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THE SAME ASSETS, BUT NEW IMPACTS: IT-ENABLED COORDINATION AND ENVIRONMENTAL PERFORMANCE

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Abstract

In this paper we analyze the effect of information technologies (IT) on the environmental performance of firms. In particular, we study the moderating effect of IT on the relationship between a firm's environmental practices and its environmental performance. The paper considers two moderating effects –namely, IT-enabled coordination and IT-enabled control. IT-enabled coordination refers to the integration of processes and the sharing of information between a firm and its suppliers in design and manufacturing. IT-enabled control refers to the use of IT to monitor the environmental practices that a firm implements in production and logistics. The data used were obtained from the fifth (2009) round of the International Manufacturing Strategy Survey (IMSS) which includes responses from manufacturing plants within the assembly industry. Our findings suggest that IT-enabled coordination strengthens the impact of the implementation of environmental practices on the environmental performance of firms. A relevant contribution for practice is derived from this study: firms can use the same technologies (ERP, shared databases) that they once implemented to improve their operational performance to improve the environmental performance.

Keywords: Green IS, IT-enabled control, IT-enabled coordination, environmental practices, environmental performance.

1 Introduction

Information Technologies (IT) can help drive the transformative agenda towards a low-carbon, resource light economy (EU-SUST, 2011). There are two main research streams in the Information Systems (IS) literature that study the contribution of IT to reducing firms' energy footprint (Jenkin et al., 2011). The first stream, called 'Green IT' focuses on how to redesign the hardware, networks and their components in order to reduce the amount of waste and energy consumption throughout their life cycle. The second stream, called 'Green IS', looks at the indirect impact that IT can have on environmental sustainability through the improvement of supply chain activities such as manufacturing, inventory management and transportation.

The Operations Management (OM) literature has a long tradition in the study of sustainability. In particular, OM scholars have extensively examined the impact of environmental practices –i.e. products' eco-design, environmental audits, routes distribution, waste management and recycling– on environmental performance –i.e. the accomplishment of environmental goals such as the reduction of GHG emissions, or savings on energy or water consumption– (Azzone and Noci, 1996, Dobos and Floriska, 2007, Zhu and Sarkis, 2004, Zhu et al., 2005). This literature suggests a positive direct effect of environmental practices on environmental performance. Although 'Green IS' scholars acknowledge the importance of IT for improving firms' environmental performance by shaping their operational and supply chain activities, no research has considered the interrelation between supply chain environmental practices, IT and environmental performance. This paper addresses this gap by showing that IT has a moderating effect on the relationship between environmental actions and firms' environmental performance.

The findings from this paper contribute firstly to the IS field by providing an empirical evidence of the indirect impact of IT on the environmental sustainability of the firm. In particular, we show the moderating effect of IT-enabled control and coordination over the relation between environmental practices and environmental performance. Secondly, this paper also contributes to practice. We show that a firm can use its current IT assets (ERP, shared databases) to improve not only its operational performance through better coordination and control of its operations, but also the environmental performance.

This paper is structured as follows. We first review the literature on sustainable operations and the literature that has studied the impact of IT on environmental performance. We then present our research model and develop two hypotheses. Next we present the methodology used. Next, we present and discuss the results. Finally, we end with some implications and concluding remarks.

2 Literature review and hypotheses development

2.1 The impact of environmental practices on environmental performance

The OM field has a strong tradition of doing research about environmental practices such as waste reduction, pollution reduction, energy efficiency, emissions reduction, consumption of hazardous/harmful/toxic materials, frequency of environmental accidents, etc. For instance, O'Brien (O'Brien, 1999) pointed out that environmental considerations have to be integrated into the corporate culture and business planning at all levels of design, manufacturing, distribution and disposal.

In the literature, numerous articles examine the impact of different practices (design, manufacturing, distribution and recycling) on environmental performance. For example, Azzone and Noci (Azzone and Noci, 1996) developed an approach to evaluate the environmental performance of new products. With respect to manufacturing processes, Rothenberg et al. (Rothenberg et al., 2001) and King and Lenox (King and Lenox, 2001) studied the interaction between lean initiatives and environmental performance. Regarding logistics, Quariguasi Frota Neto et al. (Quariguasi Frota Neto et al., 2008) developed a framework for the design and evaluation of sustainable logistics networks in which profitability and environmental impacts are balanced. Finally, other authors have analysed the economic impact of recycling practices (e.g., Dobos and Floriska, 2007). Although all these help to improve environmental performance, de Ron (de Ron, 1998) pointed out that companies need to implement environmentally-friendly production by considering not only the activities within their own factory but within the entire production chain. Following this recommendation, some authors have extended their framework of analysis to the supply chain (e.g., (Corbett and Klassen, 2006, Koh et al., 2011, Rao, 2002, Vachon and Klassen, 2006, Vachon and Klassen, 2008, Zhu and Sarkis, 2004).

Prior OM literature has drawn upon the natural resource base view (Aragon-Correa and Sharma, 2003, Hart, 1995) to link environmental practices to environmental performance. Empirical studies such as Rao (Rao, 2002), Zhu and Sarkis (2004) and Zhu et al. (2005) have found that the adoption of environmental practices (e.g. waste management, environmental management systems, total quality environmental management, design of environmentally-friendly products, etc.) leads to better environmental performance. Accordingly, we hypothesize that:

H1. Firm's environmental practices have a positive impact on environmental performance.

2.2 The impact of IT on environmental performance

Scholars within the 'Green IS' research stream argue that IT can enhance environmental sustainability through energy eco-efficiency as well as through instilling changes in the behaviour and actions of organizational actors about the environmental sustainability of the firm activity. On the one hand, IT improves energy eco-efficiency because it integrates, systematizes, and captures data and meta-data (i.e., temperature, geographical location) that allow the firm to optimize transport routing (Chen et al., 2008, Erdmann et al., 2004, Melville, 2010), and energy management in housing and facilities (Erdmann et al., 2004). On the other hand, IT instils changes in our behaviour and actions by making visible indicators which encourage organizations to commit to sustainability actions (Bengtsson and Agerfalk, 2011) and by providing information to the employees about their footprint in the environment (Jenkin et al., 2011). However, IS research has not empirically studied the effect of IT on the firms' environmental performance. Most of the research done so far about the impact of IT on environmental performance or sustainability enhancement has been mainly conceptual.

Furthermore, Supply Chain Management (SCM) scholars that have studied the impact of environmental actions in firms' environmental performance argue that collaboration with members of the supply chain can help to reduce the overall impact of the firm on the environment (Klassen and Vachon, 2003). In this sense, Geffen and Rothenberg (Geffen and Rothenberg, 2000) found that strong partnerships with suppliers and the members of the suppliers' staff were successful elements in the application of innovative environmental technologies. Similarly, Vachon and Klassen (Vachon and Klassen, 2008) claimed that joint planning and knowledge sharing about environmental matters have a positive effect on firms' environmental performance. Moreover, Handfield et al. (Handfield et al., 1997) found that environmental strategies are more likely to be successful when they are integrated across the stages of the supply chain (i.e. procurement, product design, manufacturing, etc). In short, collaborative activities, information sharing, and the integration of different processes along the supply chain are expected to enhance the performance of environmental strategies, projects or technologies.

Although environmental practices enhance the environmental performance of the firm, we hypothesize that this effect is amplified when the coordination and monitoring of those environmental practices is enabled by IT. Hence, the improvements in the monitoring (or control) and the coordination of operations facilitate the deployment of integrative environmental practices as it will easier to assess the impact of the latter on the overall environmental performance of the firm. For instance, IT-enabled control and coordination of environmental practices will enable the anticipation of side effects from those practices that hinder the overall environmental performance, and hence managers will be able to adapt or correct those environmental practices accordingly. Therefore, we hypothesize that:

H2: IT-enabled control and coordination moderates the relationship between firms' environmental practices and environmental performance.

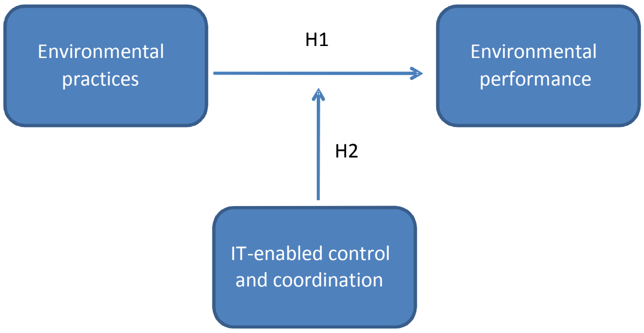


Figure 1: Theoretical model and hypotheses

3 Methods

3.1 Sampling and data collection

To test the hypotheses presented above, we used data from the fifth (2009) round of the International Manufacturing Strategy Survey (IMSS-V). IMSS is carried out by an international network of manufacturing strategy researchers in more than 20 countries. It studies manufacturing and supply chain strategies within the assembly industry (ISIC 28-35 classification). The criteria for selecting firms for the survey were: their financial and competitive strengths, their sensitiveness and ability to adopt a variety of advanced manufacturing practices, and because they are among the first to bring in technological advances (http://www.manufacturingstrategy.net). Questionnaires were administered simultaneously in each country by local research coordinators. They were mailed or e-mailed to the Director of Operations/Manufacturing or the person with the equivalent position in the organization, because he/she is best suited to self-report the decisions made regarding the operations strategy and the results of the environmental practices implemented.

The IMSS-V sample consists of 678 manufacturing plants from 19 countries, with an average response rate of 18.3%. For the purposes of this study, we considered responses from those countries with at least 30 responses in order to be able to apply Generalizability theory: Brazil, China, Germany, Hungary, Italy, Spain and USA.

Non-response bias tests were performed in each country by the local research coordinators. No noticeable pattern among the variables that could indicate the existence of a non-response bias was found. Also, since each questionnaire was filled in by only one respondent at a single point in time, common method bias (CMB) could be regarded as a concern (Podsakoff *et al.,* 2003)..Therefore, in the design of the study, some actions were taken to consider CMB (Conway and Lance, 2010): (1) respondent anonymity was protected; and (2) the items of interest were distributed in different sections of the questionnaire (i.e. some questions were in the operational performance section, some were in the quality section and others were in the supply chain practices part).

3.2 Measures

The items of IMSS questionnaire are divided into various sections, starting with some general information (size, industry, etc.) and then focusing on different strategies, programmes (organisational, lean, quality, supply chain, etc.) and performance. The items employed to measure environmental practices were the ones that include environmental actions aiming to improving the environmental performance of products and processes (following Zhu and Sarkis, 2004 and Zhu et al., 2008) and actions to improve the environmental impact generated by transportation of materials/products (following the Business Guide to a Sustainable Supply Chain published by the New Zealand Business Council for Sustainable Development, 2003).

Regarding IT, we used indicators of enablers of coordination and control: the use of Enterprise Resource Planning (ERP) systems and shared databases to coordinate design and manufacturing, the implementation of product/part tracking and tracing programmes (bar codes, RFID) and IT supporting information sharing and process control in production. An Exploratory Factor Analysis (EFA) revealed that two constructs had to be used to measure IT: IT-enabled control and IT-enabled coordination.

Although previous studies have considered constructs with multiple items, the team of researchers responsible for designing the IMSS questionnaire decided to measure environmental performance using a single item ("environmental performance"). The item selected has been previously used in the literature (e.g. (Pullman et al., 2009)). Although using single items to measure environmental performance may be a limitation of this study, the team's need to keep the IMSS questionnaire to a reasonable length made the researchers select only the most relevant item. Thus, this item measures the environmental performance improvement compared to three years ago.

3.3 Reliability of measures

We applied Generalizability theory, or G-theory (Cronbach et al., 1972), to examine the generalizability of the scales developed, and to measure latent constructs across groups of interest. It is essentially an approach to the estimation of measurement precision in situations where measurements are subject to multiple sources of error. In our design we consider three different factors or facets (using the G-theory nomenclature): Items (I) in each scale, countries (C) and subjects in each country (S). The items and countries are completely crossed facets here because subjects in each country respond to the same items. The subject facet, however, is nested within country. Such, a design consisting of both nested and crossed facets, is referred to as a mixed design. We used the MIXED procedure for estimating variances. This procedure assumes equal sample sizes across groups. For unequal sample sizes, the various sources of variation are not orthogonal and the variation of each source may be confounded with other sources (Malhotra and Sharma, 2008). Given that multi-facet analysis requires a balanced design, random sampling within country was used to achieve an equivalent sample size of 30 in each country for analysis purposes. The results supported the generalizability of the measures in Brazil, China, Germany, Hungary and USA. Spain and Italy had to be disregarded for further analysis as the results of G-theory did not support the generalizability of the meausures in these two countries. In Appendix 2 we provide the results of the G-theory analysis. The overall generalizability coefficient (GC) for each scale is equal to 0.84, 0.73 and 0.76 which are quite high (Rentz, 1987), thus lending support to the generalizability of these scales across Brazil, China, Germany, Hungary and USA. The reliability of each scale (Cronbach alpha) is also above the benchmark value of 0.70.

4 Data analysis and results

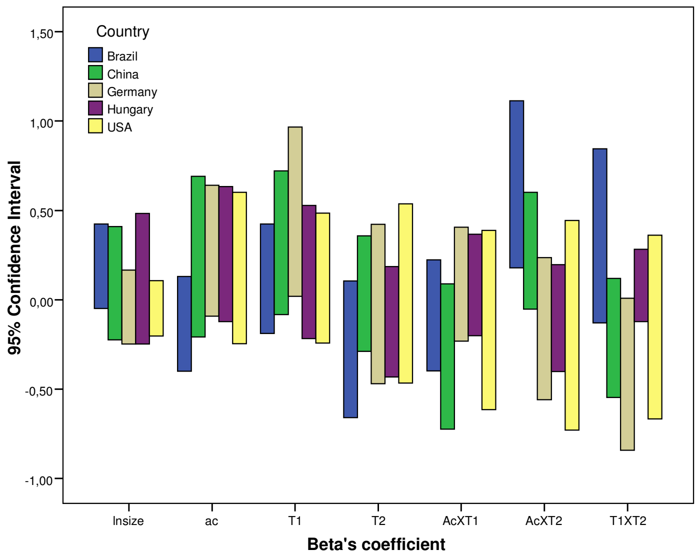
We used hierarchical regression to analyse our model. The underlying assumptions of regression analysis – linearity, homocedasticity, normality and independence of errors – were tested to ensure that there were no serious violations of these assumptions. We used the firm's size as control variable and environemtal practices, IT-enabled control and IT-enabled coordination as independent variables. The results of the regression analyses are presented in Table 1.

In the first step, we entered the control variable. The results show that size has a statistically significant effect on environmental performance and explains 2.3% of its variance. The addition of environmental practices as predictor in the second step explains a significant amount of additional variance (change in R^2= 24.8%). The F statistic for the regression is significant ($p \leq 0.001$), and the adjusted R^2 is 26.8%. The independent variable of interest in this step is environmental practices, which is positively and significantly associated to environmental performance ($p \leq 0.001$), providing support for hypothesis H1.

In the third step of our analysis, the addition of the IT-enabled control and IT-enabled coordination explains an additional variance in environmental performance of 5.3%. The F statistic for the regression is significant ($p \leq 0.001$), and the adjusted R^2 is 31.2%. The environmental practices construct remains statistically significant ($p \leq 0.001$) with a positive impact on environmental performance. Regarding the IT constructs, only IT-enabled control has a statistically significant and positive effect on environmental performance ($p \leq 0.05$).

Finally, in the fourth step, the interaction terms were included. The addition of these variables marginally explains an additional variance of 3.1%. The F statistic for the regression is significant ($p \leq 0.001$), and the adjusted R^2 is 33%. The environmental practices construct remains statistically significant ($p \leq 0.001$) with a positive impact on environmental performance. Regarding the IT constructs, both IT-enabled control and IT-enabled coordination have a statistically significant and positive effect on environmental performance ($p \leq 0.05$ and $p \leq 0.10$, respectively). However, only the interaction of IT-enabled coordination and environmental practices is statistically significant ($p \leq 0.05$). Therefore, hypothesis H2 is partially supported. We can only support the moderating effect of IT-enabled coordination on the relationship between environmental practices and environmental performance. This result provides evidence that IT strengthens the impact of environmental practices on environmental performance.

We checked for multicollinearity in our model, and the tolerance of the estimators ranges from 0.851 to 1. This allows us to make inferences about the direct effect of the variables included in the model on the dependent variable. Furthermore, we performed the correlation between the residuals of the step 4 of the regression and industry in order to see if there was any pattern across industries that had not been included in our model. The results showed that there is no pattern across industries. Additionally, we tested for differences among the estimators of the regression across countries (see figure 2). We found that there are no differences among the countries of our sample.



ac: environmental practices; T1: IT-enabled control; T2: IT-enabled coordination

Figure 2: Environmental. 95% confidence interval for the beta's coefficients

Table 1: Impact of environmental practices and IT-enabled control and coordination on environmental performance

	Step 1			Step 2			Step 3			Step 4		
	Beta Coeff	SE	T-Stat	Beta Coeff	SE	T-Stat	Beta Coeff	SE	T-Stat	Beta Coeff	SE	T-Stat
Firm size	0.097**	0.045	2.13	0.041	0.04	1.02	0.003	0.041	0.07	0.01	0.041	0.25
Env actions				0.462***	0.065	7.1	0.468***	0.063	7.41	0.433***	0.064	6.77
IT-enabled control							0.192**	0.064	3.00	0.205**	0.065	3.16
IT-enabled coord							0.101	0.062	1.64	0.112*	0.061	1.83
Env.act x IT-enabled cont										0.022	0.063	0.34
Env.actX IT-enabled coord										0.139**	0.058	2.38
IT-enabled control X IT-enabled coord										-0.083	0.06	-1.37
F-stat	4.540**			28.25***			17.91***			11.47***		
Adjusted R^2	0.023			0.268			0.312			0.330		
ΔR^2	0.300			0.248			0.053			0.031		

Note: ***p ≤ .001. **p ≤ .05, and *p ≤ .10

5 Discussion and Conclusions

Our results show that environmental practices have a positive impact on environmental performance thus corroborating the findings from the OM literature (Rao, 2002, Zhu and Sarkis, 2004, Zhu et al., 2005). This means that the implementation of environmental practices (i.e. designing products taking into account their environmental impact, considering the environmental impact of production, manufacturing and logistics) leads to improvements in the environmental performance of the firm.

Regarding the moderating effect of the use of IT, our results show that IT-enabled coordination (through process integration) strengthens the impact of environmental practices on environmental performance. On the other hand, IT-enabled control (through visibility and information sharing) does not moderate the effect of environmental practices on environmental performance. The integration of processes enabled by ERP and shared databases increases the impact of environmental practices on environmental performance. However, the implementation of RFID, bar codes and other technology supporting information sharing, although contributing to improve the environmental performance of the firm (because they have a positive direct effect on environmental performance), does not enhance the impact of environmental practices on environmental performance. From these results it can be concluded that information visibility does not improve the effect of environmental practices unless this information is used by the different functional areas involved in the implementation of the environmental practices. It is the use of IT for coordination and not simply the availability of information what enhances the impact of environmental practices on environmental performance.

This paper tries to make some contributions to research and practice. Firstly, we contribute to the limited literature on 'Green IS' with an empirical study that provides evidence of the indirect impact of IT on the environmental sustainability of the firm. In particular, we show the moderating effect of IT-enabled coordination over the relation between environmental practices and environmental performance. Secondly, this paper contributes to practice. We show that existing IT assets (ERP, shared databases) can be used not only to improve the operational performance of the firm through better coordination and control of its operations, but they can also contribute (directly and indirectly) to improve the environmental performance.

The results presented should be considered exploratory for the following reasons: the IT-enabled control and IT-enabled coordination factors need to be validated in future empirical research. The outcome variable was measured with a single item, this could be a problem because it does not allow capturing much variation of the phenomenon studied, and certain effects may be simplified or not visible. Thus objective measures for environmental performance are recommended for further research. Finally, the sample size may be a problem for the stability of the estimations obtained. Therefore future studies should take larger samples.

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Appendix 1

Table A1. Variables

Environmental action programmes[a]
Improving the environmental performance of processes and products (e.g., environmental management system, Life-Cycle Analysis, Design for Environment, environmental certification)
Improving the environmental impact of products through appropriate design measures, e.g., design to recycle
Improving the environmental impact generated by transportation of materials/products and outsourcing of process steps
IT-enabled coordination[b]
Using enterprise resource planning (ERP) systems to coordinate the design and manufacturing
Using shared databases to coordinate the design and manufacturing
IT-enabled control
Engaging in product/part tracking and tracing programmes (bar codes, RFID)
Implementing ICT supporting information sharing and process control in production
Performance[c]
Environmental performance
Control variables
Size (number of employees)
Industry classification
Country

[a] In the questionnaire, these action programmes were measured as the effort dedicated over the last three years. A 1-5 Likert scale was used in which 1= None and 5= High.

[b] Level of use to technologically coordinate design and manufacturing, being 1= no use and 5= high use.

[c] In the questionnaire, performance was measured as performance changed over the last three years. A 1-5 Likert scale was used in which 1= Compared to three years ago, the indicator has deteriorated more than 5%, and 5= Compared to three years ago, the indicator has improved more than 25%

Appendix 2

Table A2. Generalizability theory results

Source of variance	Variance component	% of total variance	G index	Reliability
Country	0.112	6.64%		
Dimension	0.230	13.59%		
Subject: country	0.338	20.00%		
Item: dimension	0.015	0.88%		
Subject: country * dimension	0.361	21.32%		
Item: dimension * country	0.017	0.98%		
Country * dimension	0.045	2.68%		
Error	0.574	33.91%		
Total	1.692	100.00%		
Environmental practices			0.84	0.80
Country	0.226	16.31%		
Item	0.036	2.63%		
Subject: country	0.553	39.93%		
Country * Item	0.007	0.51%		
Error	0.563	40.63%		
Total	1.386	100.02%		
IT-enabled control			0.73	0.73
Country	0.137	9.25%		
Item	0.000	0.00%		
Subject: country	0.717	48.29%		
Country * Item	0.032	2.13%		
Error	0.598	40.32%		
Total	1.484	99.98%		
IT-enabled coordination			0.76	0.75
Country	0.084	5.57%		
Item	0.000	0.00%		
Subject: country	0.828	55.07%		
Country * Item	0.020	1.36%		
Error	0.571	37.98%		
Total	1.503	99.98%		