The value of incremental environmental sustainability innovation in the construction industry: An event study

To cite this article : Duong, L. N. K., Wang, J. X., Wood, L. C. Torsten R., & Kourshan M. (Forthcoming). The value of incremental environmental sustainability innovations in the construction industry: An event study. *Construction Management and Economics*

Abstract

Investment in the innovation of environmental sustainability in construction has been encouraged due to the industry's resource-intensity. However, it remains unclear how to convince shareholders and construction companies to invest in environmental innovations. This research used the event study method with a sample of 129 announcements in the construction industry from 2011 to 2017 to investigate the relationship between incremental environmental sustainability innovation and the stock market reactions of construction firms. The research finds evidence that the stock market reaction has a strong positive relationship with these announcements. There is also evidence for a relationship between strategic alliance, capital turnover, and the project start date with the stock market reaction. The results provide insight into the benefits of incremental innovations in the construction industry and extend the literature of environmental sustainability innovation by considering contributing factors that affect the relationship between environmental sustainability innovation and firm performance. They provide a useful reference for shareholders to integrate environmental sustainability innovation into their business strategies and allocate their resources more efficiently.

Keywords: sustainability, innovation, construction industry, stock market, event-study

Introduction

The construction industry is resource-intensive and a source of pollution worldwide. The environmental impact of construction includes greenhouse gas and carbon dioxide emissions, energy consumption, and waste generation (Killip *et al.* 2018). The industry accounts for approximately 40% of global final energy use (UN Environment and International Energy Agency 2018). Thus, investment in environmental innovation and sustainable solutions for construction activities are proliferating to minimise the negative impacts of the construction industry (Çıdık *et al.* 2017). The investments are driven by expected long-term value for shareholders and better performance risk-return profiles (Lu *et al.* 2016).

The objective of this research is to extend past studies on environmental sustainability initiatives in the construction industry and understand what factors generate greater stock market reactions for incremental environmental innovations. As part of the investigation into the economic incentives to sustainable innovations in construction, this research addresses the research question: what is the relationship between construction sustainability innovation and the stock market reaction, and what are the influential factors to this relationship? Our objective is to deepen the analysis of environmentally sustainable construction challenges (Chan 2020) and provide evidence that investments in environmental sustainability contribute to economic growth (Taghikhah *et al.* 2019). Several studies show the benefits of construction innovation and environmental sustainability to construction firms. Kajander *et al.* (2012) used an event study to demonstrate the value of radical sustainability innovations. Since then, Tan *et al.* (2015) found a positive relationship between sustainability performance and the business competitiveness of international construction contractors. Chang *et al.* (2016) identified and analysed twenty-nine aspects of sustainability practices in Chinese construction companies; while the companies are leaders in the construction industry, their sustainability behaviours varied significantly with time. Together, these results suggest that construction companies need better insight into how sustainability practices and innovation can improve business performance and determine the role that incremental environmental innovations may play a project portfolio. Moreover, to incentivise further incremental environmental innovation, it is necessary to investigate the factors that affect the innovation process and how to enhance this process.

Our research is important as it shows that incremental environmental sustainability innovations in the construction industry generate a positive stock market reaction; the improved financial performance will encourage managers to undertake related projects using such environmental innovations. Therefore, the results should convince shareholders and construction companies to invest in sustainable innovations and reap the benefits of sustainable innovation. Showing a positive incentive for sustainable innovations is crucial in business economics, as leadership has a vital role in improving the performance of construction companies by increasing investments in innovation (Ozorhon and Oral 2017). We further show the enduring benefit from incremental innovation in this industry as opposed to riskier more radical innovations. This research will address the gap in the link to sustainable innovation and performance in construction research.

To answer the research question, we used the event study methodology and a sample of 129 environmental sustainability innovation announcements in the construction industry from 2011 to 2017. We analysed the stock market reaction to these and then used cross-sectional, robust regression to study the influential factors to the relationship between construction sustainability innovation and financial performance. In this way, we respond to the call for having more empirical research in the field of sustainability (Atasu *et al.* 2020) and offer guidance to the implementation of sustainability innovations (Reefke and Sundaram 2018).

Background and Hypotheses Development

Innovation provides firms with the opportunity to achieve environmental sustainability in a dynamic environment and has benefits such as cost reductions, quality improvements, and competitive advantages (Walker 2016). Building on their research synthesis, Varadarajan (2017, p. 17) defined sustainability innovation as "a firm's implementation of a new product, process, or practice, or modification of an existing product, process, or practice that significantly reduces the impact of the firm's activities on the natural environment." In the construction industry, sustainability innovations are defined as "innovations that bridge the gap between business and environment actors to achieve sustainability" (Kajander *et al.* 2012, p. 666). The innovations may be radical, including changes in technology, process, policy, or system that are new to the firm (Kajander *et al.* 2012). Such innovations may happen at any stage from predesign, to design, and operation, and is critical to long-term values and successes in the construction industry. Radical innovations in the construction industry might include new processes to enable the use of recycled materials or renewable resources while maintaining or exceeding engineering requirements or having innovative designs to either reduce energy use or maximize energy capture from renewable resources. Alternatively, innovations may be incremental, implying a smaller improvement, refinement, or use of innovation from elsewhere and adapted to the current scenario. Such innovations may be more suited to the construction industry (Sivunen *et al.* 2013). Incremental innovations might include larger scale, adapting technology to new physical environments (representing new external challenges to the construction), or using an established environmental innovation in a new context. Lai *et al.* (2016) investigated the impact of firms orientation to innovation creation (suggesting a propensity to more radical innovations) or innovation adoption (suggesting more incremental innovations).

Despite the apparent benefits from innovation, construction companies appear reluctant to adopt innovations, mostly due to the lack of capital and business environment (e.g., a collaboration between companies) (Herazo and Lizarralde 2015) or the lack of economic incentives for innovation (Whyte and Sexton 2011). While sustainable innovation could reduce costs and improve margins, it still lacks attention, especially in the construction industry (Gledson and Phoenix 2017). Two main challenges defined in the literature are the low economic incentives for innovation (Loosemore and Richard 2015) and the failure to raise funds from shareholders (Nanda and Rhodes-Kropf 2016). These challenges are mostly due to there being many partners involved in the sustainability innovation, a lack of performance evaluation of the innovation, and the risk of adopting new technology (Walker 2016).

Background

Innovation is referred to as change (Walker 2016) and can include the development of new products, new production methods, or new sources of supply. An innovation is practical or successful if it results in significant improvements compared with previous achievements. Innovation contributes to the profitability and long-term development of a firm or an organisation. It reinforces the competitiveness of a firm, a section, or a country and motivates quality improvement, product diversification, and improves turnover, profitability, operational efficiency, reputation, and cost reduction. It also brings non-economic benefits which will enhance social and environmental corporate performance (Herrera 2016). In the context of the contemporary economy, innovation supports differentiation and creates sustainable competitive advantages for firms. Innovation is a crucial factor for economic growth and has been discussed extensively (Singh and Gaur 2018). Research on innovation mainly focuses on understanding the development, emergence, and expansion of innovations. Recently, innovation is understood as a demand to be considered in social and environmental issues (Fagerberg *et al.* 2018). This validates the sustainability approach, where a firm's results are measured in the interrelated environmental, economic, and social dimensions.

On the other hand, sustainability has been recognised as an innovative transformational force that develops new products and processes (Claudy *et al.* 2016). Sustainable development is a crucial issue for business practices. Recently, companies have focused not only on quality and price but also on environmental matters, viz., sustainable development, and corporate social responsibility (Varadarajan 2017). It has been clear that our way of life damages natural systems and their recovery. Therefore, companies have a crucial role in providing sustainable products and services through technological development and innovation (Kanashiro and Rivera 2019). They have to focus on and stimulate innovation to reduce the environmental burden on natural systems. It encourages companies to focus not only on economic viewpoints but also on sustainability.

Sustainable innovation has been defined as innovations in which new or renewed products, services, or processes improve economic performance, reduce the environmental burden, and improve social performance (Kusi-Sarpong *et al.* 2019). It integrates the demands of all shareholders and transforms existing practices. The integration of the economic, social, and environmental dimensions makes sustainable innovations different from conventional innovations, as not all innovations are sustainable. Sustainable innovations should be classified as one of three types, i.e., technological, social and institutional (Ba *et al.* 2013). There is increased awareness of sustainable innovations on the part of the government, society, and the marketplace (de Medeiros *et al.* 2014). In this context, companies have paid more attention to the importance of sustainable innovations (Handley and Gray 2015). Companies have focused on the dissemination of technological innovation to improve quality of life and considered current and future environmental requirements over a range of projects, such as public sector construction (e.g., Wood *et al.* 2016), new residential house construction (e.g., Islam *et al.* 2016), and the adoption of vertical greenery systems (e.g., Wang *et al.* 2016).

The increasing awareness of sustainability has fully reached business in general, and the construction sector in particular (Herazo and Lizarralde 2015). Construction is one of the oldest human activities. It has crucial effects on the development of socio-economic surroundings, as well as natural resources and waste management. Companies are looking for alternatives to mitigate environmental requirements as they have to compete in scenarios where innovation is a survival requirement (de Medeiros *et al.* 2014). Governments around the world ask construction companies to adopt sustainable innovations to promote sustainable buildings (Meng and Brown 2018). This attention arises from the reality that energy consumption in the construction industry accounts for approximately 40% of total global energy used (UN Environment and International Energy Agency 2018). The construction sector has an increasing rate of energy consumption compared with other sectors; however, it also has the highest potential to save energy (Peyramale and Wetzel 2017). Consequently, sustainable construction is a priority for sustainability and construction companies have been paying more attention to sustainable innovations to have more sustainable buildings (Kajander *et al.* 2012). Tetlow *et al.* (2017) found that sustainable innovation in the construction industry has economic significance.

Investors in the construction industry benefit from sustainable innovation through decreased energy costs and increased property value. For example, Sanderford *et al.* (2018) investigated the adoption of Energy Star, the eco-labelling programme in the US, which provides insights into the energy efficiency of homes. They found that Energy Star-labelled houses obtain premium prices and have low probabilities of mortgage default. An eco-label is a standard metric of energy efficiency and an essential criterion to categorise property.

Thus, property agents are willing to include an eco-label in their reports or advertisements (Wong *et al.* 2018).

Sustainable innovation brings many benefits to the construction industry. They include the ability to attract new customers and investors and to enhance product differentiation (Meng and Brown 2018). Ogunbiyi *et al.* (2014) surveyed UK-based construction professionals to explore the contribution of implementing sustainable construction. The results indicate that sustainable construction improves competitive advantages, environmental quality, corporate image, and compliance with customers' expectations.

Investments in radical innovations should be more valuable than incremental innovations based on innovation theory (Chaney *et al.* 1991). While larger firms may be more able to develop and implement radical innovations (Dewar and Dutton 1986), this may not always be beneficial. Xin *et al.* (2008) showed that radical innovation in product development (over multiple industries) might improve sales growth but not profitability (measured by return on assets, ROA). In comparison, Kajander et al. (2012) focused on radical innovations, and leaves open the question of whether incremental innovations are valuable in construction.

Given the prominence of sustainable innovations has risen recently, researchers have evaluated the performance of sustainability, focusing on financial measurements. Kajander *et al.* (2012) tested the statistical relationship between sustainability innovations and the market value of companies in the construction sector. Using a sample of construction companies in three Nordic stock markets in the year 2007-2010, the authors found that sustainable innovation has a positive relationship with the market value of companies in the construction sector. However, innovation is a long process that involves many factors in the industry. A company is considered as either an innovation-adopting or innovation-generating organisation if it adopts or generates and implements an innovation idea. In the construction industry, which includes manufacturing (e.g., materials, equipment) and services (e.g., design, consulting) (Dallasega *et al.* 2018), analysis of innovation must take into account the specific factors of the construction industry (Ozorhon and Oral 2017). Current literature provides an understanding of the benefits of sustainable innovation and the relationship between sustainable innovation and the market value of construction companies (e.g. Kajander *et al.* 2012, Tan *et al.* 2015, Chang *et al.* 2016). However, there is an argument that innovation in the construction industry occurs at a low rate (Meng and Brown 2018).

This argument provides an opportunity to understand the factors that influence construction innovation. With this in mind, this research conducts a cross-sectional analysis to investigate influential factors and to understand under what circumstances a positive stock market reaction to the sustainability innovation occurs. Therefore, we extended the study of Kajander *et al.* (2012) by exploring the influential factors to sustainable innovation as the business strategies of these construction companies.

Hypotheses Development

Market Performance

The increasing concern about sustainability has forced companies to explore the costs and benefits of sustainability on their performance. Leonidou *et al.* (2013) evaluated the market performance based on the Return on Asset (ROA) with data from UK manufacturing firms and seven interviews with managers. The results indicated that sustainable products positively affect firms' product-market performance and ROA. Song-Turner and Polonsky (2016) interviewed and analysed data from four companies engaging in enviropreneurial marketing activities to explore the success of green marketing activities. The authors found that enviropreneurial marketing is a fundamental approach to addressing environmental issues. The results indicate that developing and adopting innovative products and services can positively affect company performance. Specifically, in the construction industry, Braun *et al.* (2017) used Google Trends and analysed 61 core-based statistical areas that occurred between 2005 and 2010. They found a positive relationship between green sentiment and green policies on the diffusion of green buildings. These works suggest that, in the construction industry, companies opt for sustainable innovations to develop green buildings or sustainable products. Therefore, we hypothesize that:

H1: There is a positive stock market reaction to announcements of sustainability-focused innovations in construction.

Strategic Alliance

A strategic alliance is a collaborative agreement between firms to execute specific projects for maximum performance. Firms enter into alliances depending on their needs for integration, such as cost reduction, market expansion, knowledge exchange, or risk-sharing (Matthews *et al.* 2018). From the managerial perspective, there is evidence that strategic alliances enhance firms' operational performance. Wassmer *et al.* (2017) studied resource allocation among business objectives. To ensure long-term success, firms regularly use alliances and access a broad range of investment portfolios to enhance revenue growth. Results from their research proved that strategic alliances help firms manage resources better and help firms improve their performance. Gomes *et al.* (2016) reviewed 22 years of strategic alliance research in management journals and found the positive effect of strategic alliances on performance. Many companies have expanded their innovation capabilities by accelerating access to new technologies through strategic alliances (Li *et al.* 2019). An example is Facebook's alliance with Deloitte Digital to develop digital businesses. Strategic alliances not only pursue product diversification but also explore technology fields to strengthen their core competencies (Elia *et al.* 2019).

In the construction industry, a strategic alliance usually refers to an informal relationship and is widely accepted as similar to a strategic partnership or reciprocal relationships between shareholders and partners (Cheng *et al.* 2004). Based on a survey in the UK construction industry, Akintoye and Main (2007) found that contractors are positive about the benefits of a strategic alliance. It can provide direct benefits within projects or at corporate levels. These benefits include reduced costs, decreased risks, increased profits, or enhance innovation opportunity (Cheng *et al.* 2004). Strategic alliances aid sustainable competitiveness in the construction industry (Lönngren *et al.* 2010). Top management of these companies makes the execution of alliance smooth for sharing skills and experiences. Rutten *et al.* (2009) suggested that close and stable strategic alliances between partners in the construction projects such as suppliers, contractors, government agencies, and research institutes positively contribute to the development of innovation. Considering these studies, we hypothesise that:

> H2: The stock market reaction to announcements of sustainability-focused innovations in construction is more positive for firms adopting a strategic alliance.

Capital Turnover

A firm generates value to shareholders depending on its capital turnover ratio or capability to make profits from capital resources. Prior studies have shown that capital turnover is a good indicator of a firm's operational efficiency (Yu *et al.* 2015). Higher capital turnover implies that a company has higher inventory turnover, needs less money to make its sales, and has better performance (Pucci *et al.* 2015). In some industries requiring large investments in high-technology assets (such as information technology), capital turnover has a positive relationship with firm performance (Wang and Chang 2005). Similarly, capital turnover is also an essential indicator in the construction industry, which requires large investments in equipment or machinery. Balatbat *et al.* (2011) showed that higher capital turnover is the result of effectiveness in generating revenues from assets in Australian construction companies. When a firm invests in innovation, they expect to increase the profit (Gledson and Phoenix 2017), so we hypothesise that:

H3: The stock market reaction to announcements of sustainability-focused innovations in construction is greater for firms with higher capital turnover.

Project Start Date

The construction industry has been criticised as a major contributor to global warming, carbon emissions (Ströbele and Lützkendorf 2019) and using up large amounts of natural resource and energy consumption (Li *et al.* 2019). Recognising the criticality of these issues, sustainable construction practices were introduced (Wong and Zhou 2015), and public awareness of the value of sustainability has been raised. Consequently, governments have created more regulations and high standards in the construction industry. Analysing natural hazards and standards in the construction industry, Li and Ellingwood (2009) found that when a higher standard is used, the severity of the damage decreases. However, higher standards and regulation also mean that companies have to spend more time and resources to develop and adapt the project according to these standards and regulations. As an example, while Leadership in Energy and Environmental Design (LEED) is a sustainability certification that is widely adopted in many countries, the process for attaining this certification is criticised as time-consuming (Ding 2008). From the shareholder perspective, the additional benefit of certification and green innovation is decreasing with time. Thus, we hypothesise that:

H4: The stock market reaction to announcements of sustainability-focused innovations in construction is less positive for projects having a more recent start date.

Project Size

Researchers have recently turned their attention to project size as an essential factor in the relationship between shareholders and the investment. For example, considering the stock market reaction to 402 UK companies' investment announcements, Jones *et al.* (2004) found that project size has a significant positive relationship to the abnormal return. A large project reduces variable costs because of the economic scale and allows higher investments for innovations (Brockmann *et al.* 2016). The size of a project also positively relates to the strategic importance of the business objectives. However, a large project is also usually more complex with higher uncertainties in technology and the business environment (Meng and Brown 2018). A large project usually has a more extended project duration; it reduces the accuracy in predicting total costs and the ability to meet the project budget. Fayek *et al.* (2006) analysed 15 years of data from heavy industrial construction projects, showing that when the project size increases, the associated supporting costs such as logistics, communication, or infrastructure increase. For such reasons, a large project is less likely to be completed (Ghosh 2018). Thus, we hypothesise:

H5: The stock market reaction to announcements of sustainability-focused innovations in construction is greater for smaller project sizes.

International Projects

In line with the trend of globalisation, construction companies have more opportunities for implementing a project in an international market. Developing countries embrace expertise and technologies from developed countries to build infrastructures and buildings. Globalisation also allows construction companies to conduct projects in developed countries. Several reasons motivate a company to expand into international markets; they include diversification for sharing the risk, competitive resources, and stagnant domestic markets (Gunhan and Arditi 2005). In the global economy, no market is safe forever. Even if a company focuses on the domestic market only; it also faces competition from foreign competitors. However, an international project is riskier than a domestic one. An international project is complex with many uncertainty variables such as culture, politics, and different laws or regulations (Hwang *et al.* 2017). Gunhan and Arditi (2005) indicated that threat factors that affect international construction projects include financial resources, currency fluctuations, and a shortage of labour. Hwang *et al.* (2017) found that political instability and cultural difference are the two most common risks for an international project. Considering these risks, we hypothesise that:

H6: Compared with domestic projects, the stock market reaction to announcements of sustainability-focused innovations in construction is less positive for international projects.

In summary, our research framework has two parts (Figure 1). We firstly use event study methodology to investigate the effect of sustainability innovation announcements on market returns (H1). Secondly, using robust regression, we examine whether crucial factors (i.e. strategic alliance, capital turnover, project start date, project size, and international projects) are related to market returns (H2-H6).

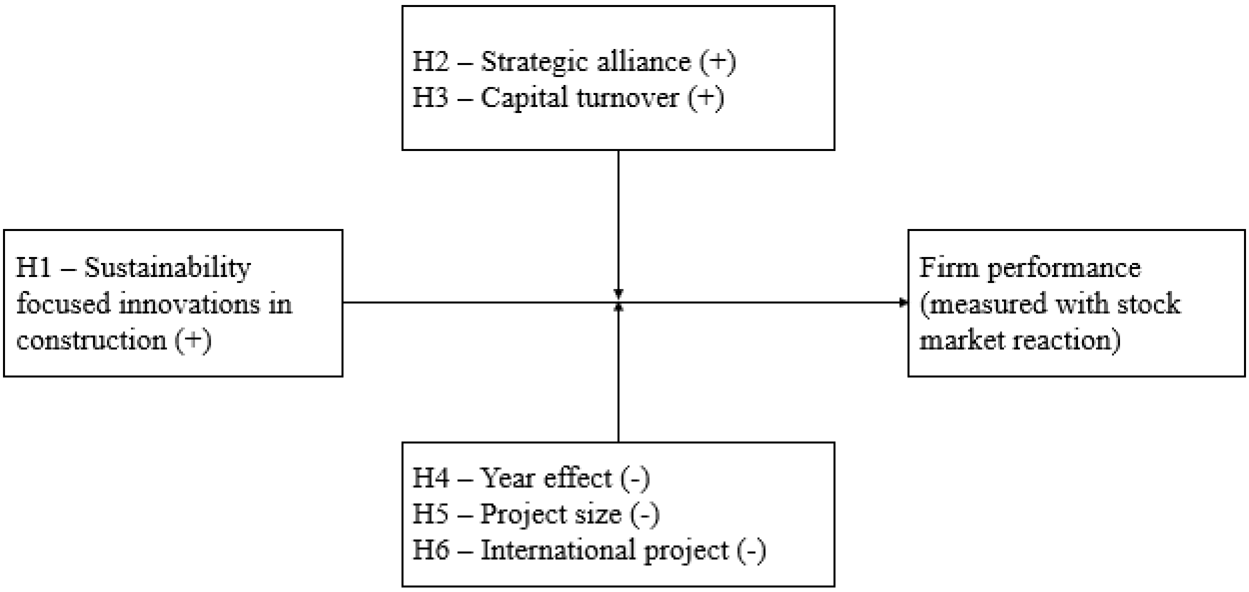

Figure 1. The conceptual framework of the hypothesized relationships

Methodology

We used the event study methodology and cross-sectional regression to test the hypotheses. The critical assumption in event study methodology is the 'efficient market hypothesis,' asserting that daily stock prices will respond rapidly to the information contained in a published announcement (i.e., event), and the stock market reaction provides a measure of future costs and benefits associated with this event (Kothari and Warner 2007). Event study methodology adjusts for the confounding factors to isolates the event-specific components of stock returns. The adjusted returns are referred to as 'abnormal returns' (AR), providing a measure of the impact of this type of event on firms' financial performance. Subsequently, regression analysis is used to relate the ARs to the characteristics of firms or sub-components of the event, where the essential attributes for explaining the variation of ARs can be explored (McWilliams and Siegel 1997). This method has been widely used the literature (Jacobs and Singhal 2017, Wood *et al.* 2017, 2018), particularly in the construction research (Kajander *et al.* 2012, Yang and He 2019).

There are several important steps in the causality incorporated by the measure of stock prices in an event study (Wood and Wang 2018). The operations practices (e.g., sustainability innovation projects in this study) are positively/negatively related to operational competence of an organisation (e.g., construction organisations in this study), which results in the increases/decrease of the direct financial metrics (e.g. cash flow). In turn, these changes in financial metrics flow to improved/deteriorated stock returns of the organisation. Therefore, there are links between construction projects, organisations, and their stock price changes; the stock market reaction (representing a change in the value of the company) is the investors' estimate of the overall impact of these sustainability innovation projects on the firms.

We opted to use the stock market reaction as a measure of firm performance in this research. The reason is that the market-based measure of firm performance is more likely to capture the overall impact of a managerial decision, especially in the sustainability-related studies, where the changes on intangible assets (e.g., credibility) are more effectively incorporated by stock price changes than accounting-based measures (e.g., return on asset) (McWilliams and Siegel 1997). The performance measures in survey-based research are subject to the social desirability bias in sustainability-related research (Walker *et al.* 2012). Hence, the use of stock market reaction is more likely to provide us with an unbiased and incorporated performance impact of sustainability innovation initiatives.

Sample Selection and Description

We collected a sample of announcements, where construction firms publicised their sustainability innovations initiatives. Next, we retrieved the announcing firms' identities and announcement dates to collect stock return data. The details of sampling methods are as follows. We searched for the announcements from significant business sources (e.g., Dow Jones Newswires, Major News and Business Sources, and Press Release Wires). These sources are most likely to provide the earliest announcements to markets and, thus, give an unbiased estimation of ARs to the events (Eroglu *et al.* 2016, Jacobs and Singhal 2017).

We developed rigorous search criteria to include the most relevant announcements in the sample. The keywords used to search for the announcements were developed based on those in Kajander *et al.* (2012). Table 1 provides the keywords used in the search. Only the announcements from 2011-2017 were included in the sample, as an extension to Kajander *et al.* (2012). The full text of each announcement was scrutinized, and we included only those relevant to sustainability innovations in construction.

We excluded the announcements having the following attributes:

- As discussed in the Introduction section, we focused on the sustainability innovation initiatives in the emerging markets. We only included the announcements into the sample, where the locations of projects are in one of the countries used by MSCI emerging market index (MSCI 2020). Investors shift their investment portfolio to emerging markets due to push factors (e.g., global risk aversion, interest rate) and pull factors (e.g., economic growth, asset returns) (Koepke 2019). In another survey, one hundred per cent of interviewed investors said that they were willing to invest more for well-governed companies in emerging markets than for a similar company in a developed market (Khanna and Zyla 2017). In recent decades, the construction industry has been faced with high uncertainty and variety surrounding competition rules, financial resources, materials, or labour (Venkataraman and Cheng 2018). In this context, leading construction companies have expanded into emerging markets via more collaborative international projects, diversifying the project types, and covering more project phases (Han *et al.* 2010). Thus, emerging markets have an important role in the growth of construction companies (Banihashemi *et al.* 2017). Given its significant impact, we decided to focus on the emerging market only.

- We excluded the announcements, where the announcing firms are not public firms, or there was not sufficient stock return data for them in DataStream.
- We excluded the announcements, where the announcement dates are overlapped with other major corporate events (e.g., earning announcements). The other major corporate events have confounding effects on the stock returns and thus is likely to bias the estimation of AR to the event of interest (i.e., sustainability innovation in this study).

Table 1. Keywords used in the search for announcements

innovat* OR develop* OR research OR partner* OR enter* OR alliance
Near10
green OR renewable OR eco-friendly OR environment* OR climate OR carbon OR LEED OR BREEAM OR sustainab* OR wave OR solar

Note: The * is a truncation operator. LEED is Leadership in Energy and Environmental Design. BREEAM is Building Research Establishment Environmental Assessment Method

The final announcement sample includes 129 observations. The selected events involve companies operating in the construction industry and offering renewable power solutions. For example, a selected announcement from Reuters (01 January 2011): The Holmes Group and Cisco will collaborate to define and identify solutions which integrate Smart+Connected Real Estate into eco-friendly communities (Reuters, 2011). Other announcements included companies aiming to promote green energy and solve their own power problem. For example, Apple plans share its best practices in procuring clean energy with its Chinese suppliers, help them with energy efficiency audits and regulatory guidance, and partner with them to install clean energy generators (Xinhua 2015). Other announcements included firms setting a new sustainable benchmark; e.g., JinkoSolar (NYSE: JKS), a global leader in the solar PV industry, partnered with Beijing University's Solar Power Engineering Center to construct the University's first experimental PV power plant on campus which would be used for collecting and analysing data on the power generation capabilities of PV modules when exposed to various conditions (PRNewswire, 2013).

Calculating Abnormal Return

We retrieved the announcing firms' identity, and announcement dates from the sample to collect stock return data and calculate ARs. The analysis was conducted using Event Study Metrics software and lmrob R package (Salibian-Barrera and Koller 2020). To isolate the event-specific components of stock returns, we used the market model (Brown and Warner 1985, MacKinlay 1997) adjusting for the confounding factors, which is widely used in comparable research (Wood and Wang 2018).

AR_{it} for firm *i* on day *t* was estimated as:

$$AR_{it} = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{mt}), \tag{1}$$

where R_{it} is the return on the stock of firm *i* on day *t*. R_{mt} is the normal return calculated with reference to the market portfolio of stocks on day *t*. The market model parameters $\hat{\alpha}_i$ and $\hat{\beta}_i$were estimated with ordinary least squares (OLS) over a 120-day estimation window, ending 10 days prior to the event day, following the literature (Kajander *et al.* 2012, Wood *et al.* 2017).

The mean abnormal return across firms at day t was estimated as:

$$\overline{\mathrm{AR}_t} = \frac{1}{N}\sum_{i=1}^{N} \mathrm{AR}_{it} \ , \tag{1}$$

where N is the number of firms in the sample.

In this study, we calculated ARs in a short event window to fully incorporate the stock market reaction to the event. Specifically, we used a two-day event window (0, 1), including the day of the announcement (day 0) and the next immediate trading day (day 1). The ARs in this event window (0, 1) are referred to as cumulative abnormal returns (CAR). CAR (0, 1) was estimated by aggregating the mean abnormal returns in the event windows as:

$$\mathrm{CAR}(0{,}1) = \sum_{\mathrm{t}=-1}^{1} \overline{AR_t}, \tag{2}$$

Our announcement sample covers various source countries/regions (e.g., Europe and Asia) and the time difference across stock exchanges would delay the response in stock markets to the events of interest. Therefore, a two-day window of CAR (0, 1) is more likely to accommodate the overall stock market reaction to the sustainability innovation announcements in our sample. A two-day event window is widely used in the event studies and is as small as practical (McWilliams and Siegel 1997, Wood *et al.* 2017). We also provided statistical evidence that only CAR (0, 1) is statistically significant in our robustness test of using multiple event windows/days (Results section), justifying the choice of using the event window (0, 1) in this study.

Variable Construction and Definitions

The estimated CAR (0, 1) was used as a dependent variable against the hypothesized variables in regression analysis to test H2-H6. This section outlines how we constructed these variables and a set of control variables for the analysis.

Strategic Alliance

A binary variable was set for coding a strategic alliance. We coded 1 for any announcement stating the announcing firm created any strategic relationship with others to conduct the sustainability innovation projects. We coded 0 if otherwise.

Capital Turnover

We measured announcing firms' capital turnover by the ratio of net sales to net assets. The data are at the most recent fiscal year before the announcement dates.

Year Effect

To evaluate the impact of how the stock market reaction to construction sustainability innovation has changed over time, we calculated the number of years by using the difference between the first year in the announcement sample and the year of the announcement for the given case.

Project Size

We used US dollar values to measure the project size in each announcement. In our sample, 47 announcements mentioned the project value (in US dollars) and 77 announcements mentioned project capacity (in MW). For analysis purposes, we converted project capacity to project value (in US dollars). We used the power generation capacity cost, estimated by the US Energy Information Administration (2019) for the conversion. This estimation assesses the costs to develop and install various generating technologies used in the electric power sector. The predicted sign is negative.

International Project

We used a binary variable to measure the impact of an international project. We coded 1 for any announcement stating the project was implemented outside announcing firms' domestic markets and coded 0 if otherwise.

We used the following variables as controls in our analysis because they were found to have effects on stock market reactions in previous event studies (Hendricks *et al.* 2009, Ni *et al.* 2016, Wood *et al.* 2017)

1. We used the sample firms' stock exchange listing to control for market and country/regional effects. We created two dummy variables for the firms listed in European and Asian countries.
2. We controlled for industry effect by using the dummy variable "Construction Industry". We coded 1 for the firms with four-digit Standard Industry Classification (SIC) codes 1531 (Construction) and 3241 (Construction Materials), following Fama and French (1997), and coded 0 if otherwise.
3. We controlled for firm size by using a logarithm form of the net sales reported in the most recent fiscal year before the announcement dates.
4. We controlled firms' growth prospects by using the market to book ratio and firms' leverage by using the ratio of the sum of short- and long-term debt to total assets. The data are from the most recent fiscal year prior to the announcement dates.

We used the following regression model to test the hypothesized variables above:

$$CAR(0,1)_{i,j} = \beta_0 + \beta_1 Europe_i + \beta_2 Aisa_i + \beta_3 Firm\_Size_{i,j} + \beta_4 Market\_to\_Book_{i,j} + \beta_5 Leverage_{i,j} + \beta_6 Construction\_Industry_{\ i} + \beta_7 Year_{i,j} + \beta_7 Strategic\_Alliance_{\ i,j} + \beta_7 Captial\_Turnover_{i,j} + \beta_7 Project\_Size_{i,j} + \beta_7 International\_Project_{i,j} + \varepsilon_{i,j}, \quad (2)$$

where $\mathrm{CAR}(0,1)_{\mathrm{i,j}}$ is the cumulative abnormal return for firm *i* and event *j* at the event window (0, 1).

Model Diagnostics

We used robust regression analysis in this study. We followed Fox (2015) and identified outliers (studentized residuals outside of the range [-2, 2]) and influential observations (over three times average hat-value) in our dataset; the traditional OLS regression relies on a strong assumption of absence of outliers. The outlying observations in our dataset would bias the OLS estimation of coefficients and statistical significance. The removal of these outlying observations would reduce the sample size and explanatory power of the model. Robust regression, using weighted least squares, can accommodate the outlying observations in the analysis while minimising their influence scale, which provides additional insight from the variances in the dataset and improves the reliability of analysis results (Johnson 2002). We used the MM-estimator in robust regression analysis, following Fox (2015). We tested the multicollinearity in the regression model by using the variance inflation factors (VIF). All VIF values less than 3, providing evidence of low multicollinearity (Cohen *et al.* 2013).

Results

Table 2 reports the stock market reactions to sustainable innovation announcements. We followed the literature (Wood *et al.* 2017) to test the stock market reaction using two parametric tests: the Patell-z and BMP-test. Besides, we used two nonparametric tests, Corrado Rank test and Binominal Sign test, to correct for any potential bias (e.g., outliers) in the parametric tests (Appendix A introduces the details of these test statistics). In the event window (0, 1), the mean (median) CAR is 0.80% (0.53%), and significant at the 5% level (two tails) across all tests. The result indicates that there is a positive stock market reaction to sustainability innovations announcements in the construction industry. Thus, H1 is supported. The ARs/CARs on other days/event windows in Table 2 provide a robustness test. All other ARs/CARs are not statistically significant by any of the tests, indicating CAR (0, 1) incorporates the stock market reaction to the announcements. The result is unlikely to be biased. We, therefore, use CAR (0, 1) as the dependent variable in the subsequent regression analysis.

Table 2. The stock market reaction and abnormal returns calculated over different event days and windows using a 120-day estimation window (n=129, the full sample).

CAR at individual days and multiple event windows

Event Day (s)	Mean (Cumulative) Abnormal Return	Median (Cumulative) Abnormal Return	% Positive	Patell Z	BMP-test	Corrado Rank Test	Binomial Sign test
-5	0.04%	0.06%	52%	-0.360	-0.443	0.433	0.057
-4	0.53%	-0.12%	46%	0.335	0.121	-0.652	-1.353
-3	-0.33%	-0.23%	43%	-1.643	-1.537	-1.035	-1.881
-2	0.20%	-0.10%	47%	1.021	0.770	0.526	-1.000
-1	0.16%	-0.01%	49%	-0.467	-0.551	-0.351	-0.648
0	0.51%	0.14%	56%	1.396	1.423	1.385	0.938
1	0.29%	0.09%	57%	1.650	1.629	1.426	1.114
(0,1)	**0.80%**	**0.53%**	**60%**	**2.154****	**1.990****	**1.987****	**1.994****
(-1,0)	0.68%	-0.06%	50%	0.657	0.492	0.731	-0.471
(-1,1)	0.97%	0.12%	53%	1.489	1.276	1.420	0.233

Note: The symbols ** and *** denote statistical significance at the 5% and 1% level respectively, using a two-tail test. The CARs were estimated using the market model.

Our sample is predominantly based on incremental environmental innovations; 112 cases are incremental innovations, while only 17 cases are radical. We conducted an additional analysis for 112 incremental innovation announcements. We found that in the event window (0, 1), the mean (median) CAR is 1.23% (0.65%), and significant at the 5% level (two tails) across all tests (Table 3). This result is similar to the analysis result of the full sample (Table 2) and we, therefore, we use the full sample (n=129) for the subsequent analysis reported in this article. We refer readers to the Appendix B for a full additional analysis of incremental and radical innovations; this further analysis shows that there is no statistical evidence that radical or incremental innovation type has an impact on the stock market reaction.

Table 3. The stock market reaction and abnormal returns calculated over different event days and windows using a 120-day estimation window (n=112; incremental innovation announcements only).

CAR at individual days and multiple event windows

Event Day (s)	Mean (Cumulative) Abnormal Return	Median (Cumulative) Abnormal Return	% Positive	Patell Z	BMP-test	Corrado Rank Test	Binomial Sign test

-5	-0.16%	0.06%	52%	-0.878	-1.0015	-0.092	-0.088
-4	0.57%	-0.12%	47%	0.282	0.0767	-0.365	-1.033
-3	-0.29%	-0.23%	44%	-1.062	-1.1212	-0.801	-1.790
-2	0.12%	-0.07%	49%	0.627	0.5238	0.756	-0.655
-1	0.35%	0.00%	50%	-0.116	-0.2411	-0.066	-0.466
0	0.83%	0.20%	57%	2.073	2.3794	1.852	1.047
1	0.40%	0.15%	59%	1.896	1.951	1.525	1.426
(0,1)	**1.23%**	**0.65%**	**62%**	**2.804****	**1.157****	**2.388****	**1.993****
(-1,0)	1.19%	-0.03%	46%	1.384	2.0173	1.264	-0.466
(-1,1)	1.58%	0.22%	54%	2.225	0.1919	1.912	0.480

Note: The symbols ** and *** denote statistical significance at the 5% and 1% level respectively, using a two-tail test. The CARs were estimated using the market model.

Table 4 reports the results of robust regression analysis, where H2-H6 are tested against CAR (0, 1), Model 1 includes only control variables and we included the hypothesized variables (i.e., H2-H6) in model 2. The larger Robust R^2 in model 2 (17.53%) indicates the increase of explanatory power in the regression model after adding the variables of interest. Both coefficients of strategic alliance and capital turnover are positive and significant at a 5% level (two tails). The results show first that the stock market reaction is more positive when firms adopt a strategic alliance with others in developing sustainability-focused innovations; second, the stock market reaction is more positive if the firm has a high level of capital turnover. H2 and H3 are supported. The coefficient of year is negative and marginally significant at a 10% level (two tails). There is some evidence showing that the stock market reaction to the more recent announcements is less positive, providing support for H4. Finally, the coefficients of project size and international project are not statistically different from zero, indicating H5 and H6 are not supported.

Table 4. The cross-sectional regression results using robust regression (for the full sample).

Independent Variables	Model 1 (Control Variables Only)	Model 2 (Main Effects)
Intercept	0.0245	-0.0330
	(0.0312)	(0.0730)
Europe	-0.0007	-0.0089
	(0.0090)	(0.0228)

Asia	-0.0063	-0.0088
	(0.0100)	(0.0115)
Net Sales	-0.0017	0.0031
	(0.0043)	(0.0084)
Market-to-Book	-0.00002	-0.0001
	(0.0003)	(0.0004)
Leverage Ratio	0.0002	0.0001
	(0.0002)	(0.0002)
Construction Industry	0.0065	0.0048
	(0.0106)	(0.0183)
Year (H4)		**-0.0052***
		(0.0026)
Strategic Alliance (H2)		**0.0219****
		(0.0088)
Capital Turnover (H3)		**0.0024****
		(0.0011)
Project Size (H5)		0.0092
		(0.0088)
International Project (H6)		0.0131
N	117	95
Robust R^2	0.0083	0.1753

Note:* and ** denotes the significance at 10% and 5% level (two tails), respectively. The standard errors are given in parenthesis. Robust regression (MM-estimator) was used in both models. The dependent variable is CAR (0, 1) estimated with the market model.

Discussion

This research provides empirical evidence of the stock market reaction to sustainability innovation announcements in the construction industry. Based on a sample of 129 announcements from 2011 to 2017, we found evidence that a sustainability innovation announcement has positive impacts on the stock market reaction. In addition, our findings provide evidence that construction companies having high capital turnover and working together have higher positive financial performance; however, the more recent the project, the lower the financial impact. On the other side, we do not find evidence that project size and international projects influence the stock market reaction. The environmental sustainability impact is consistent with Kajander *et al.* (2012), and we demonstrate that the results hold in more recent years and also that incremental innovations have value in the construction industry.

The Value of Incremental Environmental Sustainability Innovation

Our findings provide several important implications. First, our study complements the literature of sustainability innovation in the construction industry. Kajander *et al.* (2012) found a 0.82% stock market reaction to the announcements in the period of 2007-2010. While our finding confirms the positive relationship, we used a relatively large and more recent sample, showing a stable and consistent shareholder wealth effect (i.e., 0.80%) over the years. One may assume that the increasing awareness of and knowledge about sustainable operations in recent years may substantially strengthen the positive impact (Leonidou et al. 2013, Song-Turner and Polonsky 2016). However, our finding indicates the improvement is marginal. The potential explanation is the increasing explorations of trade-offs in sustainability innovation (Pinkse and Kolk 2010), where, for example, the market uncertainty (e.g., investment in niche markets for sustainable products vs mainstream markets) may weaken the performance improvement. Hence, the influential factors in the sustainability-performance link must be explored to guide construction firms' sustainability innovations. Furthermore, our results (showing positive stock market reactions) suggest that construction firms can benefit from incremental environmental sustainability innovations, not just to radical innovations. We extended the study of Kajander *et al.* (2012) by investigating a set of influential factors, providing managers with strategies to improve firm performance with incremental sustainability innovation initiatives.

The issues of sustainability innovation in the construction sector are growing ever more important because the construction sector provides benefits to society and is a crucial driver for sustainable development (Opoku *et al.* 2015). Investors could use the information about sustainability innovation to assess the future growth of a construction company. An announcement of sustainability innovation can signal the commitment of the management team in terms of social responsibilities and link to sustainable business development. Also, it could be seen as a proxy for a firm's capability in pursuing research and development programmes and a better quality of management system, which results in higher future cash flow.

The Impact of Strategic Alliances

Second, when companies form a strategic alliance, they create a learning environment and a self-managed team. This team can operate and manage mutual strategic actions and conveys the new practices back to its own company. A strategic alliance can reinforce the commitment of managers and employees to a company's performance (Cheng *et al.* 2004). Due to the increasing speed of technology change, the strategic alliance has become a key factor for success in many industries (Akintoye and Main 2007). Specifically, in the construction industry, we identified a significant contribution of a strategic alliance to the sustainability innovation. For a construction project, a strategic alliance is supported by the dependency theory, where resources (e.g., skills, finance, and technology) are the means to join contractors, consultants, or clients together. There is now a shift from traditional labour-intensive to knowledge-intensive in the construction industry (Akintoye and Main 2007). The construction industry is characterised by a complex environment, technology, and unique design. Innovation in this sector is driven by environmental pressure, technology capability, knowledge exchange, and boundary spanning (Bossink 2004). Bossink (2004) empirically indicated that construction companies used strategic alliances to develop and deliver sustainable innovation results. As innovation in the field of sustainability requires advantages of technical capabilities and financial risks; some companies are not able to be innovative themselves and prefer to ally with others (Lönngren *et al.* 2010, Elia *et al.* 2019). Through a strategic alliance, construction companies have more opportunities to access new technologies, to share risks, and to improve the project-based performance (Li *et al.* 2019). When companies are involved in a strategic alliance, the differences between common and individual objectives also stimulate efforts towards innovation (Xue *et al.* 2018). Moreover, from the risk perspective, such sustainability innovation projects involve higher risk, even when they undertake more incrementally innovative projects as used in our sample. Thus, we provide evidence that investors expect partnerships with other firms in environmentally innovation projects to share risks.

The Impact of Capital Turnover

Third, our findings indicate that operations efficiency is an essential factor in sustainability innovation. The results provide evidence that the stock market has a higher positive reaction to firms with a higher capital turnover ratio, showing the importance for companies to be efficient in generating revenue from capital resources. The development of sustainability innovation requires substantial and long-term investment and thus, negatively affect the return on asset (Marti *et al.* 2015, Pucci *et al.* 2015). The allocation of such considerable capital resources significantly increases firms' business risks, particularly in the construction sector, where financial strengthen is vital to support business growth (Balatbat *et al.* 2011) . The construction companies with a high level of operations efficiency can quickly convert their capital investment in sustainability innovation to cash flows and thus reduce the business risks. Especially in the long-term development of competitive advantages through sustainability innovation, construction firms need to focus on developing such operations efficiency to explore performance improvement. When the innovation results are stable, it could allow companies to obtain profits. This finding suggests benefits to finance-constrained contractors in the construction industry, providing industry-specific support to the broader demonstration that environmental innovations overcome financing constraints (Zhang *et al.* 2020). Construction firms that have established expertise and higher capital turnover (Balatbat *et al.* 2011) are well-positioned to undertake environmentally sustainable projects and reap the benefits. Weaker construction firms should be wary of launching such environmentally sustainable projects or should use strategic alliances during the project. However, high capital turnover could also suggest a lack of funding in the business and we interpret this relationship with care. The relationship may not be a positive linear relationship (as modelled with our data) but an inverted "U" relationship, where higher levels of capital turnover are associated with low levels of capital and less successful outcomes and a deeper investigation of the relationship would require a follow-up study. The relationship may also be driven by the context. While our results show the effectiveness of operational efficiency in the context of sustainable construction, in other contexts (e.g., high environmental dynamics), the slack resources supported by large capital (i.e., a smaller capital turnover ratio), may be required to fund future business developments.

The Impact of the Project Start Date

Fourth, our findings evidence that the more recent the project, the less positive relationship with the stock market reaction. Despite the increasing economic growth and environmental outcomes (Alwan *et al.* 2017), we show that the benefit to the firms may be decreasing. This finding should increase the awareness of the emerging business risks in recent years relating to sustainability innovation in construction. While there is broad agreement that recent technological innovation has facilitated knowledge management and improved performance (Ghaffarianhoseini *et al.* 2017), we demonstrated a different sustainability-innovation-specific time effect in the construction sector. Sustainability research continuously develops more advanced and rigorous approaches (e.g., circular economy) to fully capture the businesses' environmental impacts. However, the recent studies started exploring potential trade-offs between economic and environmental performance (Dam and Petkova 2014, Pagell and Shevchenko 2014), and disclosure of sustainability misconducts (Jacobs and Singhal 2017, Wood *et al.* 2018). Together, these findings demonstrate the modern development of sustainability, where more complete and rigorous criteria are established in recent years, and thus more resources and foundational business upgrades are required to explore competitive advantages. Our finding of a positive financial impact (H1) shows that construction companies can still achieve economic viability, possibly due to their traditionally solid resource base (Hatush and Skitmore 1997).

Nonetheless, firms should be cautious about this sustainability trajectory. Notably, there are increasingly stringent standards and fiercer competition in terms of sustainability innovation in the construction sector, which would reduce such business opportunities in the near future. Society has recently paid more attention to not only the economic but social and environmental impacts of projects. Where such environmental innovations once would have been seen as a benefit, they may now be seen as a requirement for the firms continued operations through introduced environmental sustainability practices (Wong and Zhou 2015). Thus, companies must spend more time and resources to evaluate options that meet the evolving requirements. Investors in new projects may carefully consider the complexity of environmental requirements. Our results also empirically suggest that there is a long-term trend in the decrease of environmental sustainability certification (Ding 2008) and construction companies can form strategic alliances and develop business efficiency to maintain performance improvement in sustainability innovation effectively.

The Impact of Project Size

Fifth, contrary to our hypothesis, the project size does not have a significant effect on the stock market. It could be because a large project, especially in the construction industry, usually results in high risk (Brockmann *et al.* 2016). This result implies that the market may emphasise other essential factors, such as potential profits, environmental, or social issues. For instance, the market could place attention on other critical elements such as macroeconomic and budgetary issues (Venkataraman and Cheng 2018) or technical requirements (Hendricks and Singhal 2008). In a similar finding, Emuze and Smallwood

(2014) found that project size is not a success factor in a construction project. In other words, investors focus more on the possibility of generating profit in the future. Moreover, there is difficulty in defining the size of a project in this research. As discussed earlier, 47 announcements mentioned project value (in US dollars) and 77 announcements mentioned project capacity (in MW). For this analysis, we converted the project capacity to project value. This limitation could be addressed in future research.

The Impact of International Projects

Finally, the international nature of projects does not have a significant impact on the stock market reaction. This finding can be explained as there are many critical concerns for an international project. When a firm invests in an international project, the stock market reaction depends on the location of the project, the international experience, or the entry mode (López-Duarte and García-Canal 2007). The project location is the most crucial aspect of an innovation project as local regulation, or local standards could hamper innovation (Mollaoglu *et al.* 2016). This research focuses on sustainability innovation in the construction industry. Such innovation projects involve many risks; therefore, investors place emphasis on reducing them. Thus, evaluating the project location is an essential factor in the success of the project. However, due to the full range of project locations in this sample, we could only group them as domestic or international projects. Future research could find a way to group project locations based on geography and investigate the stock market reaction on each geographic area. Cultural and political barriers are two common risks for an international project (Hwang *et al.* 2017), grouping projects based on geography could provide a pattern of the relationship between these risks and the stock market reaction.

From these results, we can draw several important implications for managers that may be making practical decisions about sustainability innovations in the construction sector. First, as time goes on, there appears to be a slightly reducing positive stock market reaction to sustainability innovations. This reduction may occur as investors consider such innovations as a requirement and providing reducing advantage to the firms. Therefore, over time a manager should exert increasing care in their incremental sustainability innovation investments. Engagement in a long-term strategic alliance to develop and deploy the innovation will be advantageous. Therefore, managers should seek appropriate partner organisations for collaborations. The positive impact of capital turnover suggests that the overall managerial capability of the firm should be lifted, and core operational requirements improved in sequence before intensive investments are made in sustainability innovations in the construction industry. Together, our results suggest that a construction firm that focuses on improving their operational capability and selects partners (either domestic or international) for the project carefully, will benefit even from relatively incremental environmental innovations. From a managerial perspective, this suggests that a lower-risk incremental innovation may often be preferable rather than a radical, high-risk innovation as incremental innovation still delivers a reasonable financial performance gain without additional risks.

Theoretical Contributions

We provide two theoretical contributions. First, we provide insight into the comparability of the values/benefit to firms from incremental vs radical environmental innovations in the construction industry. While Kajander *et al.* (2012) focused on radical innovations, expected to deliver greater value to firms (Dewar and Dutton 1986, Chaney *et al.* 1991, Sivunen *et al.* 2013), our sample also predominantly consists of incremental environmental innovations. Despite our focus on incremental innovations, the stock market reaction is very similar (as findings from H1), suggesting that investors in construction firms continue in recent years to value environmental sustainability innovations, adding depth to the analysis of radical innovations over other industries (Xin *et al.* 2008), and in contrast to findings that radical innovations are better in construction (Sivunen *et al.* 2013). The findings suggest that further analysis of the stock market reactions to different forms of innovation may need to account for factors such as the industry slow clock speed relating to the firms and projects. Our findings of incremental innovations being beneficial suggest that orientation to innovation adoption (Lai et al. 2016) may be more valuable for construction firms and future research may investigate this further. Managers can capitalise on these findings by prioritising less risky incremental innovation while still having evidence that investors are favourable to these innovation decisions.

Our second theoretical contribution is the extension of the literature of environmental sustainability innovation by considering contributing factors that affect the relationship between sustainability innovation and firm performance (as findings from H2 – H6). In contrast to Kajander *et al.* (2012), which examines whether environmental sustainability innovation announcements affect the stock market reaction, we also examine how the stock market reaction for companies depends on the following factors: strategic alliance, capital turnover, and the project start date. These additional hypotheses add value by providing a more comprehensive framework for shareholders and managers to understand environmental sustainability innovations in the construction industry.

Policy Implications

Our findings have implications for government policymakers. While businesses face urgent calls for investments in low carbon activities, governments are recognising there is a role to provide firms with tax support to address financial constraints the firms face that prevent them from investing in environmental innovation activities (UNEP, 2016). Such support reduces the financial barrier for firms to make environmental innovation investments; and from a cost perspective, it positively effects on profitability, competitiveness, and investment decisions of stakeholders (Testa *et al.* 2011, Owen *et al.* 2018). Given the context of construction as a significant contributor of carbon emissions (Ströbele and Lützkendorf 2019), our results show that environmental innovations can be both privately (financially) beneficial to the firm while also providing the public benefit of reduced emissions. In our study, we found that firms experience a positive stock market reaction to their incremental environmental innovations (as findings from H1). Thus, we suggest that the presence of a financial benefit to the firm suggests less need for policymakers to consider tax breaks (Testa *et al.* 2011, Owen *et al.* 2018) or other additional support for construction companies to increase environmental innovations. Tempering this result, however, is our finding that there are diminishing financial benefit from these types of projects over the years (H4); it may become increasingly important for policymakers to consider tax support or other policy support. For example, policymakers may consider the positive relationship between strategic alliances and financial performance that we identify (H2). Government support may overcome the barrier of competition with peers by developing collaborative infrastructure and motivate cooperation between firms. It may also support construction companies to develop relationships with technology providers beyond the traditional sector partners in a way that may support more radical environmental innovations.

Conclusion

With increasing challenges of sustainable development, environmental sustainability innovation is a driver for construction companies to achieve competitive advantage in long-term. Based on a sample of 129 environmental sustainability innovation announcements in the construction industry from 2007 to 2017, this research indicates that there is a positive stock market reaction to incremental sustainability innovation announcements in the construction industry. We also find evidence for a positive relationship between strategic alliance and capital turnover with the stock market reaction; there is a negative relationship between the project start date and the stock market reaction. However, we do not find strong evidence for the relationship between project size and international projects to the stock market reaction.

Given the inevitable trade-offs, there are limitations in this study that provide avenues for future research. First, we used the event study methodology and shareholder value as a performance measure of sustainability innovation. While the shareholder value provides an objective measure, the operations factors leading to the shareholder value changes may not be fully understood. Based on the moderating factors explored in this study, future research could adopt, for example, case study or survey-based approaches to explore the required operations changes (e.g., construction process) to the performance improvement. Innovation is often seen as risky; an in-depth case study could provide additional insights into risk factors and approaches to manage these risk factors and also show the role of innovation creation vs adoption orientation as a factor in the model. Where we had no evidence for some of the relationships we hypothesized, a follow-up study might use a panel or interview process with industry experts to identify whether there are any additional moderating or mediating factors that would need to be incorporated into the model. Second, alternative measures of project size could be used in future studies. We estimated the dollar value of project size for a part of observations with project capacity (in MW), due to the constraint of secondary data. Future research could use primary data (e.g., using the case study approach), where the dollar value of project size can be provided by the company, providing explicit insights into the effect of project size on firm performance. Third, our sample includes the projects in diverse global locations, and thus we were unable to conduct location-specific comparative analysis. As discussed earlier, there are concerns relating to different regulations and standards of construction projects across international markets. Future research could examine the geography-specific differences, providing construction companies with strategies for global sustainability innovation projects. Finally, more comprehensive research into incremental and radical innovations could be conducted. Investor expectations and the industry clock speed could be studied to understand under which circumstances investors would more value each form of innovation.

Acknowledgements

The authors gratefully acknowledge the helpful, encouraging, and constructive comments of the Editor, Associate Editor, and the three anonymous reviewers.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix A: Test statistics used in the analysis

We used four broadly used tests in our analysis of the stock market reaction to demonstrate the robustness of our test results. We introduce these test statistics as follows:

Patell-z test (Patell 1976) is a widely used test statistic in many event studies (Ding *et al.* 2018). The AR_{it} is first standardized as:

$$SAR_{it} = {}^{AR_{it}}/_{SD_{it}}, \quad (1)$$

where

$$SD_{it} = \left\{ S_i^2 * \left[1 + \frac{1}{M} + \frac{(R_{mt} - R_m)^2}{\sum_{t=E_1}^{E_2} (R_{mt} - R_m)^2} \right] \right\}^{0.5}, \quad (1)$$

where S_i^2 is the variance of firm i, R_m is the mean return in the market portfolio estimated during the estimation window, M is the number of days in the estimation window, and E_2 and E_1 are the end and start day of the estimation window.

The test statistic for testing H_0: cumulative standardized abnormal return (CSAR) = 0 is given by

$$Patell_z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\frac{\mathrm{CSAR}_i}{S_{\mathrm{CSAR}_i}}, \quad (2)$$

Where CSAR_i is

$$\mathrm{CSAR}_i = \sum_{t=T_1+1}^{T_2} SAR_{it}, \quad (3)$$

Where S_{CSAR_i} is

$$S_{\mathrm{CSAR}_i} = \left[(\mathrm{T}_2 - T_1 + 1)\frac{M_i-2}{M_i-4}\right]^{0.5}. \quad (4)$$

BMP-test (Boehmer *et al.* 1991) advances Patell-z test by additionally adjusts cross-sectional variance to avoid over-rejection on a null hypothesis because of increasing variance around event dates, providing more robust test results. BMP-test is also widely used in many event studies (Ding *et al.* 2018).

The abnormal returns are standardized as in Patell-z test, and then CSAR in the event window (t_1, t_2)across N securities (i.e., cross-sectional average CSAR) is calculated as:

$$\overline{\mathrm{CSAR}_{(t_1,t_2)}} = \frac{1}{N}\sum_{i=1}^{N} CSAR_i\ (t_1, t_2), \quad (5)$$

The standardized cross-sectional test statistics for the null hypothesis is

$$BMP_{test} = \frac{\overline{\mathrm{CSAR}_{(t_1,t_2)}}}{S_{\overline{CSAR}}}, \quad (6)$$

Where $S_{\overline{CSAR}}$ is

$$S_{\overline{CSAR}} = \left[\frac{1}{N(N-1)}\sum_{i=1}^{N} CSAR_i(t_1, t_2) - \overline{\mathrm{CSAR}_{(t_1,t_2)}}\right]^{0.5}. \quad (7)$$

The rank test (Corrado 1989) and binominal sign test (Cowan 1992) are two nonparametric tests broadly used in the literature (Ding *et al.* 2018) to avoid the misspecification of the parametric tests (e.g., non-normality). The rank test first transforms into the ranks a sample of L abnormal returns of each security for the joint time period consisting of the estimation window and event window; second, it tests if the rank of abnormal return on the event day is significantly different from the expected rank of $(L+1)/2$ under the null hypothesis. Binominal sign test determines if the percent positive (negative) abnormal returns are significant different from the expected proportion under the null hypothesis of 50%.

Appendix B. Additional test for incremental and radical innovations

We conducted two additional analyses testing the impact of innovation type (i.e., incremental and radical) on the stock market reaction. First, we included 'radical innovation' as an additional variable in the regression analysis (Table 5). While the radical innovation is not statistically different from zero, the coefficients and significance of the main exploratory variables (i.e., year, strategical alliance, and capital structure) are consistent with those reported in Table 4.

Table 5. The cross-sectional regression results using robust regression, including the variable 'radical innovation' (Gray-shaded in the table)

Independent Variables	Model 1 (Control Variables Only)	Model 2 (Main Effects)
Intercept	0.0131	-0.0393
	(0.0290)	(0.0751)
Europe	-0.0010	-0.0098
	(0.0089)	(0.0234)
Asia	-0.0041	-0.0083
	(0.0096)	(0.0122)
Net Sales	-0.0013	0.0045
	(0.0042)	(0.0089)
Market-to-Book	0.0001	-0.0001
	(0.0003)	(0.0004)
Leverage Ratio	0.0001	0.0001
	(0.0003)	(0.0002)
Construction Industry	0.0073	0.0066
	(0.0106)	(0.0180)
Year (H4)		**-0.0047***

		(0.0028)
Strategic Alliance (H2)		**0.0206****
		(0.0094)
Capital Turnover (H3)		**0.0025****
		(0.0012)
Project Size (H5)		0.0076
		(0.0097)
International Project (H6)		0.0121
		(0.0161)
Radical Innovation		-0.0226
		(0.0331)
N	117	95
Robust R^2	0.0083	0.1792

Note:* and ** denotes the significance at 10% and 5% level (two tails), respectively. The standard errors in parenthesis. Robust regression (MM-estimator) was used in both models. The dependent variable is CAR (0, 1) calculated with the market model.

Second, we excluded all observations coded with 'radical innovation' in the sample and used this trimmed sample to test all variables again by regression analysis. The result table is in Table 6. The results are qualitatively consistent with those reported in Table 4.

Table 6. The cross-sectional regression results using robust regression, with a trimmed sample of excluding the observations coded with 'radical innovation.'

Independent Variables	Model 1 (Control Variables Only)	Model 2 (Main Effects)
Intercept	0.0169	-0.0220
	(0.0330)	(0.0688)
Europe	-0.0011	-0.0050
	(0.0114)	(0.0215)
Asia	-0.0041	-0.0099
	(0.0116)	(0.0114)
Net Sales	-0.0018	0.0014
	(0.0051)	(0.0078)
Market-to-Book	0.0004	0.0002
	(0.0003)	(0.0003)
Leverage Ratio	0.0001	0.0002
	(0.0003)	(0.0002)
Construction Industry	0.0173	0.0115
	(0.0141)	(0.0171)
Year (H4)		**-0.0048****
		(0.0023)
Strategic Alliance (H2)		**0.0211*****
		(0.0079)
Capital Turnover (H3)		**0.0022***
		(0.0012)
Project Size (H5)		0.0087
		(0.0092)
International Project (H6)		0.0123
		(0.0152)
N	101	89

Robust R^2	0.0340	0.2038

Note:*, **, and ** denotes the significance at 10%, 5%, and 1% level (two tails) respectively. The standard errors in parenthesis. Robust regression (MM-estimator) was used in both models. The dependent variable is CAR (0, 1) calculated with the market model.

We found no statistical evidence on the effect of innovation type, potentially due to the overwhelming proportion of incremental innovation cases in our sample. However, both test results indicate the robustness of our main findings. The year effect, strategic alliance, and capital structure are significant factors to financial performance in environmental sustainability innovation of construction.