation via changing managerial practices, tend to perform better in terms of profitability. Our findings also show that leverage has an adverse impact on firm performance over the sample period, but firms with better managerial practices and innovative activities derive a positive effect from leverage. Additionally, the paper shows that, in the aftermath of the financial crisis, the impact of intangible assets on firm's performance, when complemented with R&D activity, was positive. We infer from this that, even during and after the crisis, the firms that focus on R&D and intangibles tend to overcome the negative impact of the financial crisis better than others. Because the firms that continually focus on innovation can create new processes and products, they generate higher productivity and thereby enable greater competitive advantage.

In summary, we have three main contributions. First, we find that the firms which focus on R&D activities jointly with better managerial practices tend to show a positive impact on their performance. Second, higher intangible assets are only beneficial in improving firm performance when they are combined with R&D activity in the post-crisis period, while in the pre-crisis period, intangibles did not reflect their true valuation which became apparent in the post-crisis period, explaining the mixed effect on firm performance. Third, we show that the impact of leverage on firm performance was negative over the sample period as expected, but firms with better managerial practices and innovative activities derive a positive effect from higher leverage. Finally, the paper finds an inverse U-shaped relationship between intangible assets and performance, supporting the Schumpeterian theory of creative destruction.

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