Statistical Process Control: How Level Three Leadership affects its effectiveness

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Abstract

This study focuses on the analysis of level three leadership model proposed by Clawson, analyzing how leadership practices influence the relationship between statistical process control and competitive manufacturing performance. Ordinary least squares multiple regressions were performed using data from the international High-Performance Manufacturing project, including international plants in three industries. The findings show that just visible behavior leadership practices negatively moderate the relationship between statistical process control and competitive manufacturing performance, as it leads to create hostile work environment. Additionally, unconscious thought leadership practices seem to have a direct effect over CMP, promoting a favorable leaders' exchange relationship with their subordinates.

Keywords: Process control, Leadership Practices, Competitive Manufacturing Performance.

Introduction

The relationship between Quality Management (QM) practices and competitive manufacturing performance (CMP) has been largely addressed in the field of Operation Management (OP) (Merino-Díaz De Cerio, 2003; Kaynak, 2003; Parvadavardini et al., 2016). In spite of some exceptions, studies indicate that QM practices have a positive and significant impact on quality performance (Ebrahimi & Sadeghi, 2013). However, it has been stated that many organisations fail to achieve QM success, as a result of problems in the organisational implementation of these practices (Fotopoulos et al., 2010).

Some researchers propose to re-examine the link between QM practices and QM performance, paying more attention to internal and external contingency factors, or

even considering the role of moderating factors that influence each specific relationship between various QM practices and CMP (Dubey & Gunasekaran, 2015). In this line, several studies have analyzed the effect of different factors as moderators in this relationship, such as high commitment human resource strategy (Bou & Beltrán, 2005); organizational culture (Kanapathy et al., 2017); knowledge management (Yusr et al., 2017) and shop-floor contact and supervisory interaction facilitation (Bello-Pintado et al. 2018); however, no papers have analyzed the role of practices that leaders can use in this relationship.

The founders of QM movement (Deming, 1982), QM theoreticians (Dean and Bowen, 1994) and empirical QM studies (Sousa & Voss, 2002) have stressed the importance of leadership to QM, but leadership has not been fully explored in the QM research to date. Deming and other quality practitioners considered visionary leadership to be an essential requirement for an effective QM program (Anderson et al., 1994; Curkovic et al., 2000). Many QM researchers have identified leadership as a critical factor for the successful implementation of QM (Ahire, 1996; Saraph et al., 1989). But, there are no rigorous examinations of what type of leadership is the most appropriate for QM. In the QM research literature, top management support/commitment construct has been used to measure management's support of QM initiatives and programs, but it differs from the different styles and leadership practices (LPs) that can be found in the management literature. As state Laohavichien et al. (2011), the role of leadership in QM has not been fully explored to date.

This paper aims to cover this existing gap in the literature by analyzing the moderating role of LPs defined by Clawson (2009), indicating how leaders have to behave, in the relationship between "statistical process control" (SPC), practice in the core of QM (Kaynak, 2003), and CMP. Therefore, our research question can be formulated as: What role do LPs play in the contribution of SPC practices to enhance CMP?

The paper is organised as follows. The following section develops theoretical reasoning through an overview of the related literature and proposes three research hypotheses. The empirical part of the paper includes a description of the survey instrument and data collection methods, the statistical treatment of the measures and finally, three regression models to test our hypotheses. Section 4 includes the estimation results, and the discussion. Finally conclusions and implications are drawn from the research findings, and some limitations are pointed out.

Theoretical Framework

Quality Process Control and Competitive Manufacturing Performance

SPC is in the core of QM (Kaynak, 2003). These include the use of Statistical Process Control practices and other ways to control the production processes, such as the designing of 'full-proof' processes. SPC is, by far, one of the most popular organizational interventions in the field of QM (Lascelles & Dale, 1988; Modarress & Ansari, 1989). The fact that SPC implementation improves quality performance is a common conviction among quality practitioners. According to Rungtusanatham (2001), SPC implementation can have a positive impact on product quality through improved process quality. By monitoring, controlling and minimizing the variation that affects the transformation process, the SPC practices makes the transformation process more capable, stable and reliable (Anderson et al., 1994). Moreover, SPC

reassigns responsibility and control of the transformation process away from specialists towards process operators who can, therefore, respond faster in detecting, correcting and preventing causes of variation.

This better-quality process leads to a higher quality product, understood as conformance to requirements (Crosby, 1979). From this view, a highly conforming product has measurable dimensions whose numerical values approximate their target nominal values (low variance), requiring, in turn, that the manufacturing process be statistically stable and capable (Deming, 1982; Zeng et al., 2015). Normally, managers and engineers have emphasized the benefits that SPC interventions provide to the technical side of the production process (i.e., better quality or operational performance), but it is interesting to highlight the impact of these practices on STS aspects—creating more enriched jobs for process operators and enhancing work motivation and job satisfaction (Rungtusanatham, 2001).

In spite of the positive relationship between the adoption of QM practices and manufacturing CP documented in the operations management (OM) literature (Laohavichien et al., 2011; Zeng et al., 2015; Lim et al., 2017), failures in QM practices generally indicate a lack of knowledge on which factors are determinants for their successful implementation. In this sense, some researchers emphasizes the need to analyze the association between QM practices and competitive performance, paying special attention to internal and external contingency factors, in particular, soft practices such as leadership (Dubey & Gunasekaran, 2015). So, we hypothesize:
H_1: SPC positively influence CMP.

Leadership practices

For years, there is an ongoing debate about the effects of leadership over competitive performance (Avolio & Yammarino, 2013). Multiple leadership theories has been developed, always under the assumption leadership skills cannot be acquired. Some of them focus mostly on exploring the environment where leadership is developed, such as contingency theory (Fiedler, 1978), which emphasizes the importance of both the leader's personality and the situation in which that leader operates, outlining two styles of leadership: task-motivated and relationship-motivated (fiedler leadership model). However, others focus on analyzing the exchange relationship (psychological approach), such as trait-leadership theory and relational theory.

Trait-leadership theory (Kirkpatick, & Locke, 1991) focuses primarily on finding a group of heritable attributes that differentiate leaders from non-leaders. Through much research conducted in the last three decades of the 20th century, a set of core traits of successful leaders have been identified (Brandt & Edinger, 2015). On the other hand, relational theory (Graen & Uhl-Bien, 1995) (leader-member exchange model (LMX)) suggests that leaders develop an exchange with their subordinates, and that the quality of these leader–member exchange relationships influences subordinates' responsibility, decisions, and access to resources and performance. Relationships are based on trust and respect and are often emotional relationships that extend beyond the scope of employment (Bauer et al., 2015), which lead to promoting positive employment experiences and organizational effectiveness.

On the other hand, special attention has been paid to transactional and transformational theory (Burns, 1978). Transactional leaders are those who focus on supervision, organization and performance, promoting compliance by followers though rewards or punishments. In contrast, transformational leaders are those who stimulate and inspire followers to both achieve extraordinary outcomes and, in the process, develop their own leadership capacity. They exhibit charisma and shared

vision with their followers, stimulating others to produce exceptional work, besides they promotes motivation by responding to individual followers' needs as well as aligning the objectives and goals of the individual followers, the leader and the group (full-range of leadership model) (Bass & Avolio, 1995).

In recent years, attention has gone from the supposition that leaders are born to the point that anyone can be a leader by teaching her the most appropriate behavioral response for any given situation. Behavioral theory of leadership examines leaders' behavior, that is, it looks at what leaders actually do and how leaders must act (Conger & Kanungo, 1987). In the sense, there is an emerging leadership model developed by Clawson (2009), which does not focus on identifying effective leadership, but on how leaders have to behave (knowhow). In doing so, he facilitates different practices that help to develop leadership presence; such practices are allocated in the following three levels or dimensions, depending on how they affect human behavior. These levels or dimensions are:

a) *Visible behavior*: It refers to what people say and do. Practices used in this level (clear commands, yelling, coercion or threats) lead to an entire obedience from followers to leader, which can generate negative responses such as anger, resentment, passive aggression or possible sabotage.

b) *Conscious thought*: It represents what people want to show to others. Clawson establishes practices such as data, evidence, careful listening, debate and analysis to catch this behavior catch what people are really thinking.

c) *Unconscious thought*: It refers to values, assumptions, beliefs and expectations that control our judgments about what we view to be right or wrong, and it therefore influence the way the world is or should be seen. Practices such as candor, clarifying vision and self-disclosing help to obtain a commitment and the trust of others.

Most of the preceding leadership theories, except Clawson's framework, have been subject to discussions in different contexts such as the impact of transformational leadership over organizational innovation and creativity (Rahim et al., 2016), even over teamwork (Bai et al., 2016) or how different particular types of leadership affect task and relational conflicts and market orientation (Calisir et al., 2016).

The relationship of LPs with SPC and CMP.

A field, which has paid attention to leadership, is QM, since leadership is viewed as a key factor for the success of any quality improvement programme (Jamali et al., 2010). Leadership is also considered critical to the success of QM practices (Kumar et al., 2014); however, few studies address this relationship in detail (Laosirihongthong et al., 2013) and, the type of leadership always refers to top management support and commitment in order to implement QM practices.

The first dimension encompasses a set of LPs that, taken as a bundle, can generate a hostile and closed work environment. Their high use may hinder the necessary involvement and fluid communication required by the implementation of quality practices, such as process control. The literature leads to the assumption that implementation of employee involvement (as one of the infrastructure QM practices) might be crucial for the implementation of process approach, (Bakotic & Rogosic, 2017). Furthermore, as indicated by Tepper (2007) , this behavior fosters the lack of communication between subordinates and supervisors and, even among workers themselves; since subordinates who are mistreated by their supervisors, avoid interacting with them; in addition to being unwilling to speak out (e.g. reporting about problems, ideas sharing, improvements and so on). Consequently, all of them, it negatively affects process control implementation and competitive manufacturing

performance, as process control requires effective employee involvement and communication to be implemented appropriately.

Normally managers and engineers emphasize the benefits that SPC interventions provide to the technical side of the production process (better quality or operational performance). Empirically the positive relationship between SPC practices and manufacturing performance has been supported (Baird et al., 2011). Nevertheless, it is interesting to highlight the impact of these practices on socio-technical aspects, creating more enriched jobs for process operators, enhancing work motivation and job satisfaction (Rungtusanatham, 2001). In addition, the relationship between SPC practices and CMP may differ depending on the intensity of the application of LPs that make up "visible behavior". In those plants in which this type of LPs are applied with greater intensity, it is expected that this relationship will be weaker than in the rest, due to the effects on the involvement of workers and the communication between them and their supervisors mentioned above. Thus, we state the following hypothesis:

H_2: The use of "visible behavior" LPs negatively moderates the relationship between SPC implementation and CMP.

Concerning the second leadership dimension, Clawson (2009) establishes that practices such as data, evidence, careful listening, debate and analysis help to know what people think and want to show, as they are source of communication. As Robbins et al. (2010) claimed, the main factor in a communication process is feedback, since it helps to test if the message has been undertaken successfully. Some theories, such as control theory (Wiener, 1948) and goal-setting theory (DeNisi & Kluger, 2000) emphasize the importance of adequate feedback to apply practices, as it allows to identify problems, share information, transfer knowledge and control processes and, turn, improve the outcome at work.

On the other hand, leaders who listen attentively to their subordinates are able to identify and know more quickly what employees need to better develop their work (Mahsud et al, 2009). This leads to greater effectiveness in the use of certain practices. In addition, all these leadership practices can help generate a climate of trust with employees helping avoid skepticism and uncertainty in the application of QM practices by promoting a common dialogue about quality within the organisation (Bou & Beltran, 2005).

In manufacturing plants where leaders are able to create this culture of communication, based on data and evidence, it is more likely that SPC practices, which have in the statistical treatment of the data about process performance their core, (Kaynak, 2003), are used more efficiently because the operators imbued in that culture believe more in the importance of providing feedback to improve CMP.

From the discussion above, "conscious thought" could interact with process control and influence in the magnitude of his impact on performance. Thus, we hypothesize:

H_3: The use of "conscious though" LPs positively moderates the relationship between SPC implementation and CMP.

Finally, in the third leadership dimension, Clawson (2009) claimed that candor, clarifying vision and self-disclosing help leaders lead to their followers. Scholars agree that the quality of leaders' exchange relationship with subordinates has important implication for leadership effectiveness; in fact, a favourable exchange relationship leads to higher subordinates satisfaction, better job performance, greater employee commitment and lower turnover (Dhar, 2016). In this regards, Mahsud et al. (2009) points out that a favourable exchange relationship is more likely when subordinates' values, belief and attitudes are similar to those of the leader.

It is reasonable to think that this identification of employees with their leaders in the plant promotes the exchange and creates a climate of greater confidence that helps the development of certain quality improvement practices such SPC to achieve better results. Take in account the preceding ideas, we propose the following hypothesis:
H_4: The use of "conscious though" LPs positively moderates the relationship between SPC implementation and MC.

Empirical Strategy

Data collection, sample, measures and method

To test our hypotheses, the fourth round of the international HPM project was used. Our simple consists of 173 plants from 11 countries (Spain, Italy, China, Germany, South Korea, Brazil, Finland, Austria, Taiwan and the United Kingdom), which operate in automative, machinery and electronics industries. The items are based on one-to-five Likert scales ranging from 1 "strongly disagree" to 5 "strongly agree".

The scale used to SPC variable suggests that they should be treated as reflective indicators (MacKenzie, 2005), so explanatory factor analysis and confirmatory factor analysis were performed to prove the constructs' reliability and to verify the validity and unidimensionality of the measures for latent constructs (Cronbach's > 0.6) (Nunnally, 1978). To verify discriminant validity, the root square of the average variance extracted shared between the constructs and its measures and the correlation with the rest of constructs are compared and, the measurement model for each construct has a good global, parsimonious and incremental fit. However, LPs and CMP variables should be treated as formative indicators (MacCallum & Browne, 1993), so discriminant validity is assessed by testing the absence of collinearity among the items that make up the construct (Podsakoff et al., 2006) (see table I).

Finally, three control variables (size, industry and country) were included. The size of the plant was measured by the logarithm of the number of workers and, the industry variables in combination with country are represented by dummy variables.

Table I
Validity and reliability of factors

	Eigen v.	**α Cronbach**
Quality Process Control (reflective indicators)	**3.566**	**0.8973**
Processes in our plant are designed to be "foolproof"	0.769	
A large percent of the processes on the shop floor are under statistical quality control.	0.883	
We make extensive use of statistical techniques to reduce variance in processes.	0.883	
We use charts to determine whether our manufacturing processes are in control.	0.823	
We monitor our processes using statistical process control.	0.859	
Leadership practices (formative indicators)	**Mean**	**VIF**
Visible behavior	**2.684**	
	4.008	1.003
	2.277	2.110
	2.125	3.400
	2.265	3.063
Conscious thought	**3.773**	
Data	4.054	1.672
Evidence	3.840	1.684
Careful listening	3.687	1.276
Debate	3.429	1.314
Analysis	3.854	1.835
Unconscious thought	**3.426**	
Candor	3.832	1.248
Clarifying vision	3.597	1.273
Self-disclosing	2.791	1.023
Competitive manufacturing performance (formative indicators)	**3.715**	
Costs		

Unit cost of manufacturing	3.316	1.000
Quality		
Conformance to products specifications	3.916	1.000
Delivery	3.817	
On time delivery performance	3.871	1.617
Fast delivery	3.763	1.617
Flexibility	3.809	
Flexibility to change product mix	3.854	1.832
Flexibility to change volume	3.809	1.832

Ordinary least squares multiple regression (OLSMR) models were used to test the hypotheses. We first estimated a model with CMP as the dependent variable, and then, one model with moderating variables was developed. After that, we tested the moderating roles of each leadership dimension by three interaction models.

Findings

Table II offers an overview of the relationship between SPC and CMP, taking into account LPs as moderator. Model 1 shows the main effect of SPC over CMP. Model 2 integrates the main effects of moderating variables, which shows that only unconscious thought has a main effect over CMP. Model 3, 4 and 5 integrates the main effects of moderating variables and interaction effects of each dimension, confirming H1 and H2. These findings corroborate our premise that SPC positively influences CMP and, VB moderates this relationship negatively. In addition, UT seems to have a direct and positive effect over CMP.

Table II

MOLS regression models: Dependent Variable: Competitive Manufacturing Performance.

	Model 1	Model 2	Model 3	Model 4	Model 5
SPC	**0.1893** (0.056)**	**0.158** (0.057)**	**0.159** (0.055)**	**0.157** (0.058)**	**0.161** (0.058)**
Moderating variables					
VB		0.058 (0.061)	0.094 (0.062)	0.058 (0.605)	0.55 (0.060)
CT		0.032 (0.061)	0.0234 (0.066)	0.324 (0.065)	0.033 (0.065)
UC		**0.1392** (0.067)**	**0.158** (0.037)**	**0.141** (0.066)**	**0.134** (0.066)**
Moderating effects					
SPC x VB			**-0.109** (0.037)**		
SPC x CT				-0.008 (0.039)	
SPC x UT					0.018 (0.041)
_Cons	**4.519*** (0.328)**	**4.284*** (0.363)**	**4.324*** (0.563)**	**4.289*** (0.366)**	**4.285*** (0.366)**
R^2	0.265	0.3288	0.361	0.329	0.329
F	**3.80***	**4.5***	**6.07***	**4.23***	**4.23***

*p < 0.1, **p < 0.05, ***p < 0.001.

Note: Standard error between ( ). All estimations include the control variable described in the section 3. SPC: Statistical Process Control; VB: Visible behavior; CT: Conscious thought and UT: Unconscious thought.

Conclusions, limitations and future research

This study provides empirical evidence for the emerging discussion about the positive relationship between SPC and CMP. Additionally, it analyzes the

moderating effect of soft practices such as LPs, over SPC and CMP within manufacturing organizations. It found that one of leadership dimension proposed by Clawson (2009), in particular, VB moderates this relationship negatively. These LPs generate a hostile work environment, hindering employees' involvement and fluid communication needed in QMP adoption. Additionally, it is necessary to remark that the three dimension (UT) influences positively CMP, given that, it promotes the quality of leaders' exchange relationship, generating a friendly work environment between leaders and follower and among employees and, turn, increasing trust and commitment.

Our study has important implications for academics, since it sheds new insights to the current paucity of literature on LP aimed to "made" leadership in practice. It also offers empirical evidence for the emerging discussion on whether the lack of participation and involvement of all workers; in combination with the lack of managers' skills such as leadership are the main failure factors on SPC and, in turn their impact over CMP. Moreover, the empirical evidence in this study may be useful for both practitioners and employers seeking ways of improving business value and competitive position.

Our study is not free of limitations. It is a cross-sectional study, that includes plants from three industries where leadership practices may differ significantly, making comparison difficult. Our study focus on one of quality management, so future studies might analyze and compare these results to other practices in operations management.

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