The impact of off-site construction on firms' operating performance

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Abstract

Off-site construction (OSC) offers an innovative building solution to produce and assemble construction components in factories. It has been claimed to have major contributions in reducing production costs, complexity and improving quality. However, there is a lack of empirical evidence if off-site construction can actually improve firms' performance. Our study aims to review off-site construction projects, and therefore we use panel data and apply a long-horizon event study to investigate the influential factors and their impacts on off-site construction financial performance. Our results suggest that OSC implementation requires significant time and money investment, can increase sales, but short-term ROA is not obvious.

Keywords: off-site construction, long-horizon event study, operating performance

Introduction

Off-site construction is a process innovation where the major construction productions are conducted in specialised factories, and then the components are transported to the construction site for direct installation (Zhai, Zhong et al. 2017). Contrary to traditional on-site construction, off-site construction divides a whole structure into a number of prefabricated/precast sections, to be effectively produced and transported to construction site which is aimed at reducing costs and improving quality (Ma, Le et al. 2018).

Extant literature indicates limited empirical evidence on measuring OSC firms' operating performance (Hussein, Eltoukhy et al. 2021). The UK government has recently called for new approaches to modernise and innovate the construction industry through various means including, chiefly, off-site construction regarding the contributions to firms, industry, and society (Infrastructure and Projects Authority 2020). Therefore, the study supports the policymaking in dealing with the UK Government's Grand Challenges (such as Clean Growth) and provides a timely investigation of this nascent research.

Literature review

Off-site construction has been widely regarded as an effective approach in the construction industry and at the leading edge of innovation for a number of years (Zhai, Zhong et al. 2017). The advantages of producing prefabricated construction parts off-site not only include better productivity and lower costs (Hussein, Eltoukhy et al. 2021), but also, more importantly, with less material waste (Ji, Li et al. 2018), more effectively to control energy (Krug and Miles 2013), and significant potential to increase the use of recycled materials (Yin, Liu et al. 2019). Hence, off-site construction has been considered as a sustainable practice (Ma, Le et al. 2018). It has recently attracted increasing attention from researchers and practitioners because it shows great promise to transform the built environment from a labour-intensive to a modernised green industry (Yin, Liu et al. 2019). A recent study (Oti-Sarpong, Shojaei et al. 2022) on the variations of advances in OSC between countries revealed that institutional pressures and resources are key to explain why some countries are more advanced in OSC than others. Accordingly, adoption of OSC across borders should be cautious due to the mimetic, coercive, and normative institutional pressures in addition to resource differentiation such as labour, technology, finance and materials (Oti-Sarpong, Shojaei et al. 2022). Recently, financial gains of OSC have come to the fore. In a study of cost of OSC in Western Australia using three representative case studies, Sutrisna *et al.* (2018) found out that compared to theoretical base, overall cost of projects delivered through OSC is more relatively higher than delivering it using conventional construction methods. one potential reason for that finding is that OSC depends largely on production standardisation and supply side factors which means that for companies to scoop out benefits of OSC, measuring the cost effectiveness should take place across multiple projects (Sutrisna *et al.*, 2018). Recently, (Oti-Sarpong *et al.*, 2022) argued that studying cost elements in OSC is complex, due to different project stages and variant project specifications, which entails any cost benefit analysis should specify the cost elements to study in OSC projects. That said, cost effectiveness of OSC might be noticed in some cost categories such as cost savings due to standardisation and reduced waste of construction materials. in addition, OSC may include some on site construction (aka residual onsite activities) (Hammad *et al.*, 2020) which cost may outweigh any benefits reaped of OSC.

However, off-site construction also brings new challenges. The nature of its fragmented process (Yin, Liu et al. 2019), demands higher flexibility and customisation in resources planning, effective communications, and more advanced skills and technologies in production and supply chain management (Hussein, Eltoukhy et al. 2021). In study of barriers to adopt OSC in China, Gan, Chang et al. (2018) identified four groups of barriers including (1) inadequate offsite construction policy and regulations, (2) knowledge and expertise gap, (3) resistance to change traditional processes, and (4) low standardisation. Similarly, Ghannad, Lee et al. (2020) suggested that production conservatism coupled with cultural barriers slow the adoption of OSC.

Past research focused on developing models to find optimal production and logistics decisions to improve supply chain performance (Ji, Li et al. 2018). For example, Pero, Stößlein et al. (2015) studied modularisation in construction supply chains and found that the relationship between product modularisation and supply chain integration is influenced by product level factors such as level of customisation and product size and innovativeness and firm level factors such as firm size. Hedging for space and time in production sites has been used to handle the risk of spiralling cost of OSC through reducing assembly time and onsite congestion (Li, Shen et al. 2017). However, this hedging strategy may fuel cost-overruns in construction projects. Owing to this problem, Zhai, Choi et al. (2020) introduced a hedging effort-sharing (HES) mechanism to improve the decision making of optimal hedging strategy. Despite these efforts (see also Hussein, Darko et al., 2022), the literature has yet to consider off-site construction firms' economic performance and its relationships with the other two sustainability dimensions, namely environmental and social performance.

Research objectives and Methodology

In this study, we investigate the operating performance of the off-site construction firms. We focus on two measures of the operating performance, sales and cost of goods sold, as in our research questions below.

> **RQ1**: What is the impact of off-site construction on firms' sales?
> **RQ2**: What is the impact of off-site construction on firms' cost of goods sold?

Long-horizon Event study has been widely used in the operations and supply chain literature to study the impact of operations changes on firm performance (Shou, Shao et al., 2021; Lyon, Barber et al., 1999). The principle of this approach is to adjust sample firms operating performance (e.g., sales and cost of goods sold) by the benchmark portfolio performance of 'control firms' that share similar firm attributes (i.e., size, industry, and past performance). After controlling for the benchmark portfolio performance, our sample firms' statistically significant excess performance is deemed as 'abnormal operating performance to the events of interest'.

We contacted 75 UK registered off-site construction companies for their starting date of their OSC implementation between 2001 and 2019 and collected their financial performance data from FAME (e.g., sales, and costs of sales). Due to missing data (many off-site construction firms are private firms), there are only 19 firms included in our final samples for analysis. We followed the literature (Lo, Pagell et al. 2014) to conduct a long-horizon event study. The approach defines the base year as the year when the organisation was free from the impact of an event and the event year as the starting year of the event. Thus, we defined the year of off-site implementation as the event year and Year -2 as our base year, as on average it takes around 12 to 24 months for an organisation to prepare for the off-site construction transformation. Therefore, this study investigated the abnormal operating performance within a four-year range, that is between year-2, year -1, year 0 and year 1. We also followed previous studies (Hendricks, Singhal et al. 2007, Lo, Pagell et al. 2014) to create a benchmark portfolio of control firms and estimate the excess/abnormal operating performance of our sample firms. We followed the literature (Fan and Lo, 2012; Lyon, Barber et al., 1999) and used the following approach to generate a rigorous sample of control firms. We controlled the industry by using the two-digit SIC code to our sample firms. We controlled firm size by using total assets in the range of 50-200 percent to our sample firms. We controlled past performance by using Return on Assets (ROA) in the range of 90-110 percent to our sample firms. For each sample firm, we extracted all listed firms in the FAME database that meet these three criteria, and calculate the abnormal operating performance of our sample using the formula below:

Equation (1):

$$AP_{t+j} = PS_{t+j} - EP_{t+j}$$
$$EP_{t+j} = PS_{t+i} - meidan\,(PC_{\ t+j} - PC_{t+i})$$

where AP is the abnormal performance, PS the actual performance, EP the expected performance of sample firms, PC the actual performance of control companies, t the adoption year of off-site construction, i the starting year of comparison (I = -2) and j the ending year of comparison (j = 1, 0 or 1).

We subsequently examined three firm-level abnormal performance indicators: ROA, sales and cost of goods sold. Given the small sample in our study, we focus on non-parametric tests to avoid potential bias. We employed Wilcoxon signed-rank test and binominal sign test to test median and percentage of the abnormal operating performance. We also investigated the year-to-year abnormal performance for their changing patterns and off-site construction implementation impacts.

Results and discussions

We first compared the three operating performance indicators between the sample companies and the benchmark portfolio of control firms. Table 1 illustrates the results. Due to the missing information on one or more financial performance categories in FAME, the sample observations were varied across the three measures. We successfully obtained ROA from 18 companies, sales record from 17 companies and costs of sales data from 13 companies within the study event window (i.e., year -2 to year 1). The results indicated significant positive changes on sales and costs of sales: i.e., the median cumulative abnormal change for sales was 5496.50 thousand pounds and the median cumulative abnormal change for cost of goods sold is 9415.50 thousand pounds. They showed that off-site construction significantly improved these companies' sales but also increased their operating costs. The abnormal change of ROA is found not statistically significant. The median cumulative abnormal change of ROA was -1.28 percent. This finding seemed agree some existing studies that the high initial cost is a major barrier to implement off-site construction (Gan, Chang et al. 2018), especially in the early stage of the implementation (Bendi, Rana et al. 2020).

Table 1 Abnormal operating performance in year -1 to year 1

Measure	Observations	Median	Mean	% of Positive
Abnormal ROA (%)	18	-1.28	-1.59	0.500
p-value		(0.702)	0.809)	(1.000)
Abnormal Sales (in thousands of UK£)	17	5496.50	55612.41	0.647
p-value		(0.098)*	(0.221)	0.332)
Abnormal cost of goods sold (in thousands of UK£)	13	9415.50	149053.90	0.846
p-value		(0.013)**	(0.143)	(0.022)**

Note: * and ** denotes the significance at 10% and 5% level (two tails), respectively; Wilcoxon signed-ranked test is used for the median; binomial sign test is used for the percentage of positive abnormal operating performance; t-test is used for the mean. Year -2 is the base year to identify the control firm portfolios matched with industry (two-digit SIC codes), past performance (ROA), and firm size (total asset).

We then studied the change pattern of the three operating performance indicators within the four-year event window (from year -2 to year -1, from year -1 to year 0 and from year 0 to year 1). Table 2 shows the yearly abnormal changes of the three indicators. The results indicated that the cost of goods sold had started to increase significantly in year -1 to year 0 and had continued to rise significantly in year -0 to year 1. They suggested that it would take at least 12 months and a significant investment for an organisation to prepare for and implement off-site construction. The results also showed that the sales were only improved significantly from year -1 to year 0 and ROA had no significant changes over the 4-year event window. Moreover, we found the none of abnormal operating performance indicators is significant at the pre-even window of (-2, -1). It provides statical evidence on our choice of base year of -2 and reported main event window (-1, 1) in Table 1.

Table 2 Abnormal operating performance in different event windows

	Year -2 to Year -1				Year -1 to Year 0				Year 0 to Year 1			
Measure	Observations	Median	Mean	% of Positive	Observations	Median	Mean	% of Positive	Observations	Median	Mean	% of Positive
Abnormal ROA (%)	19	-0.480	-8.424	0.316	17	-1.820	-4.119	0.353	16	-0.615	2.902	0.438
p-value		(0.134)	(0.161)	(0.167)		(0.284)	(0.310)	(0.332)		(0.940)	(0.560)	(0.804)
Abnormal Sales (in thousands of UK£)	18	-16373.750	-307104.800	0.333	16	2699.250	63613.620	0.625	15	1074.500	-5627.933	1.000
p-value		(0.167)	(0.371)	(0.238)		(0.074)*	(0.252)	(0.455)		(0.804)	(0.633)	(0.533)
Abnormal cost of goods sold (in thousands of UK£)	14	913.750	49537.040	0.571	13	2615.000	73080.500	0.692	12	3540.250	31797.210	0.388
p-value		(0.426)	(0.157)	(0.791)		(0.027)**	(0.219)	(0.267)		(0.092)*	(0.226)	(0.667)

Note: * and ** denotes the significance at 10% and 5% level (two tails), respectively; Wilcoxon signed-ranked test is used for the median; binomial sign test is used for the percentage of positive abnormal operating performance; t-test is used for the mean. The results in event window of Year -2 to Year -1 demonstrate operating performance of our sample firms is not statistically different from those of control firms, while the significant abnormal operating performance is first found in the event window of Year -1 to Year 0. Together, they indicate the robustness of our choice in the base year (i.e., Year -2), and the main event widow of Year -1 and Year 1.

Recommendations

This study provided preliminary empirical evidence of the emerging off-site construction's impacts on firms operating performance. The results suggested although there was a significantly positive overall sales of implementing off-site construction, off-site construction firms bear a substantial increase in cost, demonstrating a requirement of significant investment for the firms that apply off-site construction approach. One of potential resulting cost is transportation costs. Traditional on-site construction companies are not necessary to deal with substantial transportation challenge. However, as off-site construction shifts the manufacturing process to remote factories. Off-site construction firms must carefully develop their specialist logistics capacity to manage this emerging issue. While the new model of off-site construction is discussed to have social resistance, relating to safety and ergonomic concerns (Golabchi, Liu et al., 2018), our finding of increased sales shows the decreasing of such concern in recent years. One of potential reason is the establishment and development off-site construction verification scheme, which significantly improves the market confidence in this innovative approach.

Our study offered empirical evidence from the off-site construction companies' key financial performance indicators. The contributions of this study are twofold. First, the study contributes to the off-site construction literature by developing a theoretical framework to explore the necessary resources that firms should adopt and develop for effective off-site construction projects. Second, practitioners will be able to use the findings of this study to support their policymaking in the motivation of industrial propagation of off-site construction for sustainable performance.

This preliminary study provides scholars with interesting results to further explore the off-site construction. First, future research can move onto investigating sustainability performance. The off-site construction may contribute substantially to firms' environmental management in response to the increasing social outcry of carbon neutrality initiatives. Abnormal environmental performance can be explored, while a large sample and measure of appropriate environmental performance (e.g., ESG scores) need to be explored. Second, multiple moderating factors that contribute to the abnormal operating performance can be explored. For example, "intensity of off-site construction in public sectors" and firms' characteristics (e.g., working capital turnover, supply chain position) provide the insight of policymaking and firms' capacity in implementing a successful off-site construction project.

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