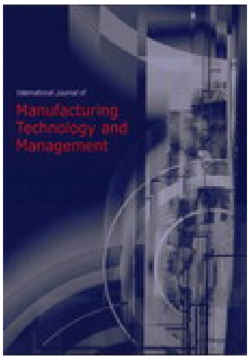

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Lean bundles and operational performance: the moderating effect of operational absorptive capacity

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Abstract: The positive effect of lean bundles (LBs) on operational performance (OP) has been widely investigated. However, the moderating mechanism on the relationship between LBs and OP remains unclear. Lean literature suggested that the contextual factors (such as, plant size) would affect the effectiveness of LBs. However, existing literatures focused on external environmental factors, whereas this research examined the effect of contextual factors inside of firms. As a source of competitive advantage, operational absorptive capacity (OAC) can improve the ability to integrate resources through acquiring and utilising knowledge effectively, thereby enhancing the efficiency of production management activities. Hence, OAC were introduced to explore the moderating effect of OAC on the relationship between LBs and OP. This research identified four bundles of lean practices, namely just in time (JIT), total preventive maintenance (TPM), total quality management (TQM) and human resource management (HRM). Ordinary least square analysis was adopted for analysing whether OAC can enhance the effectiveness of the LBs. This research deepens the exploration of the relationship between the LBs and OAC. Moreover, this research contribute to literature on the mechanism that LBs effect OP by offering new insights with contingency theory.

Keywords: operational performance; operational absorptive capacity; OAC; lean bundles.

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1 Introduction

In the era of diversified customer demands, enterprises are required to counter challenges of improving operational efficiency, production quality and supply chain management (Hines et al., 2004; Poongothai et al., 2011; Liu et al., 2017). In response to these challenges, many enterprises implemented lean production to improve operational performance (OP) (Negrão et al., 2017). Extensive researches on lean practices and its bundles indicated that lean bundles (LBs) influence OP significantly (Rahman et al., 2010; Liu et al. 2020). For instance, Radnor and Johnston (2013) and Chavez et al. (2015) proposed that LBs can enhance the operational process and OP. However, researchers find that the direct effect of LBs on OP is still not explicit (Fullerton et al., 2003). More recent study reveals that some of the LBs have a less, or even negative effect on OP (Belekoukias et al., 2014). Mackelprang and Nair (2010) suggest that the lack of consistency is due to the complexity of implementing LBs. Agarwal et al. (2013) indicated that the lack of adoption of depth managerial implications leads to the lack of significance. However, these explanations are preliminary descriptions, so there is an urgent need for further research.

The contingency theory is widely adopted to interpret the lack of the consistency (Chavez et al., 2013, 2015; Kull et al., 2014; Azadegan et al., 2013; Sousa and Voss, 2008), which indicates that LBs application and its effect may vary in different context (Wong, 2007; Browning and Heath, 2009). In related research, White et al. (1999) find that factory scale have a positive effect on the relationship between LBs and OP. Similarly, Shah and Ward (2003) analysed the differences in the application effects of lean practices with different factory age, and factory scale. However, these factors are all classic environmental factors. Literatures proposed the need of further empirical studies from a perspective of organisation knowledge, since the application of LBs is a process of knowledge creation and management (Grant, 1996; Secchi and Camuffo, 2016).

From the concept of resource-based view (RBV), resources owned by firms would affect all the activities inside and outside the firm. Therefore, the application of lean production is inevitably affected by the resources owned or invested by the firms. In a changing market environment, as the applicability of the company's existing experience, knowledge and resources decreases, the value of those resources owned by the company will also decrease. Operational absorptive capacity (OAC) represents the capability of an enterprise to generate, absorb, conversion, and develop knowledge from the operations circumstances in and outside of firm (Zahra and George, 2002; Patel et al., 2012). Thus, some researchers begin to investigate the impact of OAC in enhancing the effectiveness of operational improvement practices (Yang et al., 2017). The OAC would strengthen the ability to acquire and exploit knowledge by integrating and reorganising the internal and external resources owned by firms, helping enterprises to quickly acclimatise to the dynamic market (Teece et al., 1997; Tsai, 2001; Patel et al., 2012). As reported earlier, the application of lean production in the enterprise is a process of knowledge integration. Therefore, this study introduced OAC into the lean literature. The main purpose of this study is to empirically test the moderation role of OAC that may enhance the influence of LBs on OP.

Besides, some preliminary research mainly showed interest on the whole picture of lean and its relationship to organisational performance (Lawrence and Hottenstein, 1995). Shah and Ward (2003) use a notion of LBs to explore the influence of sub-dimensions of lean production on business operations. However, the classification of LBs has changed over time. Thus, this research tries to carry out a system literature review and identify the most important LBs and its measures. Moreover, LBs need to be understood from a perspective of knowledge management as researchers highlighted (Secchi and Camuffo, 2016). Thus, this research proposed the following research question:

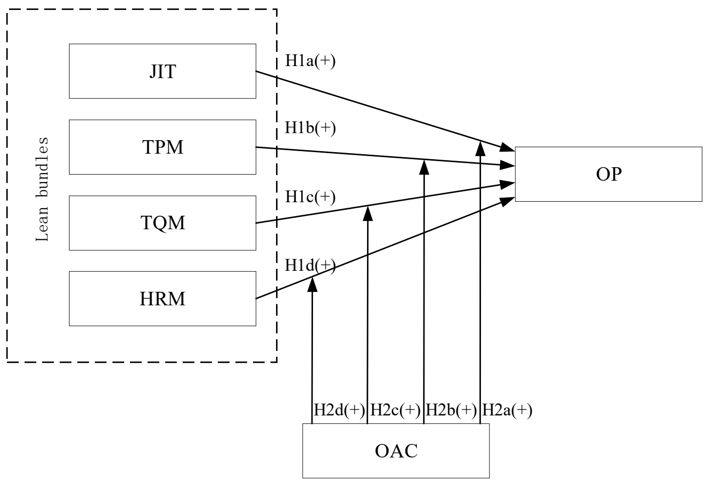
1. RQ1: Are LBs positively associated with OP?
2. RQ2: Does OAC acts as a moderator on the relationship between LBs and OP?

The following sections: literature review of the key concepts and related hypotheses are presented in Section 2. Section 3 describes the research methodology. The process of data collection and analyses were conducted in Section 4. Research results and conclusions are proposed in Section 5.

2 Literature review and research design

Key LBs initially identified from literature, which includes just in time (JIT), total preventive maintenance (TPM), total quality management (TQM), HRM. Then, this research described the relationship between these bundles and OP. Finally, this research provided a discussion in support of the literature of OAC. This research built the framework of hypotheses, which is described in Figure 1. It is hypothesised that JIT, TPM, TQM, HRM have positive influences on OP (see Section 2.1) and this effect can be moderated by OAC (see Section 2.2).

Figure 1 Framework of hypotheses



2.1 LBs and OP

The term 'lean' is initially derived from the famous automobile manufacturing system known as Toyota Production System. Existing researches defined lean production as a set of activities and tools that aim at eliminating waste and reducing non-value added activities (Hines et al., 2004; Yang et al., 2011; Jaiganesh and Sudhahar, 2013). Most recent researches suggested that some of LBs have positive effect on OP (Negrão et al., 2017). Nonetheless, prior researchers found that the relationship between LBs and OP is not explicit (Fullerton et al., 2003). Accordingly, our research tries to identify key LBs and carry out a further research.

Existing researches used different measures for examine the relationship between LBs and OP. Table 1 presents the classification of LBs. As shown in Table 1, four LBs are adopted by most research, namely JIT, TPM, TQM, and HRM. Practices relate to JIT include pull system, quick changeover techniques and reengineered production processes, etc. Practices relate to TPM include preventive maintenance, new equipment or technologies, safety improvement programs, and maintenance optimisation. Practices relate to TQM include process capability measurements and supplier quality involvement. Practices relate to HRM include training employees to perform multiple tasks, self-directed work teams, encourage employees to work together, and suggestions schemes.

Table 1 LBs

Practices	*(R1)*	*(R2)*	*(R3)*	*(R4)*	*(R5)*	*(R6)*	*(R7)*	*(R8)*	*(R9)*	*(R10)*	*(R11)*	*(R12)*
Cellular manufacturing				JIT					JIT			
Quality management projects				TQM								
Self-directed work teams				HRM			HRM					
Continuous flow	JIT											
Training employees to perform multiple tasks					HRM		HRM				HRM	HRM
Supplier quality involvement		TQM	TQM		TQM							
encourage employees to work together				HRM							HRM	
Safety improvement programs				TPM								
Cycle time reductions	JIT			JIT				JIT	JIT			
Competitive benchmarking				TQM								
equipment layout			JIT				JIT					
Focused factory production systems				JIT								
Formal sustaining improvement plan				TQM	TQM	TQM	TQM					
JIT delivery			JIT									
Total quality management				TQM		TQM						
Significant reduction	JIT			JIT					JIT	JIT		
New craft equipment or technologies			TPM	TPM								
Customer involvement			TQM		TQM							
Planning and scheduling				TPM								
Recommendations											HRM	
Prevention of defective products	JIT											
Reengineered production processes				JIT		JIT		JIT		TPM		
Process feedback		TQM					TQM					
Top management leadership for quality		TQM										
Quick transformation techniques		JIT	JIT	JIT	JIT			JIT				JIT
Supplier partnership		TQM										
Process capability measurements			TQM	TQM	TQM		TQM			TQM	TQM	
Preventive maintenance			TPM	TPM			JIT	JIT			TPM	
Pull system		JIT	JIT	JIT	JIT	JIT	JIT		JIT	JIT	JIT	JIT

Notes: (R1) Lawrence and Hottenstein (1995), (R2) Cua et al. (2001) (R3) Sakakibara et al.(1997), (R4) Shah and Ward (2003), (R5) Ahmad et al. (2003), (R6) Yang et al. (2011), (R7) Swink et al. (2005), (R8) Rahman et al. (2010), (R9) Bortolotti et al.(2013), (R10) Kull et al. (2014), (R11) Netland (2016), (R12) Bevilacqua et al. (2017).

In the literature, JIT usually refers to improvement project with the purpose of waste reduction in all business processes (Zelbst et al., 2010; Mistry, 2005). Mackelprang and Nair's (2010) proposed that JIT embed in operational index such as costs, time, speed and delivery all of which are positive related to OP. Mistry (2005) revealed that a prevail advantage of JIT bundle is that it simplify production activities to improve the effectiveness of production process.

TPM is a cost-effective maintenance procedure aimed at thoroughly improvement for organisations (Brah and Chong, 2004). Researchers suggested that TPM is crucial to organisation capacity to successfully compete in its market on the basis of quality and cost (Fredendall et al., 1997; Ahuja and Khamba, 2008; McKone et al., 2001).

TQM refers to a quality-focused management approach to long-term success through customer satisfaction (Okes and Westcott, 2001). Researchers suggested that TQM have a positive effect on OP when the context is appropriate. For instance, York and Miree (2004) suggested that the arguments of the effect of TQM focused on customer satisfaction and efficiency improvement. Corredor and Goñi (2011) suggested that TQM could help firms get better performance if they are pioneer TQM adopters.

Similarly, HRM is also an important bundle in lean production. Researchers suggested that HRM is positively related to business performance. Moreover, some researchers indicated that HRM may positively influence OP as it motivates employee's improvement behaviour (Katou, 2017).

Based on the describe of the preliminary work about LBs and OP, this research hypothesise that there is a positive relationship between the LBs and OP.

H1a There is a positive relationship between JIT and OP.

H1b There is a positive relationship between TPM and OP.

H1c There is a positive relationship between TQM and OP.

H1d There is a positive relationship between HRM and OP.

2.2 The moderating effect of OAC

2.2.1 LBs, OAC, and OP

Prior studies suggested that LBs help firms to improve operations processes and business performance. However, as reported earlier, there are still some researchers who question those research results (Callen et al., 2000; Belekoukias et al., 2014). Some researches indicated that the lack of consistency in empirical research results is due to a complicacy connection between production practice bundles and performance (Swink et al., 2005). Other researchers explained that the obstacles may cause by mismatching between the practices proposed and specific organisation environment. In the field of operation management research, contingency theory argues that contextual factors are important variables, and different contextual factors would influence the applicability in research conclusions (Negrão et al., 2017; Kull et al., 2014).

Given the complexity of the environment and the contextual dependence of LBs (Marodin and Saurin, 2013; Lewis, 2000), researches suggested that the contextual factors of LBs may affect the effectiveness of lean activities (Inman et al., 2011; Bamford et al., 2015). Therefore, researchers investigated the moderating effect of contingency factors on the relationship between LBs and OP. For example, Kull et al. (2014) focused on the discrepancy of LBs application effects using national culture as moderator. Azadegan et al. (2013) suggested that there is a positive moderate impact of environmental complexity on the relationship between LBs and OP.

Prior researches mainly focused on external environmental factors of the firm, but these studies ignore the internal factors of firms. The fit relationship between LBs and internal factors would affect the application of lean production. Hence, exploring the fit relationship between organisational factors inside of firms and LBs would permit the firm to understand the mechanism of lean production better. As an important concept to explain the source of corporate competitiveness, OAC has received enormous attention from scholars (Zahra and George, 2002; Patel et al., 2012). The OAC can enhance organisation capacities to acquire and utilise knowledge by integrating the resources of firms, thus affecting the effect of LBs on OP.

2.2.2 Hypotheses

As mentioned above, OAC can aid in gaining competitive advantage. In the context of applying LBs, OCA can improve the ability of enterprises to manage production knowledge through efficient knowledge processing, thus, enabling firms to identify problems encountered in the application of LBs systematically.

Generally, knowledge-based view focuses on the effect of knowledge on the competitiveness of enterprises, and believes that knowledge is an essential organisational asset (Yeung et al., 2008). Zhang and Chen (2016) indicated that the application effect of lean construction largely relies on team learning and knowledge acquisition and transformation. Moreover, OAC is related to the acquire and exploit knowledge ability. In other words, OAC may have a moderating influence on the relationship between LBs and OP.

In related research, the moderating effect of the OAC may vary depending on the LBs because every LBs have different application area and procedure. Furlan et al. (2011a) suggested that the application of different LBs improve OP of firms greatly, whereas previous study has emphasised the importance of testing the influence of various dimensions of LBs on performance (Shah and Ward, 2007). Therefore, this research focuses on the effect of OAC on different LB. As mentioned before, the four most important LBs are JIT, TPM, TQM, and HRM.

As for JIT, some researchers suggested that the application of JIT needs a repetitive context (Reichhart and Holweg, 2007; Lander and Liker, 2007). Related researches asserted that organisational elements (such as cultural factors) are of greater importance in JIT implementation (Wong, 2007). However, there are still limited researches focusing on the impact of contextual factors on JIT (Chen and Hua Tan, 2013). Even though acquired knowledge is precious and valuable by nature, it cannot be used when the recipients do not assimilate it into their task environment (Park et al., 2007). A high OAC level may positively related to the application of knowledge of JIT. Therefore, this research hypothesise that:

H2a OAC moderate the relationship between JIT and OP.

TPM is reagraded as a strategic process to improve operating efficiency through equipment maintenance (Dossenbach, 2006). Obstacles that affect TPM implementation occur when enterprises fail to transform culture and have a misunderstand on the TPM concepts and principles (Ahuja and Khamba, 2008). From the insight of assimilating and applying new knowledge, OAC may enhance the effect of TPM. Therefore, this research hypothesise that:

H2b OAC moderate the relationship between TPM and OP.

Preliminary work has considered the role of quality management with knowledge (Linderman et al., 2004) or learning (Anderson et al., 1994). Linderman et al. (2006) suggest further research on quality management should take a perspective of knowledge management. Moreover, quality management improvement is essentially a knowledge-based process that focus on learning (MacDuffie, 1997) and knowledge exploitation (Osterloh and Frey, 2000). Absorptive capacity stands for learning capacity (Tsai, 2001) or a composition of a learning process (Fosfuri and Tribó, 2008). Thus, this research hypothesise that:

H2c OAC moderate the relationship between TQM and OP.

HRM implementation is crucial for organisation to acquire knowledge and leveraging employees at all levels participating in production practice (Youndt et al., 1996; Collins and Clark, 2003). The implementation of HRM can be utilised to improve capabilities of an organisation to understand, share, and adopt knowledge, in which employee will be motivated to exploit knowledge (Guest, 2011; Chen and Huang, 2009). Thus, it is hypothesised that:

H2d OAC moderate the relationship between HRM and OP.

3 Methodology

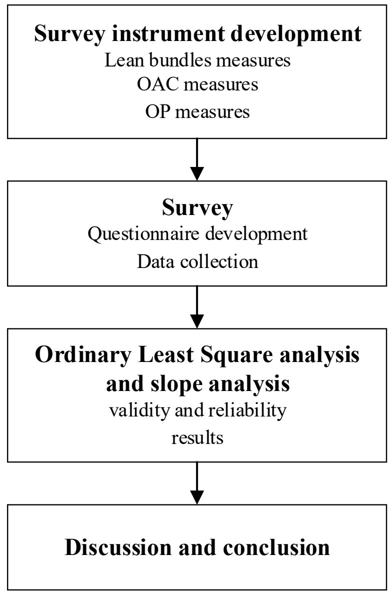
The research approach consists of four steps. First, this research identified the measures of LBs, OAC, and OP. Then this research developed a questionnaire and collected data. Furthermore, this research used an empirical-driven approach to test hypotheses. The detailed procedures of the methodology are given in the following subsections.

3.1 Questionnaire development

Before implementing the survey, the questionnaire was modified in several aspects to ensure that the respondents, especially managers of small firms, can correctly understand the constructs and items. First, operation managers, production managers, or plant managers served as respondents since they usually have a complete picture of their firms encompassing the characteristics of LBs and OP. Second, the content validity of the questionnaire was clarified after adopting suggestions of two lean production researchers and three production managers (EMBA students). Finally, this research invited five production managers to participate in the pilot survey. Based on the feedback, this research improved the description of the five constructs and items.

The questionnaire is organised into three parts. Organisation information, which includes questions about the respondent's job title, the firm's size, and the industry sector, is the first part of the questionnaire. The second part is dedicated to the LBs (JIT, TPM, TQM, HRM) and OP adopting a five-point Likert scale. The third part is the OCA measurement adopting a five-point Likert scale, too. The specific information of the survey questionnaire is recorded in the attachment.

Figure 2 Research framework



3.2 Data collection

E-mail and an internet-based method were used to get data. For the internet-based method, this research used an online electronic questionnaire to collect data, which is more effective. The main respondent chosen in this study came from 550 manufacturing firms located in China. These firms were chosen because they applied lean production in their firm to purse excellent production operation. Operation managers, production managers, and plant managers in these firms were invited to participate in the survey. Further, contact though phone calls were made to explain the aim of the questionnaire and remind them to fill in the questionnaire. In total, 270 questionnaires were collected and 253 were applicable, which takes an overall response rate of 46%. Table 2 shows details of the sample characteristics.

3.3 Validity and reliability

Three stages for survey measurement validation are performed, including content validity, construct validity and reliability (O'Leary-Kelly and Vokurka, 1998). In the first stage, content validity was done by draft questionnaire pre-testing. Then the modified draft-questionnaire was sent to EMBA students for their feedback, thus the terminology, instructions, and format of the survey were clarified.

Second, construct validity was established through confirmatory factor analysis (CFA). A pooled CFA of the model is carried out. Through the CFA, a modified model was formed (Figure 3). The overall fitting degree of the measurement model was quite well: of and RMSE = 0.061. According to related literature, the numerical value of RMSEA reflects good fit (0 < value of RMSEA < 0.05), acceptable (0.05 < value of RMSEA < 0.08) or reject (value of RMSEA > 0.08) of survey data (Kadipasaoglu et al., 1999). Other relevant indexes (IFI = 0.917, TLI = 0.905, CFI = 0.916) also indicates acceptable fitting degree (Hooper et al., 2008).

Table 2 characteristics of the sample

Characteristics	*Sample (%)*
Number of employees	
Under 100	29.6
100–299	18.6
300–499	24.9
500+	26.9
Respondent's job	
Operation manager	42.3
Production manager	35.2
plant manager	12.6
Other	9.9
Industry sector	
Motor vehicles and parts	13.8
Products of wood	11.5
Fabricated metal products	10.3
Manufacturing of food	9.1
Medical devices	8.3
Electronics	7.9
Basic metals and other minerals	7.1
Plastics	6.7
Textiles and apparel	6.3
Chemicals	5.9
Machinery	5.5
Pharmaceuticals	4.3
Other	3.2

Final, reliability was estimated by Cronbach's α coefficient, as shown in Table 3. Analysis results showed that all the alpha values are higher than 0.7, which illustrates that the measurement are reliable for further analysis (Babbie, 2015; Chen et al., 2009).

3.4 Control variables

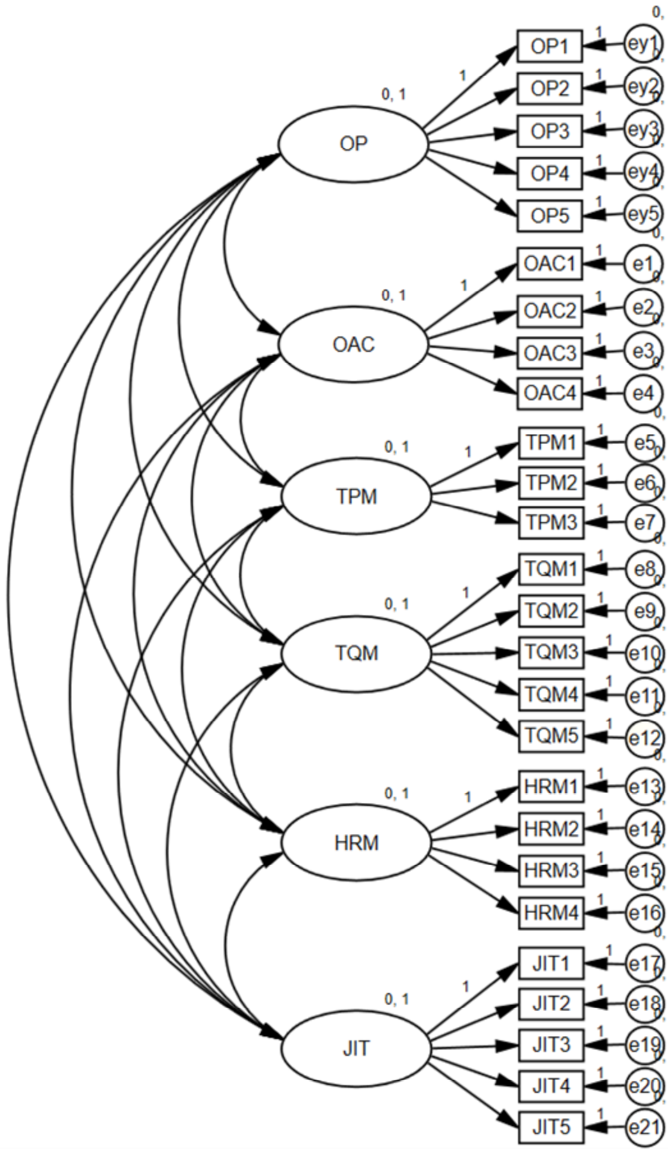
Organisation size and industry type are two control variables used in this research to ensure the generalisability of research results. The number of employees was used to represent firm size (Chavez et al., 2013). These variables may affect performance measurements (Antonio et al., 2007). For this reason, these variables were included in the ordinary least square analysis as control variables.

Table 3 CFA factor loadings, reliability, and SE

Latent variables	*Observed variables*	*Item*	*Cronbach's α*	*SE*	*Standardised loading*
JIT	Pull system	JIT1	0.824	–a	0.822
	Quick changeover techniques	JIT2		0.044	0.846
	Cycle time reductions	JIT3		0.043	0.767
	Lot size reductions	JIT4		0.051	0.784
	Reengineered production processes	JIT5		0.046	0.819
TPM	Preventive maintenance	TPM1	0.887	–a	0.815
	Planning and scheduling	TPM2		0.056	0.824
	New process equipment or technologies	TPM3		0.058	0.837
	Safety improvement programs	TPM4		0.052	0.822
	Maintenance optimisation	TPM5		0.053	0.83
TQM	Process capability measurements	TQM1	0.898	–a	0.938
	Continuous improvement program	TQM2		0.038	0.895
	Supplier quality involvement	TQM3		0.041	0.817
HRM	Training employees to perform multiple tasks	HRM1	0.867	–a	0.857
	Self-directed work teams	HRM2		0.049	0.842
	encourage employees to work together	HRM3		0.055	0.804
	Suggestion schemes	HRM4		0.053	0.791
OP	Higher product quality	OP1	0.851	–a	0.839
	Shorter delivery time	OP2		0.054	0.874
	Ability to adjust capacity rapidly	OP3		0.051	0.832
	Production cost	OP4		0.054	0.755
	Reducing inventory	OP5		0.056	0.865
OAC	Multiskilled employees work	OAC1	0.831	–a	0.813
	Analysis and interprets various market and operational demands	OAC2		0.048	0.857
	Discuss results of new products, process or logistics, and distribution developments	OAC3		0.050	0.844
	Constantly considers how to better develop operational knowledge	OAC4		0.055	0.733

Notes: χ^2 / *df* = 1.92; RMSEA = 0.061; IFI = 0.917; TLI = 0.905; CFI = 0.916.
[a]Indicates a parameter fixed at 1.0 in the original solution.

Figure 3 Model of CFA



3.5 Ordinary least square analysis and slope analysis

Ordinary Least Square analysis was carried out to examine the relationship between four LBs (JIT, TPM, TQM, HRM) and OP, and the moderating effect of OAC.

Before performing regression analysis, the independent variables were centred to avoid multicollinearity. A centred overall analysis might be informative and less multicollinearity when the interaction terms were involved in the model (Aiken et al., 1991). Furthermore, the variables were tested for multicollinearity using the variance inflation factor (VIF). If the maximum VIF is higher than 10, the multicollinearity will probably influence independent variables (O'Brien, 2007). As is shown in Table 4, all variables in the model are lower than Max VIF (1.088).

Then the ordinary least square analysis was carried out. First, control variables were entered into the model. Secondly, independent variables and moderator variable were put into the model. Finally, the interaction terms were entered into the model.

Furthermore, slope analysis (Aiken et al., 1991) was conducted to test whether the slopes of the simple regression differ significantly from zero. This involved the calculation of the slopes, the standard errors of the slopes and t-tests for the significance of the slopes (Friedrich, 1982; Aiken et al., 1991). A low level and a high level of OAC were entered into the slope analysis.

4 Results

4.1 Regression analysis

Analysis results showed that H1a, H1b, H1c, H1d are statistically significant, which indicated that LBs impact OP strongly. Theoretically, the results supported existing research on the significance of the impact of LBs on OP (Chavez et al., 2015). Moreover, the results confirming H2a, H2c, H2d indicated that OAC have moderating effect on the relationship between LBs (JIT, TQM, HRM) and OP. The analysis results of the ordinary least square analysis are shown in the Table 4.

Table 4 Results of ordinary least square analysis

	Standardised estimates			
Variables	*Step1*	*Step2*	*Step3*	*Outcome*
JIT				
Control variables				
Industry type	0.009	0.013	0.015	
Firm size	0.034	0.034	0.031	
JIT		0.273**	0.269**	H1a: supported
Moderator: OAC		–0.104	–0.105	
Interaction term				
JIT*OAC			0.221*	H2a: supported
R^2	0.004	0.067	0.088	
R^2 change	0.004	0.062	0.021	
F	0.558	4.430**	4.762**	
F change	0.558	8.269**	5.753*	
Max VIF	1.023			
TPM				
Control variables				
Industry type	0.009	0.009	0.010	
Firm size	0.034	0.042	0.039	

Notes: *Significant at 0.05level. **Significant at 0.01 level.

Table 4 Results of ordinary least square analysis (continued)

	Standardised estimates			
Variables	*Step1*	*Step2*	*Step3*	*Outcome*
TPM		0.337**	0.326**	H1b: supported
Moderator: OAC		–0.049	-0.033	
Interaction term				
TPM*OAC			0.086	H2b: not supported
R^2	0.004	0.164	0.171	
R^2 change	0.004	0.160	0.007	
F	0.558	12.175**	10.176**	
F change	0.558	23.692**	1.986	
Max VIF	1.088			
TQM				
Control variables				
Industry type	0.009	0.019	0.019	
Firm size	0.034	0.001	–0.005	
TQM		0.298**	0.287**	H1c: supported
Moderator: OAC		–0.135	–0.143	
Interaction term				
TQM*OAC			0.150*	H2c: supported
R^2	0.004	0.117	0.132	
R^2 change	0.004	0.112	0.015	
F	0.558	8.188**	7.508**	
F change	0.558	15.752**	4.344*	
Max VIF	1.037			
HRM				
Control variables				
Industry type	0.009	0.004	0.001	
Firm size	0.034	0.027	0.028	
HRM		0.394**	0.375**	H1d: supported
Moderator: OAC		0.083	–0.072	
Interaction term				
HRM*OAC			0.164*	H2d: supported
R^2	0.004	0.210	0.229	
R^2 change	0.004	0.205	0.019	
F	0.558	16.449**	14.637**	
F change	0.558	32.201**	6.048*	
Max VIF	1.055			

Notes: *Significant at 0.05level. **Significant at 0.01 level.

JIT enhances OP (H1a) and OAC have a moderating effect on this relationship (H2a). From the ordinary least square analysis, the control variables, industry type and organisation size, have non-significant effect on OP (as shown in Table 4). In the next model of the ordinary least square analysis, the effect of JIT on OP is significant ($p < 0.01$). Then, interaction term of JIT and OCA was inputted the analysis model, and the analysis results show that there is a significance impact on the interaction term ($p \leq 0.05$) and a significant change on moderating effect of OAC ($p \leq 0.05$).

TPM enhances OP (H1b), whereas OAC shows no moderating effect on this relationship (H2b). From the analysis results, neither of industry type's and organisation size's effect on OP are non-significant (as shown in Table 4). Then, the effect of TPM ($p < 0.01$) is non-significant. In the third model of the analysis, including the two-way interaction term, the moderating effect of OAC was also examined. But, the result is not significant, which illustrate that H2c is not supported. The results indicate that there is no significant empirical evidence which suggest that OAC moderates the impact of TPM on OP.

TQM enhances OP (H1c) and OAC have a moderating effect on this relationship (H2c). From the Ordinary Least Square analysis, neither of industry type's and organisation size's effect on OP are non-significant (as shown in Table 4). The effect of TQM ($p < 0.01$) is significant. Interaction term of JIT and OCA was inputted the analysis model, and the analysis results show that there is a significance impact on the interaction term ($p \leq 0.05$) and a significant change on moderating effect of OAC ($p \leq 0.05$).

HRM enhances OP (H1d) and OAC have a moderating effect on this relationship (H2d). From the Ordinary Least Square analysis, neither of industry type's and organisation size's effect on OP are non-significant (as shown in Table 4). Second, the effect of HRM ($p < 0.01$) is significant. Interaction term of JIT and OCA was inputted the analysis model, and the analysis results show that there is a significance impact on the interaction term ($p \leq 0.05$) and a significant change on moderating effect of OAC ($p \leq 0.05$).

4.2 Slope analysis

Furthermore, the analysis results in terms of the slopes, standard errors, and t-tests are shown in Table 5. These slopes analysis results are shown in Figure 4, Figure 5 and Figure 6. As shown in Figure 4, the slope of the simple regression of JIT and OP differs significantly from zero (slope = 0.4416, $p \leq 0.01$) when OAC is high. On the contrary, there is no significance when OAC is low. The results illustrate that when OAC level is high, OAC can effectively adjust the relationship between JIT and OP. This effect may result in the reason that high OAC helps the application of balanced production, SMED, and the pull system. Lean is a process of knowledge output, transfer, and spread (Secchi and Camuffo, 2016).

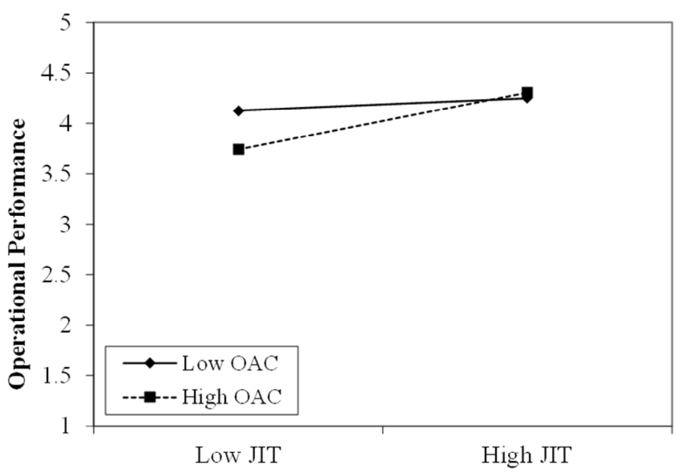
As shown in Figure 5, when the OAC level is high (slope = 0.4042, $p \leq 0.01$), the effect of TQM on OP is stronger, while low level of OAC mitigate effect of TQM on OP (slope = 0.1698, $p \leq 0.05$). This result shows that under high-level OAC, TQM has a greater impact on operating performance than low-level OAC. This finding play a supporting role for previous research, that is, knowledge heterogeneity helps to protect existing quality advantages, meanwhile helps to explore and develop new quality advantages (Choo et al., 2007).

Table 5 Results of slope analysis

Variables	*Coefficients*	
	Low OAC	*High OAC*
JIT		
Slope	0.0964	0.4416
SE	0.1043	0.1043
t-test	0.9237	4.2337**
TQM		
Slope	0.1698	0.4042
SE	0.0778	0.0778
t-test	2.1830*	5.1957**
HRM		
Slope	0.2469	0.5031
SE	0.0837	0.0623
t-test	2.9501**	8.0784**

Notes: *Significant at 0.05 level. **Significant at 0.05 level.

Figure 4 JIT and OP in low/high OAC



Similarly, HRM is more strongly associated with OP when OAC is high (slope = 0.5031), while low level of OAC mitigate effect of HRM on OP (slope = 0.2469), as shown in Figure 6. The results show that HRM has a stronger impact on OP under a high level of OAC than a low level of OAC. This finding supports previous researches which indicated that individuals can reduce errors or increase efficiency and reduce redundancy, by effectively applying knowledge.

In summary, the first goal of this research is to empirically validate the effect of LBs (JIT, TPM, TQM, HRM) on OP. Analysis results support these hypotheses. The second goal of this research is to explore the moderating role of OAC. And three out of four hypotheses are support. While not all of results are significant, the finding could be helpful to broaden the application of the contingency theory in the lean production research.

Figure 5 TQM and OP in low/high OAC

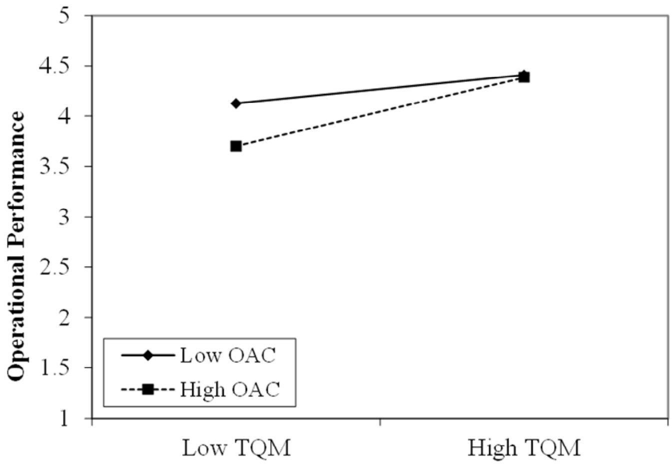
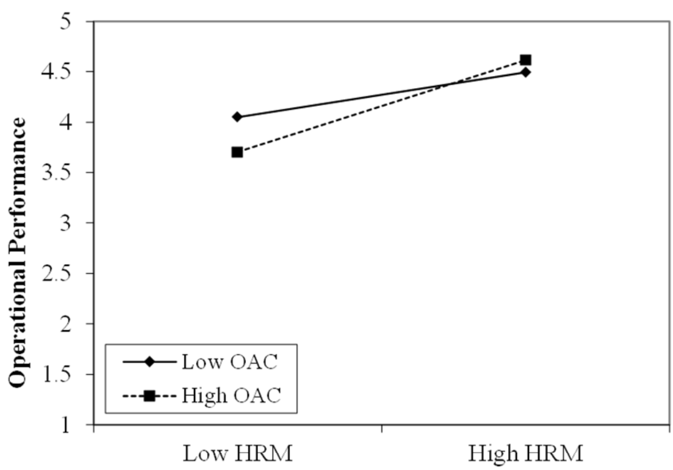


Figure 6 HRM and OP in low/high



5 Discussion and conclusions

Our research aims to validate the moderating role of OAC on the application effect of LBs. In this research, control variables such as company size and industry type that these factors may affect the application of production practices (Kadipasaoglu et al., 1999; Chavez et al., 2013), were taken into consideration to ensure the accuracy of the relationship analysed. Then the positive impact of JIT, TPM, TQM, HRM in improving OP are confirmed. Furthermore, the positive moderating effect of OAC on the relationship between LBs (JIT, TQM, HRM) and OP are confirmed using ordinary least square analysis.

5.1 Discussion of results

The empirical results that support H1a to H1d mean that implementing LBs can improve firm's OP. Considering that some researchers argued that some LBs (such as TPM) may have a lesser, even negative, effect on OP (Belekoukias et al., 2014), the research results deepen the understanding of existing literature that have a controversial description on the relationship between OP and LP (Jayaram et al., 2008; Liu et al., 2020). The results also provide extra evidence to support the majority of studies on LBs and its application effect (Shah and Ward, 2003).

More importantly, this study explored the mechanism of LBs on OP under the moderating effect of OAC.

First, empirical results that support H2a mean that the role of the OCA have a moderating effect on the relationship between JIT and OP. JIT is a technical tool of lean production (Furlan et al., 2011b). From a practical perspective, knowledge and management tools are critical antecedents of JIT bundles. Practices such as quick changeover techniques, Kanban, and pull systems require a wealth of lean knowledge and employees who have such knowledge to implement lean activities within the firm (Chavez et al., 2013). Hence, deploying resources to integrate these practical activities effectively becomes key factors in the application of JIT.

Second, H2b is not supported, which means that the moderating effect of OCA on the relationships between TPM and OP is not significant. One possible explanation is that TPM bundles are considered to be a team-based practice (Méndez and Rodriguez, 2017). TPM bundles are closely related to other technology-oriented practices, for example, the application of TMP is based on the application of TQM (Modgil and Sharma, 2016; Jostes and Helms, 1994). Therefore, the acquisition and transformation of TPM knowledge needs to be based on technology-oriented practices to a certain extent, which may lead to an non-significant moderating effect.

Third, the empirical results that support H2c mean that the moderating effect of OCA on the relationship between TQM and OP is validated. The results indicate that the application of TQM is the process of acquisition, assimilation, and transformation of knowledge, thereby answering the call for further research on quality management from a knowledge management perspective (Linderman et al., 2006). Therefore, this research complements the previous research and expands the understanding of the impact of OAC on TQM.

Finally, the empirical results that support H2d mean that the moderating effect of OCA on the relationship between HRM and OP is validated. An enterprise with the ability to absorb and utilise knowledge can give full play to human management activities and improve organisational performance effectively. Moreover, it shows that HRM, as a lean tool, can be implemented with the help of knowledge management activities

5.2 Theoretical implications

This research makes three theoretical contributions for the existing lean practices research. First, it is helpful to further reveal the relationship between LBs and organisational performance. Research findings also reinforce the viewpoint made by Shah and Ward (2003) that LBs have a positive effect on OP.

Second, this research introduced OCA into the lean literature with analysing the relationship between the LBs and OCA. The results show that the OCA is related to application of LBs. This means high OCA can enhance the effectiveness of lean implementation. Furthermore, OAC is broadly concerned with the ability to adapt to dynamically changing external environments (Martinez-Sanchez and Lahoz-Leo, 2018), which is consistent with the goal of implementing LBs to enhance market response capabilities.

Third, it contributes to explain the mechanism of LBs on OP under the perspective of contingency theory. Previous studies usually focus on the external environmental moderators. Chavez et al. (2015), for example, validated the moderating effect of technological turbulence. In contrast, this research examine the moderating effect of OAC from internal of the firm. Moreover, the results support previous studies that emphasised the importance of OAC to operations management.

5.3 Practical implications

This research also proposes several practical implications. First, research results suggest that managers should invest time and resources in implementing LBs. The goal of lean transformation is to achieve high performance, and the role of LBs in improving manufacturing efficiency and OP has been validated. JIT bundles would make problems visible, which helps to reduce waste and inefficiency. The application of TQM and TPM would improve product quality. HRM would affect the motivation and satisfaction of employee, therefore, leading to competitive advantage.

Furthermore, the findings suggest that OAC contributes to the relationship between LBs and OP. OAC enables organisations to acquire and keep adaptable to environment changes, and enhance the effectiveness of JIT, TQM, and HRM activities. Hence, this research suggest that firms are developing lean programs should make investments in the activities that could help them to manage lean related knowledge, simultaneously. Employees should also engage in communication with other teams or firms to acquire and exploit knowledge.

5.4 Limitations and future research directions

Although this research analysis the moderating effect of OAC, but a multi-dimension OAC would be better for exploring the relationship among lean production, OP and OAC. Potential and realised absorptive capacity are sub-dimensions of OCA, which are used to create and utilise operational knowledge, respectively (Setia and Patel, 2013). Researchers could investigate the moderating effect of different dimensions of OAC in future research. Furthermore, this research validates the moderating effect of OAC, but there may other contextual factors that may have a moderating effect. Researchers could identify and explore whether other contextual factors also act as a moderating variable on the application effect of lean production.

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Appendix

Latent variables	*Observed variables*
JIT	Cycle time reductions
	Quick changeover techniques
	Pull system
	Re-engineered production processes
	Lot size reductions
TPM	Preventive maintenance
	Maintenance optimization
	New process equipment or technologies
	Safety improvement programs
	Planning and scheduling
TQM	Measurement of process capability
	Continuous improvement program
	Supplier quality involvement
HRM	Training employees to perform multiple tasks
	Self-directed work teams
	Encourage employees to work together
	Suggestions schemes
OP	Higher product quality
	Shorter delivery time
	Ability to adjust capacity rapidly
	Production cost
	Reducing inventory
OAC	Workers are engaged in cross-functional task
	Analysing and interpreting the operation demands of market
	Discussing results of new products, process or logistics, and distribution development
	Keeping think about how to make better use of operational knowledge