The effects of pollution prevention on performance

Introduction

A key question asked by researchers and practitioners over the past two decades regards the performance implications of investments in environmental management (Rao and Holt, 2005; Dam and Petkova, 2014). While arguments for a positive relationship between environmental practices and performance have been supported empirically by a number of studies (Rao and Holt, 2005; Vachon and Klassen, 2008; Zhu et al., 2012; De Burgos-Jiminez et al., 2014; Graham and Potter, 2015), others have identified negative or non-significant relationships suggesting that a firm conclusion cannot yet be reached (Wagner et al., 2002; Thornton et al., 2003; Srivastava, 2007; Iwata and Okada, 2011). In light of these seemingly conflicting results, recent studies have begun to highlight the complexity of the relationship between environmental practices and performance, suggesting a need to consider other factors that may influence this relationship (Lopez-Gamero et al 2009; De Burgos-Jiminez et al., 2014).

A wide range of environmental practices have been examined in seeking to identify potential links with performance (Vachon and Klassen 2008). These practices can be implemented at the internal operations level or the broader supply chain level of an organisation. At the internal operations level, environmental practices emanating from a pollution prevention strategy have received substantial research attention as a number of studies have sought to assess links with performance (Hart and Dowell, 2011; Schoenherr, 2012). Pollution prevention seeks to reduce negative environmental impacts generated throughout the production process (Schoenherr, 2012). At the broader supply chain level, research has considered the effect of environmental practices implemented at different stages of the supply chain on dimensions of performance (Zhu et al., 2012; Paulraj et al., 2014). A number of studies have generated support for a link between environmental practices at both internal operations and supply chain levels and various dimensions of performance (Rao and Holt, 2005; Schoenherr, 2012; Zhu et al., 2012). Breaking these performance dimensions down, the link between environmental practices and environmental performance has received substantial empirical support (Rao and Holt, 2005; Vachon and Klassen, 2008; Green et al., 2012; Zhu et al., 2012; Graham and Potter, 2015), while results in relation to other dimensions of performance such as cost, quality and flexibility have been mixed (Srivastava, 2007; Iwata and Okada, 2011). In seeking to understand the relationship between environmental practices and performance, it is important for studies to explore a range of factors that could potentially support or facilitate their effective implementation (Hart and Dowell, 2011). As pollution prevention practices are the most commonly adopted in industry (Schoenherr, 2012; Thoumy and Vachon, 2012), exploration of factors that might facilitate their implementation and enhance performance outcomes is an important starting point (Hart and Dowell, 2011).

The dynamic capabilities perspective has the potential to contribute to research efforts to further understand the relationship between environmental practices and performance. Environmental strategies may be perceived as dynamic capabilities that require support from internal structures and systems to ensure effective implementation (Aragon-Correa et al., 2003; Hart and Dowell, 2011). The natural resource-based view (NRBV) outlines pollution prevention as a key starting point in the pursuit of performance improvements through environmental practices (Hart, 1995). Building upon the existing support for a link between pollution prevention and environmental performance (Schoenherr, 2012; Wong et al., 2012), it is useful to consider other factors that might further enhance this link through the lens of the dynamic capabilities perspective (Hart and Dowell, 2011). Some studies have considered the role of internal factors such as top management support (Daily et al., 2012), training (Sarkis et al., 2010) and change management (Ronnenberg et al., 2011), in implementing environmental practices. Findings suggest that these factors may facilitate the implementation of new practices, enabling them to generate further improvements in performance. Integration, learning, and configuration have been highlighted as key supporting processes for dynamic capabilities (Ambrosini and Bowman, 2009). Taking the view that a pollution prevention strategy has the characteristics of a dynamic capability (Hart and Dowell, 2011), it is of interest to consider the role of these processes in supporting its implementation.

A link between environmental practices and other dimensions of performance is not as well established as the link with environmental performance. While some studies provide support for a direct link with dimensions of performance such as cost, quality and flexibility (Montabon et al., 2007), conflicting and non-significant results have also been noted (Wagner et al., 2002; Srivastava, 2007). This has led to suggestion that improvements in other dimensions of performance may derive from improvements in environmental performance rather than directly from environmental practices (Green et al., 2012; De Burgos-Jiminez et al., 2014). Thus, improvements in environmental performance may have a positive impact on other dimensions of performance, albeit indirectly. Given the ambiguity in results relating to these links, it is of interest to consider a potential indirect relationship between pollution prevention and performance.

In light of these issues, this study responds to the call from Hart and Dowell (2011) to assess links with performance using an approach that integrates the ideas of the Natural Resource-Based view (NRBV) with the dynamic capabilities perspective. To facilitate this, a theoretical model, grounded within both perspectives is developed and tested using data collected from the UK food industry. The two key research questions underpinning this model are; (1) do internal support processes facilitate the implementation of a pollution prevention strategy leading to greater improvements in environmental performance? and; (2) is the relationship between a pollution prevention strategy and cost performance mediated by environmental performance?

This study generates a number of contributions to the operations management literature. Firstly, it sheds further light on the important debate surrounding the benefits of environmental practices. Secondly, it adopts a novel perspective in considering pollution prevention as a dynamic capability being supported by internal processes. Thirdly, it is one of the first studies to consider a mediated relationship between pollution prevention and cost performance. Further, it addresses these issues within the UK food industry which provides a context facing somewhat unique environmental challenges that need to be addressed (Maloni and Brown, 2006; Pullman et al., 2009). The following section discusses the theoretical background of the study.

Theoretical Background

The Resource-Based View (RBV) of the firm considers the ability of firms to effectively utilise their internal resources and capabilities to generate a sustainable competitive advantage (Barney, 1991; Christmann, 2000). Extensions of the RBV such as the Natural Resource-Based View (NRBV) and the dynamic capabilities perspective have highlighted factors that might facilitate the link between resources and competitive advantage. These two extensions are of particular interest for this paper as they provide a theoretical lens to understand the potential impact of internal supporting processes on environmental performance improvements derived from pollution prevention.

The Natural Resource-Based View (NRBV)

The NRBV extends the RBV by highlighting the natural environment as a fundamental aspect in the pursuit of competitive advantage. It outlines three interrelated environmental strategies, namely, pollution prevention, product stewardship and sustainable development. Pollution prevention is a process-based approach that focuses on the elimination of unnecessary pollution within internal operations (Christmann, 2000; Hoque and Clarke, 2013). This approach is often viewed as a starting point in proactive environmental management, as in order to progress to the latter two environmental strategies, it is essential for a firm to have obtained the resources required to implement a pollution prevention strategy and to follow the path dependent progression to the next approach (Hart, 1995; Christmann, 2000).

At the next level, product stewardship is an externally-oriented environmental strategy, involving the development of environmental practices beyond the scope of the firm's internal boundaries (Hsu et al., 2013). This strategy seeks to address environmental concerns at different stages of the production process from sourcing to disposal at the end of the product's life cycle (Hart, 1995). The final environmental strategy, sustainable development, takes a step beyond the other strategies in calling for the involvement of stakeholder groups from competitors to governments, in dealing with environmental concerns (Michalisin and Stinchfield, 2010). Sustainable development has since been broken into two sub-dimensions, namely, clean technology and base of the pyramid strategies, to reflect its development as a concept since the NRBVs introduction (Hart and Dowell, 2011).

Environmental strategies are the higher-order guidelines and principles that direct a company's practical response to environmental pressures and challenges. They can be implemented through a wide range of environmental practices that target the key areas of focus outlined in the environmental strategy (Hart, 1995). For example, companies seeking to implement a pollution prevention strategy will express this through practices that target key areas of pollution within their internal operations (Hart and Dowell, 2011). The link between environmental strategies and competitive advantage is a key area of focus within the NRBV (Hart, 1995; Hart and Dowell, 2011). This link has been explored by a number of studies, generating mixed results (Christmann, 2000; Ronnenberg et al., 2011). The complexity of this link is being recognised with studies now seeking to identify factors that might influence the performance outcomes from environmental practices. Factors such as complementary assets

(Christmann, 2000), top management support (Daily et al., 2012) and change management practices (Ronnenberg et al., 2011), have been found to exert a positive influence on the performance outcomes from environmental practices. This suggests that the link between environmental practices and performance is not always straightforward and direct, but may be mediated or moderated by other factors. Acknowledging this possibility, Hart and Dowell (2011) highlight the need for future studies to consider the dynamic capabilities perspective in assessing the link between environmental efforts and performance.

Dynamic Capabilities

Dynamic capabilities relate to *"the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments"* (Teece et al., 1997: 516). This is distinct from the RBV in the sense that it is the process by which resources are adapted and configured that becomes the main point of focus as opposed to the resources themselves (Ambrosini and Bowman, 2009). Within the highly volatile, dynamic markets firms operate in, consideration of the external environment is important (Ambrosini and Bowman, 2009). Under conditions of fast and unpredictable change, the capabilities of firms are constantly under threat of redundancy as heterogeneity is continually being introduced. Thus, the focus is on the continual generation of short-term advantages rather than long-term advantage which is infrequently achieved in dynamic markets (Eisenhardt and Martin, 2000). Dynamic capabilities enable a firm to continually refresh its resource stocks and sustain competitive advantage through continuous adaptation and generation of short-term advantages (Ambrosini and Bowman, 2009). They are tools in the form of specific, identifiable and often simple processes (Eisenhardt and Martin, 2000).

Three types of process have been noted as important facilitators in the development of dynamic capabilities: namely, integration, learning, and reconfiguration (Teece et al., 1997; Ambrosini and Bowman, 2009). Integration processes relate to the knowledge and routines used within firms to group resources together in a synergistic way (Tashman and Marano, 2009). Learning processes support the development of knowledge and know-how in order to generate innovative ways of dealing with existing and emerging problems (Tashman and Marano, 2009). Their development is dynamic in nature in the sense that the level of learning will change and adapt as the firm develops greater experience in a particular practice (Schreyogg and Kliesch-Eberl, 2007). Reconfiguration processes are used in efforts to optimise resource allocation in response to changes in the external environment and efficiency problems (Eisenhardt and Martin, 2000). This involves a firm identifying how they can use what they have in a new way to meet a new or existing need. Together these processes can be termed orchestration processes as they enable the firm to adapt and adjust what they are doing to suit the changing environment in which they operate (Teece, 2009).

The NRBV and dynamic capabilities perspective have been applied independently to studies within the Operations Management field (Christmann, 2000; Azadegan et al., 2008; Vachon and Klassen, 2008). Hart and Dowell (2011) suggest that the linkage of these two perspectives may help to develop our understanding on the link between environmental practices and performance. Specifically, the environmental strategies outlined in the NRBV framework, namely pollution prevention, product stewardship and sustainable development, can be considered as dynamic capabilities due to the socially complex, firm specific processes required for their effective implementation (Aragon-Correa et al., 2003). This study develops a theoretical framework grounded in the NRBV and dynamic capabilities perspective to assess the relationship between environmental management and performance. The following section presents and discusses the framework.

Theoretical Framework and Hypothesis Development

The theoretical framework developed for this study is presented in Figure 1. There are two key aspects to the framework. Firstly, the influence of the internal supporting processes of integration and learning on the relationship between pollution prevention and environmental performance is considered. The suggestion is that pollution prevention practices should lead to improved environmental performance, especially when their implementation is supported by internal processes. Secondly, the relationship between pollution prevention and cost performance is considered. The suggestion here is that pollution prevention may have a positive impact on other dimensions of performance, such as cost, through environmental performance. Each arrow in the model represents a hypothesis. The following sections will discuss the concepts comprising the model and their hypothesised relationships. Table 1 outlines the definitions for each of the constructs included within the model. These definitions have been developed based on the apriori literature.

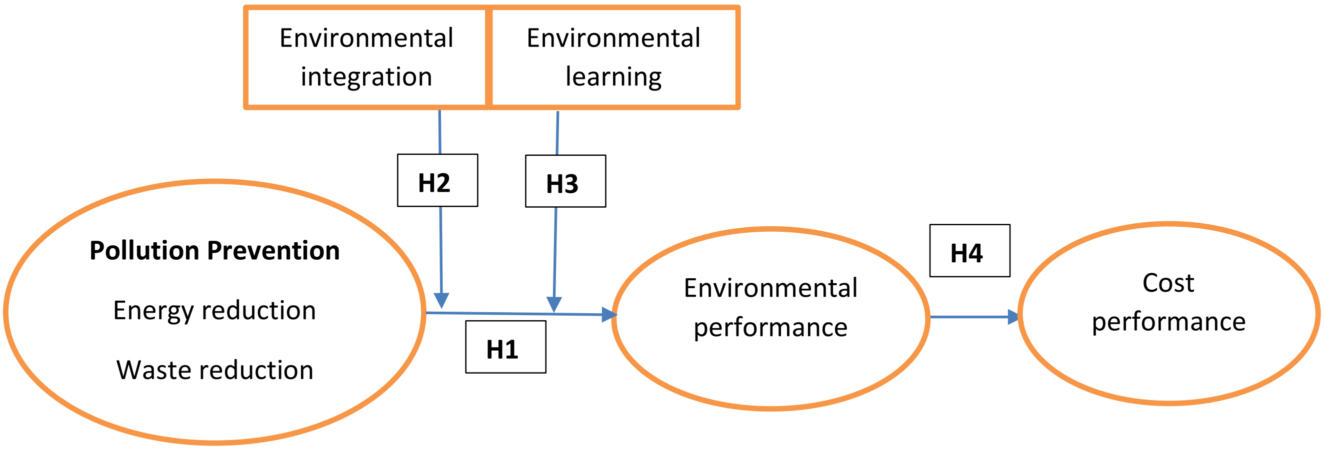

Figure 1

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Pollution Prevention

Pollution prevention is the first environmental strategy outlined in the NRBV framework (Hart, 1995; Hart and Dowell, 2011). It can be viewed as a preliminary stepping stone in the pursuit of more sustainable operations and supply chains (Christmann, 2000). Pollution prevention can involve either product or process based modifications that result in the reduction of negative environmental impacts (Klassen, 2000; Schoenherr, 2012). Product-based modifications can be broadly defined as adaptations that reduce environmental impact throughout the use, disposal and reuse stages of the product’s life cycle; whilst, process-based modifications relate to adaptations that reduce the environmental impact during various stages of the process from materials acquisition to production to the delivery process (Klassen, 2000). Whether, the process or the product is the focus of pollution prevention efforts, an emphasis on reducing pollution at its source will be inherent (Hoque and Clarke, 2013).

Pollution prevention is one of the most commonly adopted environmental strategies within manufacturing companies (Schoenherr, 2012; Thoumy and Vachon, 2012). Accordingly, research interest on pollution prevention has been more prominent than that of the other dimensions of the NRBV (Hart and Dowell, 2011). In spite of this research interest, there appears to be no clear definition of pollution prevention or how it should be operationalised. This may be due to the variation in drivers and responses to pollution across different industry contexts. Further, some studies suggest that pollution prevention can be applied at both the product and process level (Klassen, 2000; Schoenherr, 2012), whilst others focus solely on processes (Abou-Elela et al., 2008; Hoque and Clarke, 2013). In considering the potential impact of pollution prevention strategies, some focus on environmental and operational performance improvements (Abou-Elela et al., 2008; Schoenherr, 2012), whilst others consider a much broader range of factors such as potential health benefits for workers (Munguia et al., 2010) and relationships with managerial factors (Klassen, 2000). For the purpose of this study, consistent with Hart's (1995) classification of pollution prevention, the focus will be on the internal production process. While no specific practices are outlined within Hart's (1995) framework for any of the environmental strategies, there is a clear emphasis on the reduction of the physical waste and emissions generated throughout the process (Hart, 1995; 1996; Michalisin and Stinchfield, 2010). Thus, for the purpose of this study, pollution prevention has been broken down into two sets of practices relating to energy and waste reduction. A number of studies have considered the influence of energy and waste reduction practices on environmental and operational performance dimensions (Rao and Holt, 2005; Montabon et al., 2007; Pullman et al., 2009), yet they have not always labelled these practices as pollution prevention or considered these relationships within the context of the NRBV. Thus, by employing the NRBV and dynamic capabilities perspective, our study casts a different light on what is already known about the relationship between pollution prevention practices and performance.

The link between Pollution Prevention and Environmental Performance

Energy emissions and physical waste are often highlighted as key factors when it comes to pollution prevention (Tate et al., 2010). Excess in either dimension can be viewed as symptomatic of inefficient operations (Bansal and McKnight, 2009) as well as being environmentally irresponsible. A process-based pollution prevention strategy will seek to reduce emissions and levels of waste within the internal operations. Pollution prevention practices are often tailored to respond to the most prominent forms of pollution within specific industries. Process based pollution prevention practices are more prominent within the food industry due to the perishability of the products and the resource intensive production processes inherent. Energy and waste management are key concerns within the food industry (Maloni and Brown, 2006; Pullman et al., 2009), thus, energy and waste reduction are appropriate measures of pollution prevention within this context of study.

The NRBV suggests that pollution prevention may lead to improved environmental performance and the generation of competitive advantage. A number of empirical studies have found support for a positive link between internal environmental practices and environmental performance (Montabon et al., 2007; Pullman et al., 2009; Yang et al., 2010; Graham and Potter, 2015). While these studies consider a broad range of environmental practices, taken together, the findings suggest that the positive relationships between internal practices and environmental performance should be applicable in the case of internal practices related to pollution prevention. Thus, the following hypotheses have been developed;

H1a: Energy reduction practices are positively associated with environmental performance.
H1b: Waste reduction practices are positively associated with environmental performance.

The moderating effect of environmental integration and environmental learning

The implementation of a pollution prevention strategy is a complex process that will require support from other processes within the firm (Galeazzo et al., 2014). In developing new practices within existing processes, it may be useful for a firm to draw from their experience of past practice implementation. There may be complementary capabilities that have been historically developed that can be used across different practices to generate above-normal benefits (Christmann, 2000). Further, there may be certain processes that are used across the implementation of various new practices that facilitate the generation of positive outcomes.

Internal processes play a fundamental role in supporting the development of dynamic capabilities (Schreyogg and Kliesch-Eberl, 2007). Teece (2009) outlines three key internal processes: namely, integration, learning and reconfiguration. These processes can be viewed as mechanisms through which dynamic capabilities are put in use (Ambrosini and Bowman, 2009). The concept of integration represents a static component of supporting processes in that it seeks to coordinate and extend the use of a particular practice or process within the firm (Schreyogg and Kliesch-Eberl, 2007). This involves communication and coordination of a new practice or process across the different functions within the firm to ensure that everyone is working towards the same goal (Pagell, 2004). In order to develop a dynamic capability, it is also important for firms to develop supporting processes that are more dynamic in nature. The latter two supporting processes, namely, learning and reconfiguration represent more dynamic supporting processes. Learning enables a firm to perform activities more effectively based on the experience they have gained over a period of time (Ambrosini and Bowman, 2009). Thus, a firm is able to adapt and improve what they are doing through the experience they gain, rather than continuing to do things the same way. This represents an internally-oriented dynamic approach whereby the firm is able to utilise their experiential learning to advance their capability base in a path dependent manner (Ambrosini et al., 2009). Reconfiguration involves a firm adapting their existing resources and capabilities in response to a new or emerging external requirement (Teece et al., 1997). This presents an externally-oriented dynamic approach in the sense that the firm seeks to respond to external opportunities or threats through the reconfiguration of their resource base. For the purpose of this study, the focus is on the internally-oriented processes of integration and learning and their influence on the development of a pollution prevention strategy. As the research on environmental management and dynamic capabilities is emergent in nature (Hart and Dowell, 2011), it is of interest at this stage to explore the factors that might facilitate development of environmental dynamic capabilities. Following this, it might be of interest for future studies to consider how these capabilities might be adapted through reconfiguration processes to meet new and emerging future needs.

Environmental Integration as a support process

The terms integration and coordination are often used interchangeably to describe a process whereby different functions within a firm are encouraged to work towards the same goals and objectives in relation to new or existing practices. Without integration, these functions might be working at cross-purposes leading to potentially poorer performance outcomes (Pagell, 2004). A number of studies have noted the importance of integration in relation to the implementation of new environmental initiatives (Pagell and Wu, 2009; Daily et al., 2012). Regarding pollution prevention practices, Klassen (2000) states that structural investments in these practices may be complemented by infrastructural investments in management practices that support their implementation. In other words, the development of a pollution prevention strategy will need to be supported internally by appropriate managerial processes and investments in order to obtain the desired benefits. Galeazo et al. (2014) further build on this point by highlighting a need for the linkage of environmental management and operations management, noting the importance of integrating environmental practices into the production process. Thus, in order for environmental practices to be fully supported internally, they must become a part of the day to day operations of the firm. Low levels of integration may result in unfocussed efforts to improve environmental performance, thus, generating a detrimental effect. High levels of integration may encourage a more focussed effort whereby everyone understands the importance of working towards improving environmental performance. Thus, with higher levels of integration, the potential to improve environmental performance should be enhanced;

H2a: Environmental Integration positively moderates the relationship between energy reduction practices and environmental performance.
H2b: Environmental Integration positively moderates the relationship between waste reduction practices and environmental performance.

Environmental Learning as a support process

Learning is another important supporting process outlined in the dynamic capabilities perspective. This process involves firms learning from experience in continuing to develop and improve dynamic capabilities as reflection on successes and failures facilitates improvement (Ambrosini and Bowman, 2009). Path-dependence and causal ambiguity represent some of the characteristics of learning as a firm's experience with a practice or process is often something that is idiosyncratic and unique to them and cannot be transferred or replicated easily by another firm. This experience can feed into how they develop and manage their capabilities and improve their performance as a result. This process contributes to the dynamic nature of the capabilities as adaptations are continually triggered by experience (Schreyogg and Kliesch-Eberl, 2007). In the context of environmental management, Sarkis et al. (2010) highlight a need for studies to consider the implications of intangible processes such as learning on the development of organisational capabilities. The effectiveness of learning as a supporting process depends on the existence of internal structures to enable the adoption of any knowledge obtained via learning (Tashman and Marano, 2009). Thus, it is important not only for the firm to learn from their experience, but also to have an internal environment that supports the use of any knowledge gained. The extent to which a firm has experience with a particular practice or process will likely influence performance outcomes (Zollo and Winter, 2002). Thus, the following hypotheses have been developed;

H3a: Environmental Learning positively moderates the relationship between energy reduction practices and environmental performance.
H3b: Environmental Learning positively moderates the relationship between waste reduction practices and environmental performance.

The link between Pollution Prevention and Cost Performance

The NRBV proposes that the development of environmental capabilities should generate sources of competitive advantage for firms. A competitive advantage can be described as a firm's ability to produce more economically and/or better satisfy customer needs leading to superior levels of performance relative to competitors (Barney, 1991; Armstrong and Shimuzu, 2007). Empirical studies have translated the concept of competitive advantage into different dimensions of performance such as; environmental, cost, flexibility, delivery, quality (Rao and Holt, 2005; Vachon and Klassen, 2008; Ronnenberg et al., 2011; Daily et al., 2012). Cost performance in particular has been subjected to substantial investigation within the literature on environmental operations (Christmann, 2000; Rao and Holt, 2005; Montabon et al., 2007; Schoenherr, 2012). This is not surprising considering the high levels of competition under which firms operate today and the pressure to reduce costs and increase margins. Mixed support for a link between environmental practices and cost performance has been generated to date and there is a need for other studies to investigate this link further (Pagell and Wu, 2011; Hofer et al., 2012). One potential explanation for this mixed support might relate to the different ways that this performance outcome has been measured and assessed across studies. Different terms such as cost, economic or financial performance have been used in defining this outcome. Within this, some studies focus on aspects such as return on sales and return on assets (Wong et al., 2012; De Burgos-Jiminez et al., 2014), while others focus on outcomes relating to shareholder value (Paulraj and De Jong, 2011) and yet others focus on the ability of environmental practices to influence costs relating to the production process (Rao and Holt, 2005; Vachon and Klassen, 2008; Yang et al., 2010; Green et al., 2012; Schoenherr, 2012). Consistent with the latter approach, we focus on the link between environmental practices implemented at the operations level and production costs. Of the studies that have investigated the link between environmental efforts and cost or financial performance, a number have found that while these efforts are linked to improvements in environmental performance and some operational performance outcomes, a direct link with cost is not supported in the case of some environmental practices (Vachon and Klassen, 2008; Pullman et al., 2009; Wong et al., 2012; De Burgos-Jiminez et al., 2014; Graham and Potter, 2015). Rao and Holt (2005) suggest that efforts to improve environmental performance may help reduce production costs associated with inefficiency as the reduction of waste and pollution can enhance the overall process. Further, Green et al. (2012) consider the link between environmental performance and cost performance and find strong support for a direct link between these two outcomes. This suggests that the relationship between environmental efforts and cost performance may be indirect as links between improved environmental performance and cost performance have been identified. Thus, as companies improve their environmental performance through adopting various environmental practices, this may lead to further improvements across other performance dimensions such as cost. This is an important consideration that may shed light on the mixed support for the link between environmental efforts and cost performance. Further, it is consistent with the NRBV which does not specify direct relationships but rather notes the potential benefits for companies pursuing environmental strategies (Hart and Dowell, 2011). In light of this, the following hypotheses have been developed;

H4a: Environmental performance mediates the relationship between energy reduction practices and cost performance.
H4b: Environmental performance mediates the relationship between waste reduction practices and cost performance.

Research Methodology

Research Context

Focus on a single-industry context enables the control of industry specific factors that might influence results (Vachon and Klassen, 2008). Due to the unique range of environmental pressures and challenges faced by the food industry, it is an interesting context for further research on environmental issues (Mattas and Tsakiridou, 2010). As the largest manufacturing sector in many developed and developing countries, the impact of its operations on the environment is an important consideration (Accorsi et al., 2014). Further, the competitive, low-cost nature of the food industry positions it as an appropriate context for exploring the link between operations and performance. The data for this study was collected within the context of the UK food industry from April to October 2011 in two stages. Details of each stage are presented in the discussion below.

Data Collection- Stage One

The first stage of the data collection process involved the development and validation of the survey instrument used in the second stage. Five semi-structured interviews were conducted with environmental and operations managers to facilitate this. A pre-defined interview guide was developed based on the literature and a convenience sample of 50 food processing companies was targeted for participation. From this, a total of five interviews were completed. Respondents came from different sub-industries including red meat, prepared vegetables, bakery, poultry and potatoes. The qualitative data collected at this stage was useful in highlighting some of the challenges and experiences of firms in the UK food industry. It also enabled a narrower focus on the environmental practices relevant to the context. The interviews confirmed that energy and waste reduction are important challenges facing the food industry. Further insight was drawn from online sources such as the Food and Drink Federation (FDF) and the Department for Environment, Food and Rural Affairs (DEFRA), as well as literature on environmental issues in the food industry. Once developed, the survey instrument was subjected to pilot tests with a further six managers and six senior academics to ensure quality (Drucker, 2005). A number of revisions were made to the survey as a result of this process.

Data Collection- Stage Two

A sample of 1200 food processing firms was targeted for data collection. The focus was on medium to large manufacturing firms as they are likely to generate a higher environmental impact and be in a stronger financial position to respond to environmental pressures than smaller firms. The firms included in the sample operate within the Standard Industrial Classification (SIC) DA 15 which includes a number of sub-industries such as meat, dairy, animal feed, grain, starch, fruit and vegetables. This sector was selected as it includes a number of sub-industry groups and is therefore, representative of the broader food industry. The focus and unit of analysis was the production process as this is where the majority of environmental impact is likely to generate from. A key informant approach targeting operations and production managers was utilised as these respondents are likely to have the most process related knowledge.

Dillman's (2007) tailored design method was adhered to in the design and distribution of the survey. Follow up phone calls were made four weeks after the first mailing to pursue further responses (Forza, 2002). Further mailings of the survey were sent out six and twelve weeks after the initial mailing in attempt to generate more responses. A total of 149 responses were received generating a response rate of 12.4%, which is consistent with previous cross-sectional surveys in the area (e.g. Rao and Holt, 2005). A number of sub-industry groups were represented in responses including, processed food (20.8%), beverages (18.1%), meat (17.4%), dairy (14.1%) and other (29.6%). An additional question was included at the end of the survey to assess the level of knowledge of responding managers on environmental operations management within their company. A mean response of 5.9 out of 7 generates confidence that the responding managers were knowledgeable about the issues under investigation.

In order to assess for potential limitations imposed by response bias, a comparison of early and late responders was conducted (Armstrong and Overton, 1977). This test assumes that late respondents possess similar characteristics to non-respondents (Foerstl et al., 2013). No statistically significant differences were identified suggesting that non-response bias is not a concern for the data. As an additional test of non-response, we compared the size and age of the companies who responded with that of companies within the sample frame who did not respond using an independent samples t-test. The results supported the previous findings that suggest that non-response bias in not a concern as there did not appear to be any statistically significant differences between the two groups.

Operationalization of variables

The constructs explored in this study are outlined in Table 1. A number of new scales had to be developed to measure these constructs. To ensure content validity, these measures were grounded strongly in the existing literature (Chen and Paulraj, 2004). Further, the findings from stage one of the research design were drawn upon. Established guidelines for scale development were followed throughout this process (Hair et al., 2006). Multiple indicators were used to measure each construct to further ensure the validity of the measures. A seven-point Likert scale anchored from either "strongly agree" to "strongly disagree" or "not at all" to "a very great extent" was used to assess the responses to each of the questions.

To assess the relationship between pollution prevention and environmental performance, three scales were developed: five items to measure energy reduction, six items to measure waste reduction and five items to measure environmental performance. The items for these measures were developed based on research within the food industry context (Maloni and Brown; 2006; Pullman et al., 2009). To assess the moderating effects of internal processes, two further scales were developed: three items to measure integration and four items to measure the construct of learning. The former items were adapted from Chen and Paulraj (2004), while the latter was informed by the literature on dynamic capabilities (e.g.

Ambrosini and Bowman, 2009). To assess relationships with cost performance, four items were adapted from Vachon and Klassen (2008).

Exploratory Factor Analysis

Exploratory factor analysis (EFA) using Varimax rotation was conducted on the scales to assess their effectiveness as measures of the constructs (Hair et al., 2006). Bartlett's test for spherecity as well as Kaiser Meyer Olkin's (KMO) test were also applied to the scales to assess the significance and strength of relationships among their comprising items (Vogt, 2005). The scales were put into the rotation in two sets of three (see Appendix Tables 1 and 2). In both sets, the KMO scores were above 0.8 with highly significant Bartlett's test of sphericity figures ($p<.001$), suggesting that the items were suitable for factor analysis. All of the standardised loadings were statistically significant and above the .60 threshold which suggests that convergence validity is achieved (Hair et al., 2006). In both analyses, three-factor solutions were suggested, with eigenvalues above 1 and a high level of variance explained (>70%). There were no cross-loading factors above 0.4, providing support for discriminant validity in all cases. Inspection of scree plot diagrams provided further confirmation of the suggested three-factor solutions. In addition to factor analysis, the Cronbach Alpha scores for each of the variables were calculated to assess their overall reliability as measures. These values ranged from 0.85 to 0.94 indicating a high level of measurement reliability (Hair et al., 2006). Finally, we conducted Harman's single-factor test (Podsakoff, 2003) to determine whether common method bias is a concern for the data. This test sought to identify whether a single latent factor provided a better indicator for all the items than our suggested multi-factor measurement model. The percentage of variance explained in the single-factor analysis along with the significance of the difference (Δx^2= 3287.24, $p<.001$) suggest that common method bias is not a cause for concern. Overall, this analysis confirms that the items comprising each of the variables are valid and reliable measures of their overall construct.

Data Analysis and Results

In order to test the model and hypotheses, hierarchical regression analysis was used. Prior to the analysis, all of the independent variables were mean-centred in order to avoid the problem of multicollinearity. Furthermore, the variance inflation factor (VIF) and tolerance values were examined to ensure that multicollinearity was not a concern for the data. All of these values were within the recommended intervals. Two regression models were run; the first to test the moderation hypotheses and the second to test the mediation hypothesis. In both models, control variables (i.e. firm size and sub-industry group) were considered in the first step (Model 0 in Tables 2, 3 and 4). Firm size was measured using a logarithm of the number of employees. Sub-industry was incorporated into the regression models using a series of four dummy variables. The category 'other', representing minority sub-industry groups that did not fit into the other categories, was adopted as the baseline/comparison group. The next step in the analysis required the inclusion of the independent variables within the regression model (Model 1 in Tables 2, 3 and 4). In the final step of the regression analysis, the interaction terms were included (Model 2 in Tables 2, 3 and 4).

<<<<<<<<<<<<<<<<<<<<<<insert Table 2>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Moderation Model

The results for the regression model that included moderation are displayed in Table 2. Model 0 represents the first step of the analysis. Three of the controls, namely, firm size, processed food industry and beverages industry appear to be significant, explaining around 15% of the variance in environmental performance. In models 1 and 2 the effect of all controls is non-significant, suggesting that the results of the regression are not affected by any of the controls. Inclusion of the independent variables in Model 1 explains a significant amount of additional variance (change in R^2 = 41%; the change in F statistic is 32.30, $p \leq 0.001$). Both energy and waste reduction are significantly related to environmental performance, providing support for *H1a* and *H1b*. Model 2 of the regression analysis shows the changes to the main variables when the interaction term is included. A moderated effect is demonstrated when the coefficient of the interaction term is significant and the value of R^2 increases (Danese and Romano, 2013). The coefficients for the interactions between waste reduction and environmental integration; and energy reduction and environmental learning are positive and statistically significant, supportive of *H2b* and *H3a*. The increase in R^2 between models 1 and 2 (0.03) provides additional support for these interactions. Hypotheses 2 and 3 are only partially supported as the interaction between energy reduction and environmental integration is non-significant and the interaction between waste reduction and environmental learning is negative, contrary to the hypothesis. Thus, *H2a* and *H3b* are rejected on these grounds.

To further examine the significant interactions, simple slopes computations were conducted (Dawson and Richter, 2006). To assess the influence of the moderator at high and low levels of the independent variable, the standard deviation of the moderator was used (Aiken and West, 1991). The first relationship to be analysed was the interaction between waste reduction and environmental integration. To calculate the value for high levels of integration, one standard deviation (1.65) was added to the mean (0) giving a value of +1.65 to be included in the simple slopes calculation whilst for low levels of regulatory pressure this same value was subtracted from the mean, giving a value of -1.65. A significant *t*-value (b=2.15, $p \leq 0.05$) is indicative of a moderating effect when levels of integration are high. The *t*-value for low levels of integration is non-significant suggesting that this effect is only triggered when integration efforts are above a certain level. Graphical analysis further supported this moderating effect.

The same steps were followed for the other significant interaction. One standard deviation of the moderator (1.48), was both added to and subtracted from the mean (0) to represent high and low levels of learning. Again, the high level slope is significant (b=2.41, $p \leq 0.05$), indicating that environmental learning or expertise may enhance the potential for energy reduction efforts to improve environmental performance. Again, this is further supported by the graphical analysis. Overall, the post-hoc probing of the interactions provides further support for *H2b* and *H3a*. Discussion of these effects and their implications is provided in the discussion section.

Mediation Models

The results for the models assessing mediation effects are displayed in Tables 3 and 4. Three conditions are required for mediation to exist; (1) the independent variable must affect the mediator; (2) the independent variable must affect the dependent variable and; (3) the mediator must affect the dependent variable (Baron and Kenny, 1986). The first condition is supported through the results for the moderation analysis in Table 2, where it is evident that both energy and waste reduction have a significant and positive affect on environmental performance. Table 3 provides support for a mediated relationship between energy reduction, environmental performance and cost performance. Condition 2 is satisfied in the Model 1 section of the results where a significant relationship between energy reduction and cost performance is evident (β =.18, p<.05). Condition 3 is satisfied in the Model 2 section of the results where a significant relationship between environmental performance and cost performance is evident (β =.47, p<.001). Further, the effect of energy reduction on cost performance becomes non-significant upon the inclusion of the mediating variable (environmental performance), providing support for full mediation. Sobel's test for mediation was conducted in accordance with guidelines from Preacher and Hayes (2004). The results for this test were both positive and highly significant (3.90, p<.001), providing further support for full mediation. Thus, *H4a* can be accepted.

<<<<<<<<<<<<<<<<<<<<<**insert Table 3**>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

The same steps were followed in assessing for a mediated relationship with waste reduction as the independent variable. Again, all three conditions for mediation were met by the data. Model 1 indicates the significant influence of waste reduction on cost performance (β =.27, p<.001). This effect becomes non-significant in Model 3 when the mediating variable is introduced and a significant mediating effect is evident (β =.37, p<.001). Again, these findings were further supported by a positive and highly significant Sobel test result (3.59, p<.001). In support of *H4b*, these results suggest that complete mediation exists between the variables included in this model.

<<<<<<<<<<<<<<<<<<<<<**insert Table 4**>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

<<<<<<<<<<<<<<<<<<<<<**insert Table 5**>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Discussion

Using the NRBV and dynamic capabilities perspectives we developed and tested a theoretical model examining moderating and mediating effects of pollution prevention on performance. A summary of the results for the hypothesised relationships is displayed in Table 5. Overall, there has been strong support for some but not all of the proposed relationships in the theoretical model (Figure 1). The key findings and their implications for theory and practice will now be discussed in detail.

There was strong support for *H1* which proposed a positive relationship between the pollution prevention practices of energy and waste reduction and environmental performance. Building upon the well-established link between environmental practices and environmental performance (Zhu and Sarkis, 2004; Rao and Holt, 2005; Hollos et al., 2012; Zailani et al., 2012), these results suggest that the implementation of pollution prevention practices may lead to improvements in environmental performance. While a link between pollution prevention practices and environmental performance has already been established to some extent within the extant literature base (Graham and Potter, 2015), it was necessary to reaffirm this link in our study to enable the testing of *H2* and *H3.* These hypotheses generate a novel perspective on the relationship between pollution prevention and environmental performance by exploring the interaction effects of internal processes. Support for *H2* and *H3* was mixed, with two of the four interaction effects hypothesised being supported. This provides partial support for *H2* and *H3* and suggests that internal processes may play an important role in the implementation of environmental practices. This partial support is consistent with a number of studies that highlight the complexity of implementing environmental practices and the need for internal support processes to ensure their effective implementation (Christmann, 2000; Schreyogg and Kliesch-Eberl, 2007; Ronnenberg et al, 2011; Galeazo et al., 2014). Integration and learning have been identified as important support processes in the implementation of environmental practices (Pagell, 2004; Pagell and Wu, 2009; Tashman and Marano, 2009; Longoni and Cagliano, 2015). While some studies consider the direct (Daily et al., 2012) or mediating (Sarkis et al., 2010) influence of internal support processes on the implementation of environmental practices, our study is among the first to consider the interaction between these practices and support processes in determining environmental performance. Our findings suggest that the implementation of pollution prevention practices may be more effective in terms of improving environmental performance where internal processes are used to support this implementation. This is consistent with other recent studies (Ronnenberg et al., 2011; Daily et al., 2012) as well as the arguments of the dynamic capabilities perspective which suggest that internal support processes are an important element in the development of dynamic capabilities within firms (Schreyogg and Kliesch-Eberl, 2007). The non-significant results for two of the interactions were unexpected and lead to questions regarding the conditions under which internal support processes might be more beneficial. It might be the case that some practices are supported better by certain processes than others, or that the firms in the sample had achieved higher levels of integration and learning with one practice over the other. For example, if waste reduction had been implemented over a longer time period than energy reduction, it is likely that the level of integration would be higher. While the support for *H2* and *H3* is not strong enough to lead to a unanimous conclusion, there is some indication that internal support processes may complement the implementation of environmental practices enabling firms to generate a higher level of improvement in their environmental performance. This generates some preliminary support for the perspective advocated by Hart and Dowell (2011) and facilitates the next phase of development for the NRBV by extending the consideration of environmental management as a set of practices, policies or strategies to a set of dynamic capabilities that can be implemented, developed and reconfigured with the support of appropriate internal processes.

Regarding cost performance, the results from this study provide strong support for an indirect relationship with pollution prevention practices suggesting that as companies improve their environmental performance through adopting these practices, improvements in production costs can also be derived. Thus, it is not the practices themselves that are directly influencing cost performance, but rather the improvements in environmental performance generated through these practices. This is consistent with the argument that improvements in environmental performance can lead to more efficient processes therefore reducing production related costs (Rao and Holt, 2005). Our findings also build upon the work of Green et al. (2012) who identify strong direct relationships between environmental and cost performance. Further, De Burgos-Jiminez et al. (2014) found no support for a direct link between environmental efforts and financial performance but strong support for a link between environmental performance and this outcome. These studies have begun to highlight that improving environmental performance may be the key to improving cost and financial outcomes. Our study takes this a step further by seeking to identify whether environmental performance plays a mediating role in the relationship between pollution prevention and cost performance. The strong support provided by our results suggests that environmental performance does mediate this relationship.

These findings shed some new light on the debate surrounding the benefits of environmental efforts which has generated mixed results to date (Vachon and Klassen, 2008; Iwata and Okada, 2011). Of the studies that have noted mixed results in relation to cost performance, a number have considered its direct relationship with environmental practices (Vachon and Klassen, 2008; Pullman et al., 2009; Wong et al., 2012; Graham and Potter, 2015). The confirmation of a mediated relationship between environmental practices and cost performance through environmental performance suggests that the relationship between these practices and this dimension of performance may not always be direct. Thus, interpretation of the mixed results in relation to cost performance may not necessarily lead to the conclusion that some environmental practices do not impact cost performance. It may rather be the case that these practices do have an impact on cost performance, albeit indirectly. This is consistent with the arguments of the NRBV linking environmental efforts to competitive advantage (Hart, 1995; Hart and Dowell, 2011) and may have implications for the way in which results from past studies are understood. The identification of negative or non-significant results has led recent studies to highlight the complexity of the relationship between environmental efforts and performance (De Burgos-Jiminez et al., 2014). Thus, it may be the case that some of the negative or non-significant results generated by previous studies imply that the link between practices and performance is not always direct. As our study has noted, this does not necessarily mean that these practices are not impacting cost performance but rather, environmental efforts may be lead to other improvements indirectly.

Implications for Theory

This study makes some important theoretical contributions. In particular, it generates some novel insights into the debate on the link between environmental efforts and performance outcomes by applying the dynamic capabilities perspective in conjunction with the NRBV (Hart and Dowell, 2011). As the complexity of the link between environmental efforts and performance is being increasingly noted it is becoming important for researchers to look beyond exploring a direct link between practices and performance to identify other factors that may exert a potential influence (Lopez-Gamero et al 2009; Hart and Dowell, 2011; De Burgos-Jiminez et al., 2014). Our study makes two important contributions in this regard. Firstly, we provide preliminary support for the indirect influence of internal support processes on the implementation of environmental practices. This support is consistent with Hart and Dowell’s (2011) suggestion that environmental efforts can be viewed as dynamic capabilities that may benefit from other supporting practices in their implementation. The partial support generated by our results for this proposition suggests that certain environmental practices may be implemented more effectively, in terms of environmental performance improvements, in the presence of internal supporting practices. A second key contribution relates to the link between environmental practices and cost performance. Our study appears to be among the first to examine a mediated link between pollution prevention practices and cost performance. The strong support provided by our results for this link suggests that efforts to improve environmental performance through pollution prevention may lead to reduced production costs as processes become more efficient. This novel perspective moves away from suggesting a direct relationship between environmental efforts and production costs and recognises that there may be an indirect relationship between practices and cost performance. These findings may have further implications for the interpretation of results from other studies, particularly those that have noted non-significant relationships between environmental practices and cost performance (Vachon and Klassen, 2008; Wong et al., 2012; Graham and Potter, 2015). Initial conclusions around non-significant findings may suggest that these practices do not benefit cost performance, however, in light of our results, it may be suggested that such conclusions may be premature and the link between these variables may be indirect. Considered together, these results provide broad support for the NRBVs key proposition that environmental practices can lead to sources of competitive advantage and thus, aid its development as a theoretical perspective (Hart, 1995; Hart and Dowell, 2011).

Implications for practice

Our findings also have important implications for organisations and managers. Firstly, our findings generate convincing support for managers to invest more heavily in implementing environmental strategies. We show that these investments have the potential to improve environmental performance which is an increasingly important requirement for organisations and managers. Further, these investments may lead to improvements in other dimensions of performance indirectly through the improvements generated in environmental performance. This offers some valuable insights to managers who may be somewhat cynical about the potential benefits of implementing environmental strategies. Our results suggest that while other performance improvements may not always directly emerge from environmental practices, the improvements these practices generate in environmental performance can have a wider impact on other dimensions such as cost. Secondly, regarding the implementation of environmental strategies, our findings suggest that organisations should seek to align their environmental strategies with other areas of business. Thus, managers should encourage employees at all levels across all functions to be working towards environmental goals in conjunction with other key organisational goals. In doing this, they can ensure that environmental efforts are supported across the organisation whilst also drawing on insights or experience from other areas that may enhance or complement the implementation of their environmental strategies. This integrative approach may facilitate and enhance the translation of environmental strategies into improved organisational performance.

Our findings relate specifically to the implementation of pollution prevention strategies which are focused on the reduction of waste and energy within the internal production process. We highlight the potential for improvements in both environmental and cost performance to be obtained through implementing pollution prevention strategies. Further, we demonstrate the potential for integration and learning to enhance the performance outcomes from pollution prevention. These results should highlight the potential benefits of investment in pollution prevention to managers as well as the importance of companywide commitment to the implementation of such strategies. Further, it may be useful for managers to consider the experience and learning obtained through implementing other practices that may complement the implementation of pollution prevention practices. The level of pressure being placed on organisations and managers to reduce the environmental impact of their operations is increasing. Our study offers some insights into how organisations might benefit from dealing with these pressures through investing in pollution prevention. We show that there may be rewards and benefits beyond responding to external pressures. Organisations that adopt a more reactive approach to these pressures may miss out on the potential benefits of an integrated, companywide pollution prevention strategy as they merely respond to challenges as they emerge. This means they will be seeking to control their levels of pollution when they become problematic which might lead to unanticipated expenses. This fire-fighting approach to controlling pollution will incur expenses without the same potential for benefits to be obtained.

Conclusion

The aim of our study was to assess the relationships between pollution prevention and performance through the lens of the NRBV and dynamic capabilities perspective. Our findings generate some novel insights for this relationship whilst building upon recent studies that consider the influence of other relevant factors. The first research question addressed the potential for internal support processes to enhance environmental performance outcomes from pollution prevention. The results suggest that the internal processes considered have the potential to enhance these outcomes in the case of certain practices, but not others. This means that a solid conclusion cannot be reached regarding this research question and that more research is needed to explore these links further. The second research question considered whether the link between pollution prevention and cost performance was mediated by environmental performance. Our results are generalizable to the food industry and provide strong support for the hypotheses underpinning this question, suggesting that in the context of the UK food industry, improvements in cost performance resulting from pollution prevention are indeed mediated by environmental performance. Energy and waste reduction are key objectives for the food industry (Maloni and Brown, 2006; Pullman et al., 2009). The findings from this study suggest that the pursuit of these objectives may lead to improvements in the cost of running the operations as firms improve their environmental performance. Thus, the focus on improving environmental performance may lead to other operational improvements down the line, if not directly through the practices implemented. As companies in many industries face increasing pressure to be more environmentally responsible (Simpson and Sroufe, 2014; Naor et al., 2015), environmental performance has become a key consideration for managers. Our findings shed light on internal supporting practices that may aid effective implementation of environmental practices enabling higher levels of environmental performance improvement to be achieved. Further, our results suggest that improvements in environmental performance may indirectly lead to benefits in other areas such as cost performance.

Limitations and future research directions

An important limitation of this work relates to the cross-sectional data that does not account for the dimension of time, i.e. how long the practices have been implemented. This may be an important consideration as firms who had implemented the practices over a longer time period may have realised greater levels of improvement. This is something that future studies should try to incorporate as it may have an influence on the results. A further limitation stems from the lack of established measures for a number of the concepts which meant that new measures had to be developed. While these appear to have met the requirements of validity and reliability, as shown in the analysis (Appendix Table 3), further applications will add to their effectiveness.

The pressure for firms to improve the environmental performance of their operations is only heightening so the choice of whether or not to do so is diminishing and it is becoming more important for firms to identify the most effective ways to do so. Future studies should continue to address questions relating to how companies can effectively improve environmental performance whilst generating competitive advantage. In contexts like the food industry where profit margins are small and competition is high, it is of particular importance that firms are able to respond to these pressures in a way that will benefit their cost performance. A similar study could be conducted in other sectors to see if the results are applicable in other contexts. Further, in relation to research question one; an in-depth case study approach might help to generate more insight with regard to the non-significant findings.

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Appendices

<<<<<<<<<<<<<<<<<<<<<<insert Appendix Tables 1-2>>>>>>>>>>>>>>>>>>>>>>>

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