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Improving performance of green innovation practices under uncertainty

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ABSTRACT

Environmental issues have received substantial attention in corporate green operations. Environmental practices have been well studied but only a few studies have presented the green innovation practices of corporate firms. This study proposes to evaluate green innovation practices with a particular focus on the managerial, process, product and technology innovation aspects. This analysis focuses on Taiwanese printed circuit board manufacturing firms. Such a study does exist and the performance of the focal firm's green innovation activities has been evaluated. This study identified the appropriate green innovation aspects and criteria for the case firms and, subsequently, developed the following hybrid method: (i) evaluate the weights of the aspects and criteria as described by linguistic preferences; and (ii) use an analytical network process with entropy weights to evaluate the proposed framework. This study presents the evidence of green innovation practices and has interesting implications for operations management research and practices. This knowledge contributes towards decision-making and implementation of green innovation practices.

1. Introduction

The European Union has established a variety of environmental policies, including RoHS (the restricted use of hazardous substances in electrical and electronic equipment) and WEEE (waste electronics and electrical equipment) directives. These directives ban manufacturers, sellers, distributors and recyclers of electrical and electronic equipment from launching new equipment containing hazardous materials onto the market (Tseng, 2009, 2010). While WEEE directives are aimed at the life cycle of the product, RoHS is targeted at the product design stage. Electronic original equipment manufacturing (OEM) firms, in particular, are considered to make a major contribution to environmental pollution (Tseng et al., 2008). It has been well recognized that electronic products contribute significantly to environmental pollution and this phenomenon has been increasing worldwide since the early 1990s. Hence, all corporate activities now relate to green innovation practices. Improvements in a firm's environmental performance and compliance with environmental regulations contribute to a firm's competitiveness. This innovation is a dynamic capability, i.e., a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness (Yam et al., 2004). However, the limited understanding of firms' green innovation practices have hampered the development of a widely accepted framework that would characterize and categorize firm's green innovation activities. Nevertheless, few studies can be found in the literatures that seek the drivers of firm's green innovations (Lin et al., 2011; Tseng, 2013). Firms must improve their green innovations in order to strengthen their competitiveness due to the situation of ever-changing green technology and the short life cycle of products. Unfortunately, green innovation practices involve high uncertainty and risk and many resources are consumed in the process. Hence, through this study, understanding green innovation is a feasible way for firms to acquire the necessary techniques and assistance.

In the literature, Sharma (2000) and Wu (2009) argued that different environmental strategies or practices are found to be associated with managerial interpretations, which can be seen either as threats or as opportunities for tackling various environmental issues. It is also argued that, today, management innovations may represent one of the most important and sustainable sources of competitive advantage for firms due to its context

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specific nature, among others (Eiadat et al., 2008). From this point of view, firms have been implementing proactive environmental strategies and practices by using management initiatives to mitigate the impact of their innovation activities on the environment (Melnyk et al., 2003; Tseng, 2010; Lin et al., 2011). Other studies have noticed the application of environmental friendly equipment and technologies (Klassen and Whybark, 1999), and the investment in environmental protection measures in focal electronic manufacturing firms (Klassen and Vachon, 2003; Buysse and Verbeke, 2003). Moreover, well-designed environmental standards can increase a manufacturer's incentive to introduce green products and technologies, and differentiating their products and lowering the cost of production through product and process innovations are necessary. Therefore, green innovation can be classified into four main categories: managerial innovation; product innovation; process innovation; and technological innovation (Tseng et al., 2009a; Yung et al., 2011). Chen et al. (2006a, b) presented that green products and manufacturing process innovations are positively associated with a firm's competitive advantage. Chen (2008) introduced the concept of green core competencies as collective learning, and the capabilities of green innovations and environmental management have a positive influence on a firm's ability to develop green product and process innovations. Chiou et al. (2011) presented an empirical evidence to encourage firms to implement a green supply chain and green innovations in order to improve their environmental performance and to enhance their competitive advantage in the market. These studies presented green innovations specifically for environmental performance as drivers of the manufacturing firms and the supply chain.

Aforementioned, this evaluation requires identification of appropriate measures in order to complete a robust study and to advance the body of knowledge in the field, both academically and practically. Academically, greater attention needs to be focused on employing multi-criteria, assessing the criteria for content validity and purifying them through extensive literature reviews in order to effectively and empirically advance theory within this field (Malhotra and Grover, 1998; Lee et al., 2009). This study contributes to this aspect as it attempts to integrate a number of criteria from various literatures on innovation and environmental management (Lin et al., 2011; Tseng, 2013). Practically, firms can benefit from the development of reliable and valid aspects and criteria taken from the practices of case firms. The practitioner can apply these criteria for benchmarking and continuous improvement when seeking to harmonize environmental and innovation goals. The top managers may be aware of multiple aspects and criteria for forging green innovation but with different priorities in mind, thus positioning the weighting on aspects and criteria for evaluating the suitability. In contrast, the method of weighting aspects and criteria also reveals the priorities for the distribution of resources. This implies that the priority of the aspects and criteria and the relative weights set will interact with each other. In addition, this study can guide firms in green innovation practices and find practical applications for the multi-criteria decision making (MCDM) whilst considering expert opinion regarding environmental concerns.

In the real world, MCDM often deals with subjective human preferences. People express thoughts and perceptions using natural language, which can often be vague or difficult to state mathematically. Since linguistic variables are not directly mathematically analyzable, to cope with this difficulty, each linguistic variable is associated with a fuzzy number that characterizes the meaning of each generic verbal term (Zhang et al., 2005). In existing literatures, linguistic variables are converted to triangular fuzzy numbers (TFNs) in the decision making process (Tseng et al., 2009a, b). The meaning of a word might be well defined and determining the boundaries with which objects do or do not belong becomes uncertain when using the word as a label for a set (Tseng, 2009). Hence, the proposed method uses entropy weights to appropriately express human judgment in proposed criteria. However, the traditional statistical approach is no longer suitable for evaluating the proposed dependence relations of green innovation. A typical study to understand the hierarchical dependence relations and framework is through the use of the analytical network process (ANP) and it provides a more generalized model in decision-making without making assumptions about the independence of the higher-level aspects from lower-level criteria (Tseng et al., 2008). ANP has been successfully applied in solving a variety of MCDM problems and the entropy weight for this evaluation will avoid the subjectivity and overcome the error influences of extreme conditions in the real application. This study summarizes the principles of the theories and its modeling schemes in prediction and diagnosis, and reviews its practical application combined with linguistic preferences (Tseng, 2013; Lin et al., 2011). This study developed a hybrid approach to determine and integrate green innovation aspects and criteria.

Hence, this study evaluates the ability of different aspects and criteria that will enable focal electronic manufacturing firms to adopt green innovation practices. This leads to the following study question of how to determine the key criteria of green innovation practices. In order to identify the aspects and criteria, it is necessary to understand the effects of green innovation in previous years with regard to management, process, product and technology innovation aspects on the adoption of green innovation practices. Accordingly, this study is designed to explore how the criteria are related to a firm's decisions when adopting various practices and showing which criteria will affect firms' green innovation. The next section provides a literature review and introduces green innovations used by various firms. The methodology used to develop and validate the aspects, and the criteria which satisfied content validity, is presented in Section 3. Section 4 gives the results of this study, followed by a discussion and implications of these results in Section 5. Section 6 concludes with a summary of the findings, implications, limitations, and potential topics for future research.

2. Literature review

This section introduces the green innovations employed towards minimizing environmental impacts. Indeed, innovation is one of the key forces used to increase corporate competitive advantage. The firms have increasingly needed to consider the product life cycle assessment in order to enhance product and design process decisions and initiate a qualitative survey of the information available in the electronics industry on how green product and process innovations have affected their corporate competitive advantage (Noci and Verganti, 1999; Tseng et al., 2009b; Yung et al., 2011).

2.1. Green innovation

Green innovations are categorized into technology, management functions, product design and production process aspects. Green innovations during the product's life cycle assessment include the process of modifying an existing product design in order to reduce the negative impact on the environment (Klassen and Whybark, 1999). Zhu and Sarkis (2004) found that getting a commitment from top or middle level managers has a significant influence on the implementation of successful internal environmental management. Defining green product innovation, green process innovation and green managerial innovation is important to the Chinese manufacturing industry. Fergusson and Langford