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# Assessing the role of IT-enabled process virtualization on green IT adoption

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**Abstract** Green Information Technology (IT) tools and practices contribute to environmental sustainability and business processes virtualization. To assess whether IT-enabled process virtualization capabilities impact organizational Green IT initiatives, Bose and Luo 2011 proposed a conceptual model that combines three theories: technology-organization-environment framework, process virtualization theory, and diffusion of innovation theory. We conducted an empirical analysis of data from 251 European firms, and found that environment context (competition intensity and regulatory support) was more important to Green IT initiatives than organization or technology context. Technology factors (sensory readiness, relationship readiness, synchronism readiness, and identification and control readiness) facilitating process virtualization were not found significant to organizational Green IT initiatives.

**Keywords** Green IT · Process virtualization · Technology-organization-environment (TOE) · Process virtualization theory (PVT) · Diffusion of innovation (DOI)

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## 1 Introduction

With the growing consumer preference for goods and services that align with social and environmental benefits, there is a heightened drive among businesses to incorporate sustainability initiatives as an important strategic directive. Information technology (IT) resources (i.e., hardware platforms and network components, software applications, and hosting environments) are a major source of carbon emission and energy consumption. Corporate sustainability initiatives thus increasingly recognize the importance of incorporating IT tools and practices that are environmentally sustainable and ecologically friendly (Dao et al. 2011a; Murugesan 2008; Sang-Hyun et al. 2012). Green IT is the use of IT resources in an energy-efficient and cost-effective manner (Bose and Luo 2011). It offers value added return on investment via cost saving, reduced risk, increased revenue, and brand value (Esty and Winston 2006). Building environmental thinking into the business strategy is not only economically compelling, but also meaningful in ensuring social responsibility and environmental integrity (Bansal 2005; Cai et al. 2013; Hertel and Wiesent 2013). As a result, Green IT initiatives are becoming common in organizations across differing industries (Jain et al. 2011).

Among the various business transformations brought forth by information technology (IT), process virtualization is one of the most recognizable and widely implemented business practices of the recent years (Overby et al. 2010). Process virtualization is the transformation of a physical process involving the interactions of humans, objects, and social structures to a virtual process (Overby et al. 2010). Online shopping, mobile banking, maintaining friendship via social media, and distance learning are some examples of virtual processes that parallel or replace processes that traditionally took place in a physical environment. Innovative technology (Harris 2008), competitive pressures (Chou and Chou 2012), and globalization (Liu et al. 2008) have resulted in the proliferation of virtual processes. In an effort to attain operational, tactical, and strategic advantages over competitors, companies increasingly redesign business processes as virtual processes (Harris 2008; Jenkin et al. 2011). Overby 2008 points out that the extent to which a process is amenable to being conducted virtually depends on the representation, reach, and monitoring capabilities provided by IT.

Redesigning business processes, as viable IT-enabled virtual processes are not just limited to increases in organizational efficiencies (Jain et al. 2011; Hertel and Wiesent 2013). They also help organizations attain environmental sustainability goals (Harris 2008; Jenkin et al. 2011). Virtualization technology, cloud based services, and Software as a Service (SaaS) are examples of IT based tools and practices that leverage people, capital, and knowledge sources to achieve improvements in productivity, value, and operational efficiency (Bose and Luo 2011). In addition, they also fall within the realms of investments that minimize the environmental impact of IT (Chauhan and Saxena 2013). Recent advancements in technology and research thus not only enable the virtualization of business processes but also cater to the environmental sustainability goals of Green IT (Chowdhury, 2012).

Bose and Luo 2011 proposed a conceptual model to assess the factors that contribute to a firm's potential to undertake green IT initiatives. Their model combined three well recognized IS theories, namely technology-organization-environment (TOE) framework, process virtualization theory (PVT), and diffusion of innovation (DOI). In their conceptual model, the innovation decision (i.e., a firm's readiness to implement IT-enabled process virtualization) is assessed using an integrated TOE and PVT analysis, and the adoption stages are guided by the DOI analysis. Their study presents a significant step toward investigating the impact of IT-enabled process virtualization within the context of organizational Green IT initiatives. However, it falls short of empirical validation. The purpose of this research is to fill this gap by empirically testing the conceptual model proposed by Bose and Luo 2011. As IT tools and practices enable the virtualization of an increasingly broad range of business processes, the related economic and ecological benefits also position them as important drivers of Green IT. To the best of our knowledge, no research has studied the firm's adoption of Green IT initiatives by considering the impact of IT-enabled process virtualization. Using an integrative approach that includes the conceptualization of process virtualization, this research aims to assess the determinants of the technology, organization, and environment context on organizational Green IT initiatives.

The rest of the paper is organized as follows. In the next section we provide an overview of Green IT and process virtualization, and the theoretical foundations of the conceptual model. Section 3 presents the conceptual model and the hypotheses. The research method is discussed in Section 4 and the results are analyzed in Section 5. Section 6 discusses the major findings of the study, managerial implications, and theoretical contributions. Finally, we conclude the paper by summarizing the limitations of the study and suggesting directions for future research.

## 2 Background

### 2.1 Green IT

Green IT is conceptualized in several ways, and with descriptors covering a wide variety of terminologies and concepts (Dedrick 2010). Consequently, there is a lack of universal definition of Green IT (Velte et al. 2008). Murugesan 2008 defines Green IT as the designing, manufacturing, using, and disposing of computers, servers, and associated subsystems efficiently and effectively with minimal or no impact on the environment. Butler 2011 describes Green IT as existing IT-based platforms that have been transformed to support environmentally sustainable business processes. Elliot 2011 argues that the term Green IT is misleading. He defines it as activities to minimize the negative impacts and maximize the positive impacts of human behavior on the environment through the design, production, application, operation, and disposal of IT and IT-enabled products and services throughout their life cycle. He suggests the use of 'environmental sustainability of IT' as an alternative broader concept. According to Bose and Luo 2011, Green IT refers to the strategic use of IT resources in an energy-efficient and cost-effective manner. More recent publications in the Green IT domain seek to distinguish between "greening of IT" and "greening by IT" (Cai et al. 2013; Murugesan et al. 2013). The former perceives IT as negatively impacting eco-sustainability (Cai et al. 2013), and describes Green IT as making IT production, use, and disposal greener in order to mitigate the problem (Molla 2013). "Greening by IT," also referred to as "sustainable IT services", is the strategic approach that focuses on the customer and societal value associated with the firm's commitment to environmental sustainability practices. Nonetheless, both concepts share common sustainability goals, and call upon harnessing the power of technology in the enterprise, as well as personal activities to address growing environmental concerns and social problems (Murugesan et al. 2013).

Capra et al. (2009) classify the benefits of Green IT into three areas: energy efficiency of IT, eco-compatible management of the lifecycle of IT, and IT as an enabler of green governance. Green IT enables energy and material savings (Chauhan and Saxena 2013; Hertel and Wiesent 2013), minimizes environmental impact (Hedman and Henningsson 2011), and facilitates improvement in organizational efficiency (Loos et al. 2011; Ryoo and Koo 2013). It aids stakeholders to express interest in social and environmental responsibility

(Elliot 2011), and helps companies sustain a competitive advantage through branding and image creation (Dao et al. 2011b; Velte et al. 2008; Watson et al. 2010).

Very little research has empirically assessed Green IT adoption. Molla et al. 2009 summarize the inhibitors to Green IT adoption. They include cost of Green IT solution, unclear business value of greening IT, lack of government incentives and business leadership, inadequate skills and IT sophistication, extent of mimetic pressure, and the absence of government regulations. Chen et al. (2009) studied the effect of institutional pressure on Green products and practices across organizations. Molla and Abareshi 2012 investigate the influence of organizational eco-sustainability motivations on the adoption of Green IT and IT for green. Cai et al. 2013 draw upon the stakeholder theory (Freeman, 1984) to determine political and economic antecedents to green IT adoption. (Bai and Sarkis 2013) proposed an evaluation approach for the justification of green and sustainable IT. None of the studies have addressed the impact of IT-enabled virtual capabilities on Green IT initiatives.

The importance of Green IT initiatives in the strategic context of organizations is discernible and significant. As with any other technological diffusion, Green IT implementation is a process that has to pass through several stages of adoption once its benefits to the business model are recognized. Bose and Luo 2011 assess the innovation capability of a firm to implement Green IT using a three-stage process. Stage I - *Green IT initialization* is the pre-adoption stage in which the organization starts evaluating Green IT practices in its value chain activities; Stage II – *Green IT integration* is the effective adoption of the practices as a strategic approach; and finally, Stage III – *Green IT maturation* is the post-adoption stage in which the practices are routinized as part of the value chain activities.

### 2.2 Process virtualization

Process virtualization is perhaps the most recognizable business practice where the impact of IT has a positive and direct effect on organizational efficiency (Jain et al. 2011) and environmental sustainability (Harris 2008; Jenkin et al. 2011). Overby 2008 defines process virtualization as the migration of physical processes to a virtual environment. An increasing number of societal and business processes that were traditionally carried out via physical mechanisms have transitioned to the virtual environment (Overby et al. 2010). For example, electronic commerce has successfully transitioned various aspects of the physical shopping experience as a virtual process. It is to be noted that a process may be virtual without requiring IT, as would be the case of writing letters to maintain relationships (Overby et al. 2010; Saltz et al. 2007). This distinction between IT-based and non-IT-based virtual processes is important, as this research addresses only the former. Specifically, this study considers the impact of IT-enabled process virtualization on Green IT initiatives.

Process virtualization enables businesses to attain efficiencies in value chain processes such as customer relationship management, online transaction management, after sales support, electronic exchange of data with business partners and customers, and integration of business processes with partners. IT used to virtualize processes also enable firms to achieve economic benefits and target environmental sustainability.

### 2.3 Theoretical foundation

In this research we test the conceptual model proposed by Bose and Luo 2011. The conceptual model combines the PVT and TOE theoretical framework to assess the organization's potential to undertake Green IT initiatives. PVT provides the technological basis of process virtualization. TEO framework specifies the technology, organization, and environment perspectives of IT-enabled process virtualization. DOI theory identifies the adoption stages of Green IT. The following sections summarize each of the three established IS theories.

#### *2.3.1 Technology-organization-environment (TOE) framework*

Tornatzky and Fleischer 1990 proposed the TOE framework to explain the organization's adoption of technological innovation. The framework considers three contexts that influence the adoption of innovation: technology, organization, and environment. The technology context refers to existing technologies used by the organization (internal) and new technologies that are available for adoption (external). The organization context refers to the descriptive characteristics of the firm (firm size, managerial structure, degree of centralization, etc.), available resources (human resources and slack resources), and the process of communication (formal and informal) among the employees. The environment context refers to the external elements that influence the organization to adopt new technologies (for example, market elements, competitors, and government regulations).

The TOE framework has been used in several studies to understand the adoption of new technologies such as Green IT (Bose and Luo 2011), electronic data interchange (EDI) (Kuan and Chau 2001), e-business (Oliveira and Martins 2010; Zhu and Kraemer 2005; Zhu et al. 2006a, 2006b; Zhu et al. 2003), and e-commerce (Liu et al. 2008).

#### *2.3.2 Process virtualization theory (PVT)*

The PVT (Overby 2008) is based on the premise that some processes are more amenable to being conducted virtually than others. It describes how amenable the process is to functioning without physical interaction between people or between people and objects. The dependent variable of this framework, process virtualization, is explained using four independent variables: (1) *sensory requirements* of the process participants to enjoy a full sensory experience, which includes the five senses: taste, sight, hearing, smell, and touch, (2) *relationship requirements* of the process participants to interact with others, (3) *synchronism requirements*, the degree to which the process activities can take place with minimal delay, and (4) *identification and control requirements*, the degree to which the process provides unique identification of the participants and the ability to control or influence their behavior. The theory suggests that all four requirements have a negative influence on the dependent variable (i.e., process virtualization). However, three IT-enabled moderating constructs positively influence the process virtualization. They are: (1) the representation capability of IT to present audio, video, and haptic facilities, (2) reach, which is IT's capability to allow participation across time and space, and (3) monitoring capability, which is the capability of IT to authenticate process participants and track activities. Within the technology context of the organization, Bose and Luo 2011 posit that sensory readiness, relationship readiness, synchronism readiness, and identification and control readiness will positively influence Green IT initialization.

The PVT has been used in several research settings, including understanding the shift from physical to electronic trading processes in the wholesale automotive market (Overby 2008), in the telecommunication sector (Czarnecki et al. 2010), and in cross-channel instant messaging (Li et al. 2009).

#### *2.3.3 Diffusion of innovation (DOI) theory*

DOI (Rogers 1995) is a prominent adoption model used in information systems (IS) research (Alam 2009; Azadegan and Teich 2010; Ifinedo 2011; Zhu et al. 2006a; Zhu et al. 2006b). It proposes four elements that influence the diffusion of a new idea: innovation, communication channels, time, and a social system. Rogers 1995 states that the assimilation of an innovation passes through five stages of adoption. They include: (1) knowledge: advancing awareness of an innovation and some idea of how it functions, (2) persuasion: developing a favorable or unfavorable attitude toward the innovation, (3) decision: engaging in activities that lead to a choice to adopt or reject the innovation, (4) implementation: employing the innovation and evaluating its usefulness, and (5) confirmation: finalizing the innovation decision already made. In the conceptual model proposed by Bose and Luo 2011, the stages of Green IT adoption are guided by the DOI analysis. Stages 1, 2, and 3 are incorporated at Green IT initialization (i.e., pre-adoption) when firms make the initial assessment of Green IT. Stage 4 is part of the Green IT integration (i.e., formal adoption), and stage 5 is Green IT maturation (i.e., post-adoption) where Green IT is integrated into the firm's value chain activities.

DOI has been used in several research areas including web development (Beatty et al. 2001), enterprise resource planning (ERP) (Bradford and Florin 2003; Ruivo et al. 2012), e-procurement (Li, Y.-h 2008), and radio frequency identification (Wang et al. 2010).

## 3 Conceptual model and hypothesis

### 3.1 The conceptual model

In accordance with the conceptual model proposed by Bose and Luo 2011, the objective of this research is to determine the technology, organization, and environment factors that influence the adoption of Green IT initiatives. Thus, the purpose of this study is to empirically test the nine propositions hypothesized by Bose and Luo 2011 which represent the organization's potential to undertake Green IT practices. The conceptual model grounded on the three IS theories (i.e., TOE, PVT, and DOI) is shown in Fig. 1. The TOE framework posits the technology, organization, and environment contexts that influence the organizational adoption of Green IT. The constructs of PVT theory provide the technology context that facilitates process virtualization. The stages of Green IT adoption are defined by the DOI theory.

### 3.2 Hypotheses

#### *3.2.1 Technology context*

**H1. Sensory readiness will positively influence Green IT initialization.** Sensory readiness is the degree to which process virtualization enables participants to experience the sensory elements of the physical world (Overby 2008). IT-enabled virtualization of business processes offers a wide range of sensory functions to the process participants (for example, online shoppers can use 3D visual interfaces to gauge the finer details of clothing or footwear, vocal interfaces for information search and retrieval, and interactive audio and visual support in distance learning environments). By enabling participants to enjoy the relationship experience of the process and the other process participants or objects, the sensory readiness capability of the technology context positively influences Green IT initialization (Bose and Luo 2011; Overby 2008).

**H2. Relationship readiness will positively influence Green IT initialization.** Relationship readiness refers to the need for process participants to interact with one another in a professional context (Bose and Luo 2011). It is possible to establish relationship requirements during the conduct of a virtual process (Overby 2008). Interaction capabilities and media richness provided by virtual environments allow users to participate (for example, via email, instant messaging, video chat,

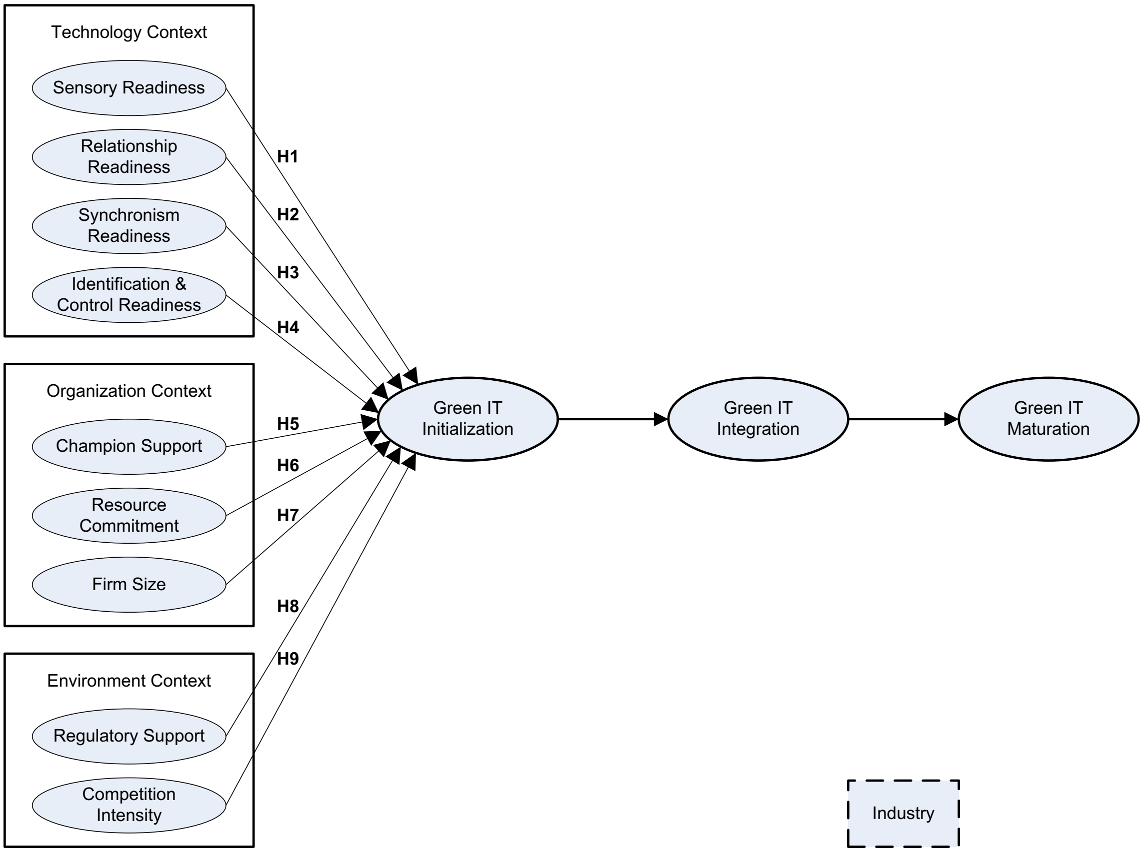


**Fig. 1** The conceptual model adapted from Bose and Luo 2011

social networking sites, etc.) and communicate (for example, use gestures, provide cues, convey emotions, etc.) similar to face-to-face interactions (Bose and Luo 2011; Hitsch et al. 2010). By enabling participation in the virtual process across space and time, the relationship readiness capability of the technology context positively influences Green IT initialization (Bose and Luo 2011; Overby 2008).

**H3. Synchronism readiness will positively influence Green IT initialization.** Synchronism readiness is the degree to which the activities in a process need to occur quickly with minimum delay (Bose and Luo 2011). Physical processes tend to be inherently synchronous as process participants interact with one another with little delay (Overby 2008). Process virtualization enables parties to establish synchronous communication virtually. For example, technologies such as instant messaging, video conferencing, and VoIP allow interaction between participants and process objects in a real-time basis with minimal delay, even when the participants in the process are geographically dispersed. Thus, synchronism readiness of the technology context positively influences Green IT initialization.

**H4. Identification and control readiness will positively influence Green IT initialization.** Identification and control readiness refers to the degree to which the process requires unique identification of process participants and provides the ability to exert control over their behavior (Overby 2008). In an organizational setting, it is unlikely that the participants remain anonymous when establishing process relationships. Although virtualization makes it easier for participants to hide their identity, technological advancements in the field of identification management (for example, biometrics and profile management) and authentication control (for example, password verification and directory services) make it possible to accurately identify the process participants. Furthermore, it is possible to control and monitor the activities conducted in a virtual process (Bose and Luo 2011). Hence, the identification and control readiness of the technology context positively influences Green IT initialization.

*3.2.2 Organization context*

**H5. Organizations with greater champion support are more likely to initiate Green IT.** Top management's commitment and support are crucial to the success of a project (Lacity et al. 2009; Lacity and Willcocks 1998). Top management commitment is required to promote the acceptance and adoption of a new technology and help overcome the challenges of the implementation (Beath 1991; Crum and

Premkumar 1996; Zhu et al. 2006b). The support of a champion at the top management level (for instance, the CEO) who recognizes the benefits (Meyer 2000) of Green IT initiatives to the organization can provide the necessary drive to influence its adoption. Earlier studies have shown that champion support is crucial for the adoption of emerging business and technological processes (Grover and Goslar 1993; Teo and Ranganathan 2004). Thus, the adoption of Green IT initiatives requires support from the organization's top management.

**H6. Organizations with greater resource commitment are more likely to initiate Green IT.** The commitment of the organization to adopt an innovation is reflected in the financial resources available to implement that innovation (Zhu and Kraemer 2005). Availability of resources is an important antecedent to IS diffusion (Iacovou et al. 1995; Low et al. 2011; Ramamurthy et al. 1999; Zhu and Kraemer 2005). As the implementation of Green IT requires investment in hardware, software, and workforce, it will be easier for organizations with greater resource commitment to adopt Green IT initiatives.

**H7. Large organizations are more likely to initiate Green IT.** Bose and Luo 2011 define firm size based on the number of employees in the organization. Firm size is a widely studied organizational factor in the innovation and adoption literature (Bose and Luo 2011; Lee and Xia 2006; Oliveira and Martins 2010). According to Rogers 1995 and Damanpour 1996, large-size firms undertake innovation initiation and adoption as they tend to have more resource advantages than smaller firms. The implementation of Green IT initiatives requires qualified and skilled human resources in operational and managerial units. Hence, large organizations are more likely to have the workforce and allocate resources required to implement Green IT (Bose and Luo 2011; Zhu et al. 2006b).

#### *3.2.3 Environment context*

**H8. Organizations with greater regulatory support are more likely to initiate Green IT.** Regulatory support refers to the support given by the government authority to encourage IT innovation by firms (Zhu et al. 2006b). Legislations, regulations, and incentives instituted by the government can be critical to the adoption of new technologies (Coffey et al. 2013; Zhu and Kraemer 2005; Zhu et al. 2006b). Government regulations related to business processes (for example, the Telework Enhancement Act), innovation diffusion (for example, the Carbon Reduction Commitment Energy Efficiency Scheme), and environmental impact (for example, the National Energy Conservation Policy Act) can influence Green IT initiatives in an organization (Dasgupta et al. 1999; Umanath and Campbell 1994). Regulatory incentives such as tax relief and monetary support for implementing Green IT can help organizations achieve their sustainability goals (Bose and Luo 2011). Thus, organizations with greater regulatory support are more likely to initiate Green IT.

**H9. Organizations facing higher competition intensity are more likely to initiate Green IT.** Competitive pressure has long been recognized in the innovation diffusion literature as an important driver for technology diffusion (Al-Qirim 2007; Battisti et al. 2007; Iacovou et al. 1995; Lai et al. 2007; Zhu et al. 2003). It refers to the pressure felt by the firm from competitors within the industry (Low et al. 2011; Oliveira and Martins 2010; Zhu et al. 2003). In a competitive market environment, building environmental thinking into the business is a strategic necessity for image creation and brand recognition (Coffey et al. 2013). Green IT can help create market differentiation by improving products and processes, and increase market share by entering new markets (Cai et al. 2013). Hence, the degree of competition within the industry influences the adoption of Green IT (Bose and Luo 2011).

### 3.3 Controls

We used industry to control data variation not explained by the other variables. As suggested in IS literature, we incorporate industry dummy variables as control variable (Bresnahan et al. 2002; Chatterjee et al. 2002; Oliveira and Martins 2010; Soares-Aguiar and Palma-dos-Reis 2008; Zhu et al. 2006b; Zhu et al. 2003).

## 4 Method

### 4.1 Measurement

To test the model presented in Fig. 1 we conducted a survey of organizations spanning diverse industries in Europe. Following Moore and Benbasat 1991, and taking into consideration the recommendations by Bose and Luo 2011, a survey instrument was developed from the literature by choosing appropriate items and creating items as necessary. A group of five established academic IS researchers and two language experts reviewed the instrument for content validity (Brislin 1970; Venkatesh et al. 2012). The measurement instrument was then tested among a small sample (pilot study with 30 firms) that was not included in the main survey. The objective was to examine whether the respondents have difficulty answering the questionnaire, as well as test the reliability and validity of the scales. Some items were dropped to reduce the instrument length and others were slightly modified to reduce ambiguity and simplify interpretation. The results of the pilot study provided preliminary evidence of the reliability and validity of the scales.

The resulting survey instrument and measurement items are shown in Appendix A. The dependent variable *Green IT*

*Initialization* was measured based on how the firms rated the potential benefits of Green IT before the adoption of process virtualization. Following the recommendation of Bose and Luo 2011, four items were used to measure this construct: increase productivity, market expansion, entering new businesses, and supply chain coordination (Liu et al. 2008; Zhu et al. 2006b). The items were assessed using a five point Likert scale with one representing "not important" and five for "very important". *Green IT Integration* was measured using the approach of (Zhu et al. 2006b). As per the suggestion of Bose and Luo 2011, the firm's use of green IT initiatives in the value chain activities (for example, marketing, sales, after-sales services, and inbound and outbound logistics management) were aggregated to form this dependent variable. *Green IT Maturation* was measured by the extent of virtualization–driven Green IT initiatives to support value chain activities (Zhu et al. 2006b). Three items were measured: percent of total sales, total services, and total procurement conducted through IT-enabled process virtualization (Bose and Luo 2011).

The independent variable *Sensory Readiness* was measured by two items indicating the importance of sensory experience in a virtual environment (Overby and Konsynski 2008). *Relationship Readiness* was measured by two items adapted from Overby et al. 2008 reflecting the importance of the relationship between parties in a virtual process. *Synchronism Readiness* was measured by two items denoting the need to complete transaction tasks quickly (Overby and Konsynski 2008). *Identification and Control Readiness* was measured by two self-developed items in accordance with Bose and Luo 2011 indicating the importance of identifying the participants. All of these items in the technology context were assessed using a five point Likert scale with one representing "strongly disagree" and five indicating "strongly agree". *Champion Support* was measured by three self-developed items based on Bose and Luo 2011 to determine the importance of top management support in Green IT initiatives. *Resource Commitment* represents the financial resources assigned to Green IT initiatives and was measured by two items to estimate the percentage of budget allocated to Green IT (Zhu and Kraemer 2005). *Firm Size* was measured by the number of employees in the firm (Zhu and Kraemer 2005). *Regulatory Support* was measured by three self-developed items, also in accordance with Bose and Luo 2011, to determine the role of legislations, regulations, and incentives in Green IT adoption. *Competition Intensity* was measured by three items to determine the degree of competition that the firm faces in local, national, and international markets (Zhu et al. 2006b). *Champion support* and *regulatory support* were measured using a five point Likert scale with one representing "strongly disagree" and five indicating "strongly agree". *Competition Intensity* was assessed using a five point Likert scale with one representing "not affected" and five representing "strongly affected".

### 4.2 Data

Data were collected over a period of eight weeks (April-May 2012) using an online version of the questionnaire that was emailed to qualified individuals (for example, CEO, CFO, and business managers) from 2000 companies in Europe. The company and contact information were provided by Dun & Bradstreet, one of the world's leading sources for commercial information and insight on businesses. In total, 426 accepted the invitation. 162 valid responses were received in the initial four weeks. A follow-up email was sent to improve the survey response rate. 89 valid responses were received from the late responders for a combined total of 251 usable responses. The respondents were knowledgeable about the company's "go green" processes, which suggests a good quality of the data. The sample covered varying types of businesses and represented small (fewer than 50 employees) (34.7 %), medium (between 50 and 250 employees) (41.4 %), and large companies (more than 250 employees) (23.9 %) in accordance to the European Commission standard for enterprise classification (Stenkula 2006). The profile of the sample is shown in Table 1.

To examine the possibility of bias due to the position held by the respondents, we compared the sample distribution between IS managers and non-IS managers. The Kolmogorov-Smirnov (K-S) test was used to compare the sample distributions of the two groups (Ryans 1974). As shown in Table 2 the K-S test for each factor is non-significant at 1 % ($p>0.01$), with the exception of firm size, which was found to be significant at 1 % ($p<0.01$). Firm size is an objective characteristic of the organization that is not influenced by the opinion of the respondents. We therefore concluded that no significant bias exists between IS and non-IS managers. Furthermore, we examined the common method bias using the Harman's one-factor test (Podsakoff et al. 2003). The results suggested no significant common method bias in the data.

Nonresponse bias was tested in two ways. First, the sample distributions of the early and late respondent groups were compared using the K-S test (Ryans 1974). The sample distributions of the two groups did not differ statistically at the 1 % significance level ($p>0.01$) indicating the absence of nonresponse bias (Ryans 1974). Second, we used the t-student test to determine if the average of firm size is different between all companies and the valid responses that were received. The results revealed no statistically significant difference ($p>0.01$), indicating the absence of nonresponse bias.

## 5 Results

To examine the causal relationships of the conceptual model, Bose and Luo 2011 proposed the use of Structured Equation Modeling (SEM). We used Partial Least Squares (SmartPLS

**Table 1** Sample characteristics

| Sample characteristics $n$=251 | | Obs. | (%) |
|---|---|---|---|
| Respondent title | | | |
| IS managers | | 42 | 16.7 % |
| | IS Manager, Director, Planner | 31 | 12.4 % |
| | Other Managers in IS Department | 11 | 4.4 % |
| Non-IS managers | | 209 | 83.3 % |
| | CEO, President, Director | 48 | 19.1 % |
| | Business Operations Manager, COO | 21 | 8.4 % |
| | Administration/Finance Manager, CFO | 50 | 19.9 % |
| | Quality Manager | 23 | 9.2 % |
| | Others (Marketing, HR, Other Managers) | 67 | 26.7 % |
| No. of employees | | | |
| <50 | | 87 | 34.7 % |
| 50–250 | | 104 | 41.4 % |
| >250 | | 60 | 23.9 % |
| Industry | | | |
| Manufacturing | | 64 | 25.5 % |
| Wholesale and retail trade | | 40 | 15.9 % |
| Construction | | 19 | 7.6 % |
| Accommodation and food services activities | | 18 | 7.2 % |
| Human health and social work activities | | 15 | 6.0 % |
| Information and communication | | 14 | 5.6 % |
| Public administration and defense | | 14 | 5.6 % |
| Transportation and storage | | 13 | 5.2 % |
| Professional, scientific, technical activities | | 13 | 5.2 % |
| Others | | 41 | 16.2 % |

(1) The firm size is presented in accordance with European enterprises size class (Stenkula 2006)

(2) The industries of activity are presented in accordance with NACE (European standard classification of productive economic activities)

2.0.M3, (Ringle et al. 2005)) to estimate the research model. Since this research is an early stage assessment, and the conceptual model proposed by Bose and Luo 2011 has not been tested before, the use of PLS is suitable and adequate

**Table 2** Testing possible biases: Is managers vs. non-is managers

| | Full sample ($n$=251) | | IS managers ($n$=42) | | Non-IS managers ($n$=209) | | Kolmogorov-Smirnov test | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Z score | $P$-value |
| Sensory readiness | 3.77 | 0.92 | 3.35 | 1.11 | 3.86 | 0.85 | 1.60 | 0.01 |
| Relationship readiness | 3.58 | 0.96 | 3.48 | 1.02 | 3.61 | 0.95 | 0.41 | 1.00 |
| Synchronism readiness | 3.38 | 0.74 | 3.00 | 0.65 | 3.46 | 0.74 | 1.43 | 0.03 |
| Id & control readiness | 3.33 | 0.86 | 3.21 | 0.88 | 3.35 | 0.85 | 0.44 | 0.99 |
| Champion support | 4.19 | 0.66 | 4.24 | 0.84 | 4.18 | 0.63 | 0.47 | 0.98 |
| Resource commitment | 11.60 | 20.16 | 9.60 | 20.29 | 12.00 | 20.15 | 0.86 | 0.46 |
| Firm Size | 374.95 | 1199.18 | 398.74 | 558.41 | 370.17 | 1291.05 | 1.73 | 0.00 |
| Regulatory support | 3.66 | 0.60 | 3.67 | 0.61 | 3.65 | 0.60 | 0.32 | 1.00 |
| Competition intensity | 3.06 | 0.76 | 3.11 | 0.74 | 3.05 | 0.76 | 0.69 | 0.74 |
| Green IT initialization | 3.46 | 0.90 | 3.36 | 0.75 | 3.48 | 0.93 | 0.85 | 0.46 |
| Green IT integration | 3.71 | 2.53 | 3.31 | 2.36 | 3.79 | 2.56 | 0.66 | 0.78 |
| Green IT maturation | 15.07 | 20.47 | 11.62 | 19.35 | 15.77 | 20.67 | 0.86 | 0.45 |

(Hair et al. 2011; Hair et al. 2012). Before testing the structural model, we examined the measurement model to assess reliability and validity.

### 5.1 Measurement model

The results of the measurement model are reported in Tables 3 and 4. We assessed construct reliability, indicator reliability, convergent validity, and discriminant validity. Construct reliability was tested using the composite reliability coefficient. PLS prioritizes indicators according to their individual reliability. Composite reliability was used instead of Cronbach's alpha to analyze the reliability of the constructs, since the former takes into consideration indicators that have different loadings (Hair et al. 2011; Hair et al. 2012; Henseler et al. 2009; Werts et al. 1974), while Cronbach's alpha assumes that all indicators are equally reliable (Raykov 2007). As shown in Table 3, all the constructs have a composite reliability above 0.7, which suggested that the constructs are reliable (Straub 1989).

The indicator reliability was evaluated based on the criteria that the loadings should be greater than 0.70, and that every loading less than 0.4 should be eliminated (Churchill 1979; Henseler et al. 2009). As shown in Table 4, the loadings (in bold) are greater than 0.7, with the exception of two items (SYNC1 and REG3), which are lower than 0.7 but greater than 0.4. Hence, no items in the table were eliminated. All the items were statistically significant at 0.001. Overall, the instrument presented good indicator reliability.

Average variance extracted (AVE) was used as the criterion to test convergent validity. The AVE should be higher than 0.5, so that the latent variable explains more than half of the variance of its indicators (Fornell and Larcker 1981; Hair et al. 2012; Henseler et al. 2009). As shown in Table 3, all constructs have an AVE higher than 0.5, meeting this criterion.

Discriminant validity of the constructs was assessed using two measures: Fornell-Larcker criteria and cross-loadings. The first criterion postulates that the square root of AVE should be greater than the correlations between the construct (Fornell and Larcker 1981). The second criterion requires that the loading of each indicator should be greater than all cross-loadings (Chin 1998a; Götz et al. 2010; Gregoire and Fisher 2006). As seen in Table 3, the square roots of AVEs (diagonal elements) are higher than the correlation between each pair of constructs (off-diagonal elements). Table 4 shows that the patterns of loadings are greater than cross-loadings. Thus, both measures are satisfied.

The assessments of construct reliability, indicator reliability, convergent validity, and discriminant validity of the constructs were satisfactory, indicating that the constructs can be used to test the conceptual model.

### 5.2 Structural model

The structural model was assessed using $R^2$ measures and the level of significance of the path coefficients. Figure 2 shows the model results. The $R^2$ of dependent variables are respectively 0.33, 0.16, and 0.30 for Green IT Initialization, Green IT Integration, and Green IT Maturation. The significance of the path coefficients was assessed by means of a bootstrapping procedure (Hair et al. 2011; Henseler et al. 2009) with 500 iterations of resampling (Chin 1998b). Figure 2 also shows the path coefficients and t-value results.

**Table 3** Correlation matrix, composite reliability (CR), and square root of AVEs

| Constructs | CR | SENS | REL | SYNC | IC | CHAMP | RES | SIZ | REG | COMP | INI | INTEG | MAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sensory readiness | .85 | 0.86 | | | | | | | | | | | |
| Relationship readiness | 0.91 | 0.40*** | 0.92 | | | | | | | | | | |
| Synchronism readiness | 0.71 | 0.29*** | 0.39*** | 0.75 | | | | | | | | | |
| Id & control readiness | 0.80 | 0.22*** | 0.19*** | 0.15** | 0.82 | | | | | | | | |
| Champion support | 0.92 | 0.12 | 0.10 | 0.06 | 0.10 | 0.89 | | | | | | | |
| Resource commitment | 0.96 | 0.13** | 0.07 | 0.08 | 0.02 | −0.12 | 0.96 | | | | | | |
| Firm size | n.a | −0.02 | −0.08 | −0.06 | −0.08 | 0.12 | −0.07 | n.a | | | | | |
| Regulatory support | 0.75 | 0.06 | 0.10 | 0.09 | 0.05 | 0.31*** | −0.03 | 0.04 | 0.71 | | | | |
| Competition intensity | 0.91 | 0.07 | 0.06 | 0.13** | 0.07 | 0.12 | 0.19*** | 0.14** | 0.23*** | 0.88 | | | |
| Green IT intialization | 0.90 | 0.15** | 0.06 | 0.18*** | 0.12 | 0.17*** | 0.14** | −0.05 | 0.37*** | 0.42*** | 0.84 | | |
| Green IT integration | n.a | 0.04 | −0.01 | −0.01 | −0.01 | 0.09 | 0.17*** | 0.03 | 0.15** | 0.25*** | 0.35*** | n.a | |
| Green IT maturation | 0.90 | 0.05 | −0.01 | −0.05 | −0.05 | 0.03 | 0.33*** | −0.03 | 0.05 | 0.25*** | 0.28*** | 0.52*** | 0.86 |

(1) n.a. Composite reliability and average variance extracted are not applicable to the single-item constructs

(2) First column are CR (composite reliability)

(3) Diagonal elements are square average variance extracted (AVE)

(4) Off-diagonal elements are correlations

(5) * Significant at the 0.1; ** significant at the 0.05; *** significant at the 0.01

**Table 4** Loadings and cross-loadings for the measurement model

| Construct | ITEM | SENS | REL | SYNC | IC | CHAMP | RES | SIZ | REG | COMP | INIT | INTEG | MAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sensory readiness | SENS1 | 0.98 | 0.35 | 0.28 | 0.21 | 0.12 | 0.13 | 0.00 | 0.09 | 0.08 | 0.17 | 0.07 | 0.05 |
| | SENS2 | 0.72 | 0.42 | 0.23 | 0.17 | 0.06 | 0.07 | −0.08 | −0.04 | 0.02 | 0.05 | −0.06 | 0.05 |
| Relationship readiness | REL1 | 0.42 | 0.89 | 0.39 | 0.14 | 0.09 | 0.05 | −0.11 | 0.08 | 0.04 | 0.05 | −0.03 | −0.02 |
| | REL2 | 0.32 | 0.94 | 0.32 | 0.20 | 0.09 | 0.08 | −0.04 | 0.10 | 0.06 | 0.06 | 0.00 | 0.00 |
| Synchronism readiness | SYNC1 | 0.23 | 0.28 | 0.58 | 0.07 | 0.03 | 0.15 | −0.10 | 0.03 | 0.18 | 0.10 | −0.05 | 0.02 |
| | SYNC2 | 0.22 | 0.31 | 0.88 | 0.14 | 0.06 | 0.00 | −0.01 | 0.09 | 0.05 | 0.17 | 0.02 | −0.07 |
| Identification & control readiness | IC1 | 0.22 | 0.21 | 0.19 | 0.91 | 0.15 | 0.06 | −0.08 | 0.05 | 0.07 | 0.11 | −0.02 | −0.06 |
| | IC2 | 0.12 | 0.07 | 0.01 | 0.71 | −0.04 | −0.06 | −0.04 | 0.02 | 0.04 | 0.07 | 0.00 | 0.00 |
| Champion support | CHAMP1 | 0.05 | −0.01 | 0.06 | 0.01 | 0.84 | −0.19 | 0.12 | 0.22 | 0.11 | 0.13 | 0.06 | −0.04 |
| | CHAMP2 | 0.14 | 0.15 | 0.06 | 0.14 | 0.93 | −0.06 | 0.05 | 0.32 | 0.12 | 0.19 | 0.11 | 0.07 |
| | CHAMP3 | 0.10 | 0.08 | 0.04 | 0.08 | 0.89 | −0.09 | 0.19 | 0.26 | 0.08 | 0.10 | 0.07 | 0.05 |
| Resource commitment | RES1 | 0.13 | 0.07 | 0.08 | 0.03 | −0.09 | 0.98 | −0.07 | −0.02 | 0.23 | 0.16 | 0.19 | 0.34 |
| | RES2 | 0.12 | 0.07 | 0.07 | 0.01 | −0.16 | 0.95 | −0.06 | −0.05 | 0.11 | 0.09 | 0.13 | 0.29 |
| Firm size | SIZE | −0.02 | −0.08 | −0.06 | −0.08 | 0.12 | −0.07 | 1.00 | 0.04 | 0.14 | −0.05 | 0.03 | −0.03 |
| Regulatory support | REG1 | 0.02 | 0.04 | 0.00 | 0.09 | 0.36 | −0.06 | 0.10 | 0.77 | 0.19 | 0.23 | 0.12 | 0.00 |
| | REG2 | −0.02 | 0.00 | −0.04 | −0.04 | 0.38 | −0.03 | 0.09 | 0.71 | 0.18 | 0.24 | 0.14 | 0.11 |
| | REG3 | 0.12 | 0.15 | 0.19 | 0.05 | −0.03 | 0.02 | −0.08 | 0.65 | 0.13 | 0.30 | 0.06 | 0.00 |
| Competition intensity | COMP1 | 0.10 | 0.05 | 0.14 | 0.13 | 0.10 | 0.13 | 0.13 | 0.20 | 0.88 | 0.40 | 0.20 | 0.18 |
| | COMP2 | 0.09 | 0.09 | 0.12 | 0.11 | 0.10 | 0.23 | 0.11 | 0.19 | 0.91 | 0.33 | 0.20 | 0.21 |
| | COMP3 | 0.00 | 0.02 | 0.08 | −0.07 | 0.12 | 0.16 | 0.13 | 0.22 | 0.84 | 0.38 | 0.25 | 0.27 |
| Green IT initialization | INIT1 | 0.01 | −0.07 | 0.10 | 0.04 | 0.20 | 0.06 | −0.02 | 0.30 | 0.38 | 0.76 | 0.32 | 0.25 |
| | INIT2 | 0.19 | 0.08 | 0.17 | 0.13 | 0.05 | 0.12 | −0.09 | 0.31 | 0.35 | 0.87 | 0.27 | 0.21 |
| | INIT3 | 0.16 | 0.09 | 0.17 | 0.11 | 0.04 | 0.14 | 0.04 | 0.30 | 0.35 | 0.85 | 0.26 | 0.22 |
| | INIT4 | 0.15 | 0.10 | 0.18 | 0.11 | 0.25 | 0.14 | −0.10 | 0.33 | 0.35 | 0.87 | 0.33 | 0.26 |
| Green IT integration | INTEG | 0.04 | −0.01 | −0.01 | −0.01 | 0.09 | 0.17 | 0.03 | 0.15 | 0.25 | 0.35 | 1.00 | 0.52 |
| Green IT maturation | MAT1 | 0.09 | 0.00 | 0.02 | −0.05 | 0.01 | 0.33 | −0.06 | −0.01 | 0.21 | 0.27 | 0.44 | 0.88 |
| | MAT2 | 0.06 | 0.02 | −0.07 | 0.02 | 0.06 | 0.27 | −0.05 | 0.05 | 0.26 | 0.24 | 0.46 | 0.90 |
| | MAT3 | −0.01 | −0.04 | −0.06 | −0.09 | 0.02 | 0.26 | 0.03 | 0.08 | 0.16 | 0.21 | 0.44 | S0.80 |

With regard to the technology context, the study found that sensory readiness ($\widehat{\beta} = 0.10$; $p>0.10$), relationship readiness ($\widehat{\beta} = -0.09$; $p>0.10$), synchronism readiness ($\widehat{\beta} = 0.08$; $p>0.10$), and identification and control readiness ($\widehat{\beta} = 0.05$; $p>0.10$) were not statistically significant. Thus, hypotheses H1, H2, H3, and H4 were not supported. Within the organization context, champion support ($\widehat{\beta} = 0.06$; $p>0.10$), resource commitment ($\widehat{\beta} = 0.06$; $p>0.10$), and firm size ($\widehat{\beta} = -0.09$; $p>0.10$) were not statistically significant in explaining Green IT Initialization. Thus, hypothesis H5, H6, and H7 were not supported. Within the environment context, the results showed that regulatory support ($\widehat{\beta} = 0.28$; $p<0.01$) had a significant and positive path to Green IT Initialization. Moreover, competition intensity ($\widehat{\beta} = 0.35$; $p<0.01$) also had a significant ($p<0.01$) and positive path to Green IT Initialization. Thus, the two hypotheses (H8 and H9) for the environment context were supported. With regard to the adoption stages, it was found that the pre-adoption stage (i.e., Green IT initialization) had a statistically significant ($\widehat{\beta} = 0.36$; $p<0.01$) and positive path to Green IT integration (i.e., formal adoption stage). The formal adoption stage had a statistically significant ($\widehat{\beta} = 0.49$; $p<0.01$) and positive path to explain Green IT maturation (i.e., post-adoption stage).

## 6 Discussion

As business re-engineering transforms more physical processes to virtual processes, understanding the significance of IT-enabled process virtualization phenomenon becomes imperative. Using an integrative approach that includes the conceptualization of IT-enabled process virtualization, this study fills the research gap in assessing the impact of technology, organization, and environment context on Green IT initiatives.

The results of the study indicated that none of the four process virtualization constructs (i.e., sensory readiness,

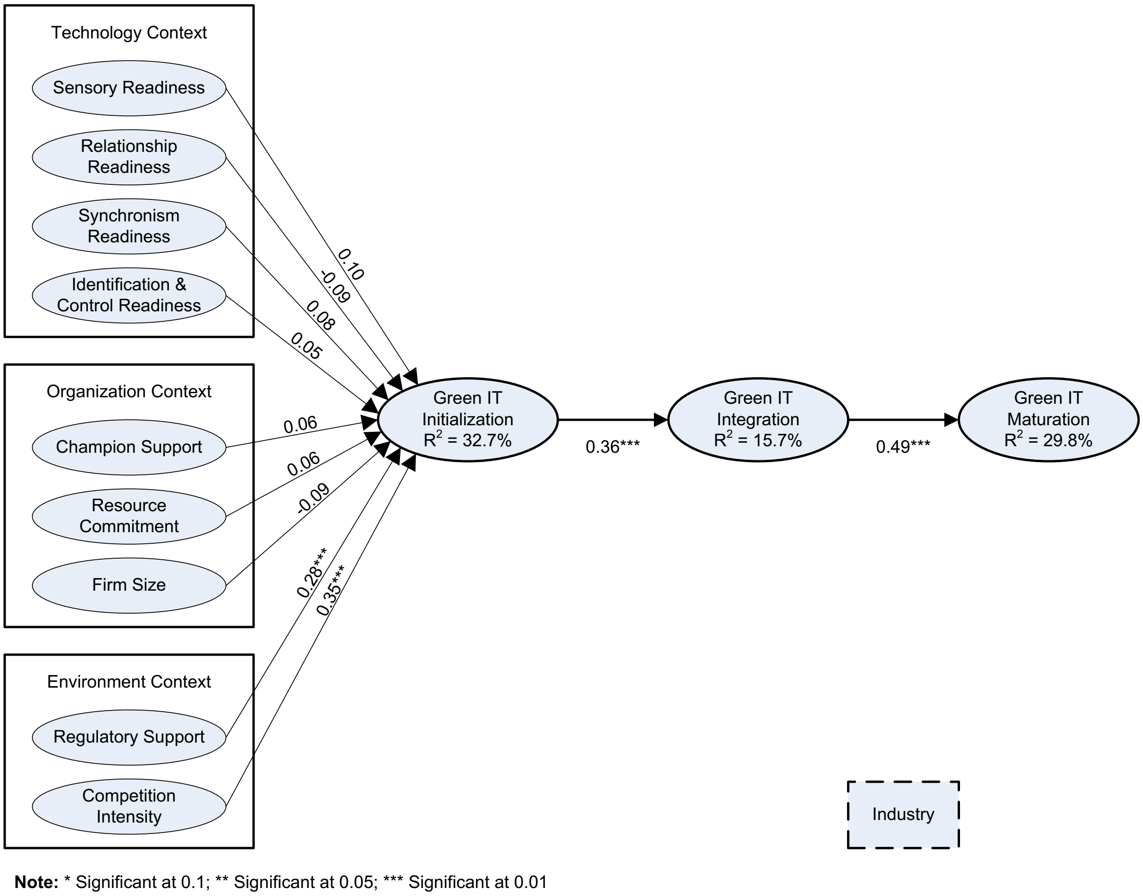


**Fig. 2** Model with results

relationship readiness, synchronism readiness, and identification & control readiness) have effects consistent with the propositions suggested by PVT. The results are a first step in understanding whether process virtualization may explain Green IT initiatives. The insignificance of the process virtualization characteristics indicate that, although the effects of the constructs proposed in PVT seem plausible, they do not directly contribute to the organization's consideration of Green IT initiatives.

With regard to the organization context, our study found that champion support was not significant in explaining organizational Green IT initiatives. Furthermore, resource commitment and firm size were also not found significant. The findings contradict prior research that indicates a positive influence of top management support on the firm's adoption of Green IT initiatives (Coffey et al. 2013). A plausible explanation may be that businesses in Europe, irrespective of firm size, may not recognize the business value of investing in IT for environmental sustainability. It is also likely that managers view investments in Green IT as additional capital expenses. This may explain the lack of enthusiasm among firms to commit financial and organizational resources towards Green IT.

For firms to initiate Green IT practices, our study suggests that the environment context in which the firms function is more important than the technology context of process virtualization capabilities and organization context. In the environment context, competition intensity and regulatory support was found significant to the organization's intention to pursue Green IT initiatives. The results indicated that firms were aware of the benefits of Green IT, but factors from the technology and organization context were not substantial in materializing Green IT initiatives. The significance of competition intensity represents strategic opportunities for business in Europe. Prior study has indicated that Green IT practices have a positive effect on environmental performance and indirect effect on organizational performance via coordination with business functions such as manufacturing and marketing (Ryoo and Koo 2013). Integrating Green IT practices in the value chain activities thus present market opportunities for organizations to differentiate from competition. Our study thus provides valuable support to literature that have sought strategic justification of Green IT initiatives (Bai and Sarkis 2013). The analysis of results also indicated that increasing awareness and understanding of national and international industry practices among managers may lead to the firm undertaking Green IT initiatives. Thus, our study provides additional support to the importance of incorporating awareness training and environmental education in the firm's management development programs. Such programs may help influence the decision maker's attitude towards environmental sustainability and sustainable practices (Coffey et al. 2013).

Our study results also support prior findings that have suggested the impact of legislations on organizations' decision to pursue Green IT initiatives (Delmas and Toffel 2004). Wagner 2005 found that regulations to establish standards of environmental compliance can provide the impetus for organizations to adopt Green IT initiatives. The results of our study also offer additional evidence indicating that regulatory support from the government may contribute to the organization's adoption of Green IT practices. Thus, organizational strategies that link the business value of Green IT practices to the economic performance of the organization, and a regulatory environment that encourages sustainable IT practices are more crucial in influencing the adoption and integration of Green IT initiatives in the organization's value chain activities. The implications of this study for practice and theory are summarized below.

### 6.1 Practical implications

Every firm has an environmental impact, whether it produces goods or services. In realizing the challenges of environmental sustainability, Elliot 2011 highlighted the importance of technology and research, in addition to business transformation, for inducing local, national, and global innovation and behavioral change. Our results indicate that environment context (competitive intensity and regulatory support) plays an important role in the initial stages of Green IT adoption. Our study results suggested that technology and organization context were not significant in assessing the organization's potential to undertake Green IT initiatives. Specifically, the study indicated that the technology factors (sensory readiness, relationship readiness, synchronism readiness, and identification and control readiness) that facilitate process virtualization did not play a role in the organizational Green IT initiatives. Thus we may conclude that IT-enabled process virtualization may not be motivated out of concern for the environment. It is unlikely for companies to invest in process virtualization technologies unless they meet objectives of competitive advantage or regulatory support. With regard to organization context, the study found that firm size, champion support, and resource commitment are not significant factors in the firm's readiness for Green IT.

Green IT can serve as a strategic directive to create corporate social responsibility (Dao et al. 2011a). This may provide an explanation of the role of competitive intensity in organizational Green IT initiatives. For example, reporting carbon footprint of goods, services, and production facilities, environmental accountability and transparency in business practices, and compliance with international environmental management standards (such as ISO 14000) are indicative of an organization's commitment to societal and environmental concerns. Harnessing the power of IT to address environmental concerns not only demonstrates corporate social responsibility, but also serves as effective market-facing strategies (Murugesan et al. 2013). Other factors related to competitive intensity that compel organizations to undertake Green IT are mimetic pressures (imitating other organizations), coercive pressures (compliance requirements), and normative pressures (brand recognition benefits from "going Green") (Butler 2011; Coffey et al. 2013; Elliot 2011). Promoting Green IT initiatives at the enterprise level (Coffey et al. 2013) and the employee level (Melville 2010) not only allow organizations to be proactive in their management and optimization of natural resource consumption and output, but also enable them to showcase their concern for the environment (Pollard 2013).

Regulatory support also emerged as an important factor for the adoption of Green IT initiatives. Prior studies (Molla et al. 2009; Pollard 2013) have indicated that firms are less likely to engage in meaningful environmental sustainability practices without strong government incentives and reward programs. Companies are more willing to adopt green initiatives when there are economic gains associated with the sustainability directive (Pollard 2013; Ryoo and Koo 2013). Our findings make a sound argument for elevated roles of supportive government actions in the form of incentives, legislations, and leading by example (Coffey et al. 2013). Loan programs that finance investments in renewable energy and energy efficient technologies, tax credits for energy efficient and environmentally friendly goods, services and business processes, and preferred vendor lists for organizations engaged in sustainable environment practices are examples of incentives that can persuade firms to invest in Green IT, and still meet the objective of economic performance (Ryoo and Koo 2013). Government agencies may also lead by example by initiating Green IT adoption. One such example is the Executive Order 13514 by the President of the United States, establishing sustainability goals for Federal agencies to make improvements in their environmental, energy, and economic performance.

### 6.2 Theoretical contributions

This research makes important contributions to the body of research on Green IT. First, most studies in this area focus on the technical, operational, or solution management of Green IT technology. Only few studies have attempted to comprehensively evaluate Green IT from an organizational perspective. Although numerous conceptual models and research agendas on Green IT have been proposed (Elliot 2011; Melville 2010; Murugesan et al. 2013), to the best of our knowledge, no research has been conducted to empirically evaluate and understand Green IT adoption. Our study fills this research gap by holistically evaluating the organizational readiness for Green IT initiatives by considering the technology, organization, and environment context of IT-enabled process virtualization. Second, we developed a survey instrument with items corresponding to the contextual attributes of Green IT proposed by Bose and Luo 2011 and process virtualization characteristics proposed by Overby et al. 2010. The instrument was tested for reliability and validity of the scales, and used successfully to collect data from organizational decision makers across 251 companies in Europe who were knowledgeable about their company's "go green" processes. Future researchers can readily use the instrument to replicate the study across industries in other countries. Third, unlike most studies in innovation diffusion that use an "adoption versus non-adoption" approach, we test the link between the different adoption stages. To our knowledge this is also the first study to validate the stages of Green IT adoption, starting with the evaluation of Green IT (initialization stage), to its formal adoption (integration stage), and finally to its integration in the firm's value chain activities (maturation stage). Our study thus adds new knowledge to this emergent area of IS research. It provides insight into the impact of technology context for process virtualization, and its influence on Green IT initiatives. The research contributes not just to IS researchers, but also to a diverse audience such as environmentalists, organizational decision makers, IT specialists, and policy makers whose interests include technology and environmental sustainability. The next section brings to attention the limitations of this study and future research directions.

### 6.3 Limitations and future research

As with all empirical studies, this study has limitations. First, we used cross-sectional data, which does not allow us to observe the evolution of a firm's Green IT initiatives. The diffusion of technology in an organization is a complex process that takes time to incorporate and mature. To address this limitation, a longitudinal study might be more appropriate to analyze the different stages of adoption of Green IT. Second, this study was carried out in Europe. It will be interesting to determine whether the findings differ in other countries in accordance to their corresponding technological advancements and regulatory support for Green IT. To address this limitation, we encourage future researchers to apply the model and adapt the instrument for use in other countries. Third, our focus was not on any particular sector of the industries. Some industries (for example, the service sector) are more technologically advanced than others (for example, agriculture), and the results could be different. To address this limitation, we encourage additional research to test the model in different target industries. Fourth, the model used in this research only analyzed the relationship between the three adoption stages. We encourage additional research that focuses on the effects of TOE and PVT factors on all stages of the diffusion process. Finally, the study determined that competitive intensity and regulatory support played a critical role in the organization's potential to undertake Green IT initiatives. Further research to confirm the impact of these factors on the economic and environmental performance of a firm can be beneficial to policy makers for proposing incentives and developing policies that promote the organizational adoption of sustainability initiatives.

Melville 2010 developed a set of research questions associated with philosophical perspectives, research methodology, and data sources of sustainability phenomena. The locus of our research is congruent with macro-level constructs (organizational sustainability programs and their economic and environmental outcomes) associated with the belief-action-outcome (BAO) conceptual model proposed by Melville 2010. Micro-level concepts (human beliefs and behavior) involving individuals and corporate actors are not investigated in our study. Whether the transformation at the micro-level brought by digitization of everyday activities can influence organizational sustainability practices (for example, effectiveness of social media in communicating environmental sustainability and responsibility) may be determined by combining the conceptual framework used in this study with the BOA model. Future research can address these research questions.

## 7 Conclusions

Organizations have the knowledge, resource, and power to invest in innovation, and bring changes that can have a positive impact on the environment (Elliot 2011; Shrivastava 1995). Green IT has emerged as a strategic initiative that offers economic, social, and environmental benefits to organizations. It plays an important role in implementing sustainable processes and practices, addressing social responsibility, and minimizing ecological impacts (Molla 2013). To assess whether IT-enabled virtual capabilities are determinants of an organization's potential to undertake Green IT initiatives, Bose and Luo 2011 proposed a conceptual model based on three popular IS theories namely, TOE framework, PVT, and DOI theory. This study empirically evaluated the conceptual model using data collected from Europe. Environment context (regulatory support and competition intensity) is found to be more meaningful in explaining the adoption of Green IT than the process virtualization capabilities of the technology context and factors in the organization context. The adoption stages of Green IT are also evaluated. Using the conceptual model, we validate that the pre-adoption stage (Green IT initialization) influences the formal stage of adoption (Green IT integration), and finally, its integration into the firm's value chain activities (Green IT maturation).

# Appendix

**Table 5** Survey questionnaire

| Constructs | Items | Source |
|---|---|---|
| Adoption stages | | |
| Green IT initiation | Please indicate how significant each of the following potential benefits of Green IT via virtualization was rated when your organization was considering using these technologies (On a scale 1 – 5, 1 is Not Important and 5 is Very Important.).<br>INIT1. Increased Productivity.<br>INIT2. To expand market for existing products/services.<br>INIT3.To enter new businesses or markets.<br>INIT4.To improve coordination with customers and suppliers. | (Bose and Luo 2011) |
| Green IT integration | Check the box describing applications of Green IT via virtualization in your value chain processes (check as many as apply):<br>INTEG1. Advertising and marketing. (Y/N)<br>INTEG2. Making sales online. (Y/N)<br>INTEG3. After-sales support. (Y/N)<br>INTEG4. Customer management. (Y/N)<br>INTEG5. Exchanging operational data with suppliers. (Y/N)<br>INTEG6. Making purchases online. (Y/N)<br>INTEG7. Exchanging operational data with business partners and customers. (Y/N)<br>INTEG8. Integrating business processes with business partners (e.g., real-time transaction of orders, integrated channel management, etc.) (Y/N) | (Bose and Luo 2011; Zhu et al. 2006b) |
| Green IT maturation | Please indicate the percentage of usage of virtualization to support your company value chain activities:<br>MAT1. What percent of your total sales B2C/B2B is conducted through Green IT initiatives?#<br>MAT2. What percent of your total services B2C/B2B is conducted through Green IT initiatives?#<br>MAT3. What percent of procurement (supplies and equipment) is conducted through Green IT initiatives?# | (Bose and Luo 2011; Zhu et al. 2006b) |
| Technology context | | |
| Sensory readiness | Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).<br>SENS1. I like to touch / see / hear / smell the products.<br>SENS2. It's important to physically inspect the products before purchasing them. | (Overby and Konsynski 2008) |
| Relationship readiness | Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).<br>REL1. I like to have a personal relationship with the seller when I buy a product/service.<br>REL2. I consider my relationship with the seller when I purchase a product/service. | (Overby 2008) |
| Synchronism readiness | Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).<br>SYNC1. After I purchase a product, I need to get it that day or the next.<br>SYNC2. I like to take care of all purchasing-related activities on the day that I make an order. | (Overby and Konsynski 2008) |
| Identification and control readiness | Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).<br>IC1. It is possible that people can hide their identity in the virtual process.<br>IC2. Participants in the virtualization process can be properly identified.* | (Bose and Luo 2011), self-developed |

**Table 5** (continued)

| Constructs | Items | Source |
|---|---|---|
| Organization context | | |
| Champion support | Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).<br>CHAMP1. The implementation or acceptance of Green IT initiatives requires support from the organization's top management.<br>CHAMP2. Champion support can help overcome possible resistance in adoption of new technologies.<br>CHAMP3. Support of a champion is a significant factor in successful adoption and implementation of a Green IT strategy. | (Bose and Luo 2011) |
| Resource commitment | Please indicate the percentage allocated for:<br>RES1. Green IT operating budget, as percent of total revenue. #<br>RES2. Green IT spending, as percent of total revenue. # | (Zhu and Kraemer 2005) |
| Firm Size | SIZ1. How many employees does your organization have in total? # | (Zhu and Kraemer 2005) |
| Environment context | | |
| Regulatory support | Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).<br>REG1. Regulatory support (legislation and regulation) can aid organizations to adopt Green IT.<br>REG2. Incentives for greening IT (technical support, tax relief, funding, etc.) can aid organizations to adopt Green IT.<br>REG3. There is legislation that protects companies to adopt technologies such as virtualization. | (Bose and Luo 2011) |
| Competition intensity | Please rate the degree to which your business activities are affected by competitors (On a scale 1 – 5, 1 is Not Affected and 5 is Strongly Affected).<br>COMP1. In the local market.<br>COMP2. In the national market.<br>COMP3. In the international market. | (Zhu et al. 2006b) |

(1) #, continuous variable; Y/N, dummy variable; 1 – 5, 5-point Likert scale. (2) Items with an * are reverse scales

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