ISO 14001 certification and operating performance: a practice-based view

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Abstract

Despite the growth of ISO 14001 a lot is still unknown about the impact of environmental management systems on firms' operating performance with much of the academic literature focusing on the financial, market and environmental benefits of ISO 14001. The research in this paper employs the practice-based view along with the event study methodology to determine whether firms can enhance operational efficiency through adopting replicable management practices prescribed under the ISO 14001 standard. This research involved examining performance for both certified and non-certified firms in the UK and Ireland. Whilst ISO 14001 was shown to have a positive and prolonged effect on certified firms' manufacturing cost efficiency, employee productivity, and return on assets, the sample firms' operating cycle displayed evidence of diminishing returns in the long-run. This study advances upon previous ISO 14001 research studies by applying the event study methodology and measuring the effect of environmental management system adoption through utilising operating performance metrics rather than relying on subjective measures of firm performance. Moreover, this research is important as few firms actually quantify the benefits of the ISO 14001 standard. However, the findings come with the caveat of diminishing returns for some operating indicators emphasising that firms can become overly efficient to the detriment of the initial operating speed gains.

1.0 Introduction

In today's business environment firms are facing greater market and institutional pressures to operate in a socially responsible and environmentally friendly manner. As a corollary of this, firms are pursuing environmental strategies and implementing environmental management systems such as ISO 14001 (Lo 2012, Su et al 2015). Introduced by the International Organisations for Standardisation (ISO) in 1996, ISO 14001 is an environmental management standard which prescribes transferable environmental practices for the implementation of an environmental management system (EMS) (Boiral and Henri 2012). As ISO 14001 is a process standard, the main objective of the aforementioned environmental practices is to reduce the impact of a firm's operating processes on the environment through the continual improvement of operations (Curkovic and Sroufe 2011).

Crucially, the number of ISO 14001 certifications in the UK and Ireland has steadily increased year on year since the standard was introduced, placing the UK first in Europe for the number of ISO 14001 certifications in the 2017 ISO survey (ISO 2018). Despite the growth of ISO 14001 in the UK and Ireland, a lot is still unknown about the impact of EMSs within organisations (Adebanjo et al 2016). For instance, the academic literature has largely focused on the financial, market and environmental benefits of ISO 14001 (De Jong et al 2014, Feng and Wang 2016). Missing from the literature however are studies which examine the causal impact of ISO 14001's environmental practices on operating performance indicators such as employee productivity and the operating cycle (De Jong et al 2014, Prajogo et al 2014). A key consideration however is that existing theoretical frameworks often overlook the study of imitable and transferable practices (Bromiley and Rau 2016), underlining the need for a novel approach to study the relationship between ISO 14001 adoption and operating performance. As Boiral and Henri (2012 p. 84) have highlighted: *"the ISO 14001 standard is not based on any predefined performance objective, but on a range of practices whose efficiency remains to be clearly demonstrated"*.

In light of the above observations, the aim of this study is to examine whether ISO 14001 environmental practices can enhance firms' operating performance. The research employs the Practice-Based View (PBV) (Bromiley and Rau 2016) in conjunction with the event study methodology (Fama et al 1969) to determine if firms can enhance operational efficiency from the adoption of replicable management practices prescribed under the ISO 14001 standard. This entails examining performance for both certified and non-certified firms. As part of this study, the research will also consider the long-term operating implications of ISO 14001 adoption by taking a longitudinal perspective of firm performance. Hence, issues such as diminishing returns can be identified. Finally, this study will also advance upon previous ISO 14001 research studies by applying the event study methodology and measuring the effect of EMS adoption via utilising operating performance metrics rather than relying on subjective measures of firm performance often utilised in survey-based research or case studies (De Jong et al 2014). This is important as research by Comoglio and Botta

(2012) concludes that few firms actually quantify the benefits of adopting the ISO 14001 standard.

2.0 ISO 14001 and firm performance: a literature review

Research that examines the performance effects of third-party environmental management systems typically focuses on two distinct environmental reference standards, namely the EU's Eco-Management and Audit Scheme (EMAS), and the ISO's environmental standard; ISO 14001 (Comoglio and Botta 2012). While the ISO 14001 standard is issued by private authorities (environmental verifiers), EMAS is a publicly regulated EMS and therefore sets more stringent requirements on external communication in areas such as legal compliance and the measurement of environmental performance. According to Testa et al. (2014), the literature on EMAS is not as advanced as the ISO 14001 literature due to the limited geographic scope of EMAS, and lower levels of the standards diffusion in Europe compared to ISO 14001. As such, few studies have yet to fully study the internalisation of EMAS, with only very recent studies examining the performance implications of the standard (see Daddi et al 2016, Testa et al 2018a). Accordingly, while Tuczek et al. (2018) note that EMAS studies are growing in number, EMAS research in the realm of firm performance is still at a nascent stage (Testa et al 2014). Conversely, while the ISO 14001 firm performance literature is substantially more developed than that of EMAS, existing ISO 14001 studies have largely focused on financial or stock market aspects of performance (De Jong et al 2014). Moreover, the results from these studies have been largely mixed. For example, while studies by Jacobs et al (2010); Lo et al (2012) and De Jong et al (2014) conclude that ISO 14001 has a positive impact on financial performance, other studies have found exactly the opposite (Paulraj and De Jong 2011). Thus, there appears to be a lack of consensus in the ISO 14001 literature regarding the relationship between ISO 14001 adoption and financial performance.

An interesting finding that has emerged from the ISO 14001 and financial performance literature however, concerns the methodologies used in the financial studies. For instance, studies that have adopted longitudinal methodologies such as event studies, as opposed to a cross sectional or survey methodology, generally obtained positive results (Lo 2012, De Jong et al 2014). Hence, there is an emerging argument from the ISO 14001 literature that suggests the introduction of ISO 14001 and implementation of environmental practices is a dynamic process and existing literature would benefit from both an operational perspective and a longitudinal perspective (Russo 2009, De Jong et al 2014, Su et al 2015). This may be especially true for operating performance as it may take time for firms to absorb the ISO 14001 philosophy and implement the necessary practices required to integrate sustainable operations management with existing production methods (Russo 2009). Crucially however, as Klingenberg et al (2013) highlight, financial metrics such as return on assets (ROA), return on sales (ROS) and return on equity (ROE) are not adequate measures of overall manufacturing or operating performance.

Therefore, some researchers have begun to examine the ISO 14001 operating performance link by employing survey-based research methods (Montabon et al 2000, Melynk et al 2003, Schoenherr et al 2012). A key issue with these studies however, as opposed to event studies, is that much of the research is cross-sectional and therefore quite static in nature (De Jong et al 2014). For example, survey-based studies by Melnyk et al (2003) and Adebanjo (2016) examined the linkages between ISO 14001 and operating performance. More specifically, Melnyk et al (2003) found a positive relationship between ISO 14001 and firm performance in terms of waste and manufacturing cost reductions. Conversely, Adebanjo et al (2016) found that the adoption of formal sustainability programs such as ISO 14001 was not actually linked to improved manufacturing performance. As Najmi and Kehoe (2001) argue however, the long-term performance measurement aspect is important for sustained performance beyond ISO 9001/14001 implementation in order to overcome potential problems such as diminishing returns. As is often the case in cross-sectional studies, the aforementioned studies were limited in that they utilised subjective data and therefore could not determine causality between the variables (Lo 2012). Hence, a longitudinal event study can bring new insights to the ISO 14001operating performance literature (De Jong et al 2014).

A final observation relevant to the research in this paper is that while there have been many ISO 14001 research studies employing a multitude of different theories such as institutional theory, RBV and stakeholder theory (Darnall and Edwards 2006, Russo 2009, Simpson et al 2014), existing theoretical research does not sufficiently examine the 14001 operating performance relationship (De Jong et al 2014). For example, employing the RBV, Darnall and Edwards (2006) examine pre-existing operational capabilities and their impact on the cost of EMS implementation. However, the study does not directly examine the relationship between ISO 14001 adoption and operating performance. This is due to the observation that that the RBV focuses on firm resources and capabilities as opposed to external practices, and competitive advantage as opposed to firm performance. Hence, these observations pose problems for researchers who aim to directly measure the impact of external practices such as ISO 14001 adoption on operating performance (Bromiley and Rau 2016). As ISO standards are third party systems which can be adopted by firms across virtually every industry, the ISO 14001 management system itself does not fit the criteria for a VRIN (valuable, rare, inimitable and non-substitutable) resource. As such, frameworks such as the RBV (Barney 1991) or KBV (Grant 1996) are often inappropriate to the study of ISO 14001 practices. Hence, there is a gap for a practice-based theoretical study which directly examines the long term, causal impact of ISO 14001 adoption on operating performance.

2.2 Theoretical development – The practice-based view

The PBV focuses on explaining the effect of imitable or publicly available organisational practices on firm performance and/or variations in the implementation of these practices. Practices are defined by Bromiley & Rau, (2014, p. 1249) as a “defined activity or set of activities that a variety of firms might execute”. The term "variety" is key as the PBV incorporates the entire range of performance across all firms in industry not just the small proportion of firms with inimitable resources or sustained competitive advantage (Carter et al 2017). The premise of the PBV is that, due to bounded rationality, managers cannot be aware of all available practices and managers may not have the time or capacity to implement all beneficial measures (Simon, 1955). Consequently, the PBV seeks to explain performance partially by "imitable activities or practices, often in the public domain, amenable to transfer across firms" (Bromiley & Rau, 2014, p. 1249). Under the PBV, prescription to the wider business populous is possible and imitable and transferable practices can be recommended or prescribed to management (Bromiley and Rau, 2014). Hence, such empirical research is of interest to firms with poor or below average operating and environmental performance. In this sense, the PBV seeks to better align with the performance-based research objectives of many operations management (OM) researchers (Bromiley and Rau 2016; Carter et al 2017).

The above observations are fundamental to this study as ISO 14001 is essentially a third-party environmental management system comprised of a series of transferable practices (Boiral and Henri 2012). Under the PBV, ISO 14001's publicly available and imitable environmental practises of environmental training, pollution prevention and environmental planning become a key focus of study. Moreover, as the PBV's primary outcome or dependent variable is operating performance, the theoretical framework has a good degree of fit with the aim of the research in this paper. Finally, owning to the dynamic and flexible nature of management practices, the PBV can account for the entire range of performance implications of management practices such as negative performance or issues such as diminishing returns. For example, in the case of ISO 14001, institutional pressures may lead to the superficial adoption of ISO 14001 practices culminating in diminished operating performance in the long-run (Lo 2014, Testa et al 2018b). As Bromiley and Rau (2016 p.103) highlight; *"the PBV allows for the possibility that practices may have positive, negative, or neutral impacts on performance both directly and indirectly and may have different impacts in different circumstances".*

Hence, by the applying the PBV, and examining the impact of ISO 14001 on both short- and long-run operating performance, this study can add new and valuable insights to the ISO 14001/OM research field. This also supports the view of other OM researchers who argue that the PBV can bring new insights to the OM discipline. For example, Silva et al (2018) apply the PBV to examine the role of supply chain practices in response to natural disasters, while Liu et al (2016) argue in their supply chain technology research paper that future studies should apply the PBV to study the impact of supply chain technologies (imitable practices) on performance.

2.3 Theoretical development and research hypotheses

Employing the PBV, this study examines whether ISO 14001 environmental practices can enhance firms' operating performance. The operating framework outlined in figure one is a practice-based framework developed from the organisational practices (i.e. technology implementation, training and production planning) outlined in Bromiley and Rau's theory building paper (Bromiley and Rau, 2016). The operating metrics employed such as fixed asset efficiency, employee productivity are taken from peered reviewed OM journals as measures of operating performance (see Lo et al 2009, 2014) and are employed to measure the impact of ISO 14001's transferable practices on operating performance. Figure 1 presents a visual representation of the theoretical framework employed, and the logic of this framework and associated hypotheses is now outlined.

TAKE IN FIGURE 1

Physical assets:

The PBV facilitates the argument that the introduction of third-party physical assets can be a source of operating performance improvement (Bromiley and Rau 2016). This is pertinent to the study of ISO 14001, as research by (Radonjic and Tominc 2006) concludes that ISO 14001 requires a commitment to pollution prevention and, as such, represents a key driver of the modernisation of physical assets (Radonjic and Tominc 2006). According to Klassen and Whybark (1999) pollution prevention technologies are more efficient than process control technologies as prevention technologies are focused on curbing pollution in a production process before it occurs, rather than applying end of pipe control solutions. (Klassen and Whybark, 1999; Melynk et al, 2003; Radjonic and Tominc 2006). In this sense, whilst the introduction of new environmental technologies may initially cause disruption due to adjustment difficulties (Kemp 1994), efficiency gains should be realised in the years following implementation as inefficient pollution control practices and technologies are replaced by new prevention technologies/equipment which rarely require total productive maintenance (TPM). Equally important however, is the observation that complementary prevention practices such as waste elimination and continuous improvement should be combined to enhance the efficiency of fixed assets. (Klassen and Whybark 1999). An example could include more efficient logistics scheduling which leads to efficient transportation utilisation i.e. delivery vehicles operating to optimal capacity and thereby reducing unnecessary mileage and emissions (Piercy and Rich 2015; Mejias et al 2016). Hence, it can be argued:

H1: The adoption of ISO 14001's pollution prevention practices will enable the firm's physical assets to be used more efficiently, which should result in a higher fixed asset turnover ratio.

Human capital:

As ISO 14001 aims to standardise environmental management practices and operating procedures, certification mandates that all employees must undergo training in environmental management practices (Delmas and Pekovic 2013). During ISO 14001 implementation, employees will be required to assimilate and absorb new knowledge on how to reduce process materials and remove waste from production processes (Lo 2012; Su et al 2015). Accordingly, the PBV prediction would be that while employee training is a generic and imitable practice that can be implemented by all organisations (Bromiley and Rau 2014), training can be a still source of improved operating performance if it supports complementary ISO 14001 practices (Delmas and Pekovic, 2013). For example, as environmental training is geared towards waste reduction and continuous improvement, it will improve workforce productivity as employees are enhancing their knowledge and skill set whilst simultaneously making improvements to the production process (Delmas and Pekovic 2013, Wagner 2013, Gurrero-Baena et al 2015). For example, in the case of the safety standard OHSAS 18001, a study by Lo et al (2014) found that employee productivity improved after OHSAS 18001 adoption as employees made continual improvements to production processes, whilst both Hanna et al (2000) and Theyel (2000) empirically linked employee involvement practices with continuous improvement initiatives and environmental performance.

Finally, the cleaner production practices introduced by ISO 14001 implementation may lead to the working environment improved due to a reduction of toxins and dangerous chemicals (Kitzawa and Sarkis 2000), these improvements should lead to a more motivated, satisfied and productive workforce ultimately resulting in productivity improvements (Wagner 2013, Delmas and Pekovic 2013, Lo 2014). Hence, it can be argued:

H2: ISO 14001's environmental training practices will result in improvements in workforce productivity.

2.3.1 Production planning practices

According to Sambasivan and Fei (2008), environmental planning forms a key part of ISO 14001 standard implementation. Hence, the third and fourth elements of the operating performance framework employed in this study refer to production planning i.e. production control and production coordination practices. Control systems may refer to cost, inventory or quality control systems while coordination systems consider functional integration and how different business functions work together to achieve a common goal (Prajogo et al 2014). If business functions work together, important operating benefits may emerge (Prajogo et al 2014). From a PBV perspective, it is argued that while firms have been implementing production planning practices for decades, and they do not constitute a competitive advantage (Bromiley and Rau 2016), ISO 14001 adopting firms will be able to benefit from superior cost control and internal coordination practices which will lead to operating enhancements in terms of both cost efficiency and time-based efficiency (Lo 2009, Prajogo et al 2014).

Production control practices

As ISO 14001 requires the implementation of sustainable operations practices such as source reduction (Kitzawa and Sarkis 2000), continuous improvement (Sambasivan and Fei 2008) and pollution prevention practices (Melynk et al 2003), it should mean that organisations can devise a production control plan to integrate such practices within existing operations leading to reductions in both raw material consumption and energy consumption (Radonjic, and Tominc 2007). These efficiency gains should translate to reductions in the actual cost of producing or manufacturing their goods and services (Melnyk et al 2003). This is achievable through the removal of excess materials or waste and the more efficient use of energy such as electricity (Sroufe, 2003, Wiengarten et al 2013).

As Bromiley and Rau (2016 p. 102) highlight, organisational practices, as opposed to static resources, have the potential to "systematically change other organisational practices". This is supported by Naveh and Marcus (2005) who note that when a new transferable practice is introduced and utilised on a daily basis, overtime the organisation finds a fit between the ISO standard's rules and the firm's traditional mode of operation. Once an organisation embeds a practice such as waste elimination, and obtains a unique process for performing tasks such as manufacturing, it becomes a potential source of improved operating performance (Peng 2008, Modi and Mishra 2011, Prajogo et al 2014). Hence, from a PBV perspective, a firm's control processes and routines should lead to a culture of waste reduction, energy efficiency and ultimately, cost reductions (King and Lennox 2002, Sroufe et al 2003, Darnall and Edwards 2006, Prajogo et al 2014). Hence, it can be argued:

H3: ISO 14001's waste reduction practices will lead to greater operating efficiency and cost control in manufacturing leading to a decline in manufacturing costs.

Production coordination practices

ISO 14001 aims to instil a company-wide environmental planning strategy. The PBV predicts that performance improvements can stem from "practice interactions" (Prajogo et al 2014, Bromiley and Rau 2016). For example, in relation to an organisation's production cycle, a product may pass through various production stages to convert the product from the raw material stage to the finished product (Prajogo et al 2014). With each production function working together, reducing waste and sharing improvement practices, the time to manufacture the products, from the raw material stage right through to the packaging stage, should also be reduced (Lo, 2009; Prajogo et al 2014). In other words, lead times should be shorter as products spend less time in inventory and production as non-value adding activities are eliminated (Melnyk et al 2003, Sahin and Robinson 2005, Lo 2009). Hence, the time required to convert raw materials into final products (inventory days) should be shorter after ISO 14001 adoption (Melnyk et al 2003). Furthermore, as ISO 14001 also adheres to the manufacturing practices of continuous improvement and source reduction (Kitazawa and Sarkis 2000), this should lead to a decrease in both product defects and the use of harmful materials and chemicals which in turn could impact quality and delivery performance (Lo 2009, Schoenherr et al 2012). Considering the above analysis, the time-based efficiency of production processes should be enhanced, which would be evidenced through a shorter operating cycle. Hence, it can be argued:

H4: ISO 14001's cross functional improvement practices will lead to a shorter operating cycle.

H5: Organisational resources

The PBV predicts that whilst firms cannot achieve a competitive advantage from the introduction of replicable practices, they can still increase organisational efficiency leading to improved profitability. Hence, where firms focus on the implementation of ISO 14001, and engage in practices such as pollution prevention and waste management relevant to their products and processes, they can enhance organisation-wide efficiency over the long-term (Lo et al 2012, De Jong et al 2014). This can be achieved by reducing operating costs, improving productivity, and eliminating unnecessary waste and materials from the production process (Jimenez and Lorente 2001, Lo 2012). In addition, firms adopting ISO 14001 may reduce the risk of corporate fines for breaches of environmental legislation (Nga 2009). These cost savings should lead to an improved profitability (ROA) as the cost of producing the firm's product or service should decline in the long-term (De Jong et al 2014). Hence, it can be argued:

H5: Firms that adopt ISO 14001 will enhance overall organisational efficiency which will lead to a greater ROA post-certification.

3.0 Research methodology

3.1 Event study methodology

The event study methodology was employed to examine the relationship between ISO 14001 and operating performance. An event study is a statistical method of secondary data analysis that allows the researcher to measure the impact of a specific event on the value of a firm (Corbett 2005, Paulraj and De Jong 2011). In this case, the event is ISO 14001 certification and the aim is to assess the impact of ISO 14001's prescribed environmental management practices on firms' operating performance. The basic idea is to find any abnormal return attributed to the event (Hendricks and Singhal 1997). Thus, one would examine firm performance before and after the event for both certified ISO 14001 firms and non-certified firms.

The event study methodology was selected for this study, as there is a strong degree of fit between the objectives of an event study and the overall aim of this research. Firstly, by comparing the performance of ISO 14001 certified and non-certified organisations before and after the event (certification), it can be deduced if the adoption of ISO 14001 leads to any abnormal operating performance. Hence, the event study can establish causality between the variables (Lo 2012). Secondly, the adoption of an event study methodology complements the longitudinal aspect of this study. This is important as the operating benefits gained from ISO 14001 practices i.e. employee training, may only emerge over the long-term (Jacobs and Swink 2011). Finally, Comoglio and Botta (2012) have found that very few firms can quantify the performance benefits of ISO 14001 adoption. As event studies utilise secondary data sources, such as financial datasets, the performance benefits can be tracked and measured quantitatively.

3.2 Sample selection

The first step in the event study process involved selecting the type of firms for inclusion in the study. In terms of this research, the focus was on the manufacturing sector; UK SIC codes 13-32. (See table 1 for sector details). Due to the scale and consumption of manufacturing operations, the worldwide manufacturing sector has the second largest number of ISO 14001 registrations behind the construction sector (ISO 2018). Furthermore, UK and Irish-based manufacturers were selected as they provide a useful base for examining the operating aspects of ISO 14001 as both the UK and Ireland have significant experience with the standard, and registration numbers continue to grow (ISO 2018). The financial data for UK and Irish manufacturers was attained from the UK financial database FAME, which contains financial data for over seven million UK and Irish firms.

3.3 Setting the event study window

After deciding on the event to be analysed (i.e. ISO 14001 certification) and the sample selection, the next step was to set an event time frame. In this case, the proposed study adopts a total time frame of six years: two years before the event (t-2, t-1), the event year itself (t) and finally three years after the event (t+1, t+2, t+3). This allowed the research team to analyse how ISO 14001 implementation impacts the organisation in both the short and long term. The six-year event window has also been adopted in previous studies relating to ISO 9001 (Lo 2009). The decision to examine performance two years before certification is due to the observation that ISO 14001 often takes up to 6-18 months to implement prior to certification (Curkovic and Sroufe 2011). For instance, preparation for certification typically takes place in t-1 (Curkovic and Sroufe 2011). On the other hand, the year t-2 is completely free from the event, and therefore, is used to match certified and non-certified firms' operating performance (refer to Corbett 2005 and Lo 2012 for examples).

In terms of the post adoption time frame, the period of analysis is the event year itself i.e. "t" and three years after the event (i.e. t+1 t+2 t+3). Some studies that have examined the relationship between ISO 14001 and financial performance in the past have opted for a shorter event window post certification (See Lo 2012), however, as the integration of operating practices often takes place over time, a long term event analysis period is preferred (De Jong et al 2014). It is also important to ensure the event period is also free from other events or confounding factors that might skew the data. For example, firms that had adopted other management standards in the six-year time frame such as ISO 9001 or OHSAS 18001 are eliminated from the sample (Lo 2012). Crucially, the dates of any ISO 9001 and/or OHSAS 18001 certifications are often outlined on the digitally uploaded versions of the ISO certificates contained on the sample firms' websites. Hence, these firms can be eliminated if the initial certification date falls within the six-year period of analysis. Additionally, firms that have gone into receivership within the event period are eliminated. Finally, only organisations that are implementing their very first ISO 14001 certification are considered as previous implementations at subsidiaries may skew performance data (Lo 2012).

3.4 Data collection

The third step of the process was to build a dataset by identifying ISO 14001 certified firms and the year of their initial certification. Data was collected on ISO 14001 registrations from an online UK database known as the 'Quality Register'. The Quality Register retains records of UK and Irish firms that are registered for ISO standards such as ISO 9001, ISO 14001 and the British safety (BS) standards OHSAS 18001. In order to find out the year of initial certification however, firm websites were examined to view digitally uploaded versions of each firm's ISO 14001 certificate. Crucially, most ISO 14001 certificates actually display the initial year of certification on the certificate. In the event there was no certificate, the firm's news archives and twitter page were examined to see if the firm had made an announcement relating to the ISO 14001 certification. In some cases, the firm's suppliers/business partners had actually posted the news. If the year of certification could still not be identified, operations managers at the certified firms were contacted by phone/email to find out the year of certification. Any firm that was confirmed not to be ISO 14001 certified during this process, was considered to be a control firm i.e. non-certified.

Once the years of certification were determined for the ISO 14001 certified sample, the sample firms were cross checked in the financial database FAME to ensure there was no missing data and the firm was still in operation. However, only around 60% of firms in the FAME database contain full accounting data for six years or more, so this eliminated many potential firms. In addition, the FAME database only retains ten years of company accounting data so any firms certified before 2004 could not be used. This also eliminated a lot of early adopters from the sample. In the end, 140 ISO 14001 certified firms were included in the sample and 320 non-certified control firms.

The next step involved establishing the operating metrics to be collected for each firm in the sample. Table 2 below outlines the operating indicators employed in this study and also how they were calculated. The final column in table one outlines the supporting academic literature for each indicator.

TAKE IN TABLE 2

3.5 Matching sample and control firms

The next step was to carefully match sample and control pairs based on specific matching criteria. The sample group is made up of firms who experienced the event (i.e. implemented ISO 14001) while the control group is free from the event. Sample and control firms have to be in the same industry with similar firm size and pre-event performance, so as to minimize confounding factors in a particular industry. In addition, each sample firm was paired with a portfolio of control firms that fits the matching criteria so as to avoid performance fluctuations that might happen in a particular control firm. The average ratio of sample to control firms in this study is 1 : 2.28. This is a similar ratio to that of previous event studies (see Lo et al 2009). By examining the average performance of a portfolio of control firms, rather than relying on a single control firm, more reliable results can be obtained (Lo 2009, De Jong et al 2014).

The sample firms and control firms in this study were matched based on three strict criteria. The first criterion was industry SIC code. The second condition was matching firms according to their size as large firms may have more resources available for ISO 14001 implementation. Hendricks and Singhal (1997) use 33-300% of total assets, a factor of three, as the firm size matching criteria. The final criterion was to match on pre-event performance. Barber and Lyon (1996) suggest that this is the most critical factor for event studies. In their research they found that matching by a two digit SIC code and 90-110% pre event performance created the most robust matching groups. In terms of this study, the author followed the approach of Corbett (2005) and De Jong et al (2014) by using a firm's ROA to represent pre-event performance. Sample firms were also matched with control firms on the basis of 90-110% of a firm's ROA (i.e. 10% above or below sample firm performance). In cases where sample firms did not match any control firms based upon the two digit SIC code, 33-300% of total assets and 90-110% ROA, the matching criteria went through a three step process as follows (Naveh and Marcus 2005, Lo 2009):

Step 1: Two digit SIC code + 33-300% Total Assets + 90-110% ROA

Step 2: One digit SIC code + 33-300% Total Assets + 90-110% ROA

Step 3: 33-300% Total Assets + 90-110% ROA

Table 3 presents the matching data for the certified and non-certified firm in year t-2. A separate sensitivity analysis was also conducted and the performance differences between the sample firms and non-certified firms in year t-2 were not statistically significant. Hence, the three step-matching criterion employed in this study was valid. Once the firms were matched and the ratios computed, the next step was to calculate abnormal performance. This calculation is outlined in the forthcoming section (3.6).

TAKE IN TABLE 3

3.6 Abnormal performance calculation

Abnormal performance was calculated by the sample post-event performance (i.e. the actual performance) minus the expected performance.

Expected performance (or normal performance) was calculated by sample pre event performance (i.e. in year t-2) plus the average change of control firm's performance (i.e. from year -2 to year 3). The formula is implemented by Lo (2009) is as follows:

$$AP(t+j) = PS(t+j) - EP(t+j)$$
$$EP(t+j) = PS(t+i) + AVG(PC\ k(t+j) - PC\ k(t+i))$$

Where:

AP = Abnormal performance

EP = Expected performance

PS = Performance of Sample firms

PC= Performance of Control firms

t = Year of ISO 14001 certification

i = Starting year of comparison

j = Ending year of comparison

k= Number of control firms

4.0 Results

This section presents the results of the event study and the metrics associated with the PBV, namely the firm's physical assets (fixed asset turnover), the firm's human capital (employee productivity), the firm's production planning practices (manufacturing cost efficiency (MCE) and the operating cycle) and finally, the sample firms' organisational efficiency (ROA). The results of the cumulative abnormal performance analysis are shown in Table 4 whilst the year-to-year abnormal performance analysis is shown in Table 5. More specifically, Table 4 demonstrates the long-term effects of ISO 14001 implementation shown over a five year period, thus presenting a more complete picture of the performance effects of ISO 14001 adoption. Conversely, Table 5 offers an incremental (year-by-year) perspective of the performance effects of ISO 14001 certification.

TAKE IN TABLE 4

TAKE IN TABLE 5

H1 relates to the sample firms' physical assets or fixed asset efficiency. The cumulative performance results in Table 4 show that there is a positive relationship between ISO 14001 certification and fixed asset turnover post certification. This is evidenced in the period t-2 to t+1 as the t-test result is significant at the 0.1 level (t= 1.85). However, the WSR and the sign test are not significant for this period and the improvements are not statistically significant in any other period shown in Tables 4 and 5. Nevertheless, it can be suggested that ISO 14001 adoption improved fixed asset efficiency post certification when compared to non-adopters. Hence, H1 is supported.

H2 predicted that 14001 certification had a significant impact on a firm's labour productivity. The results shown in Table 4 indicate that the cumulative abnormal productivity levels improved immediately in period t-2 to t. In this period, productivity improved 24.4% compared with control firms in year t-2. Furthermore, the productivity enhancements steadily increased post certification in the period's t-2 to t+1 and t-2 to t+3 and are significant at both the 5% level and the 1% level respectively across all three tests of significance. By year three, productivity improved by 53.3% compared with the control firms in year t-2. Moreover, 67% of all certified firms achieved productivity enhancements in this period. Hence H2 is supported.

H3 predicted that ISO 14001 certification would lead to a decrease in MCE. The results in Table 4 indicate that there was a decline in manufacturing costs as the median (mean) change from (year−2 to year t) was 1.95% (2.92%). This positive change disappeared again temporarily in the period immediately after certification (t to t+1) as manufacturing costs increased (See Table 5). However, in the cumulative years post certification, the manufacturing cost reductions range from 1.71% (1.84%) in the period t-2 to +1 to 2.60% (2.43%) in the period t-2 to t+3. The periods post certification also display higher levels of significance i.e. at the 5% and 1% levels respectively. This is evidence of improved internal manufacturing efficiency over time ultimately leading to a decline in manufacturing costs. Hence, H3 is supported.

In terms of H4, the abnormal performance for the operating cycle significantly improved as was evidenced by a median (mean) decrease of 7.94 (7.91) days in the period before certification (i.e. t-2 to t). Furthermore, the performance improved substantially immediately after certification. For instance, in the period t-2 to t+1 the operating cycle reduced by 16 (15.5) days. In other words, the operating cycle became twice as fast as pre-certification cycle times. Moreover, 64% of sample firms achieved improvements in operating cycle times in this period. This is a significantly positive result as it demonstrates that firms spent less time converting raw materials into products, perhaps due to the elimination of waste, and received payment from customers earlier than non-certified firms. Interestingly, in the period t-2 to t+3, the gains disappointingly almost reverted back to pre-event performance levels i.e. 8.15 (7.99) days. In other words, the speed gains almost disappeared in the long term. It is possible that the law of diminishing returns was at play in this time period (Modi and Mishra 2011). In summary, operating cycle performance improved after certification, albeit with the caveat of diminishing returns in the long run. Therefore, H4 is supported.

Finally, H5 predicted that ISO 14001 should enhance overall organisational efficiency. The results in Tables 4 and 5 demonstrate that ISO 14001 certified firms experienced significant abnormal improvements in terms of ROA when compared to control firms. From the period t-2 to t, (before certification) no significant change is found. However, one year after certification, from t to t+1, we can see that there is a positive change in ROA as shown in Table 5. Furthermore, the cumulative improvements shown in Table 4 appear to be very strong and consistent, based on a longer time frame (e.g. from t-2 to t+3). For instance, the p values are significant at the 0.01 level not only for the period t-2 to t+1 but also for the t-2 to t+3 period. Moreover, the magnitude of the long-term change in ROA is significantly stronger. This shows that there is not only a short-term improvement in ROA, but also a sustained long-term improvement in ROA. Hence H5 is supported.

4.1 Discussion of results

The aim of this research was to examine whether ISO 14001 environmental practices can enhance firms' operating performance. The literature review concluded that there was a gap in the literature in terms of examining the long-term, causal impact of ISO 14001 environmental practices on operating performance. Accordingly, this study employed the PBV (Bromiley and Rau 2016) in conjunction with event study methodology to assess the impact of replicable and transferable environmental management practices on operating performance.

In terms of the aim of the research, the results of H1 to H5 highlight that the adoption of ISO 14001 practices leads to significant increases in operating performance in terms of employee productivity, MCE, the operating cycle, return on assets (ROA) and, to a lesser extent, fixed asset efficiency. In OM terms, the results suggest that transferable environmental practices prescribed by the ISO 14001 standard, increase the efficiency of fixed assets, improve employee productivity and enhance cost control and operating speed (Bromiley and Rau 2016).

Secondly, when examined over time, the operating performance gains are stronger for certain indicators such as MCE, Productivity and ROA, suggesting that environmental practices take time to fully implement and may need to be embedded in daily practice in order to achieve optimal performance in the long-run (Naveh and Marcus 2005, Peng et al 2008, Yin and Schmeidler 2009). The results support the idea that new organisational practices such as environmental training can also enhance similar or existing organisational practices. (Bromiley and Rau, 2016). For example, the long-term enhancements in employee productivity and MCE may be explained by the ISO 14001 operating philosophy which mandates environmental training in waste reduction and continuous improvement practices. Over time this leads to reduced process waste, lower costs and improved employee productivity, and ultimately, improved profitability (ROA) (Russo and Fouts 1997, Delmas and Pekovic 2013).

Interestingly however, some negative side effects of ISO 14001 practices were also evident. The results demonstrate that whilst the sample firms' operating cycle and fixed assets efficiency displayed short-term improvements, these gains diminished in the long-term for these metrics. Hence, evidence of diminishing returns is also observed and the importance of examining the long-term implications of ISO 14001 adoption is also underlined. In terms of fixed asset efficiency, Table 4 shows that performance declined over the longer term (t-2 to t+3). From an OM perspective, Jacobs and Swink (2011) have argued that this may be caused by an over utilisation of fixed assets in previous years ultimately leading to maintenance problems. It may also indicate that the benefits from ISO 14001's practices are very much intangible in nature and stem predominantly from changes in the firm operating philosophy i.e. waste reduction and operating efficiency (Guerrero-Baena et al 2015), as opposed to changes in the firm's tangible fixed asset base such as the introduction of new equipment.

Finally, the results highlight that the operating cycle of certified firms also displayed evidence of diminishing returns in the long-run. Modi and Mishra (2011) argue that a continued focus on efficiency may eventually leave operational resources weakened. An example of this situation may occur where a product's packaging is reduced to a level whereby costs are minimised but the packaging no longer provides adequate protection. In this case, the operating cycle time will increase as the firm will have to deal with product returns, ultimately leading to slower customer payments and operating cycles.

5.0 Implications for theory

The research highlights the utility of the PBV as a theoretical framework for studying the relationship between ISO 14001 adoption and operating performance. Due to the observation that theories such as the RBV are not fully applicable to the study of third-party standards available in the public domain, this presented an opportunity for a study which could examine the causal relationship between ISO 14001 and operating performance. In order to fill this gap in the ISO 14001 literature, a PBV approach was applied to study the impact of ISO 14001 on operating performance (Bromiley and Rau 2014;2016).

Firstly, adopting a PBV facilitated the examination of the performance effects of ISO 14001's transferable environmental practices on operating performance. For example, the results suggest that mandatory ISO 14001 practices such as environmental training, pollution prevention, waste reduction, and production planning (control and coordination practices) each have a corresponding impact on operating performance. Hence, previously overlooked transferable practices can be an important source of operational efficiency improvement, providing support for the PBV. These results also complement recent research by Delmas and Pekovic (2013) who linked ISO 14001 training practices with improved employee productivity, and research by Prajogo et al (2014) that linked ISO 14001 practice effectiveness with greater internal coordination and diffusion across functions.

Secondly, the PBV can also provide insights into the bundles of practices that enhance operating performance. For example, the results suggest that certain practices are more effective at enhancing operating performance than others. More specifically, the results suggest that operating performance improvements are greater when environmental practices are geared towards the implementation of an intangible operating philosophy of continuous improvement as opposed to practices which focus on the modernisation of physical assets (Naveh and Marcus, 2005, Guerrero-Baena et al 2015). This is evidenced by enhanced and sustained long-run performance gains in productivity, (human capital) manufacturing cost efficiency and ROA, as opposed to a decline in fixed asset efficiency in the long-term. This would also suggest that practices geared toward the establishment of environmentally focused production philosophy will see superior gains in operating performance as these practices enhance existing operational practices over time (Bromiley and Rau 2016).

Thirdly, in contrast to frameworks such as the RBV, which focuses solely on competitive advantage, the PBV facilitates the examination of environmental practices on the entire range of performance outcomes i.e. positive, negative or neutral performance (Carter et al 2017). This is important as the results of this study found that the firms' fixed asset efficiency and operating cycle experienced diminishing returns in the long-run. In the case of the operating cycle, it may mean retaining a small threshold for resource slack to ensure production speed remains at optimal levels as a complete reduction of waste leaves the firm open to production shocks (Modi and Mishra 2011). The results also suggest that the strategic deployment and measurement of environmental practices on operating performance is a key condition for the improvement of operating performance, again underlining the importance of adopting a PBV in the OM field (Najmi and Kehoe 2001).

Finally, this research adds to the PBV literature as the study sets a precedent for future studies that aim to examine the impact of management practices or external management standards on firm performance. Moreover, the framework presented in Figure 1, which is based on Bromiley and Rau's (2016) theory building paper, could be incorporated into other practice-based studies. As demonstrated in this paper, the PBV is a robust framework for the study of environmental practices and ISO standards more generally. From a theoretical standpoint, the application of the PBV allows the researcher to not only examine the impact of imitable and transferable practices on performance but also facilitate the study of the wider operating implications of a practice or process such as diminishing returns. Hence, the research in this paper has shown that the PBV can add new insights into the study of management practices and the OM field more generally, and has real value as an alternative theoretical framework for the study of transferable practices (Carter et al. 2017).

5.1 Implications for management

Management should be aware that the ISO 14001 has performance benefits that extend far beyond mere marketing benefits. More specifically, the results suggest that external third-party standards such as ISO 14001 can enhance operating performance by implementing operating practices which create a philosophy of waste reduction and continuous improvement. (Heras-Saizarbitoria et al 2011). In this sense, management should incorporate ISO 14001 alongside a culture of cost control and collaboration amongst business functions as the results here suggest the integration and diffusion of ISO 14001 environmental practices can help build operating capabilities which lead to both cost efficiency gains and operating speed gains. A recognised weakness of ISO 14001 implementation models is the lack of measurement capabilities for financial, operational and environmental performance (Comoglio and Botta 2012). The operating model applied in this study employs fixed asset efficiency, employee productivity and ROA, which can be used by management to measure post-certification performance. Finally, owing to the flexibility of the PBV, the ISO 14001 sample included firms from a wide variety of manufacturing industries, hence the results are of relevant to organisations operating in a wide variety of manufacturing sectors.

Limitations of research

The first limitation of this study relates to the researcher's access to older accounting data. As the FAME database only retains financial data for 10 years, the researcher could not examine the relationship between the early adoption of ISO 14001 and firm performance. A further limitation of this study relates to the observation that the researcher had no access to firm level emission data for UK and Irish firms. This is due to the observation that such a database does not yet exist in the UK and Ireland. On the other hand, the EPA (Environmental Protection Agency) in the USA is able to retain emission data for individual firms. Hence, it is important that a similar database be developed in the UK to further research in this area. While some firms do tend to report emission data in their annual reports in the UK, this data is largely fragmented and lacks consistency needed for longitudinal analysis.

Recommendations for future research

This study highlighted that ISO 14001 has a positive impact on what can be termed as the 'intellectual elements' of firm performance. For example, ISO 14001 enhanced the productive performance of human capital and the results also suggested that ISO 14001 enhanced intangible operating processes such as cost control and operational coordination. Hence, future research could examine the relationship between ISO 14001 practices and intellectual capital as ISO 14001 may have important benefits for human, relational, process and innovation capital (Guerrero-Baena et al 2015). Secondly, recent research relating to the quality standard ISO 9001 has set about examining the contextual factors that impact the efficacy of standard in relation to firm performance (Lo et al 2013). A similar approach could be taken for ISO 14001. At the firm level, factors that could affect the efficacy of ISO 14001 certification could include organisational structure. Thirdly, Carter et al (2017), recently developed a supply chain management -PBV framework. However, rather than focusing on the distinct differences between the RBV and the PBV, Carter et al (2017) argue that the SCPV complements the PBV, as well as the RBV and relational view and the aforementioned perspectives can exist as a continuum. Hence, future studies could incorporate this framework in their research. Finally, future studies could examine the impact of the EU's environmental standard EMAS and the effects of EMAS implementation on operating performance (Comoglio and Botta, 2012).

6.0 Concluding remarks

The results of this study demonstrate that the ISO 14001 standard has benefits that extend far beyond corporate legitimacy gains. This was evidenced by improved operating performance when compared to non-adopters. Additionally, from a PBV perspective, the results of the study demonstrate that transferable and replicable environmental practices can be a source of improved operating performance. Conversely, in the case of fixed asset efficiency and the firms operating cycle, performance was shown to diminish in the third year following certification. Therefore, it is recommended that management retain a limited threshold for operational slack to offset any production difficulties, which may be hampering long-term operating cycle performance. Finally, the study underlines the importance of performance measurement in order to avoid the prospect of diminishing returns.

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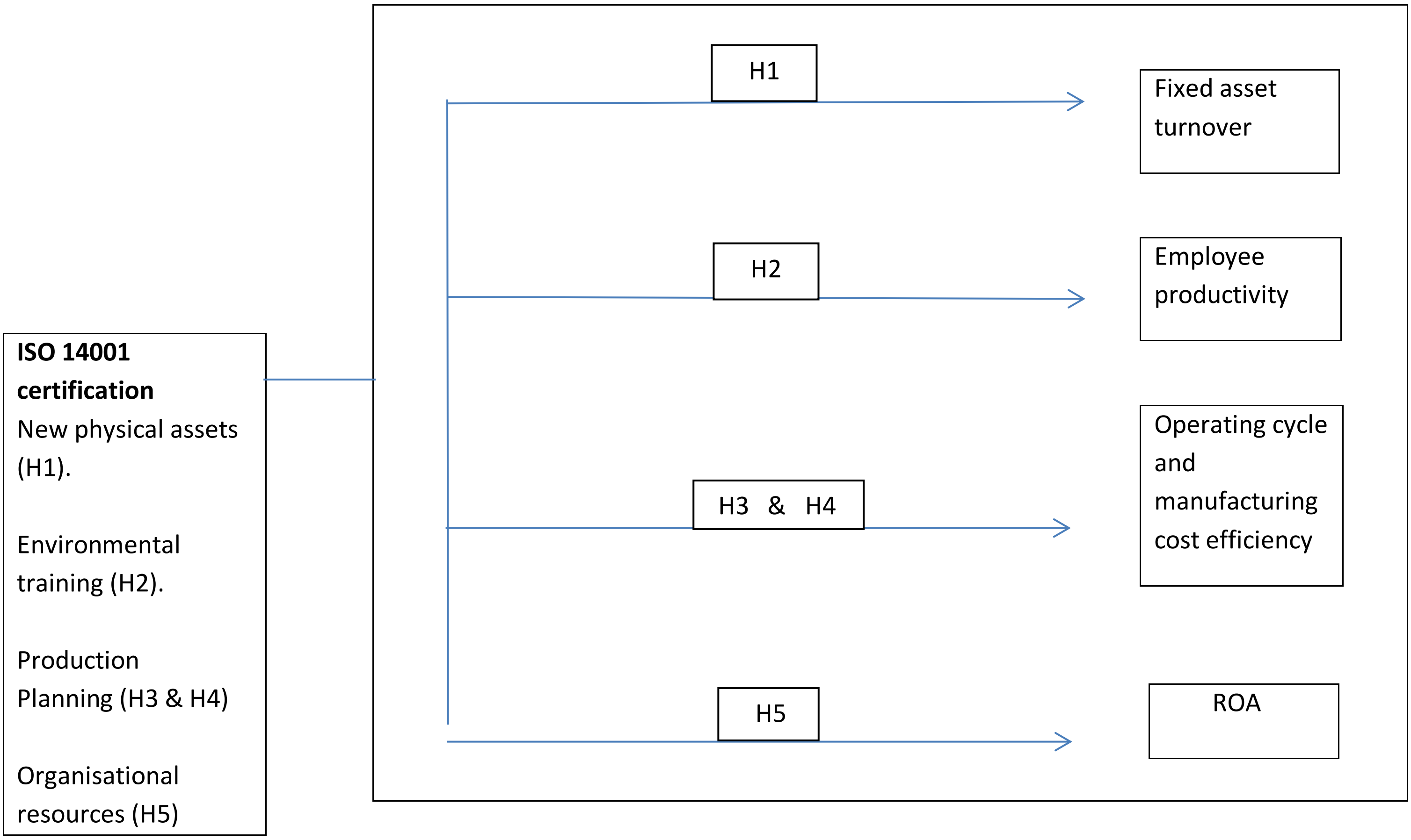

Figure 1. A practice-based model of ISO 14001 certification and operating performance

Year of Certification (t)	% of sample	**Year of company Inception**	% of sample	**Manufacturing sector**	% of sample
2003	10%	Pre-1970	47%	Computer, electronic and optical	17%
2004	20%	1970's	22%	Machinery and equipment	14%
2005	24%	1980's	13%	Electrical equipment	10%
2006	25%	1990's	15%	Chemical	13%
2007	21%	2000's	3%	Rubber and Plastics	7%
				Fabricated metal	19%
				Automotive	4%
				Other manufacturing	16%

Table 1. 14001 sample firm details

Practice type and hypothesis link	**Indicator**	**Formula**	**Supporting references**
Physical assets H1	Fixed asset turnover Ratio	$\frac{\text{Sales}}{\text{Fixed assets}}$	Brown et al 2004, Jiang et al 2006.
Human capital H2	Employee productivity	$\frac{\text{Operating income}}{\text{Number of employees}}$	Edvinsson and Malone 1997, Lo 2014.
Production Planning (1) Cost control H3	Manufacturing cost efficiency	$\frac{\text{Cost of goods sold}}{\text{Sales}}$	EIRMA 2004, Corbett 2005, Lo 2007, De Jong 2014.
Production Planning (2) Coordination Three part calculation involving inventory days and debtor days H4	Debtor days	$\frac{\text{365 (Days)}}{\text{Accounts receivable ratio}}$	Eskew and Jensen 1996, Lo 2009.
	Inventory days	$\frac{\text{365 (Days)}}{\text{Inventory turnover ratio}}$	Eskew and Jansen 1996, Lo 2009.
	Operating cycle	Debtor days + inventory days	Lo 2009.
Organisational resources H5	Return on assets	$\frac{\text{Operating income}}{\text{Total assets}}$	Corbett 2005, Naveh and Marcus 2005, Lo 2012, De Jong 2014. Su et al 2015.

Table 2. Computation of operating indicators

Indicator	N	Mean	Median	St. dev	Min	Max
ISO 14001 certified firms						
Fixed asset Turnover %	138	9.67	5.92	14.22	0.82	143.1
Employee Productivity (£ k)	136	10625.33	6570.37	16599.24	-30674	145514.28
Manufacturing cost efficiency %	117	69.44	70.44	11.13	34.81	89.78
Operating Cycle (Days)	137	112.2	109.7	35.5	25.1	270.1
ROA %	143	10.13	8.25	10.49	-11.4	79.54
Control firms						
Fixed asset Turnover %	138	10.91	7.68	11.41	0.73	90.41
Employee Productivity (£ k)	136	13871.68	9274.08	21520.65	-38048.	153722.22
Manufacturing cost efficiency %	117	67.89	69.52	11.34	22.39	93.08
Operating Cycle (Days)	137	115.77	114.11	29.11	20.04	210.69
ROA%	143	10.03	8.61	10.30	-11.70	78.98

N: number *St. dev: standard deviation*

Table 3. Descriptive statistics of pre-certification performance in year (t-2)

Pre-certification (year −2 to year 0) Post certification (year −2 to

year +1) Full event window (year −2 to year +3)

	N	Median	Percentage	Mean	N	Median	Percentage	Mean	N
Fixed asset turnover %	139	2.71	50.3%	0.48	138	3.81	50.3%	1.06	138
Statistic		1.47	-0.51	1.47		-0.37	0.00	1.85*	
Employee Pro (£ k)	141	2605.97	58.8%	3396.50	141	5355.82	59.5%	4508.30	140
Statistic		-2.19*	-2.02*	1.84+		-2.12*	-2.19*	2.11*	
Cost efficiency %	118	-1.58	55%	-1.85	118	-1.71	56.7%	-1.84	118
Statistic		-1.74+	-1.10	-1.89+		-1.97*	-2.03*	-1.98*	
Operating cycle (days)	138	-7.94	52.8%	-7.91	138	-16.0	64.4%	-15.5	137
Statistic		-1.91*	-0.59	-2.42*		-4.67**	-3.32**	-4.12**	
ROA %	144	1.47	56.25%	1.58	144	4.02	61.8%	3.83	144
Statistic		-1.72+	-1.41	1.43		-3.16**	-2.75**	3.41**	

Note: Z-statistics for WSR test (median) and sign test (percentage), t-statistics for t-test (mean). Percentage indicates the percentage of firms achieving positive abnormal changes in fixed asset efficiency, employee productivity, MCE, the operating cycle, and ROA

+Note a statistically significant difference from 0 at 0.1 level (two-tail).

*Note a statistically significant difference from 0 at 0.05 level (two-tail).

**Note a statistically significant difference from 0 at 0.01 level (two-tail).

Table 4. Results of sample firms' cumulative abnormal performance

	(year −1 to year 0)				(year 0 to year +1)				(year +1 to year +2)			
(Year t+2 to t+3)	N	Median	Percent	Mean	N	Median	Percent	Mean	N	Median	Percent	
Mean	N	Median	Percent	Mean								
Fixed asset t/o	139	0.94	49.1%	-0.62	139	1.10	51.7%	0.57	138	1.07	52.8%	1.39
Statistic		-0.42	-0.33	0.52		-0.06	-0.33	0.84		-0.32	-0.59	0.90
Employee Prod.	141	1085.5	50.3%	2467.5	140	2749.8	49.6%	1111.8	140	-1456.0	50.7%	-112
Statistic		-0.59	1.00	0.65		-0.96	0.00	0.89		-0.15	-0.08	-0.66
Cost efficiency	118	-0.98	52.5%	-1.12	118	-0.12	50%	0.01	118	-0.75	55%	-0.73
Statistic		-1.06	-0.55	-1.80+		-0.26	0.00	-0.68		-1.51	-0.92	-1.25
Operating cycle	138	-0.55	50.7%	-1.74	138	-8.06	57.9%	-7.52	138	5.17	44.2%	4.09
Statistic		-0.53	-0.08	-0.19		-2.65**	-1.78+	-3.02**		1.10**	-1.27	-2.61
ROA	144	0.07	48.6%	-0.05	144	2.54	54.8%	2.24	144	-0.29	50%	0.14
Statistic		-0.41	-0.25	0.06		-1.95*	-1.08	2.04*		-0.28	0.00	-0.21

Table 5. Results of sample firms' year-to-year abnormal performance