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The impact of advanced analytics and data accuracy on operational performance: A contingent resource based theory (RBT) perspective

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ABSTRACT

This study is interested in the impact of two specific business analytic (BA) resources—accurate manufacturing data and advanced analytics—on a firms' operational performance. The use of advanced analytics, such as mathematical optimization techniques, and the importance of manufacturing data accuracy have long been recognized as potential organizational resources or assets for improving the quality of manufacturing planning and control and of a firms' overall operational performance. This research adopted a contingent resource based theory (RBT), suggesting the moderating and mediating role of fact-based SCM initiatives as complementary resources. This research proposition was tested using Global Manufacturing Research Group (GMRG) survey data and was analyzed using partial least squares/structured equation modeling. The research findings shed light on the critical role of fact-based SCM initiatives as complementary resources, which moderate the impact of data accuracy on manufacturing planning quality and mediate the impact of advanced analytics on operational performance. The implication is that the impact of business analytics for manufacturing is contingent on contexts, specifically, the use of fact-based SCM initiatives such as TQM, JIT, and statistical process control. Moreover, in order for manufacturers to take advantage of the use of data and analytics for better operational performance, complementary resources such as fact-based SCM initiatives must be combined with BA initiatives focusing on data quality and advanced analytics.

1. Introduction

There is growing interest in the use of data and advanced analytics for various types of business problems [18,62]. Business Analytics (BA) is an umbrella industry term referring to the application of a broad range of analytical techniques and methods and data-driven analytic methodologies to different business domains. The 2011 annual Gartner survey of IT executives shows that BA is #1 in CIOs' top ten priorities [60]. Anecdotal evidence and industry press suggest a strong positive relationship between the use of BA and organizational and financial performance [15,36]. There has long been interest in BA in manufacturing (and supply chain), where it is expected to make significant contributions [5,14]. Recent studies investigating the role and impact of BA for supply chain management indicate that the use of analytics is positively associated with firm performance [47,61].

This study is interested in the impact of two specific BA resources—accurate manufacturing data and advanced analytics—on manufacturers' operational performance. The use of advanced analytics, such as mathematical optimization techniques [56,58], and the importance of manufacturing data accuracy [19,35], have been recognized as potential organizational resources or assets for improving the quality of manufacturing planning and control (MPC) and a firms' overall operational performance.

This study takes a contingent resource based theory (RBT) perspective, suggesting that the impact of primary resources on firm performance is contingent upon complementary resources. What resources are primary is context dependent. In the IS literature, for example, ITs are treated as primary resources (e.g., [42]). In the BA contexts, data and analytics are discussed as two most important elements [14,18,47,57]. Thus, advanced analytics and accurate manufacturing data are considered two "primary" resources for the use of BA for manufacturing. Complementary resources are those that are expected to interact with and increase the value of the primary resources (c.f. [21]). Our study considers SCM initiatives or programs as complementary resources. By SCM initiatives, we consider such programs as JIT, TQM, and statistical process control, which are aiming for improving operational efficiency through analytical performance improvement techniques and methods. SCM initiatives are considered "complementary" since they are expected to be interacting with and further increasing the value of manufacturing data and analytics.

The primary research goal is to investigate the role of those complementary resources by testing the mediating and moderating effect of

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SCM initiatives in the impact of primary resources (advanced analytics and manufacturing data accuracy) on operational performance. The study uses the data of 533 samples from Global Manufacturing Research Group (GMRG) survey [67], and employs structured equation modeling (SEM)-partial least squares (PLS) to test the premises. In addition, we conduct a multi-group analysis using three subsample groups depending on firm sizes (small, medium, and large).

The study obtains several important findings. First, high data accuracy improves the perceived quality of manufacturing-related plans (e.g., material, inventory, shop floor), which is positively associated with operational performance. Second, the impact of data accuracy is moderated by the use of SCM initiatives. This implies that, while there is much discussion in the literature about the importance of data accuracy, its impact is contingent upon how extensively SCM initiatives, such as JIT, TQM, and statistical process control, are deployed. Third, the use of advanced analytics positively influences operational performance, but its impact is indirect and transmitted through those SCM initiatives. Fourth, a multi-group analysis indicates that there are no significant differences in path coefficients in the PLS model with different sub-sample groups depending on firm sizes.

The research questions and findings are important, since interest in using data and manufacturing analytics for organizational competitiveness, and the relevant investments, is growing among manufacturers. The research findings imply that, in order for manufacturers to take advantage of the use of data and manufacturing analytics for better operational performance, SCM initiatives must be considered an integral part of the firm's investment in BA initiatives.

2. Background

2.1. A contingent resource-based theory

The resource-based theory (RBT) states that organizational resources or assets vary across firms and they differentiate firms' performance and competitive advantage [2]. RBT has been one of the most prominent and powerful theories in the business literature [3]. In the literature, there are numerous examples of organizational resources, which include enterprise information systems, knowledge representations and processes, and organizational information [33,39,42]. Studies have tried to explain why some resources are effective in certain contexts, but not in others. For example, while IT has been recognized in the literature as an important resource, empirical results have been mixed regarding the impact of IT on firms' performance and competitive advantage [66]. In response, recent studies include contingent variables or complementary resources as necessary elements in their research model [1,6,31]. After reviewing IS research using RBT, Wade and Hulland [66] noted that "resources rarely act alone in creating or sustaining competitive advantage" (p. 123). This leads to paying attention to the role of other resources or complementary resources, which are linked to primary resources in creating sustainable business value. It is expected that there are synergies from primary and complementary resources [43]. For example, Kim et al. [39] considered information resources, analytical and operational capabilities, and human resources as organizational resources, and their study suggested integrating them as a critical factor for CRM success.

As to the role of complementary resources in this synergy-making process, some studies have proposed a moderating effect of complementary resources [66]. In this line, Luo et al. [42] considered IT infrastructure, enterprise information systems, and financial resources as firms' resources for improving organizational capabilities, including operational efficiency. The impact of IT assets (IT infrastructure and enterprise information systems) on organizational capabilities is moderated by financial resources: the positive impact of IT assets on organizational capabilities is stronger when firms possess greater financial assets. In addition, mediation has been suggested as another potential role of complementary resources [41]. For example, IT and organizational structure as resources positively affect new product performance. This process is translated through a mediator or a contingent variable, such as cross-functional integration [11]. Thus, an RBT-based research model could benefit from considering contingent variables as potential moderators and/or mediators.

2.2. A contingent RBT for analytics

By applying the concept of contingent RBT into studying the role of business analytics, this study focuses on the effects of data accuracy and advanced analytics. When a contingent RBT is applied in studying the role of business analytics for manufacturing, the focus is on the use of advanced analytics and manufacturing data accuracy. Business analytics is defined as "the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decision and actions" [15]. Thus, data accuracy and advanced analytics could be two primary resources. The value of quality data is well recognized in the literature [52]. "You can't be analytical without *data*, and you can't be really good at analytics without really good *data*" (emphasis added) [13]. There is much promise from using advanced analytics (e.g., mathematical optimization) for manufacturing firms [10,47,58]. This would result in a research model testing the direct impact of data accuracy and advanced analytics on manufacturers' operational performance. However, this approach may find it difficult to explain why some resources are more or less effective in certain situations.

Thus, our research model considers a set of complementary resources, which represent SCM initiatives, such as JIT, TQM, and statistical process control. These increasingly popular SCM programs are examples of fact-based management initiatives in manufacturing firms [37,38,45]. The premise of a contingent RBT for business analytics is that the role of such analytic resources as data accuracy and advanced analytics is contingent upon a set of complementary resources. It is expected that when accurate data and advanced analytics are complemented with fact-based SCM initiatives, the value of accurate data would be realized through improved manufacturing planning quality, and the use of advanced analytics can achieve the increase in operational efficiency.

3. Research model

Our research model examines the role of moderation and mediation in the impact of accurate manufacturing data and advanced analytics in operational efficiency. First, a moderator is defined as a variable that "affects the direction and/or strength of the relation between an independent or predictor variable and a dependent or criterion variable" [4]. The idea of moderating effect is related to the premise of contingency theory that the effect of X variable on Y variable can be stronger or weaker, depending on other factors, which are moderators. A moderator influences the strength of the impact of X on Y [32]. Thus, it addresses "when" the effect occurs [4].

For example, the impact of information content quality and information access quality on the use of information in business processes is contingent upon analytical decision-making culture, which is a moderator [51]. Similarly, the higher the IS support and business process orientations in an organization, the stronger the impact of analytics on organizational performance [61]. The effect of supply chain analytic IT on organizational performance is contingent upon environmental uncertainty [16].

In the literature, quality data are considered to be important organizational resources or assets [10,52], impacting organizational performance [24,27]. Poor data quality is costly, having consequences on decision making and operation [53]. In SCM contexts, data is the input to the MPC process. Thus, poor data, which is often characterized by lack of information management and of advanced planning IT, can have far-reaching negative impacts on manufacturing planning [28]. On the