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Open innovation and firm performance: Evidence from the Chinese mechanical manufacturing industry

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ABSTRACT

This paper studies how human capital can affect the relationship between open innovation and the financial performance of firms. The results demonstrate that there is an inversed U-shape relationship between open innovation and firm profitability. We also indicate how human capital (both quality and structure) will differently moderate above relationship: generally, higher the education level of employees will amplify the positive effect of open innovation, but for production-oriented firms, such argument does not hold; in technology-oriented firms, as the ratio of technical staff to production staff increases, the financial performance of firms improves as a result of the implementation of an open innovation strategy. However, in production-oriented firms, the moderating role is negative.

1. Introduction

Chesbrough (2003) first introduced the concept of "open innovation" to contrast with what is called "closed innovation." Open innovation emphasizes that companies that "generate their own ideas, develop them, build them, market them, distribute them, service them, finance them and support them on their own" should take advantage of external ideas, resources, and market channels to advance technology and provide new products. It enhances firms' technological capabilities, as well as their overall competitiveness, by combining internal and external ideas in innovative activities.

The direct or indirect impact of open innovation activities on a firm's performance have been extensively studied by researchers, most of which are related to firms' innovation performance, including R&D cost effectiveness(Caloghirou et al., 2004), the production of patent (Rothaermel and Alexandre, 2009), and the proportion of new products (Grimpe & Sofka, 2009; Laursen & Salter, 2006; Atuahene-Gima, 2005). Researchers have reached something of a consensus that open innovation enhances firm innovation performance (Miotti & Sachwald, 2003; Pisano,1990), though some have suggested that excessive dependence on external knowledge may not benefit a firm's innovativeness (Laursen & Salter, 2006 ; Koput, 1997; Ocasio, 1997).

According to research on the process of open innovation West & Bogers, 2014; Chesbrough & Appleyard 2007), value creation through innovation and value capture through commercialization are regarded as two important processes for the success of open innovation. However, we noticed that above researchers focus on value creation, with an emphasis on innovation outcomes from openness, but less on value capture, i.e. the commercialization of innovation. In the view of Chesbrough and Appleyard (2007),

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"effective open strategy should balance value capture and value creation, instead of losing sight of value capture during the pursuit of innovation."

Value capture is highly related to the sustainability of open strategy, and it calls for a strategic perspective of trade-off between the benefits and cost of open innovation. This draws our attention to the profitability of open innovation, which is usually taken as the reflection of value capture in open innovation (Rothaermel & Alexandre, 2009; West & Bogers, 2014). *It* is a complementary and further-step research to the often studied relationship between openness and innovation performance.

While firms often adopt open strategies for better competitive advantages, they differ in their ability and context characteristics to capture value in open innovation. (Chesbrough, 2006; Chesbrough & Appleyard 2007). Therefore, the next core question becomes the conditions under which open innovation can contribute positively to firm profitability.

Researchers have used the lens of absorptive capacity to understand the contingency of open innovation on firm performance. The results have been well-documented (Bapuji et al., 2011; Lichtenthaler, 2009). Absorptive capacity is generally regarded as a by-product of R&D investment (Cohen & Levinthal, 1990) and proxied by R&D intensity (e.g. Kafouros & Forsans, 2012). However, some argue absorptive capacity should be more complex in nature. Firms require relevant knowledge foundation and a compatible cognitive structure to assimilate and transform external knowledge. They must build new cognitive structures and cope with path dependency when new knowledge is incompatible (Todorova and Durisin, 2007). Such process is highly dependent on firm's human resource, therefore, some researchers (Mowery & Oxley, 1995) proposed that human capital is an important but overlooked component of absorptive capacity.

This paper explores this new and potentially overlooked element and investigates how firms should align their human capital with their open innovation practices to ensure profitability of open innovation.

The specific questions this paper aims to answer include: a) What is the connection between open innovation and firm profitability? b) What is the role of human capital in the relationship between open innovation and firm performance?

The paper is organised as follows: In the second part, theories and relevant research related to open innovation, firm performance, and human capital are reviewed. In the third part, models building on the relationships between open innovation and firm performance are proposed. These models suggest that there is an inversed U-shape relationship between the two in China's mechanical manufacturing industry. In the fourth part, human capital is added to the model as a moderating factor to examine its contingent effect on open innovation. Based on the results, practical recommendations to firms regarding HR structures are provided in the final session.

2. Theoretical background and hypotheses

2.1. Open innovation

After Schumpeter's first introduction of innovation concept, it was long taken for granted that innovation refers only to activities that occurred within a firm or within an R&D department, which therefore made creativity and innovation important strategic resources guarded by careful management and legislative protections. This is now classified as "closed innovation," in which each step in the innovation process is dependent on a firm's own capabilities (Chesbrough, 2003). Toward the end of the twentieth century, this closed innovation model was gradually disrupted as a result of the increased mobility of skilled workers, more rapid technological change and increased technological complexity, and the prevalence of venture capital. Under this new paradigm, sources of knowledge and transfer of technology can be external to firms. Skilled and educated workers lie in the centre of the identification, acquisition, assimilation, and absorption of external knowledge. Rapid technology change and increased technological complexity makes 'openness' essential for firms. Venture capital translates R&D outcomes to the market because it directly contributes to the execution of an innovative idea (including those coming from external technology sources) and shares the risks in new product development (Christofidis and Debande, 2001). These processes facilitate internal and external knowledge exchanges and push innovation across the boundaries of the firm.

In this picture, external sources of technology can have a more significant impact on the innovation model that firms choose to adopt. Enkel and Gassman (2008) studied the knowledge sources of companies and established the fact that clients, suppliers, and even competitors have become main sources of knowledge. In most industries, even industry leaders cannot research and develop a new technology completely on their own. Technological challenges and financial constraints push independent organisations, or even competitors, to collaborate. With progression in technology, more interdisciplinary subjects have emerged. Therefore, a different innovation environment started to form, which Chesbrough later called "open innovation".

This triggered a series of debates among researchers, and the most discussed question is: is it always good for enterprises to use external sources to innovate and to what degree can firms rely on external sources? (Chesbrough, 2006)? Studies have discussed the pros and cons of open innovation (Almirall & Casadesus-Masanell, 2010). Chesbrough's study discovered that external forces can enhance the efficiency of projects, and shorten working time, which can make a difference for short-term projects in particular. Yet, an over-dependence on external R&D may have a crowding-out effect on long-term innovation programmes, Christensen (2006) argued that, although external knowledge can become more accessible, firms should not abandon their core technologies. Knowledge and knowhow regarding firms' core competitiveness, as well as in-depth R&D, should be maintained within the firm. But most of the research focus on the technological outcomes from openness, financial performance, as an indicator of value capture from open innovation, is less discussed.

A strategic perspective of trade-off between the benefits and the cost of open innovation is required to ensure firms with open strategy can balance between taking advantage of open innovation and maintaining core firm-specific competitive advantages

(Chesbrough, 2006; Chesbrough and Appleyard, 2007). Gassmann (2006) suggested some standards that can be used in analysing whether a firm should adopt an open innovation strategy, and whetherand when the costs of openness exceed the benefits of openness. These standards include firm's level of globalisation, knowledge stocks, knowledge upgrading, technological spillover and business models. Other studies have examined various factors that affect open innovation outcomes. General factors such as R&D intensity, firm size, capabilities, and market conditions have been investigated. Although studies have investigated aspects ranging from the reasons for open innovation to the outcomes of open innovation, open innovation has long been on the dependent side of the equation. The effect of open innovation on firm performance has yet to be thoroughly examined.

Previous research has divided open innovation into 'outside-in' and 'inside-out' processes (e.g. Enkel et al., 2009). This paper focuses on the inbound process and investigates its associations with firm performance. Firms especially those in developing countries such as China, perform more inbound than outbound open innovation. The inbound strategy may take the form of technology purchases, inter-firm R&D collaborations, technological spinoffs, and user-driven innovation (e.g. Huston & Sakkab, 2006; Waites and Dies, 2006; Kim et al., 2008; Piller, 2011). Here, we specifically focus on technology purchase, namely the acquisition of external technological resources and innovation outcomes, especially patents. It is well recognized that intellectual property plays an important role in open innovation, but what contributes to successful tradable patents and whether a firm can profit from purchased technology are still need to be identified (Gassmann et al., 2010).

2.2. Open innovation and firm profitability

Laursen and Salter (2006) carried out pioneering research using quantitative methods to study the relationships between open innovation and firm performance, which broke the dominance of qualitative study in this research area. These scholars believed that open innovation was the source of firm competitiveness. Roberts (1999) claimed that the constant introduction of new technologies that satisfy the growing needs of existing customers were the reason for sustained high profits. Koellinger (2008) claimed otherwise, suggesting that open innovation may not necessarily cause better firm performance or higher profits. To correct the bias that could be caused by studying individual cases, Rosenbusch et al. (2011) applied a meta-analysis to a sample containing 21,270 firms that appeared in 42 different studies. This project pointed out that, in order to answer the question of whether open innovation has a positive or negative effect on firm performance, researchers need to consider elements in addition to innovation per se, which is to say that a contingent model should be employed. A number of factors are thought to affect the outcome of open innovation in relation to firm performance, such as firm age, types of firm innovation, and cultural environment.

From a perspective of trade-off between the benefits and cost of open innovation, it could become generally accepted that the degree of open innovation should have a marginal value, beyond which open innovation has a negative impact on firm profitability. We choose the case of technology purchase, one form of inbound open innovation, as our example. In addition to the purchasing expenditure, other nonmonetary costs often incurred in the process of searching, evaluating and filtering proper external technology, assimilating and integrating the purchased technology, and transforming and commercialising external technology to the markets (West & Bogers, 2014; Salge et al., 2013). Until then, value created from open innovation is captured and firms are able to profit from the increased innovation outcomes. At the early stage of openness, firms are capable to handle external knowledge to commercialize it for profit, however, with more technology purchased, firms are faced with more complicated knowledge integration and transformation process, which could largely increase the cost of openness, and at the same time, reduce the benefit of open innovation (Koput,1997; Laursen & Salter, 2006). As a result, the cost of openness exceeds the benefits and the profit of the firms are gradually reduced. Therefore, we expect that:

H1. An inverted U-shaped relationship between open innovation and firm profitability exists. When investments in open innovation increase, firm profitability increases. However, after certain point, the excess cost of innovation offsets firm profitability.

2.3. The moderating effect of human Capital

Research on the moderating effects of absorptive capacity on firm performance are numerous (e.g. Park & Rhee, 1967; Zahra & Hayton, 2008; Herath & Mahmood, 2013; Ahlin et al., 2014;). Cohen and Levinthal (1990) defined the concept of absorptive capacity as the ability of a firm to recognise the value of external knowledge, assimilate and commercialise it in the market, and regarded absorptive capacity as a by-product of R&D investment.

Research by Zahra & George (2002) and Todorova & Durisin (2007) refined the definition and emphasized that in the process of assimilating and transforming external knowledge, compatible cognitive structure is often required. When external knowledge is incompatible in the firm, relevant personnel in the firm need to "*build new cognitive structures and learn to cope with path dependency*", the process of which is known as a *"competence-destroying change"* (Todorova and Durisin, 2007, p.778). This refined definition implies the importance of human capital, i.e. employee's capability to utilize and manage external knowledge. Therefore, we proposed that, compared to R&D activities, human capital is more important but overlooked strategic asset that contribute to absorptive capacity and influence the effectiveness of openness.

The accumulation of human capital and the improvement of its management are the sources of sustainable competitiveness (Barney, 1991; Hatch and Dyer, 2004). In the last decade, researchers studying management on a micro-level began incorporating the management of human capital and its impact on innovation. Vinding (2006) has found that more educated employees, more mature human capital management, and closer connections with educational and research institutes all contributed to firms' innovative capabilities. In a way, human capital directly contributes to improving the financial performance of firms (Davenport, 1998) by enhancing firms' overall capabilities to seek out and seize new technological and business opportunities, which in turn points to absorptive capacity. This therefore supports our earlier presumption that human capital affects firm performance within the open innovation paradigm in which workers perform knowledge transfers both inside and outside of firm boundaries. Franco et al. (2012) claimed that human capital facilitates the transformation of absorptive capacity into actual innovation. In a resource-based view, Hitt et al. (2001) also verified both the direct and moderating roles of human resources on firm performance.

In this study, we examine human capital from two perspectives: one is the quality of human capital and the other is the structure of human capital. Human capital quality, as indicated by staff education level, is supposed to be positively associated with better cognitive skills and greater information processing abilities (Njenga, 1994). Therefore, it is expected to reduce the cost incurred in the process of open innovation. More specifically, firms with higher quality of human capital can be more successful in searching, evaluating, assimilating and integrating external technology, and transforming and commercializing it to the markets (Salge et al., 2013). Especially for technology and patent purchase, patent valuation remains quite problematic (Gassmann et al., 2010) and thus sometime become costly. Higher quality of human capital could reduce those nonmonetary costs in open process, and help firms gain more profit from technology purchase.

H2a. The educational level of the employees has a positive moderating effect on the relationship between open innovation and firm performance.

For companies with different strategic orientations regarding technological advancements, the quality of human capital may not be sufficient to explain the effect of human capital on the relation between open innovation and firm performance. We propose that the human capital structure should be taken into consideration.

From the perspective of human capital structure, we classified firms into two categories: the production-oriented firms and technology-oriented firms. Following Kirpalani & Macintosh (1980), Fryges (2006) and Fryges (2009), "production-oriented firm" is a firm which focused on reducing costs and gaining market share through mass production. In terms of human capital structure, it has relatively higher ratio of production staff and lower ratio of technology staff compared to a technology-orientation firm.[1] For this type of firms, competitive advantages are derived from process innovation and incremental improvement which lead to lower production cost and higher efficiency. Usually, the improvement is conducted by production staffs on the production line rather than technology staff from the R&D department.

Considering the strategic orientations regarding technological advancements, production-oriented firms are more likely to purchase technology which is incremental and process-improvement-related. Such technology is easier to be assimilated and transferred by production staff and has less requirement for technology staff. Therefore, an excessive building of R&D department with high technical staff maybe a dissipation of resources, which aggravates financial burdens and mitigates the benefits from using external knowledge. Therefore, we propose :

H2b. For production-oriented firms, the ratio of technical staff has a negative moderating effect on the relationship between open innovation and firm performance.

In contrast, "technology-orientated firms" is a firm whose development is dependent on or led by technology. In terms of human capital structure, it has relatively higher ratio of technology staff and lower ratio of production staff compared to a production-orientation firm. For this type of firms, radical innovations seem to offer the greatest opportunity for performance improvement (Marsili & Salter, 2005). When adopting open strategy, a technology-oriented firm is looking for some radical knowledge, which has higher requirement for technology staff, in order to efficiently searching, evaluating, assimilating and integrating external technology, and transforming and commercializing it to the markets. Therefore, to take advantage of open innovation and technological advancement, the ratio of technical staff should have a positive moderating effect, in that firms can make better use of the open platform to improve performance through active technical staff in technology-oriented firms. Therefore, we propose:

H2c. For technology-oriented firms, the ratio of technical staff has a positive moderating effect on the relationship between open innovation and firm performance.

3. Data and methodology

3.1. Data

This paper is based on the financial statement data of 203 Chinese listed companies in the mechanical manufacturing industry. The main data comes from Wind Information Co. Ltd. (Wind Info), one of the most authoritative financial databases in China. Data related to innovation, human capital, and other general information were gathered from firms' annual reports posted on the websites of the Shanghai Stock Exchange and the Shenzhen Stock Exchange. Listed companies on these exchanges are strictly monitored by the general public and investors, so we can have confidence in the information disclosed. The mechanical manufacturing industry was chosen because: a) It is frequently studied in China (Laursen & Salter, 2006). The industry in China is representative because China is the world's largest manufacturer of mechanical equipment, which facilitates the comparison and cross-referencing of results with other studies and findings. b) The mechanical manufacturing industry in China is relatively mature but still developing, with stable innovation and R&D investment. However, in recent years, the industry has faced downward pressure, which is referred to as the "New Normal". Mechanical manufacturing companies maintain growth in technological innovation for their survival in the domestic market and for the development of foreign markets. The percentage of R&D personnel in the industry increased from 7.5% in 2003 to

15% in 2013[1]. Therefore, studying innovation and human capital in the mechanical manufacturing industry and their relationship to performance will provide timely practical implications for the development of the industry.

This paper incorporates data for eleven years, covering year 2001 to 2011, with 2233 samples. To increase the reliability of the analysis, the data has been filtered according to two principles. First, to ensure consistency for each company, all selected firms have been listed on the stock market for at least five years. Second, only firms listed on the A-share market were included. Firms listed on the B-share market were excluded to avoid complications that arise from the fact that B-shares are purchased with foreign currency. Eventually, 1496 samples passed the screening.

3.2. Variables and calculations

3.2.1. Dependent variables

As we focus on the profitability of open innovation, we use financial performance indicator, return on equity (ROE), as the dependent variable. ROE is net profit after tax divided by ordinary shareholder equity (Hutchinson & Gul, 2004). This kind of financial data for listed companies provides a more accurate input for the analysis, and at the same time it match the cost-benefit trade-off perspective adopted in the paper.

Given that the Chinese economy is in transition and the stock market suffers from greater information asymmetry, policy intervention, and the drawbacks of small or hit-and-run investors, stock values may not serve as a good indicator of firm financial performance. Thus, this paper uses **return on equity (ROE) instead**. ROE, in comparison, reflect the efficiency of firms' investment, which better demonstrate financial performance.

3.2.2. Independent variables

As stated, we focus on the inbound process of open innovation, more specifically, technology purchase, measured by the expenditure on the acquisition of external technological resources and innovations, including purchased patents and non-patented technology. The data is collected form firm annual reports.

These are all part of what we refer to here as **Royalty.**

3.2.3. Moderators

To measure the effect of human capital on the relationship between innovation and firm performance, human capital serves as a moderating variable. To indicate human capital quality and structure, this paper incorporates **educational level (EDUR)** (*number of employees with a college degree or above/total number of employees*) and **human capital structure(STRUC)** (*the ratio of technical staff to production staff*). According to our definition of technology-oriented and production-oriented firms, firms with higher STRUC are more likely to be categorized as technology-oriented firms.

3.3. Control variables

Other factors that might also affect firm performance are added to the model as control variables such as **total assets (SIZE), firm age(AGE),** and **asset-to-liability ratio (ALR)**.

A variable list with definitions is presented in Table 1. Detailed calculations for all variables are shown later in this section. Table 2 presents statistic descriptions and correlations for all variables.

A panel data model was constructed for this analysis. In order to adapt to hierarchical regression, calculate moderating effects, and reduce multicollinearity, the original data was centralised. The effects of open innovation on operations are delayed, as similar research has accounted for a lag of one to three years (Knudsen & Mortensen, 2011; Bapuji et al., 2011). This paper has adopted a one-year lag. Analysis was conducted in following steps:

We test the degree of interpretation of the control variables with Model (3-1).

$$ROE = c + \beta_1 SIZE + \beta_2 AGE + \beta_3 ALR \quad (3\text{-}1)$$

Independent variables were added to Model (3-1), which resulted in Model (3-2) shown below. As we hypothesized that there is an inverted U-shaped relationship between open innovation and firm performance, Roy^2 was added to the model.

$$ROE = c + \alpha_1 Roy + \alpha_2 Roy^2 + \beta_1 SIZE + \beta_2 AGE + \beta_3 ALR \quad (3\text{-}2)$$

In the curve model, ROE stands for return on equity, ALR is the asset-to-liability ratio, and ROY is the royalty (total cost of external knowledge, technology, and inputs into open innovation). Then, to analyse human capital's moderating effect, we chose two groups of indicators: human capital quality (EDUR) and human capital structure (STRUC). The indicators are calculated as follows:

$$\text{EDUR} = \text{Number of employees with college degree/total number of employees} \quad (3\text{-}3)$$

$$\text{STRUC} = \text{Number of technical employees/ Number of production employees} \quad (3\text{-}4)$$

[1] China Report Hall. 2016 Mechanical Industry Status Report. www.chinabgao.com.

Table 1
Variables and Definitions.

Dependent Variables	Variable Definitions
ROE	Return on equity
Explanatory Variables	
ROY	Royalty: Cost of purchasing innovation outcomes from external sources
Control variables	
SIZE	Total assets
ALR	Asset-to-liability ratio
AGE	Firm age
Moderators	
EDUR	Ratio of employees who received a college education or above
STRUC	Ratio of technical staff to production staff

Table 2
Statistic descriptions and Correlation.

Variable	Mean	Standard Deviation	1	2	3	4	5	6	7
1. ROE	5.194	38.091							
2. SIZE	12.214	1.097	0.115***						
3. ALR	0.518	0.198	−0.114***	0.341***					
4. AGE	10.406	4.539	−0.043*	0.137***	0.123***				
5. EDURE	0.26	0.194	0.034	0.017	0.055**	.001			
6. ROY	5.768	2.199	0.078***	0.327***	0.083***	.002	.002		
7. STRUC	0.721	1.856	0.024	0.021	−0.19	−0.063*	0.464*	−.006	

Notes : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

According to these calculations, using Structure's median as the dividing line, the two types of firms can be differentiated. We split the full sample into (1) technology-oriented firm sample and (2) production-oriented firm sample: When the value of Structure is above the sample median, the firm is more likely to be a technology-driven firm. When the value of Structure is smaller than the sample median, the firm is a production-driven firm (Table 3).

After adding the moderators, STRUC and EDUR, the following models are generated:

$$ROE = c + \beta_1 SIZE + \beta_2 AGE + \beta_3 ALR + \alpha_1 Roy + \alpha_2 Roy^2 + \alpha_3 Structure + \alpha_4 Structure^* Roy \tag{3-5}$$

$$ROE = c + \beta_1 SIZE + \beta_2 AGE + \beta_3 ALR + \alpha_1 Roy + \alpha_2 Roy^2 + \alpha_3 Eduratio + \alpha_4 Eduratio^* Roy \tag{3-6}$$

Table 3
Influence of Open Innovation on Firm Performance.

	Model 1	Model 2
Control Variables		
AGE	−0.280***	−0.276***
	−8.294	−8.182
ALR	−14.254***	−13.708***
	−13.319	−12.705
SIZE	3.583***	3.406***
	18.132	16.694
Independent Variables		
ROY		0.589***
		2.588
ROY Squared		−0.007**
		−2.420
c	1.281***	1.331***
	9.304	9.550
R Squared	0.189	0.191
F Value	117.379***	70.190***

Notes : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4
Moderating Effect of Educational Level.

	Model 1	Model 2	Model 3	Model 4	Model 5
	Technology-oriented companies		Production-oriented companies		Full sample
Control Variables					
AGE	−0.247***	−0.274***	−0.250***	−0.258***	−0.326***
	−5.179	−11.59	−4.267	−4.541	−9.644
ALR	−7.505***	−8.889***	−21.297***	−20.265***	−15.071***
	−7.705	−10.758	−11.559	−10.945	−13.806
SIZE	2.432***	2.876***	4.828***	4.748***	3.283***
	10.133	22.283	14.871	14.575	15.44
Independent Variables					
ROY	0.232*	0.333*	3.470***	2.376**	1.013***
	1.955	1.751	3.86	2.072	4.283
ROY Squared	−0.002*	−0.003	−0.543***	−0.747***	−0.011***
	−1.671	−1.337	−3.010	−3.233	−3.921
Moderators					
EDUR		3.031***		−2.685	3.800***
		5.864		−0.793	4.809
EDUR*ROY		3.232***		−14.996	3.369**
		2.72		−1.505	2.562
c	1.840***	1.655***	−4.650**	−6.951**	1.160***
	14.419	18.656	−2.386	−2.554	8.351
R Squared	0.188	0.484	0.319	0.319	0.208
F Value	36.021	102.167	70.183	50.33	56.966

Notes : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4. Results

4.1. Open innovation and firm performance

Regression tests were run on Eqs. (3-1) and (3-2) and the results are shown in Table 4. The paper adopted the panel data least-squares regression method. ROE was the dependent variable, cross-section weighted. Model 1 was based on Eqs. (3-1) and Model 2 was based on Eq. (3-2).

It is obvious from the test results that the dependent variable ROE is significantly related to ROY. Quadratic term coefficients are negative, confirming an Inverted-U quadratic shape (Fig. 1). Independent variables are all significant. The C-statistic measures the discriminative power of the equations; it is the area under the ROC curve with the predictive probabilities for the test variable. The C-statistics are significant, suggesting that the predictions are robust. Hypothesis 1, that an inverted U-shaped relationship between open innovation and firm performance exists in the manufacturing industry in China, is thus supported.

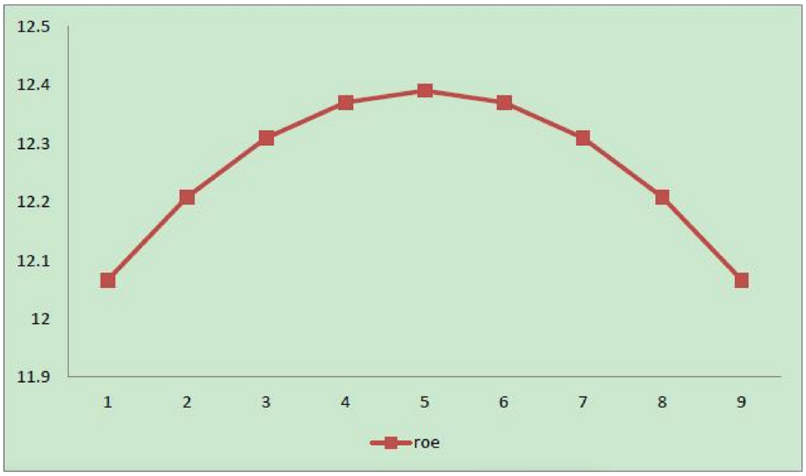

Fig. 1. Open innovation and firm performance(ROE being the dependent).

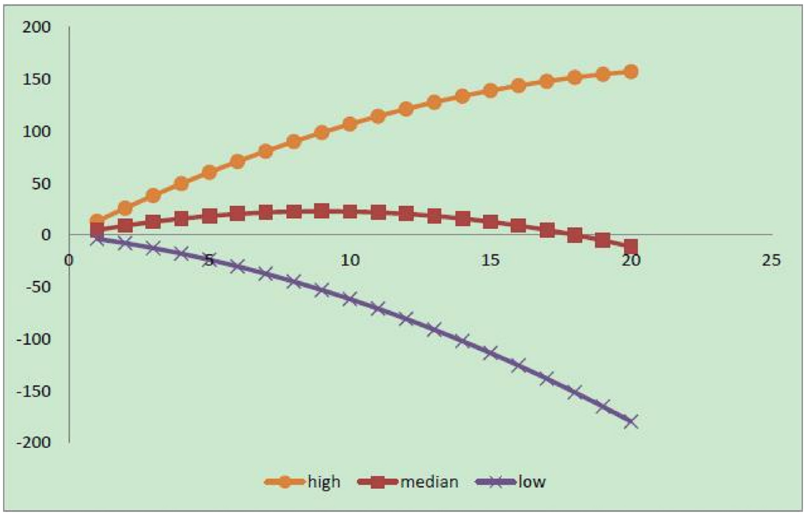

Fig. 2. The moderating effect of educational level (human capital quality) for sample manufacturing companies.

4.2. The moderating effects of human Capital

4.2.1. The moderating effect of human Capital quality

Regressions were run using EDUR as an indicator for human capital quality and the results are shown in Table 4, where Model 1 and Model 2 were for technology-oriented companies, Model 3 and Model 4 were for production-oriented companies, and Model 5 shows the results of the full sample. Model 1 and Model 3 only examined the effects of control variables and independent variables, while Model 2 and Model 4 considered the effects of moderators.

When using educational level as a moderator, its moderating effect is significant and positive for technology-oriented firms. For production-oriented enterprises, the effect is not statistically significant. When educational level (EDUR) was entered in the full sample, its overall effect was significant and positive, indicating that the higher the educational level of employees, the greater contribution open innovation will make to the firm's financial performance (Fig. 2).

Table 5
Moderating Effect of Human Capital Structures.

	Model 1	Model 2	Model 3	Model 4
	Technology-oriented companies		Production-oriented companies	
Control Variables				
AGE	−0.247***	−0.258***	−0.250***	−0.262***
	−5.179	−5.390	−4.267	−4.608
ALR	−7.505***	−7.861***	−21.297***	−20.054***
	−7.705	−7.354	−11.559	−11.295
SIZE	2.432***	2.510***	4.828***	4.914***
	10.133	9.566	14.871	16.527
Independent Variables				
ROY	0.232*	0.434***	3.470***	−24.146***
	1.955	3.565	3.86	−4.017
ROY Squared	−0.002*	−0.003*	−0.543***	−1.072***
	−1.671	−1.702	−3.010	−4.198
Moderators				
STRUC		0.428***		3.037
		3.63		0.616
STRUC*ROY		1.119***		−49.645***
		5.998		−4.532
c	1.840***	1.771***	−4.650**	−8.369*
	14.419	13.382	−2.386	−1.912
R Squared	0.188	0.241	0.319	0.354
F Value	36.021	35.319	70.183	58.777

Notes : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

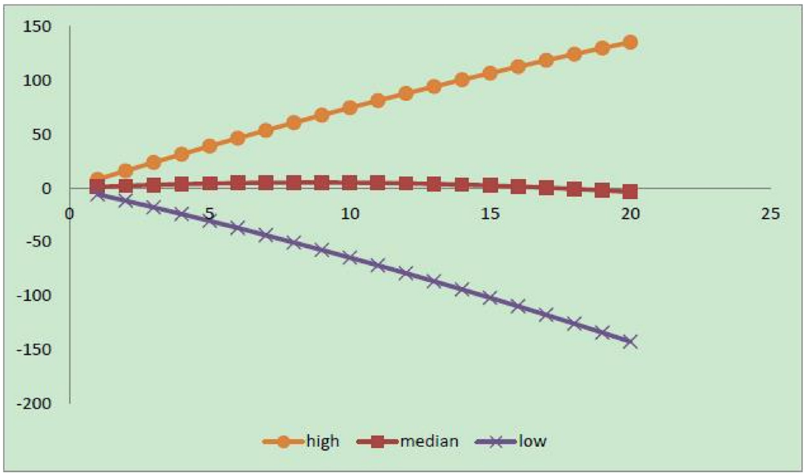

Fig. 3. The moderating effect of human capital structure for technology-oriented firms.

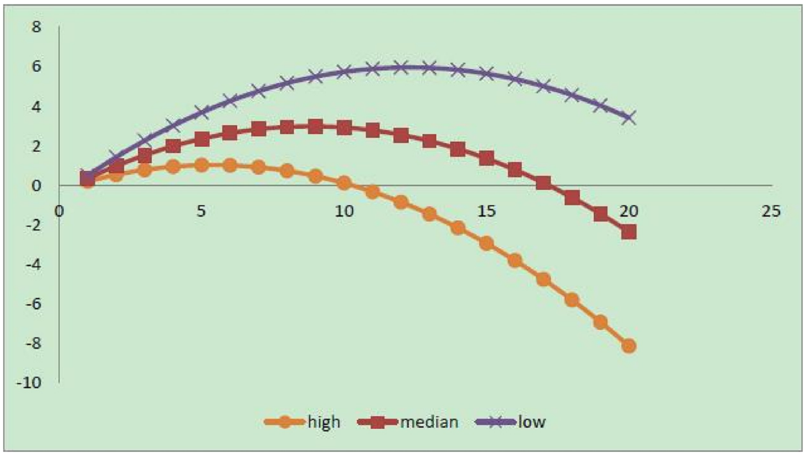

Fig. 4. The moderating effect of human capital structure for production-oriented firms.

4.2.2. The moderating effect of human Capital structure

Human capital structure (STRUC) was further used as a moderator in a regression analysis for technology-oriented companies (Model 1 and Model 2 in Table 5) and production-oriented companies respectively (Model 3 and Model 4 in Table 5). Model 1 and Model 3 only examined the effects of control variables and independent variables, while Model 2 and Model 4 took into account the moderators.

From the table, STRUC*ROY is significant (below 1%), which suggests that human capital structure has a significant moderating effect on the model. Model 2 shows that, for technology-oriented companies, human capital structure has a positive effect on the relationship between open innovation and firm performance. However, for production-oriented companies, structure has a negative moderating effect. Hypothesis H2b and H2c are hence supported.

Adopting the method in Aiken and West (1991), Fig. 3 was drawn to show the moderating effect of human capital structure on the relationship between open innovation and firm performance. The median value lines are the median values of the moderators in each model. The highest and lowest lines are respectively ± 0.5 standard deviations above and below the median. In technology-oriented firms in the sample, the structure ratio of technical staff to production staff has a positive interaction, which is to say that when inputs into open innovation are the same, the company with more technical staff will perform better.

In Fig. 3, the horizontal axis represents the independent variable 'inputs into open innovation', and the vertical axis stands for the number of enterprises. The top line is the number of companies with a high structure ratio and the bottom line is the number of companies with a low ratio.

However, this is not the case for production-oriented companies. The constant is negative, meaning that higher structure ratios are related to poor firm performance, as shown in Fig. 4. The results suggest that, in production-oriented companies, the higher the number of technical staff compared to production staff, the worse performance will be for firms within the open innovation paradigm.

5. Conclusion and discussion

This paper studies how human capital can affect the relationship between open innovation and the financial performance of firms. The analysis used the cost of purchasing external patent and non-patent technology as the operating variables measuring open innovation, which is explorative in the emerging area of open innovation study. A panel data analysis was then conducted using data from China's manufacturing industry over the course of eleven years.

First, the results demonstrate that there is an inversed U-shape relationship between open innovation and firm profitability, indicating the existence of a threshold for the effectiveness of open innovation strategy. Once investment in open innovation exceeds the threshold, firm financial performance will deteriorate. Prior researches have extensively investigated the value creation process of openness, i.e. the relationship between open innovation and innovation performance. This paper focus on the value capture process of open innovation, indicated by the financial performance. It is a complementary and further-step research to the extensively studied relationship between openness and innovative performance.

Second, the moderating effect of human capital, as an important but usually overlooked element of absorptive capacity, in open innovation is also a new experiment in our research. The fresh angle provided here will lay a good foundation for future studies and it has already yielded practical implications, which will be discussed later in this section.

We investigated human capital from two perspectives, quality and structure. From the perspective of human capital quality, the results generally indicated that the higher the education level of employees, the better financial performance will be. But for production-oriented firms, such argument does not hold (as showed in model 4 in Table 4). One possible explanation is that for production-orientation firms, profitability is highly related to process innovation and incremental improvement which lead to lower production cost and higher efficiency. Therefore, production-orientation firms are more likely to purchase technology which is non-radical and process-improvement-related. Such purchased knowledge is mainly transformed and utilized by production staff at the assemble line, who are usually not highly educated, which is why the education level (quality of human capital) does not positively and significantly moderate open innovation and financial performance in production-orientation firms.

Further, considering that companies with different strategic orientations regarding technological advancements (technology-oriented or production-oriented) tend to purchase different types of knowledge (radical or incremental), which leads to different requirement for human capital structure. The results showed that, in technology-oriented firms, as the ratio of technical staff to production staff increases, the financial performance of firms improves as a result of the implementation of an open innovation strategy. However, in production-oriented firms, the moderating role is negative. This may be explained by the fact that technical workers in production-oriented firms are limited to product modification and service support. The increase in technical staff and the investment in external sources therefore wastes organizational resources to some extent.

From the perspective of management studies, the implication of this paper is that an open innovation strategy should be implemented with caution, depending on the strategic orientation of the company. Relying on external technological resources should be balanced with the maintenance of in-house R&D competitiveness. Considering firm size, total assets, firm age, and the quality and structure of human capital, management should be able to formulate a balanced open innovation strategy. Human capital has a moderating role in the relationship between open innovation and firm performance. Therefore, Firms should align their strategic orientation, human capital investment strategy and openness strategy. For technology-oriented firms, highly educated and technical staff should be valued. For production-oriented firms, they are supposed to invest in the continued training for production staffs in order to improve the efficiency of technology adaptation and modification.

The transformation mechanism of open innovation into firm performance is rarely studied. Therefore, by studying the role of human capital and the effect of open innovation, this paper contributes to the theory and the management of open innovation practices. However, the use of secondary data puts a cap on the analysis and limits the choice of variables. Future research can collect first-hand data via surveys and try to incorporate more factors that may be specific to open innovation, such as R&D information. The balance between open innovation and in-house R&D performance may have more implications for Chinese firms that are catching up in technological and economic development.

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