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Empirical analysis of R&D in the Japanese construction industry based on the structure conduct performance model

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Abstract: This study examines the reasons for research and development (R&D) inactivity in Japan's construction industry. Specifically, it considers the structure of the construction industry in Japan and identifies contractors' patterns of behaviour regarding R&D. This study examines the relations among the structure of the construction industry, contractors' behaviour patterns and contractors' performance. The theoretical background of analysis is based on the structure conduct performance model. This study examines the impact of the public works system in Japan on contractors' R&D investments, using a regression analysis based on actual data. This study finds that only contractors with a high *Keiei Jikou Sinsa* score, which is an examination of subjective matters during the bidding process for public works projects, actively conduct R&D activity. This implies that R&D investment can enhance future profits; thus, Japanese Government's bidding system impacts contractors' R&D investments.

Subjects: Corporate Finance; Property & Real Estate Finance; Business, Management and Accounting

Keywords: innovation; regulation; bidding; pre-qualification; R&D

1. Introduction

In recent years, the Japanese construction industry has been required to create new innovation from research and development (R&D). Compared with other industries, many recent bankruptcies in the Japanese construction industry have been caused by the shortage workers, which prevents companies from bidding for public works. In the background, the industry faces problems such as ageing managements and a lack of succession planning. From fiscal year 2000 to 2012, the number of contractors decreased by more than 110,000 companies. Accordingly, the number of workers in the Japanese construction industry has decreased by more than 1.5 million people. To solve these problems, innovation such as development of construction robots, simplification of construction and labour-saving of construction works is required. To develop high-quality public works using these

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PUBLIC INTEREST STATEMENT

This study focuses on the impact of the public works bidding system on contractors' R&D investments in Japan. The government of Japan is orderer (client) in public works; therefore, it is possible to discuss the impact of the government of Japan on contractors' R&D investments.

tools created by construction industry R&D, the government of Japan has expanded order systems for public works.

Moreover, Gambatese and Hallowell (2011) argue that the innovation is essential to long-term corporate performance, in order to be successful in the construction industry. However, the construction sector's R&D investment is very low in all sectors in Japan. Compared with R&D expenditure as a percent of sales in all industries in 2013 (3.33%), R&D investment in construction industry was almost negligible (0.41%) according to Statistics Bureau, Ministry of Internal Affairs and Communications (2014). In addition, result from a questionnaire survey by the Japan Federation of Construction Contractors (2015) indicates that the mean R&D expenditures divided by sales was 0.51% in fiscal 2014. In comparison with the 2013 fiscal year, 42% of contractors decreased this ratio research and development expenditures divided by their sales and thus, R&D investment also decreased.

Why are contractors in Japan passive with regard to R&D? Lim and Ofori (2007) indicate that contribution to profit maximisation is the major driving force of innovation. Then, does not innovation (in particular, R&D) contribute to profit maximisation in Japan's construction industry?

As previous research in other countries, National Endowment for Science, Technology and the Arts (2007) mentions that the development and adoption of such innovations in UK's construction sector is chiefly informed by clients' demands, government regulation and skills levels in the sector. In addition, Ye, Shen, and Tan (2010) and Liu, Zhao, and Liao (2013) analyse China's construction market using the structure conduct performance (SCP) paradigm and indicate that the significant relationship between market structure and performance.

This study discusses the reasons for R&D inactivity in Japan's construction industry based on the SCP model. Specially, this study considers the structure in construction industry in Japan and identifies the contractors' patterns of behaviour regarding R&D. Moreover, it examines the relations among the structure of the construction industry, contractors' behaviour patterns and contractors' performance, particularly contractors' profit.

Furthermore, this study focuses on the impact of Japan's public works bidding system on the contractors' R&D investments. As the client, the government of Japan issues orders for public works; therefore, it is possible to discuss the impact of the government of Japan on contractors' R&D investments.[1] In particular, the government of Japan promotes the diversification for the order system to effectively utilise the results of contractors' R&D for the public works. This study analyses whether the order system promotes contractors' R&D investments. The originality of this study is analysing the impact of Japan's public works bidding system on contractors' R&D and investigating how contractors' behaviour patterns relate to individual performance through statistical analysis of the actual data.

2. Literature

2.1. R&D support policy

This subsection summarises the literatures of the effect of public R&D support policies to firm on R&D investment.

The literatures of the effect of public R&D subsidy on firms' R&D investments are as follows. Xu, Huang, and Xu (2014) compare how government R&D subsidy and knowledge transfer from universities and public research institutions stimulate a firm's new product development based on the investigation of 270 Chinese firms. They find that both government R&D subsidy and knowledge transfer from universities and public research institutions enhance new product development. Hud and Hussinger (2015) investigate the impact of public R&D subsidies on R&D investment of small and medium-sized enterprises in Germany during the most recent economic crisis. They show that R&D subsidies lead to an additional effect for the overall period, and the evidence for a crowding out effect for the crisis year 2009. Bronzini and Piselli (2016) investigate the effect of the grants on patent

applications by R&D subsidy programme in a region of northern Italy. They show that the effect turns out to be significantly greater for smaller firms than for larger enterprises and the programme is successful in increasing the likelihood of applying for a patent, but only for smaller firms. Yu, Guo, Le-Nguyen, Barnes, and Zhang (2016) investigate the influence of government technology development subsidies on enterprises' R&D investment behaviour, focusing on China's renewable energy sector. They find that the effect of government subsidies on increasing enterprises' intention to invest in R&D demonstrates an inverted-U relationship, in other words, government subsidies create a crowding out effect followed by an incentive effect.

The literatures of the effect of government R&D tax incentives or public low-interest loans on firms' R&D investments are as follows. Zhu, Xu, and Lundin (2006) analyse the impact of government's direct fundings and tax incentives on R&D investments of industrial sectors using the data of industry level R&D investments in Shanghai. They find that government's direct fundings have positive effects on the industrial R&D investment, but, regarding tax incentives, the enterprises have the tendency to switch to the general science and technology investments that are less costly and may yield quicker returns on investments in the short run. Thomson (2010) examines the determinants of investment in R&D with a focus on the role of tax policy based on the analysis of Australian firms' data. Thomson (2010) finds that there is no evidence that tax policy can influence firms' investment in R&D. Huergo, Trenado, and Ubierna (2016) investigate how the public low-interest loans for R&D projects affect the decision to invest in R&D for Spanish firms. They find that the effectiveness of public low-interest loans is significant, and it effects larger for SMEs than for large firms and also higher for manufacturing industry than for services industry.

From these literatures, the effect of subsidy is generally positive, that of tax incentives is nothing, and that of public low interest is positive. However, there is little study of the effect on the R&D investment by other R&D promotion system such as a bidding system which is focused by this study.

As a current situation in Japan, National Institute of Science and Technology Policy (2010) conducts the questionnaire survey on research activities of Japanese firms and find that there is little influence of public support such as tax incentives and research grants on the increase and decrease in research and development expenses. In addition, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has established a construction technology research and development subsidy system as a competitive funding system to promote technological innovation in the construction field. However, the construction technology research and development subsidy system adopts about 10 projects every year, the amount of which is less than 30 million yen per case, and most of it is used by the university (http://www.mlit.go.jp/tec/gijutu/kaihatu/josei.html).

In view of the above, it can be said that in the Japanese construction industry, public support such as tax incentives and research grants has not influenced R&D spending. Therefore, this study focuses only on the relationship between bidding system and R&D.

2.2. Construction innovation

From long ago, there has been research on innovation in the construction industry. For example, Economic Commission for Europe (1959) advocates a concept to rationalise building production and industrialise construction. However, Fairclough (2002) comprehensively investigated the construction industry and concluded that R&D investment in the construction industry is inadequate and that government's efficient support is necessary. Miozzo and Dewick (2002) investigated the innovation of the European construction industry and found that government support is important in all countries. Moreover, they find that governments can act as a broker to bring together collaborations and networks and facilitate relations between contractors and a wide range of institutions such as universities and specialist subcontractors. In order to analyse the results of R&D investment, Kulatunga, Amaratunga, and Haigh (2011) develops a performance measure of R&D expenditure. In the following, this study summarises the literature regarding the impact of regulations and the relationship

between contractors and external stakeholders on innovation. For recent research and development around the world see Hampson, Kraatz, and Sanchez (2014).

The studies on the relationship between the regulations and innovation as follow. National Endowment for Science, Technology and the Arts (2007) insists that achieving maximum productivity requires taking a sector-wide view—led by industry, supported by government and bringing in users and suppliers where appropriate, and that it involves the extension of existing policies such as the government ensuring the right conditions for innovation—through intelligent regulation, taxation, procurement and education policy. Hardie and Newell (2011) survey small and medium-sized contractors using the analytic hierarchy process and find that the greatest impact on small and medium-sized contractors' innovation is the regulatory climate in Australia. Pries and Dorée (2005) investigate the types and sources of innovation in the Dutch construction industry from 1945 and find that one-third of all new innovations are in response to new regulations. The impact of regulations concerning safety and environmental and labour conditions has been particularly dominant in the last two decades. Therefore, Hardie and Newell (2011) indicate that the role of government regulators is important for innovation. Suprun and Stewart (2015) survey contractors in the Russian Federation and find that economic and financial difficulties as well as inappropriate legislation are the most significant barriers to innovation. Through case studies of Australian contractors, Manley (2008) examines the method used by small firms to overcome the disadvantages of their size and finds that bias in the allocation of government business assistance and regulatory matters are key obstacles to innovation implementation. Studies by these researchers indicate that regulations of government regulators are important to innovation and the improper regulations inhibit innovation.

The studies on the relationship between contractors and external stakeholders including government on innovation. Manley (2006) surveys the Australian construction industry and find that the clients have a relatively high level of innovation competence compared with contractors, consultants and suppliers. Manley (2006) argues that developing the internal innovation competence of public sector clients is necessary to promote industrial innovation. Lim and Peltner (2011) empirically examines contractors in Singapore and Germany and find that German contractors develop unique firm-specific resources that induces their competitiveness edge. In addition, they find that in Singapore, contractors depend on the nation's basic science and technology research, which weakens contractors' innovation capabilities. Furthermore, they claim that the government should take the initiative to strengthen relationships with contractors in Singapore to support the development of R&D. Kulatunga, Kulatunga, Amaratunga, and Haigh (2011) analyse a case study in the northwest region of the UK. They find that clients can increase the work efficiency of the construction process and stimulate team dynamics and team action, which can strengthen the innovation process that leads to an innovative product. On the other hand, Ivory (2005) conducts three case studies in the UK and finds that the strong leadership of clients may lead to negative consequences for the innovation by suppression of the innovation and an overly narrow focus on particular types of innovation. Blayse and Manley (2004) review the literature on innovation in the construction industry and find the following factors affecting innovation: (1) clients and manufacturers; (2) the structure of production; (3) relationships between individuals and firms within the industry and between the industry and external parties; (4) procurement systems; (5) regulations/standards; and (6) the nature and quality of organisational resources. In addition, Kulatunga, Amaratunga, and Haigh (2009) conduct a questionnaire survey and interviews with R&D academic members and industrial partners regarding the critical success factors of construction R&D. They find that the emphasis is placed on the satisfaction of stakeholders from the beginning of an R&D projects. Holt (2015) explores the relation between innovation development and business evolution in the British construction industry from the eighteenth to the twentieth century. Holt (2015) finds that innovation was principally an exogenous influence. From the literatures, external stakeholders impact innovation in the construction industry outside Japan.

This study analyses the impact of the Japanese Government as regulator and client on contractor's R&D expenditures, which is one source of contractors' innovation.

2.3. Studies on contracting system and market structure

As the study of contracting system and market structure, Liu, Wang, Chen, and Shen (2013) analyse that the market structure of China's construction industry based on the Panzar–Rosse model. Liu et al. (2013) reveal that China's construction industry operates under conditions of monopolistic competition with free-entry equilibrium and there is some degree of professional monopoly in the multilayer contracting system and qualification management system.

The studies of analysing the construction market using the SCP paradigm are as follows. Ye et al. (2010) find that 23 conducts or strategies are developed and 9 performance indicators are identified with reference to the Chinese construction market using the SCP paradigm. Nevertheless, Ye et al. (2010) find that only six conducts or strategies can support contractors to respond effectively in various competition situations. Therefore, Ye et al. (2010) insist that the response strategies by construction firms should be specified in line with specific competition situations. Liu et al. (2013) analyse the market structure, ownership structure of the construction industry, and associated industry performance under the market economy system with Chinese characteristics, and show that both structure and performance are positively correlated, and performance is more greatly affected by market structure than by ownership structure. Liu et al. (2013) revise the SCP paradigm for ownership structure and market structure conduct performance (SSCP) framework so they can be applied to China's construction industry. Ye et al. (2010) and Liu et al. (2013) analyse the China's construction market using the SCP paradigm, but this study analyses Japanese construction market using the same paradigm.

2.4. Studies on R&D in Japan

The literatures on innovation policy of the government of Japan are as follows. Crow and Nath (1990) examine the factors that affect corporate technology strategies using on a survey of Japanese companies. They find that technology strategy making in the Japanese corporation is driven by market forces but directed towards overall national goals and, however, the influence of specific public policies directed towards stimulating corporate technology development is quite limited. Eto (1980) points out the problems and characteristic features of Japanese technology policy in 1960s and 1970s. Harayama (2001) summarises Japanese technology policy in twentieth century and perceive the vision for the twenty-first century. From these literatures, even in Japan, the government supported R&D investments of firm, but the effect of this policy was not verified. This study evaluates a R&D promotion policy of Japanese Government.

The literatures of the state of R&D and the relationship between R&D and productivity in Japan are as follows. Motohashi (2009) analyses the determinants of R&D for Japanese firms from 1980. Furthermore, Motohashi (2009) indicates that firms concentrate their R&D activities in highly profitable fields under harsh financial constraints and fierce global competition. Shimizu and Tamakuma (2009) analyses the factors of firm productivity using micro-data from Japan's 2003–2007 Survey of Research and Development. They find that research investment positively impacts firm productivity; however, they note that the number of employees significantly impacts firm productivity than R&D investment. Kwon, Fukao, and Kim (2008) analyse that the effect of R&D investment on total factor productivity (TFP) growth, using financial data and micro-data from Japan's 1986-2005 Survey of Research and Development. They indicate that R&D investment positively impacts TFP growth, even if it is estimated by industry and time separately.

From these studies, it has been shown that R&D also stimulates productivity in Japan. This study analyses whether R&D investment is related to the profits of contractors engaged in public works.

3. Theoretical background: SCP model

To specify the reasons for inactive R&D in the construction industry in Japan, this study analyses contractors based on the SCP model. The SCP model has been applied to the study on industrial organisation since the 1930s and Bain (1959) further developed the Model. The five forces analysis advocated by Porter (1980) is famous strategic management theory and is based on the SCP model. The SCP model provides a framework to analyse the relations among industry structure, firm conduct and firm performance. Firm performance is determined by industry structure because attributes of the industry structure determine the range and choice constraints of the firm's action. Therefore, from an SCP model perspective, finding an attractive industry for investment is the most important management strategy.

Nieto (2003) surveys past studies of innovation management and summarises research on R&D based on SCP model. Jamasb and Pollitt (2008) review the industrial organisation literature on R&D and innovation to explore the likely causes of the decline in R&D spending in the electricity sector using the SCP model. Furthermore, Clark, Hayes, and Lorenz (1985) empirically analyse the relationships between effort put into R&D by companies and the structure of industries.

This study considers the structure of Japan's construction industry and identifies contractors' behaviour patterns regarding R&D based on the SCP model. In addition, it investigates how contractors' behaviour patterns relate to individual performance.

Based on the SCP model, the research questions of this study are following.

RQ1 Does the industry structure of contractors engaged in public works affect contractors' R&D investment?

RQ2 Does the performance of contractors who undertake R&D is high?

4. Managerial background

This section summarises the industry structure in Japan's construction industry that is engaged in public works. In public works, although many suppliers exist, the orderer of public works is one entity: it is demand monopoly, where supplier selection is determined through a bidding system defined by the orderer.

There are two types of general competitive bidding system: the lowest price bidding method and the general evaluation system. The lowest price bidding method is a method of making a company that applied at the lowest price within the limit of the planned price determined by the orderer as the successful bidder. Before 2005, the lowest price bidding method was the principle.

The general evaluation system was introduced experimentally in 1999. The general evaluation system is a method of making a company that applied for the most advantageous price and other conditions to the orderer as a successful bidder. It evaluates various conditions such as not only price but technical ability and creative ingenuity of planning content. Concretely, the winning bidder is decided by the following procedure. First, information on the bidding of public works is made public by the orderer by gazette, bulletin, etc. Second, bid applicants submit the statement of participation and documents. The orderer reviews the technical competence that is set as a competitive entry qualification. As a result of the examination of technical competence, contractors that do not meet the criteria for examination (competition qualification requirements) shall not be entitled to participate in the competition. Third, in the case that it becomes a better technical proposal by improvement or in the case that some deficiencies can be solved, through technical dialogue between the orderer and the competing participant, the orderer can ask for improvement of the technical proposal or give opportunities to propose an improvement to competitive participants. Technical dialogue is conducted for all competing participants who submitted technology proposals and the scope of technical dialogue is limited to technical proposals and related construction plans.

Forth, bid applicants submitting an improved technical proposal and order evaluates it. Fifth, to draw out aggressive technical proposals from competing participants and to adopt the best proposal, the orderer can change an estimated price. Sixth, bid applicants perform bidding. Finally, the winning bidder is decided by the comprehensive evaluation of the evaluation score on performance, function and technology presented as a technical proposal and bid price.

There are three scoring types in the general evaluation system: simple type, standard type and high design proposal type. The simple type excludes procedures (4)–(6) and the standard type excludes procedure (6). The simple type is applied to construction requiring little technical improvement. In the simple type, contractors are confirmed and evaluated on the basis of their construction capabilities. The standard type is applied to construction requiring significant technical improvements using standard technologies and methods. In the standard type, contractors are confirmed and evaluated on the basis of their construction capabilities as well as the design proposal. The high design proposal type is also applied to construction requiring significant technical improvement by innovative technologies, methods and tools. Evaluation items and weights differ depending on scoring types? For the detail of three scoring types, see Table 1.

Under enforcement of the *Bill for Ensuring the Quality of Public Works*, MLIT gradually changed the general evaluation system from 2005 for determining the contractors for public works. The almost public works ordered by MLIT directly were applied the general evaluation system from 2007.

Figure 1 illustrates the relation between scoring types and scale/difficulty of the construction. If the scale of construction is large and the level of difficulty is high, then the scoring type tends to be standard type or high design proposal type. Therefore, contractors are evaluated on the basis of quality of their technical proposals.

5. Analysis

5.1. Analysis of RQ1

In Section 4, this study finds that contractors who have the high grade need to provide technical proposal as part of the bidding process. Using actual data, this section analyses whether these contractors also actively engage in R&D.

A contractor's grade is determined by the examination of subjective matters of *Keiei Jikou Sinsa* and the order's own objective matters. The criteria of the grade depend on the orderer. In the Kanto Regional Development Bureau, the score of *Keiei Jikou Sinsa* carries the same weight compared with the orderer's evaluation. *Keiei Jikou Sinsa* is a competitive bid entry qualifications examination for public works contracts in Japan. *Keiei Jikou Sinsa* rates the contractors who wish to undertake public works using objective matters, such as the financial condition and other circumstances. Under the Construction Business Act, contractors who wish to undertake public works must be examined by *Keiei Jikou Sinsa* every year. Moreover, *Keiei Jikou Sinsa* imposes penalties for falsified applications; therefore, the data of *Keiei Jikou Sinsa* are considered to be reliable. For details of *Keiei Jikou Sinsa*, see Konno (2014).

It is impossible to obtain a static orderer's evaluation. However, higher the score of *Keiei Jikou Sinsa* obtained by contractors, higher the possibility of the bids that apply the high design proposal type. Therefore, this study examines the relation between the score of *Keiei Jikou Sinsa* and R&D expenditure divided by sales. In other words, it analyses whether contractors with higher score of *Keiei Jikou Sinsa* actively conduct R&D. However, *Keiei Jikou Sinsa* considers R&D investment in calculating the score; therefore, this study uses a modified score of *Keiei Jikou Sinsa* that excludes R&D investment rating.

The contractors as subjects of this analysis, were selected according to the following criteria: (1) large-scale contractors with capital equal to or greater than 300 million yen; (2) contractors who have been involved in general civil engineering; (3) contractors who have completed the

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Table 1. The scoring types of the general evaluation system

Scoring types	Types of construction	Presence of standard proposal	Scope of technical proposal	Ordering method
Simple type	When confirming whether contractors have the ability to perform appropriate and reliable construction based on the specification indicated by the orderer	Yes	Construction technique	Design-bid-build
Standard type	When requesting a technical proposal such as ingenuity on construction for the standard specification indicated by the orderer	Yes	Construction technique	Design-bid-build
High design proposal type I	In case of expecting a considerable improvement in social benefits by advanced construction technology	Yes	Construction technique	Design-bid-build
High design proposal type II	There are multiple possible construction methods, and the optimum plan is selected in the technical proposal	No (There are multiple candidates)	Construction technique and object	Design-build
High design proposal type III	The constraint condition cannot be satisfied by the usual construction method	No	Construction technique and object	Design-build

Table 2. Descriptive of statistics

Variable	Sample size	Mean	SD	Min	Max
R&D/sales	73	0.20	0.24	0.00	0.92
Capital	73	9.10	18.73	0.31	112.45
Modified score of *Keiei Jikou Sinsa*	73	1337.12	278.91	611.00	1888.80

construction work for more than three cases ordered by the Kanto Regional Development Bureau in the past two years.

The descriptive statistics for each variable are presented in Table 2. The unit of R&D expenditure divided by sales is percent; the unit of capital is billion yen; the unit of modified score of *Keiei Jikou Sinsa* is point (original value). The number of contractors is 73 in this analysis. This study employs Tobit regression analysis to examine the impact of modified point of *Keiei Jikou Sinsa* on the R&D expenditure divided by sales. The explanatory variable is the modified score of *Keiei Jikou Sinsa* and the capital of each contractor is for fiscal 2009. The explained variable is the R&D expenditure divided by sales in fiscal 2009. Applying the capital for the explanatory variable, this study can control the effects of the contractor' scale on the R&D expenditure divided by sales.

5.2. Results of RQ1

The results presented in Table 3 indicate that the modified score of *Keiei Jikou Sinsa* and contractor capital significantly positively influence R&D expenditure divided by sales. In other words, the higher the modified score of *Keiei Jikou Sinsa* and contractor capital, the more likely R&D expenditure divided by sales will be larger. When the modified score of *Keiei Jikou Sinsa* is large, the grade is high in general.

This implies that contractors with high scores, i.e. who to participate in bidding for projects requiring technical proposals are more active in R&D. In other words, RQ1 is supported.

5.3. Analysis of RQ2

This section examines the performance of contractors who undertake R&D. Specially, this study analyses whether contractors actively engaged in R&D also generate higher profits. Similar to the previous analysis, the contractors are selected according to the following criteria: (1) large-scale contractors with capital that is equal to or more than 300 million yen; (2) contractors who have been involved in general civil engineering; (3) contractors who have completed the construction work for more than three cases ordered by the Kanto Regional Development Bureau in the past two years. Japan Federation of Construction Contractors (2015) underscores the short-term theme of most (70%) R&D undertaken by contractors over the past two years.

This study focuses on the contractors' performance one period and two periods later and the averages of those periods. This study uses multiple regression analysis to analyse the impact of R&D expenditure divided by sales in 2009 on the ordinary profit to total capital ratio (OPTCR) one period later (fiscal 2010), two periods later (fiscal 2011) and the averages for those two periods. Model P1 uses the OPTCR in fiscal 2010 as the explained variable. Model P1 uses the R&D expenditure divided by sales, contractor capital, capital to asset ratio (CAR) and OPTCR as the explanatory variables in fiscal 2009. Model P2 uses the OPTCR in fiscal 2011 as the explained variable. Model P2 uses R&D expenditure divided by sales, contractor capital, CAR and OPTCR as the explanatory variables in fiscal 2009. Model P3 uses the OPTCR with the averages of fiscal 2010 and 2011 as the explained variable. Model P3 uses R&D expenditure divided by sales, contractor capital, CAR and OPTCR as the explanatory variables in fiscal 2009.

To control for the effect of contractor' scale on R&D expenditure divided by sales, this study applies contractor capital as the explanatory variable. Moreover, because CAR significantly affects OPTCR, this study applies CAR as the explanatory variable. To analyse the impact of the OPTCR on

Table 3. Results on RQ1 by Tobit regression analysis

Variable	Coefficient
Capital	0.0048** (0.0019)
Modified score of *Keiei Jikou Sinsa*	0.0004*** (0.0002)
Constant	−0.5362** (0.2114)
Sample size	73
AIC	64.3705

Note: Standard errors in parentheses.

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

Table 4. Descriptive statistics under Model P1

Variable	Observation	Mean	SD	Min	Max
OPTCR in 2010	61	0.03	0.04	−0.11	0.13
OPTCR in 2009	61	3.44	4.77	−13.02	22.47
Capital	61	9.43	20.28	0.31	112.45
CAR	61	29.96	18.50	0.11	82.72
R&D/sales	61	0.20	0.25	0.00	0.92

OPTCR of one period and two periods later and and the averages of these periods. This study applies OPTCR as the explanatory variable at the same time of other explanatory variables (fiscal 2009). Therefore, this study can control the OPTCR in fiscal 2009 when contractors invest in R&D.

Tables 4–6 present the descriptive statistics for each variable under this analysis. The unit of OPTCR is percent; the unit of capital is billion yen; the unit of CAR is percent; the unit of R&D expenditure divided by sales is percent. Because this analysis only uses contractors' data with no missing values each period, the number of observations under each model is different.

5.4. Results of RQ2

Table 7 summarises the results for the three models, which indicate that R&D expenditure divided by sales significantly positively impacts the OPTCR. In Models P2 and P3, the OPTCR in the current period significantly positively impacts on the future OPTCR. In all models, contractor capital has no significant effect on OPTCR. In Models P1 and P3, CAR significantly positively impacts the future OPTCR.

These results suggest that the higher the R&D expenditure divided by sales, the more likely the future OPTCR will be larger for one period later, two periods later and the averages of one and two periods later.

Table 5. Descriptive statistics under Model P2

Variable	Observation	Mean	SD	Min	Max
OPTCR in 2011	61	0.02	0.03	−0.06	0.13
OPTCR in 2009	61	3.67	4.82	−13.02	22.47
Capital	61	9.12	20.24	0.31	112.45
CAR	61	29.82	17.91	0.11	82.72
R&D/sales	61	0.19	0.24	0.00	0.92

Table 6. Descriptive statistics under Model P3

Variable	Observation	Mean	Sd	Min	Max
Average of OPTCR	55	0.03	0.03	−0.03	0.13
OPTCR in 2009	55	3.67	4.87	−13.02	22.47
Capital	55	9.37	21.14	0.31	112.45
CAR	55	29.71	18.36	0.11	82.72
R&D/sales	55	0.20	0.24	0.00	0.92

Table 7. Results on RQ2 by regression analysis

	(1)	(2)	(3)
Variable	**Model P1**	**Model P2**	**Model P3**
OPTCR in 2009	0.0023 (0.0018)	0.0021*** (0.0006)	0.0018* (0.0010)
Capital	−0.0002 (0.0002)	−0.0001 (0.0001)	−0.0002 (0.0002)
CAR	0.0004** (0.0002)	0.0002 (0.0002)	0.0003* (0.0002)
R&D/sales	0.0509** (0.0213)	0.0402* (0.0219)	0.0397* (0.0228)
Constant	−0.0025 (0.0116)	−0.0004 (0.0079)	0.0034 (0.0071)
Sample size	61	61	55
R^2	0.308	0.255	0.344

Note: Standard errors in parentheses.

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

This result indicates that the R&D investment tends to enhance future profits. In other words, RQ2 is supported.

6. Discussion and conclusion

This study analyses the reason for inactive R&D in the Japanese construction industry based on SCP model. The main results are as follows. Contractors whose grades according to the orderer are higher can submit bids that require the technical proposals. Therefore, contractors who have a high grade need to conduct R&D. Contractors whose grades according to the orderer are higher can

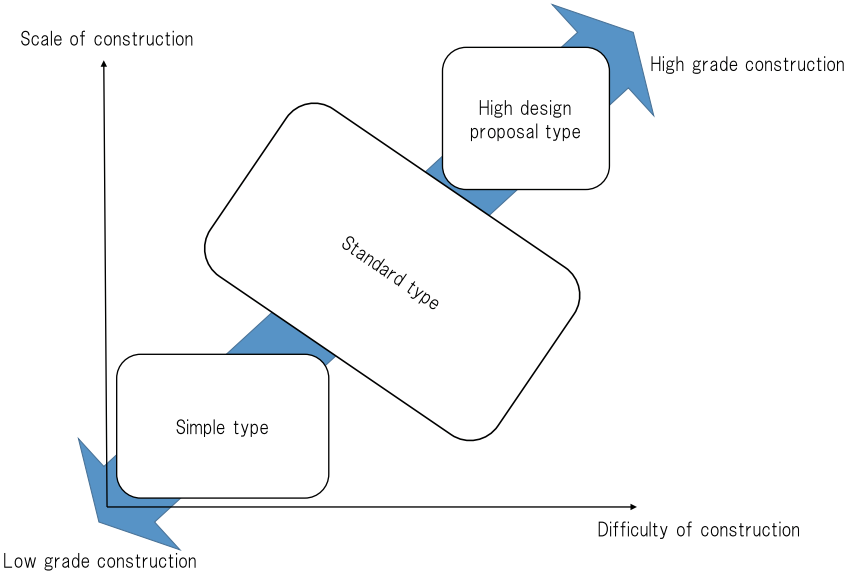

Figure 1. Relation between scoring types and scale/ difficulty of the construction.

submit bids that require the technical proposals. Therefore, contractors who have a high grade need to conduct R&D. On the other hand, contractors whose grade by the orderer is lower are limited to bidding on public works projects that do not require technical proposals and thus are exposed the competitive environment focusing on price. The empirical results indicate that R&D investment can enhance future profits.

These results reveal that contractors with high score of *Keiei Jikou Sinsa* and with high grade by the orderer actively conduct R&D, although the R&D investment can enhance the future profit. In addition, the Japanese Government's bidding system impacts contractors' R&D investment. The fact that the government impacts innovation is consistent with the findings of Hardie and Newell (2011), Suprun and Stewart (2015) and Manley (2008); the fact that the contractors engage in innovation as required by clients is consistent with the findings of Kulatunga et al. (2011), Ivory (2005), Barlow (2000) and Blayse and Manley (2004); the fact that the contracting system affects the market structure is consistent with the findings of Liu et al. (2013).

The R&D in Japan's construction industry mostly focuses on reducing cost, improving the performance and functions of construction and shortening construction time periods. Contractors with high grades need to innovate through R&D investment; regardless of their grade, contractors suffer from a shortage of workers (see Section 1) and are in need of breakthrough innovations. In particular, regardless of the grade and the scale of contractors, the contractors are required to know techniques by R&D to provide effective public service.

Sasaki (2007) analyses the decision-making of R&D investment in Japanese construction industry. Sasaki (2007) points out that because contractors bear the risk that they may not be able to receive orders during upfront investment in new technology and the individual project conditions are diverse, they take risk-averse attitude to develop technologies in two stages, taking into consideration the probability of success and profitability for the development of new technologies. In the first stage, the contractors aim to gain confidence that technology can be applied. In the second stage, when the project is materialised, the contractor negotiates the details and adapts to the conditions specific to the project.

7. Limitation and Future Research

As a limitation of this study, this study analyses the relationship between R&D and contractors' performance using the data of the Japanese construction industry from 2009 to 2011. As future research, it is necessary to lengthen the period and analyse the same thing in other countries.

In addition, this study finds that the bidding system influences R&D. By raising the weight of the evaluation items of the technical proposal of the bidding system in the future, it may reduce the uncertainty of making profit by R&D, and further R&D will be promoted.

From 2013, the MLIT revised the general evaluation system by enforcing bipolarisation such that the evaluation types of construction capability are evaluated only on the basis of construction capability; while the evaluation types of design proposal are evaluated on the basis of design proposal and construction capacity. Future research is needed to examine this impact on contractor's R&D investments.

Although there are limitations as described above, it is clear in this research that R & D investment has a positive influence on future profits. This result is useful in formulating the management strategy of the contractor by managers and creating a bidding system by national and local governances.

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Note
1. Although the clients in public works are local governments as well as government, this study focuses on the national government's order system only. However, the local governments' order systems follow the government's order system.

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