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The Relationship between Absorptive Capacity and Green Innovation

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***Abstract*—**Absorptive capacity generally facilitates the adoption of innovation. How does this relationship change when economic return is not the sole driver of innovation uptake? We investigate whether absorptive capacity facilitates the adoption of green innovation based on a survey of 79 construction companies in Scotland. Based on the results of multiple regression analyses, we confirm that existing knowledge utilisation (EKU), knowledge building (KB) and external knowledge acquisition (EKA) are significant predictors of green process GP), green administrative (GA) and green technical innovation (GT), respectively. We discuss the implications for theories of innovation adoption and knowledge enhancement associated with environmentally-friendly practices.

***Keywords*—**Absorptive capacity, construction industry, environmental, green innovation.

I. Introduction

THE environmental impact of the construction industry is well-known. The construction processes, usage, maintenance as well as renewal of the infrastructure and building, consume energy and resources that generate waste on a massive scale which globally contribute to climate change, resource depletion and pollution [1]. Many policymakers believe that construction companies should accept responsibility for minimizing their environmental impact. One mechanism for minimizing adverse effects of construction is the adoption of "green" innovations, including new technologies, management processes, and standards [2]-[5].

Green innovation management has become a topic of interest to both scholars and practitioners [6]. Evidence suggests that green innovation practices can contribute to improvement in both environmental performance and outcome [4], [7], [8]. Relatively few studies, however, specifically address the adoption of green innovation management, especially in the construction industry e.g. [9], [10].

Absorptive capacity presents an understudied, but likely important driver of green innovation adoption. Absorptive capacity is the set of interrelated organisational capabilities that enables a firm to acquire, assimilate and develop new knowledge [11]. Firms employ internal and external knowledge to create and implement innovative practices [12]. Exploring the role of absorptive capacity in the context of green innovation at construction companies presents a novel and important contribution to the literatures of management and innovation studies.

In the next section, the development of conceptual framework and hypotheses linking absorptive capacity to green innovation will be discussed. This is followed by elaboration on research methodology in which issues related to measures, sampling and data collection method. Next, the results will be highlighted and finally, this paper ends with discussion of findings.

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II. Green Innovation

'Going green' has been mentioned as a great business opportunity [13], further has been proven that by being 'green' organisations have found value [14]. In fact, it has been found that there is a positive relationship between adoption of green innovation strategies by a firm and its overall performance [15].

In general, green innovation is a type of innovation that has a reduced negative impact on the environment. In terms of terminology, there are different notions to describe this particular type of innovation. Besides 'green', the most prominent notions used in the literature to describe innovation that have a reduced negative impact on the environment are 'eco', 'environmental' and 'sustainable' [6]. In most publications, the notions are, however, used interchangeably. This type of innovation generally includes modification or change in strategies, production processes, product designing methods, waste disposal procedures and resource consumption in order to minimise the pressure on the natural environment.

In this study, green innovation practices are classified into three main categories: green technical innovation, green process innovation and green administrative innovation [7], [16]-[19]. From the technical perspective, green innovation involves application of environmentally-friendly equipment and technologies that reduce the negative impacts on the environment [18]. It refers to transition from older technologies to clean technologies. Green process innovation is any adaptation of construction process that reduces the negative impact on the environment by means of material saving, waste recycling and energy decreasing [17]. It involves the addition of new processes or improvement of existing processes to reduce environmental impact [20].

Green administrative innovation is the introduction of a new administrative process, management systems or staff development program. Those innovations occur in the administrative components and affect the social system that consists of the organisational members and their relationship

[21]. From environmental perspective, administrative innovation can occur in the form of new procedures, policies and organisational form [22] that promoting the importance of environmental consideration. It also involves changes to organisational structure, implementation of advanced management systems and techniques or introduction to new corporate strategic orientation [23] towards reducing environmental impacts.

In the construction industry, green innovation practices require actors who are involved in construction activities to increase their effort towards minimising the environmental impact through planning and managing the construction activities by (1) trying to improve the efficiency of the processes used in construction activities, (2) trying to conserve energy, water and other resources during the implementation of construction activities, and (3) trying to minimise the amount of construction waste. In addition, it also includes others strategies that do not greatly impact on the project budget or schedule, but instead, in certain condition, may reduce costs and increase productivity [9].

Previous research on construction projects which was focused at innovation in the field of sustainability has shown that "increased corporate focus on green innovation not only improved the quality of the construction projects, but also sustained and strengthened the company position in the market as well as improved and strengthened cooperative ties between involved actors" [24, p.339]. In addition, environmental responsibility demonstrated by construction firms offers many potential advantages such as increased opportunities to tender, fewer money wasted on fines, fewer money lost through wasted resources, fewer money lost on restoring environmental damages, and enhanced environmental profile [25].

It is not only within the construction industry, in fact, all business activities now have relation with green innovation practices. Improvement in environmental performance contributes to a firm's competitiveness. Therefore, firms should consider to be engaged in green innovation in order to strengthen their competitiveness. However, involvement in green innovation practices requires manipulation of knowledge either within the organisation or acquisition from external sources. Thus, through this study, understanding the role of firm's capability in acquiring and assimilating related knowledge, particularly firm's absorptive capacity, is a practicable way for firms to fully utilise the existing and available knowledge to facilitate their intention to become involve in green innovation practices turns into reality.

III. Absorptive Capacity and Green Innovation

Formerly, firms generally became involved in green innovation in order to meet external demands. They tend to react if "they are forced to do so or see a direct cost or quality advantage" [26, p.9]. Today, firms are surrounded by a lot of information and relevant knowledge that is accessible at any time it is required. This information can be used to facilitate them in engaging in innovation activities such as green innovation. Moreover, green innovation requires new knowledge [27] to be assimilated and transformed within the organisation. For that reason, firms need to develop their capability to absorb new knowledge in order to facilitate their engagement in green innovation practices. Thus, absorptive capacity could be seen as playing an important role in influencing a firm's intention to adopt green innovation practices. Defined as the ability of a firm to acquire, assimilate and develop new knowledge [11], absorptive capacity in form of ability to manage or absorb knowledge is argued to be not so much dependent on external demand, technology and other resources to become engaged in green innovation practices.

Absorptive capacity has been suggested by researchers as a concept that links knowledge generated outside the company to knowledge generated within the company [28], [29], which is one of the prerequisites to realising innovation activity. Specifically, the ability of a firm to recognise useful new external knowledge and assimilate it is developed by building on prior knowledge which has been embedded within the firm [30], [31].

This study models the relationship between absorptive capacity and the adoption of green innovation practices. Management theorists have suggested that an important prerequisite for the adoption of innovations is the acquisition, processing and assimilation of information into organisational knowledge. This learning capability is described as absorptive capacity by [11] and suggested as a key resource to support the adoption of innovation [32], [33]. It has been suggested that absorptive capacity is a critical factor that contributes to an organisation's innovativeness [34]. This is in line with a study conducted by [35] who found that absorptive capacity is one of the key determinants of adoption of information technology innovation. In order to take full advantage of knowledge transfer that is necessary for innovation, the construction companies need to have sufficient 'absorptive capacity' [36].

Developing absorptive capacity requires related organisational capabilities that could improve the firm's ability to learn. Thus, this study considers three organisational capabilities that can enhance the development of absorptive capacity: existing knowledge utilisation, knowledge building and external knowledge acquisition.

A. Existing Knowledge Utilisation and Green Innovation

A firm's absorptive capacity depends on its existing stock of knowledge, much of which is embedded in its products, processes and people. One of the important elements that lie behind the absorptive capacity framework is the existing knowledge base [37]. The external knowledge acquisition activities are closely related to the firm's existing knowledge. In the other words, it will be difficult to scan the environment and relevant knowledge from external sources if there is no internal knowledge base. Specifically, the ability of a firm to recognise useful new external knowledge and assimilate it is developed by prior knowledge which has been embedded within the firm [30], [31] which is one of the prerequisites in realising innovation activity.

The basic assumption by [11] is that prior knowledge

facilitates the use of new knowledge and therefore, determines a firm's level of absorptive capacity. In addition, the importance of prior knowledge increases in dynamic conditions because a wide knowledge base helps firms to access additional development paths [38].

In particular, the existing knowledge base of a firm is strongly related to its employees. Thus, individual skills and experiences of employees are crucial in evaluating a firm's existing knowledge base. Previous authors refer individual skills as the level of education and training of the employees as well as the experience obtained in a particular knowledge field over time [e.g. 39]. It is generally admitted that highly educated and technically qualified employees are more receptive to assimilate and transform available external knowledge [40] in order to exploit their knowledge and expertise. In other words, firms that have highly educated and trained employees will have higher levels of absorptive capacity.

In addition, the effectiveness of existing knowledge utilisation is related to the ability of a firm to stimulate and manage knowledge sharing across departments, functions as well as individuals within the firm. This aspect closely related to organisational culture and how they organise the flow of knowledge. Firms require full commitment from upper management to create a learning culture in their organisation. This can be realised by encouraging cross-functional communication as it has been found to improve absorptive capacity if it resulted in the improvement of knowledge sharing between departments and individuals in a firm [41], [42].

In addition, organisations should promote a culture that encourages employees to greater openness to change. Employees have to be given full support to suggest any improvements or changes that will lead to enrichment of knowledge by, for instance, brainstorming for new ideas as well as identifying and solving shared problems [43]. As outlined by [44], to promote knowledge sharing and transfer, firms have to provide employees with certain amount of autonomy and encourage diversity of opinions. This, in turn, will provide direction to a firm to be engaged in any types of innovation activities, including green-related innovation. Thus, he following hypothesis is derived:

H1. Adoption of green innovation at construction firms will be associated with higher level of existing knowledge utilisation.

B.Knowledge Building and Green Innovation

Knowledge sources could only be accessed through the exploitation of human capital of a firm. The key factors for innovation are the promotion of human capital and creativity [12]. To achieve this, the supporting managerial conditions and education, specifically through learning, have to be created [45]. Training and education of employees which aimed at enriching and improving related knowledge of employees will contribute to better absorptive capacity of the individual as well as the whole organisation. Also, the rationale put forward by [46] that training and education increase the stock of knowledge in an organisation. A study by [47] posits the positive relationship between the importance of investment in training by organisation with the extent of absorptive capacity.

The acquisition of relevant knowledge through education and training accelerates individuals' and teams' capability to assimilate more new knowledge, thus, in turn facilitates in developing innovative processes or products [11]. Therefore, greater absorptive capacity in the form of training and education to be provided to employees is important to facilitate the firm's engagement in green innovation practices. Hence, this study expects:

H2. Adoption of green innovation at construction firms will be associated with greater effort in providing environmental education and training to employees.

C.External Knowledge Acquisition and Green Innovation

Openness of firms to external knowledge sources is another important element when evaluating the innovative potential of a firm [30]. The use of external sources of information can assist an organisation to identify its deficiencies and promote a perception towards a need for change or improvement [48]. Furthermore, [49] claimed that, an access to greater range of knowledge sources will increases firms' odds of being lucky which contribute to a greater chance of gaining access to complementary knowledge.

In order to enhance firm's absorptive capacity, it has to build the capability to interact with other actors and access external sources of knowledge [50]. Openness to external sources of knowledge is an attitude that has been argued to be a significant contributor to the introduction of new practices [51]. Firms can access external sources of knowledge by scanning external information which can be obtained from, for instance, research databases, journals and attending conferences [52]. Professional magazines, fairs or exhibitions, and media such as newspapers and television also can provide the appropriate information to enhance the firm's knowledge base [53].

In addition, linkages are necessary to be established with outside organisations in order to facilitate knowledge acquisition and transfer. Previous research suggests that external linkages or networks are important paths in obtaining information, knowledge and building capabilities [54], [55]. The external linkages refers to cooperation with other actors within industry or with other industries, for instance, other firms, suppliers, customers, Universities or industrial associations.

These viewpoints are concomitant with statement by [27] that engaging in such relationship facilitates a firm in benefiting from external knowledge. Firms can learn and exploit external knowledge through linkages or networks. In order to introduce a specific innovation, for instance, green innovation, a firm requires a capability which can be obtained from interacting with specific actors through informal or formal linkages [56]. Thus, the following hypothesis is proposed:

H3. Adoption of green innovation at construction firms will be

associated with greater access to external sources of knowledge.

The propose model of the relationship between absorptive capacity and green innovation is shown in Fig. 1.

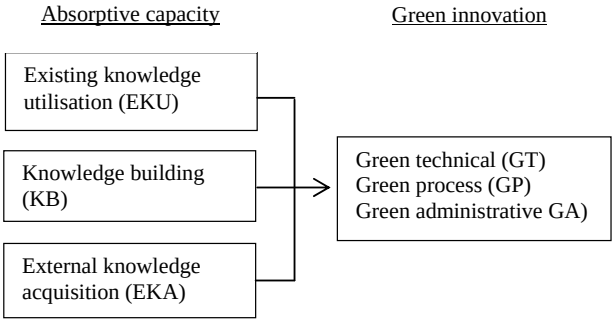

Fig. 1 Model of absorptive capacity and green innovation

IV. Method

A. Data

Survey data was used to test the hypotheses. A total of 79 construction companies throughout Scotland have participated in an online survey. The developed online survey questions were mostly using 5-point Likert scale. The green innovation and absorptive capacity constructs were derived from literature review. In order to assess face and content validity, two academics and two practitioners were contacted to get their feedback on the developed items. As a result, some items were revised to improve their precision and specificity and further administered for pilot testing.

The final version of the questionnaire comprises five sections. The first section of the questionnaire consists of the general information of the company. The second to fourth section is the measurement of the three dimensions of absorptive capacity while the final section is the measurement of green innovation practices.

Three approaches have been taken to administer the online survey. First, the survey invitation has been emailed to FMB members in Scotland which have been extracted from a large number of construction companies in Scotland to only members that considered as general builders. Second, additional invitation emails have been sent to a number of builders in Scotland that have been searched from the internet. Finally, a few visits have been done to a number of construction companies in surrounding area of Edinburgh city. The three approaches were conducted sequentially for the purpose of increasing the response rate. Out of total of 413 questionnaires administered, a total of 79 usable responses were received from all sources indicated 19.1% response rate.

In order to avoid some of the sampling biases because of collected data was came from three groups of respondent, one-way analysis of variance (ANOVA) has been used to compare the organisational characteristic between respondents who are the member of FMB (group 1), respondents that have been identified from search effort through the internet (group 2) and respondents that have been visited personally (group 3). The results indicate that there is no differences exist, at a 5% level of significant, between the three groups on firm size.

Later, non-response bias was evaluated by using ANOVA to determine whether there were significant differences in the mean values of the three green innovation factors between the three groups [57]. The results revealed that there were no differences between the three groups for any of the factor, thus proofing that the database was considered appropriate for this study.

The characteristics of the respondents' firms are shown in Table I. Majority of the firms have very small number of full time employees that is in the range of one to five people (39.2%). Most of them firms have been setting up for less than ten years and between eleven to twenty-five years (34.2 per cent respectively). The firms were mainly providing services to residential customers (36.7%) as normally served by small firms who focusing more on single sector. Majority of them are family business firms (78.5%) and only 8.9 percent of them are ISO 14000 certified firms.

TABLE I
FIRMS' CHARACTERISTICS

Characteristics	*n*	%
Number of full time employees		
Less than 5	31	39.2
5 to 15	22	27.8
More than 16	26	32.9
Age of company (years)		
Less than 10	27	34.2
11 to 25	27	34.2
More than 26	25	31.6
Industry sector		
Residential	29	36.7
Commercial	3	3.8
Residential & commercial	23	29.1
Residential, commercial & industrial	24	30.4
Ownership		
Non-family business	17	21.5
Family business	62	78.5
ISO 14000 certification		
ISO 14000 certified	7	8.9
Non-certified	68	86.1
In the process of applying the certification	4	5.1

n=79

B. Dependent Variables

GT is measured based on instruments developed by [9] and [18]. The respondents were asked to specify on a Likert scale from 1 (strongly disagree) to 5 (strongly agree) with the statements related to the adoption of listed green-related technologies in the questionnaire.

GP is measured using an instrument adapted from [16] and [58]. Based on a five-point Likert scale, the respondents were asked to state the degree of their agreement with the statements that reflect their consideration on the environment during the implementation of construction activities anchored by 'strongly disagree' (1) and 'strongly agree' (5).

By referring to the instruments developed by [18], [58]-[61], five items have been adapted to measure the adoption of GA by the construction companies. Five-point Likert scale is used to assess the degree of agreement with the statements pertaining the implementation of administrative process, new management system and employee development program

within the firm.

C.Independent Variables

EKU is determined by the stock of knowledge of employees and the existence of organisational culture that encourage all the employees to participate and contribute towards green innovation adoption. The measurement of the stock of knowledge of employees looked at the employees' level of general and technical knowledge, general education and job competencies [62]. In order to measure this construct, the respondents were asked to answer four questions by indicating their agreement on the level of particular knowledge of employees from 'strongly disagree' (1) to 'strongly agree' (5). The same scale was used to measure four items regarding organisation knowledge sharing culture based on instrument developed by [63].

The instrument developed by [28], [64], [65] were referred to measure KB in facilitating firms to become engaged in green innovation practices. The respondents were asked to state their agreement on the involvement of employees in training that directly aimed at the development and/or introduction of green innovations. A five-point Likert scale will be used to rate each particular item with 1 being 'strongly disagree' and 5 being 'strongly agree'.

EKA is measured by looking at the importance of professional and scientific information as well as external linkages as source for environmental-related information. Six items have been adapted from [51], [53], and [66] to measure the importance of following information sources: (1) conferences and fairs; (2) literature and scientific papers; (3) professional associations; (4) professional periodicals; (5) media, and (6) information network, while instruments adapted from [39], and [67], [68] were used to measure the importance of external linkages as source in gaining knowledge and building capabilities. The respondents were asked to indicate the level of agreement for the importance of each sources of information based on a five-point scale anchored by 'strongly disagree' (1) and 'strongly agree' (5).

D.Control Variable

Firm size has traditionally been considered as an important control variable. The larger the firm, the more it is likely to have more resources to adopt innovations [69] and become proactive in natural environmental management [70]. In contrast, small firms need to face the complexity and high investments in switching to greener technologies and practices [71]. Therefore, this study controls for firm size which measured by the number of full time employees in the firm.

V.Results

Preliminary analyses were conducted to ensure no violation of the assumptions of multicollinearity, normality, linearity and homoscedasticity. Table II presents the descriptive statistics and correlation matrix for all the variables that are investigated in the study. All correlations between predictor variables were weak to moderate, ranging between $r = .275$, $p < .05$ and $r = .340$, $p < .001$. The VIF are all well below the suggested cut-off of 10 [72]. This shows that multicollinearity was unlikely to be a problem. Two of three predictor variables that are KB and EKA were statistically correlated with the adoption of GT (weak to moderate) and GA (moderate) which ranging from r= 287, p<.05 to .301, p<.01, and from r=.360, p<.01 to r=.593, p<.01, respectively. While all predictor variables were statistically correlated with GP which ranging from r=.263, p<.05 to r=440, p<.01.

TABLE II
DESCRIPTIVE STATISTICS AND CORRELATIONS

Var.	Mean	SD	1	2	3	4	5	6
1 Size	28.28	68.37						
2 EKU	32.71	3.63	.089					
3 KB	14.30	3.90	-.057	.275*				
4 EKA	30.18	4.10	-.030	.151	.340**			
5 GT	11.47	2.29	.318**	.207	.287*	.301**		
6 GP	23.38	3.59	.187	.440**	.343**	.263*	.423**	
7 GA	13.03	3.93	.128	.132	.593**	.360**	.221*	.384**

$n = 79$
$^*p < .05$, $^{**}p < .01$

Further, three multiple regression analyses were performed to examine the ability of absorptive capacity to predict the adoption of green innovation among the construction firms in Scotland. Results in Table III indicate each of the hypotheses that were tested in explaining each of the dependent construct. The overall first model explains 14% of the variance in the prediction of GT with EKA was found to be the only predictor of GT.

In the second model, the total variance explained by the model as a whole was 26% and only EKU was found to be the predictor of GP while the third model as a whole explains 38% of the variance in the prediction of GA, yet only one factor that is KB was found to be the predictor of GA. Therefore, hypotheses 1, 2 and 3 are partially supported.

VI.Discussion

The general purpose of this study is to examine the relationship between firm's absorptive capacity and green innovation adoption among Scottish construction firms. Nevertheless, hypotheses 1, 2 and 3 are partly supported.

TABLE III
REGRESSION ANALYSIS SUMMARY FOR ABSORPTIVE CAPACITY PREDICTING ADOPTION OF GREEN INNOVATION

Multiple regression model	DV	R^2	F	IV	B	$SE B$	β	t	p
1	GT	.14	4.19	EKU	.08	.07	.13	1.12	.267
				KB	.10	.07	.18	1.52	.134
				EKA	.12	.06	.22	1.95	.055
2	GP	.26	8.99	EKU	.36	.10	.37	3.53	.001
				KB	.18	.10	.20	1.79	.077
				EKA	.12	.09	.14	1.35	.182
3	GA	.38	15.42	EKU	-.05	.10	-.05	-.47	.638
				KB	.55	.10	.54	5.46	.000
				EKA	.17	.09	.18	1.88	.064

$n = 79$, $p < .05$

As suggested by hypothesis 1, this study expects that high level of existing knowledge utilisation will be associated with the adoption of green innovation. The first findings present the different picture of absorptive capacity linking green innovation. Instead of reflecting the reality on the importance of strong foundation of existing knowledge in influencing the direction and intensity of every innovative activities [31], the result suggesting that the existing knowledge utilisation is only positively related to the adoption of green process innovation.

Whether the great effort in providing environmental education and training to employees is of influence on firm's adoption of green innovation is subject to hypothesis 2. The result support the idea that education and training is necessary to realise the environmental initiatives within the firm [11], particularly at the administrative side. In the other words, green administrative is likely to be implemented by firms if environmental awareness exists among the employees that could be cultivated through education and training.

Further, the result of the role of external knowledge acquisition in facilitating firm's involvement in green innovation is discussed. With respect to green technical, the result suggests that firms are increasingly relying on external knowledge in order to create innovative outcome [12], by using green-related technologies. External sources of information can be used by key decision makers in facilitating decision making about the adoption of appropriate types of green equipment or technologies. In addition, as external linkages or networks are important paths in obtaining information or knowledge, they could be useful sources in gaining innovative ideas [73]-[76].

The implications of this study are discussed as well. The results could encourage construction firms working with information and knowledge sources in utilising the existing knowledge effectively as well as building new knowledge successfully wherein will lead firms to move towards environmental improvement. Firms should put emphasis on how knowledge is used in order to adopt green process or green administrative practices.

Furthermore, management should focus on embedding and fully utilising employees' existing knowledge or expertise into daily activities to encourage them to share their lessons learned regarding environmental-related matters. Demonstrating and sharing that particular knowledge could benefit others by assisting them to implement new ideas or innovation activities.

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