A Technology-Organization-Environment Perspective on Eco-effectiveness: A Meta-analysis

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Abstract

In this research, we perform a meta-analysis to explain how organizations are deploying technologies to enforce organizational sustainability by meeting the goal of eco-effectiveness. Prior studies have studied the influences on the adoption of technologies using the Technology-Organisation-Environment (TOE) model that incorporate some aspects of technological, organizational or environmental factors. We collected prior research to test the factors of the TOE model to ascertain their relative impact and strength. Our meta-analysis found eight additional technological and organizational factors. We found strong support for IT infrastructure, perceived direct benefits, top management support, and competitive pressure. Moderate support for compatibility, technological readiness, perceived indirect benefits, knowledge (human resources), organizational size, attitudes towards innovation, learning culture, pressure from trade partners (industry characteristics) and regulatory support. Lastly, weak support was found for relative advantage, complexity, perceived risks and information learning culture. Only two dimensions, financial resources and environmental uncertainty failed to reach statistical significance.

Keywords: Green-IT; TOE; meta-analysis; eco-effectiveness

1 Introduction

In recent years, research on environmental sustainability has gained considerable prominence (Melville, 2010; Butler, 2011; Dao et al., 2011). Given a growing awareness that Information and Communications Technology (ICT) is accountable for 2% of the world's total carbon dioxide (Gartner, 2007), thus "Green Information Technology (IT)/Information Systems" (IS) has pervasively emerged as an important concept in the world of IS. More significantly, the adoption of Green IT/IS benefits enables organizations to reap competitive advantages such as better operational performance, cost reduction, and gaining a positive image as a "green" organization (Mithas et al. 2010; Rusinko, 2007; Thambusamy and Salam 2010).

To understand the concept of Green IT/IS comprehensively, it is vital to distinguish between Green IT and Green IS. Green IT is defined as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems (monitors, printers, storage devices, etc.) efficiently and effectively with minimal or no impact on the environment" (Murugesan, 2008, p. 25-26). While Green IS "refers to the design and implementation of information systems that contribute to sustainable business processes" (Watson et al., 2008, p.2). Along the same vein, Molla and Abareshi (2011) define Green IT as the first-order effects which are associated with the environmental impact of IT production, use, and disposal. Whereas they define Green IS as the second-order effect which is associated with the positive impact of using IT on the environmental sustainability of business and economic processes. In sum, we define Green IT to involve activities related to the adoption of Green IT practices, and Green IS plays a crucial role in greening organizational processes so that a more sustainable environment can be created. This research emphasizes Green IT as we are examining the implementation of Green initiatives.

Several theories have been proposed to explain the factors influencing Green IT adoption. The common theories adopted are: Resource-Based View Theory (Benitez-Amado and Walczuch, 2012; Dao et al., 2011), Transaction Cost Theory (Nedbal and Stieninger, 2014), Institutional Theory (Butler, 2011; Cai et al., 2013; Gholami et al., 2013) and Technology-Organization-Environment (TOE) (Bose and Luo, 2011). These theories provide different lenses through which to analyse the adoption of Green IT. For instance, Benitez-Amado and Walczuch (2012) provide evidence that IT capability enables the development of environmental strategy in enhancing organizational performance. Similarly, Dao and his colleagues argue that long-term adoption of Green IT can contribute to environmental performance. Nedbal and Stieninger (2014) use Transaction Cost Theory to explain how green technologies can reduce operational costs and enable cleaner production thus leading to higher organizational performance. Institutional Theory has been widely used to explain how coercive, mimetic and normative forces can influence organizations to adopt Green IT in achieving environmental and economic performance.

Given the theories mentioned above, this research is employing TOE to explain the adoption of Green IT. TOE is a generic framework that identifies various factors that influence organizational adoption of technologies. There are many factors that would drive an organization to implement Green IT. According to Lei and Ngai (2012), TOE is the only theoretical framework that encompasses all the drivers that can influence Green IT initiatives. Typically, these antecedents of adopting Green IT can be broadly categorized into three contexts: technological, organizational and environmental. The Resource-Based View Theory emphasizes on antecedents from the context of technological and organizational. In particular, the theory provides a framework for explaining the contribution of firm-specific technological/organizational resources and capabilities to influence Green IT initiatives (Barney, 1991; Eisenhardt and Martin, 2000). Transactional Cost Theory is used to analyse the co-ordination of transaction costs in the context of the green supply chain. The argument of Transaction Cost Theory is that organizations are adopting IT to support green supply chain management practices such as green procurement and green manufacturing so as to improve their environmental performance (Tate et al., 2011). The three forces of Institutional Theory are concerned with the environmental antecedents that influence Green IT initiatives. Coercive forces are enforcement mechanisms that legally regulate organizations to adopt Green IT initiatives (DiMaggio and Powell, 1983). Such coercive institutional factors encompass legal obligations, legally enforceable sanctions and, laws and regulations. Mimetic forces are mechanisms which support legitimacy through imitating the characteristics of other organizations. Examples of mimetic environmental factors are frequency-based imitation and outcome-based imitation (Chen et al., 2010).

Although there is a vast body of research utilizing TOE in examining the factors contributing to the adoption of technological innovations, the findings are fragmented (Sophonthummapharn, 2008). Therefore, the first objective of this research is to address the issue of inconclusive research on the antecedents that would motivate an organization's intention to adopt IT by conducting a meta-analysis of the literature. By identifying all potential factors that can influence organizational IT adoptions leads to our first contribution to the existing literature. The second objective is to extend the identified technological, organizational and environmental antecedents and apply them in the context of Green IT adoption. This meta-analytical review is a first attempt to identify empirically important antecedents of Green IT adoption. Thus, this study makes an important contribution by presenting a meta-analysis of empirical evidence to assess these antecedents. To our best knowledge, it is the first study to perform meta-analysis in Green IT research.

This research presents a meta-analytic review of primary quantitative studies that have investigated the relationship between Green IT adoption and the antecedents. Meta-analysis has proven to be a useful research method for statistically aggregating results across previous empirical individual results on a set of related hypotheses. It allows for better estimates of the true effect size than an individual empirical study. It is useful in correcting for statistical artefacts such as sampling error and measurement error. Our findings provide valuable insight into the effect of antecedents on Green IT adoption. Future research can use this study to understand the antecedent factors that influence Green IT initiatives.

The remainder of the paper is organized into six sections. Section two reviews background literature on Green IT and TOE. Section three develops the research framework and hypotheses. Section four describes the research method. Section five presents the results. Section six presents the discussion of the research findings. Section seven concludes with the main contributions, the limitations of the research and the implications for future research.

2 Theoretical background

2.1 Green IT

Sustainability is a broad concept that comprises three dimensions: economic, social and environmental (ecological). Extending the concept of sustainability to an organizational context, organizational sustainability can be understood as an organization's capability to achieve positive organizational performance, while at the same time managing corporate environmental issues and engaging in corporate social responsibility practices (Wikstrom, 2010). The economic dimension emphasizes on organizational activities that generate profits while reducing energy consumption and resource use (Watson et al., 2010). The social dimension focuses on organizational activities that promote social responsibility that future generations should have equal rights over the consumption of scarce environmental resources (Gary and Bebbington, 2000). The environmental dimension relates to organizational activities that help to reduce negative environmental externalities, thus creating a more sustainable society (Murugesan, 2008).

The above mentioned three main pillars of sustainability are known as the "triple bottom line" concept (Elkington, 1997). More importantly, it provides a blueprint for organizations to plan and facilitate their corporate social responsibility activities. Organizations have established a set of eco-goals to evaluate their triple bottom line performance. The eco-efficiency, eco-equity, and eco-effectiveness goals are concerned about delivering business activities under economic pressure, about the equity of all generations in access to natural resources and about doing the right things. According to Watson et al. (2010),

- Eco-efficiency refers to organizations producing competitive products and services, and on the other hand reducing costs using efficient use of resources to minimize negative impacts on the environment.
- Eco-equity refers to the equal distribution of scarce environmental resources between people and generations respectively.
- Eco-effectiveness refers to organizations designing and producing the right sustainable goods and services from the beginning. More importantly, eco-effectiveness seeks a permanent solution to restore and enhance the natural environment (Young and Tilley, 2006).

The phenomenon of Green IT is becoming more prominent this decade. This is because organizations are under pressure to create sustainable business practices (Olson, 2008). It has been argued that Green IT can be exploited to generate economic profits by creating a competitive advantage, support corporate social responsibility goals and manage environmental issues (Bose and Luo, 2011; Dao et al., 2011; Murugesan, 2008; Watson et al., 2008). More specifically, Green IT plays an important role in enforcing organizational sustainability by meeting the three eco-goals. For instance, Green IT enables organizations to achieve eco-efficiency using greening the use of hardware and software to reduce energy consumption and waste, and designing data centres to reduce power consumption and carbon emissions (Watson et al., 2008). Deploying virtualization software allows organizations to maximize natural resource utilization thus achieving eco-equity (Murugesan, 2008). Organizations can meet the eco-effectiveness goal by substituting travel and physical meetings with telecommuting, telepresence or video-conferencing that helps to contribute to environmental sustainability (Watson et al., 2008). We summarized the three eco-goals and their respective types of Green IT in Table 1.

Eco-goals	**Types of Green IT**
Eco-efficiency	Energy-efficient hardware, software, data centres.
Eco-equity	Server virtualization and storage, cloud computing, climate data sensors, remote monitoring systems.
Eco-effectiveness	Video conferencing, radio frequency identification, social networking, intelligent transport system.

Table 1: Eco-goals and types of Green IT

2.2 TOE

It is conducive to examine the mainstream technological innovation literature to understand organizational motives for implementing Green IT initiatives. Diffusion of innovation theory is an established theoretical framework for understanding technology adoption (Roger, 1995). According to Rogers, technological factors such as relative advantage, compatibility and complexity can influence the adoption of technological innovations. However, it is insufficient to evaluate an organization's decision to adopt or not to adopt IT innovations by assessing technological factors alone. As such, researchers extend the diffusion of innovation theory into their empirical research by incorporating organizational and environmental factors.

Prior literature has identified determinants of organizational innovation adoption which can be categorized into four contexts: technological, organizational, managerial action and institutional (Hameed et al., 2012, Tsai et al., 2013). For example, technological factors are associated with relative advantage, complexity, compatibility, IT capability and technology competence (Low et al., 2011; Seethamraju, 2015; Zhu and Kraemer, 2005). Organizational factors refer to organizational size, organizational readiness, and employees' attitude towards technology and ownership type (Jackson et al., 2013; Sila, 2010, Tsai et al., 2013). Environmental factors encompass competitive pressure, trading partner pressure, support from the government and environmental dynamism (Low et al., 2011; Sila, 2010). Though the motives for Green IT adoption are similar to other types of innovation adoptions, there are some differences between green initiatives and traditional initiatives (Olson, 2008). For instance, the start-up costs for green technologies are more expensive. Therefore, organizations need a longer time to reach a breakeven. Furthermore, organizations have to develop new organizational skills and transform business processes to adapt to the fresh green technologies.

We draw upon the theory of TOE to explain the organizational adoption of Green IT. It is a useful theoretical framework for studying factors that influence the adoption of Green technological innovations. TOE was developed by Tornatzky and Fleischer in 1990 which emphasize on the adoption of technological innovation. The theoretical framework identifies three dimensions of an organization's context that influence technological innovation adoption and implementation: technological context, organizational context, and environmental context. The technological context relates to both the internal and external technologies relevant to the organization. Organizational context refers to descriptive measures about the organization such as size, scope, managerial structure and internal resources. The environmental context refers to an organization's industry, competitors and government policy on intention.

3 Research model and hypotheses

Figure 1 presents the conceptual model of our study. Our model suggests that specific factors within the technological, organizational and environmental contexts can underpin green initiatives implementation. We begin unpacking the research model by first reviewing the different determinants within each context that influence adoption of technological innovation. Then, we discuss the hypothesized relationships between these key factors and organizational adoption of Green IT.

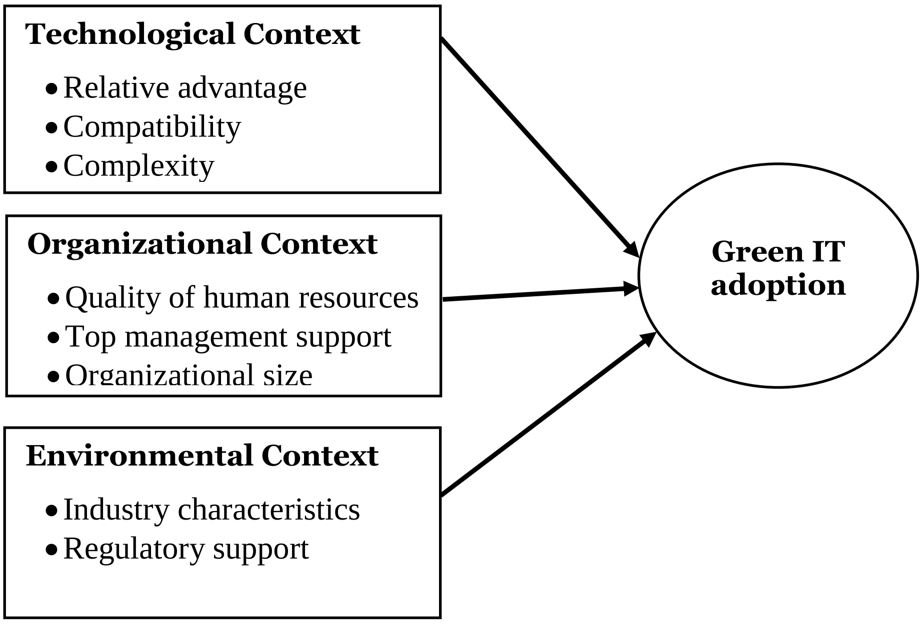

Figure 1: Conceptual model

3.1 Technological context

In a meta-analytic review of the studies of innovation attributes, Tornatzky and Fleischer (1990) identified ten innovation factors that have been widely used to study technology adoption in organizations. They are a relative advantage, complexity, communicability, divisibility, cost, profitability, compatibility, social approval, trial-ability and observability. Prior research has suggested that relative advantage, compatibility and complexity are consistently related to innovation adoption (Agarwal and Prasa, 1998; Cooper and Zmud, 1990; Premkumar and Ramamurthy, 1995). The hypothesis in this study will focus only upon on the most commonly studied factors in the technological innovation literature.

The TOE framework is consistent with the innovation theory of Rogers (1995, p. 376-383). Relative advantage is the "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 1995, p. 213). Compatibility is the "degree to which an innovation is perceived as consistent with the existing socio-cultural values and beliefs, past experiences, and needs of potential adopters" (Rogers, 1995, p. 223). Complexity is the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 1995, p. 230).

Green technological adoptions share similar fundamental characteristics that tradition technological innovation implementations do. That is to say, technological factors such as relative advantage, compatibility and complexity have significant relationships to organizational Green IT adoption. Organizations are more likely to implement green technological innovations if these Green technologies can bring about perceived organizational benefits such as better organizational performance and higher economic gains. Studies (Nedbal and Stieninger, 2014; Oliveira et al., 2014) show that economic advantages are an important technological characteristic that influences the adoption of cloud computing. Furthermore, green initiatives implementation can be driven by green technologies that are more compatible with an organization's technologies, processes and work application systems (Ho and Lin, 2012; Weng and Lin, 2011). Therefore, the following hypotheses are proposed:

Hypothesis 1: Relative advantage has a positive influence on Green IT adoption.

Hypothesis 2: Compatibility has a positive influence on Green IT adoption.

The literature suggests that more complex Green IT initiatives tend to have a negative influence on the adoption of new green innovations. Green IT initiatives implementation can be complex because it requires an organization to disseminate explicit knowledge about the initiatives to their employees. Subsequently, employees have to codify the explicit knowledge into tacit knowledge which then is shared (Nonaka and Takeuchi, 1995). For more complex Green IT initiatives, employees may take a longer time to understand and adapt to the new green technology as they need more effort to learn and share the tacit knowledge about both technological and administrative adjustments (Sila, 2010). Therefore, the following hypothesis is proposed:

Hypothesis 3: Complexity has a negative influence on Green IT adoption.

Additional factors in the TOE model such as technological readiness, IT infrastructure, perceived direct benefits and perceived indirect benefits were hypothesized as a positive influence on adoption of Green IT from prior literature studies shown in Appendix 1. Technological readiness was suggested as positive as the higher amount of structural aspects such as installed network technologies as well as specialized human resources an organization has, the more positive the adoption of Green IT (Oliveira et al., 2014; Pan and Jang, 2008). IT infrastructure also relates to higher amount of internet related resources in IT infrastructure, the more positive the adoption of Green IT (Soares-Aguiar and Palma-Dos-Reis, 2008; Pan and Jang, 2008). Perceived direct benefits relate to a reduction in transaction errors and improved accuracy, and indirect benefits relate to customer relationship. Both types of benefits are positive to the Green IT adoption (Teo et al., 2009). Perceived risks were hypothesized as a negative influence on adoption of Green IT from prior literature studies shown in Appendix 1. Risks in the online environment such as private data disclosure and hacking could bring about drastic setbacks to business. Therefore, businesses are cautious about their investment and perceived risks with the negative influence on the adoption of Green IT (Ghobakhloo and Tang, 2011). These additional factors were also tested to see if their relationship strength is stronger than the widely used factors in the conceptual model.

3.2 Organizational context

The organizational context refers to the characteristics, structures, processes and resources that constrain or facilitate technological innovation adoption. Tornatzky and Fleischer discuss the influences of a variety of organizational factors such as the role of informal linkages and communication among employees, the quality of human resources, top management's leadership behaviour, the amount of internal slack resources, and organizational size. Among all these factors, the quality of human resources, top management's leadership, slack resources and size, are the most frequently discussed factors with the organizational context that affect innovation adoption.

The hypothesis in this study will focus only upon on the most commonly studied factors in the organizational context innovation literature. The quality of human resources refers to the extent to which technical know-how knowledge is available within an organization. The study of Cooper and Molla (2014) provides empirical evidence that the greater the employees' absorptive capacity to generate Green IT knowledge, it is more likely for the organization to adopt successfully green initiatives. Top management's leadership describes the role of executive leadership in encouraging and facilitating innovation within the organization's overall strategy. In particular, top management commitment plays an important role in driving various initiatives for Green IT during the implementation stage. Cooper and Molla (2014) in their findings identified top management commitment as an essential factor in steering the organization towards the strategic importance of Green IT and realizing business value from Green IT adoption. Similarly, the empirical study of Lin et al. (2011) found that top management support has a positive influence on the adoption of cloud computing. Therefore, the following hypotheses are proposed:

Hypothesis 4: Quality of human resources has a positive influence on Green IT adoption.

Hypothesis 5: Top management support has a positive influence on Green IT adoption.

Prior research has been inconclusive about the effect of both organizational size and slack resources on innovation adoption. Tornatzky and Fleischer (1990) contend that larger organizations are more likely to adopt innovations as they have adequate slack resources and strong infrastructures to facilitate the process of technological implementation. However, larger organizations are associated with bureaucratic inertia and less flexible structure, therefore; they have more difficulty in accepting and implementing technological change (Damanpour, 2010). While smaller organizations are more likely to facilitate innovation usage as they have less bureaucratic inertia and more flexible structure, allowing them to benefit from lesser communication, coordination and influence to get support to implement the technological change (Nord and Tucker 1987). The literature suggests that larger companies tend to be more active in adopting green initiatives (González et al., 2008; Kolk, 2010). Therefore, we argue that bigger organizations are more likely to undertake the implementation of green initiatives and the concept of organizational inertia leads us to hypothesize:

Hypothesis 6: Organizational size has a negative influence on Green IT adoption.

Additional factors in the TOE model in the organizational context such as attitudes towards innovation, information sharing culture, learning culture and financial resources were hypothesized as a positive influence on adoption of Green IT from prior literature studies shown in Appendix 1. These factors were tested to see if their relationship strength was stronger than the main hypothesized factors on organizational context. Attitudes towards innovation are argued as positive as the attitude by top management will result in a more positive implementation also if they perceive that the benefits of adopting a new system will outweigh its risks and expenses they would be more willing to implement the system (Ghobakhloo and Tang, 2011). Information sharing culture relates to implementing systems such as e-procurement that require a business to share data with its business partners; this means that the process is quicker and has lower costs and lower inventory. The sharing of the data is of benefit and will have a positive influence on Green IT adoption (Teo et al., 2009). Learning culture is reasoned as the more an organization can learn from external consultants and from accumulating knowledge on the IT innovations within the firm the more positive the influence on the innovation will be (Henderson et al., 2012). Financial resources relate to the amount of resource the organization has to carry out the implementation. So more financial resources are positively relating to the adoption of Green IT (Kuan and Chau, 2001).

3.3 Environmental context

Tornatzky and Fleischer (1990) identify three categories of environmental factors: industry characteristics, government regulation, and technology support infrastructure. This study will focus on industry characteristics and government regulations that are the most commonly studied factors. The industry characteristics are comprised of competitive pressure and pressure from trading partners. This study defines competitive pressure as the pressure that arises from a threat to losing or maintaining competitive advantage, forces organizations to search for new technological adoption as alternatives to their current strategies (Lin and Lin, 2008). As more and more organizations are adopting green initiatives, this pervasive phenomenon has been pressuring organizations to adopt green technologies so as they can stay competitive in the industry or out-perform their competitors. The empirical study of Oliveira et al. (2014) contends that organizations are increasingly adopting cloud computing as they face competitive pressure from their competitors, and consequently follow their competitors' adoption of green technologies. Furthermore, the adoption of Green IT can also be driven by the organizations' trading partners. For instance, when Walmart adopted radio frequency identification, the organization made it a mandatory for its top 100 suppliers to adopt the new technology for the shipping container and case identification (Wang et al., 2006). Therefore, the following hypothesis is proposed:

Hypothesis 7: Industry characteristics have a positive influence on Green IT adoption.

Regulatory support has been identified as a critical environmental factor influencing technological adoption within the TOE framework (Kraemer et al., 2002). Government regulations can either motivate or discourage organizations from adopting technological innovations. When governments have specific mandates such as pollution control devices for energy firms and stringent safety and testing requirements on industries, these government regulations are more likely to constrain green initiative adoption (Baker, 2011). While regulatory support such as the provision of financial support, essential resources and tax breaks can encourage organizations to adopt a technological innovation (Tornatzky and Fleischer, 1990; Zhu and Kraemer, 2005). The Taiwanese government imposes green constraints on the electronics industry, and such a regulatory environment consequently motivates those organizations to adopt Green IT (Chen and Chang, 2014). Therefore, the following hypothesis is proposed:

Hypothesis 8: Regulatory support has a positive influence on Green IT adoption.

An additional factor in the TOE model in the environmental context named environmental uncertainty was hypothesized as a negative influence on adoption of Green IT from prior literature studies shown in Appendix 1. Environmental uncertainty relates to the fact that environmental uncertainty occurs when there are complex and rapid changes and information technology is necessary to be adopted to cope with this. However, they are unlikely to adopt these technologies without the support of mature infrastructure and institutions which is required for the operation of e-business. So that environmental uncertainty has a negative influence on influence of Green IT adoption (Li et al., 2010). This factor was tested to see if their relationship strength was stronger than the main hypothesized factors on environmental context.

4 Research Methodology

A meta-analysis approach (Hunter and Schmidt, 1990) was adopted to test the proposed hypotheses. A meta-analysis is a quantitative approach that aggregates findings across individual studies (see Hunter and Schmidt, 1990). The advantage of meta-analysis is to reconcile conflicting results among the research findings so as to study the strength of the variables underlying relations and causalities. This meta-analysis reviewed on empirical studies that examine how technological, organizational and environmental factors can determine technological adoption. Meta-analysis is a technique that evaluates prior statistical findings by accumulating effect sizes across all empirical studies. In this study, effect sizes are described as correlation coefficients. More significantly, meta-analysis enables the researchers to discern whether relationships exist and provide overall estimates regarding the magnitude and direction of those relationships. We followed the meta-analysis process recommended by Hunter and Schmidt (1990) to aggregate and analyse correlations reported by prior research to draw valid conclusions. The meta-analysis procedures are described below (see Figure 2).

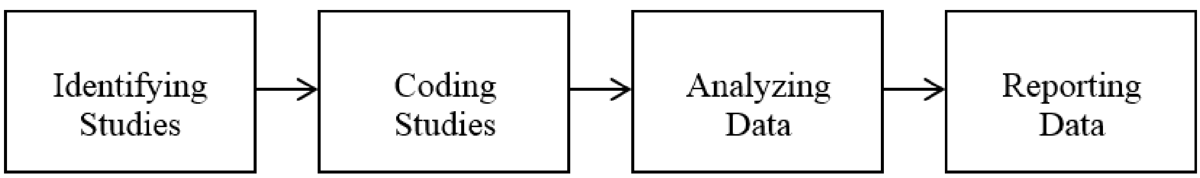

Figure 2: Research process

4.1 Identifying relevant studies

We performed a comprehensive search to identify any published journal articles of technological adoption that have studied in the context of TOE. We began by conducting a computer search with databases such as ACM Digital Library, Computer Source [EBSCO], IEEE Xplore, IGI Global, Proquest Computing, ScienceDirect, Scopus, SpringerLink, and Web of Knowledge. Keywords searched included 'technology-organizational-environment', 'adoption, 'technology', and 'innovations'. A total of 122 published empirical studies were found in the initial search.

After gathering the journal articles, we then applied three criteria to remove any unrelated to the studied phenomenon. First, we excluded studies that were purely theoretical and or review. Second, we excluded studies without quantitative empirical data. Third, we included studies that focused on TOE framework to study IT adoption. Fourth, we included studies that reported a Pearson correlation between dependent and independent variables. Applying these criteria, we ended up with 28 studies forming the basis for this meta-analytic investigation. The summary of the studies and samples used in the meta-analysis is found in Table Two.

4.2 Variable coding

The 28 empirical studies were coded based on the TOE framework. We coded technological adoption as the dependent variable while the technological, organizational and environmental factors as the independent variables. The empirical studies were coded independently by two of the authors. The first and second authors conducted the coding independently based on the variable names, construct definition and measures used in the empirical studies. Overall, there was a clear consensus about the coding of the variables as most of the initial codes were not ambiguous. The two authors resolved any discrepancies via discussion. Most of the 28 empirical studies refined the TOE framework to include more technological, organizational and environmental variables. A total of 19 variables were obtained. We will discuss how we coded the variables that were used in each article.

Technological factors: The technological variables that examined in the technological adoption research are a relative advantage, compatibility, complexity, technological readiness, IT infrastructure, perceived direct benefits, perceived indirect benefits and perceived risks. The coding scheme is depicted in Appendix 1.

Organizational factors: The organizational variables that examined in the technological adoption research are attitudes towards innovation, financial resources, organizational size, knowledge, information sharing culture, learning culture and top management support. The coding scheme is depicted in Appendix 1.

Environmental factors: The environmental variables that were examined in the technological adoption research are competitive pressure, environmental uncertainty, regulatory support and trading partner readiness. The coding scheme is depicted in Appendix 1.

Technological adoption: In existing technological adoption research, different IT adoptions that have been examined encompass: *collaborative commerce* (Chong et al., 2009); *cloud computing* (Oliveira et al., 2014) *enterprise application* (Gu et al., 2010; Henderson et al., 2012; Ramdani et al., 2013); *electronic business* (Alawneh et al., 2010; Eze, 2008; Oliveira and Martins, 2010); *electronic commerce* (Ekong et al., 2012; Ghobakhloo et al., 2011; Ghobakhloo and Tang, 2011; Hong and Zhu, 2006; Le et al., 2012; Li et al., 2010; Sila, 2013), *electronic data interchange* (Kuan and Chau, 2001; Seyal et al., 2007) *electronic procurement* (Cui et al., 2008; Li , 2008; Soares-Aguiar and Palma-Dos-Reis, 2008; Teo et al., 2009); *enterprise resource planning* (Pan and Jang, 2008); *electronic supply chain management system* (Lin, 2014); *mobile business* (Picoto et al., 2014); *radio frequency identification* (Paydar and Endut, 2013; Thiesse et al., 2011; Wang et al., 2010; Wu and Subramaniam, 2011).

4.3 Analysis

We used the Hunter and Schmidt (1990) method of calculating statistically corrected effect size estimates. This study measured an estimate of population correlation ρ by using Pearson's correlation coefficient r. We performed the weighted mean effect size ($\check{r}$) to correct for sampling error, which $\check{r}$ considers the sample size of each study and thus creates a weighted average of correlations. Based on Hunter and Schmidt (1990), the estimate of the population correlation is given by: $\check{r} = \sum N_i r_i / \sum N_i$, where N_i is the sample size of each study and r_i is the observed correlation value of each study. All estimates were calculated using Comprehensive Meta-analysis software (Borenstein et al., 2005).

For each study, we obtained the following information: sample size, the reliability of constructs (as reported using Cronbach's alpha or if not available the reported composite reliability or internal consistency scores) and correlation coefficients for each pair of the relationship. For studies that did not provide an average reliability, we used a conservative standard of 0.80 (Bommer et al., 1995). Some of the studies used logistic regression to calculate the odd ratios as the effect size estimates. We converted these effect size estimates into Pearson's r to facilitate interpretation (see Borenstein et al., 2009). We reported the weighted mean correlation coefficients for each bivariate relationship. Confidence intervals were constructed around the weighted mean correlation coefficients to facilitate hypothesis testing.

We corrected for measurement errors due to unreliability in measurement (Hunter and Schmidt, 1990). We calculated the correlation between the variables to correct for measurement error. According to Hunter and Schmidt (1990), the estimate of the true score correlation is given by: $r_c = r_{xy}/(\sqrt{r_{xx}})(\sqrt{r_{yy}})$, where r_c is the effect size corrected for measurement error, r_{xy} is the reported correlation between the variables, r_{xx} is the reliability estimate for the independent variable and r_{yy} is the reliability estimate for the dependent variable.

5 Results

Table 2 summarizes the results of our hypothesis tests. Examining the 95% confidence interval of each hypothesis, we found that the majority of the hypotheses were supported. Contrary to expectations, we did not find a significant negative relationship between organizational size and Green IT adoption.

All technological factors were found to be significantly related to Green IT adoption: relative advantage (ρ=0.255, p=0.000), compatibility (ρ=0.401, p=0.003), complexity (ρ=-0.099, p=0.027), technological readiness (ρ=0.406, p=0.000), IT infrastructure (ρ=0.585, p=0.000), perceived direct benefits (ρ=0.591, p=0.000), perceived indirect benefits (ρ=0.303, p=0.000), and perceived risks (ρ=-0.306, p =0.000).

Of the 7 organizational factors, 6 were found to be positive significantly related to Green IT adoption: attitudes toward innovation (ρ=0.424, p=0.008) knowledge (ρ=0.403, p=0.000), organizational size (ρ=0.429, p=0.000), top management support (ρ=0.511, p=0.000), information sharing culture (ρ=0.153, p=0.003), and learning culture (ρ=0.482, p=0.000). The relationship with financial resources (ρ=0.085, p =n.s.) was not significant.

Other than environmental uncertainty (ρ= -0.127, p=n.s.), all of the other environmental factors were found to be significantly related to Green IT adoption: competitive pressure (ρ=0.548, p=0.000), pressure from a trading partner (ρ=0.300, p=0.009), and regulatory support (ρ=0.342, p =0.000).

In total, we found significant relationships for 17 of our 19 variables. Only two variables, financial resources and environmental uncertainty failed to reach statistical significance. All of the variables were significant in the predicted directions. While organizational size (ρ=0.429, p=0.000) was found to be positively significantly related to Green IT adoption. The results are presented in Table 2 and 3.

Hypothesis	Total sample size for the given meta-analysis (K)	Number of studies included in the meta-analysis (N)	Corrected population correlation (ρ)	95% Confidence Interval Low	Upper	Effect size (p)	Result
Technological factors – Green IT adoption							
H1: Relative advantage	8	2090	0.255*	0.133	0.370	0.000	Supported
H2: Compatibility	8	2062	0.401*	0.142	0.142	0.003	Supported
H3: Complexity	9	2184	-0.099*	-0.185	-0.011	0.027	Supported
Organizational factors – Green IT adoption							
H4: Knowledge (Human resources)	2	1917	0.403*	0.207	0.567	0.000	Supported
H5: Top management support	11	2029	0.511*	0.389	0.615	0.000	Supported
H6: Organizational size	12	5280	0.429*	0.227	0.596	0.000	Not supported
Environmental factors – Green IT adoption							
H7: Competitive pressure (Industry characteristics)	16	7286	0.548*	0.404	0.666	0.000	Supported
H7: Pressure from trading partner (Industry characteristics)	3	607	0.300*	0.078	0.495	0.009	Supported
H8: Regulatory support	9	4118	0.342*	0.184	0.483	0.000	Supported

Table 2: Summary of hypothesis testing

Additional factors in the TOE model	Total sample size for the given meta-analysis (K)	Number of studies included in the meta-analysis (N)	Corrected population correlation (ρ)	95% Confidence Interval Low	Upper	Effect size (p)
Technological factors – Green IT adoption						
Technological readiness	6	1466	0.406*	0.362	0.448	0.000
IT infrastructure	3	1879	0.585*	0.355	0.749	0.000
Perceived direct benefits	2	719	0.591*	0.541	0.636	0.000
Perceived indirect benefits	2	719	0.303*	0.019	0.542	0.000
Perceived risks	2	1194	-0.254*	-0.306	-0.200	0.000
Organizational factors – Green IT adoption						
Attitudes towards innovation	2	1161	0.424*	0.117	0.657	0.008
Information sharing culture	2	376	0.153*	0.052	0.250	0.003
Learning culture	2	372	0.482*	0.400	0.557	0.000

Table 3: Meta-analysis results

6 Discussion

Research on Green IT started in 2007 in the IS field and many papers have provided a literature review of the existing knowledge and gaps thereof as well as future research directions (Tushi et al., 2014; Loeser, 2013; Dedrick, 2010; Brocke et al., 2013; Molla et al., 2011). These papers on literature reviews of Green IS/IT have listed the theories or frameworks used to study Green IS and have noted most of these theories/frameworks have only been used once. The issue with this is the research in Green IT is immature and as such there is not consistent knowledge being consolidated on the field and few empirical studies on Green IT being performed (Wang et al., 2015a; Wang et al., 2015b; Sahu and Srivastava, 2011; Brooks et al, 2010). The varying theories and frameworks have also been used to study the Green IT at different parts of its lifecycle from the initiation to strategy, to adoption then use. Thus, papers on Green IT/IS have many suggestions on research gaps and programs of research that should be undertaken (Wang et al., 2015).

Given the absence of a theoretical framework as a major gap in the Green IT literature and a limited number of papers have presented empirical research papers in Green IT. One of the theoretical frameworks that have been reasonably consistently applied is TOE. TOE is a reasonable framework in that it indicates what the antecedents of Green IT adoption success would be. It also covers the different areas that researchers would want to examine in adoption – the technological, the environmental and the organizational. Most antecedents would be able to be classified under one of these three areas. There have been 28 papers in the adoption area of Green IT systems which does provide us with a basis for performing a meta-analysis concentrating on Green IT and adoption.

We found that the majority of hypotheses implied by TOE were supported. Table 2 summarizes the results of our hypothesis tests. H1 relative advantage and H3 complexity were supported but not as strongly as expected. H2 Compatibility, H4 Human resource knowledge, H7 Pressure from trading partner and H8 Regulatory support were moderately strong. H5 top management support and H7 Competitive pressure we strongly supported. One unsupported hypothesis H6 was associated with Organisational Size. The prior research on this factor was inconclusive, and we hypothesized that Organizational size has a negative influence on Green IT adoption. The effect was found to moderately positive.

One of the benefits of a meta-analysis is its ability to examine the strength of the relationships between two constructs. Additional factors that were in the TOE model were also coded from prior studies during data analysis, and this enabled additional factors to be considered. Table 3 shows that the additional attributes technological factors (technological readiness, IT infrastructure, perceived direct benefits, perceived indirect benefits and perceived risks) and for organizational factors (attitudes towards innovation, information sharing culture and learning culture) were also significant. On the other hand, financial resources and environmental uncertainty failed to reach statistical significance. A plausible reason for this result might be these organizations perceive IT adoption as a critical organizational strategy. Therefore, despite insufficient financial resources and environment uncertainty, organizations would still persist with their adoption.

The meta-analysis quantifies the strength and magnitude of the relationship between two constructs. The general guideline to judge the effect sizes is by looking at the values of the correlation coefficient. Correlation coefficients are not precise but are generally classified as weak, moderate and strong. In our study, we assumed 0.00-0.09 to be insignificant, 0.10-0.29 to be weakly significant, 0.30-0.49 to be moderately significant, 0.50-0.69 to be strongly significant (Cohen and Cohen, 1983). Table 4 shows the magnitude of these relationships with technological factor complexity at -0.990 on the border line of weakly significant. However, several variables only had two data sets. While this is sufficient to perform a meta-analysis, more studies would be useful for this variable. For example, more studies would also be useful in performing moderator analysis on size, type of Green IT and industry type.

Relationship Strength	Total sample size for the given meta-analysis (K)	Number of studies included in the meta-analysis (N)	Corrected population correlation (ρ)	95% Confidence Interval Low	Upper	Effect size (p)
Strong						
Technological factors – Green IT adoption						
IT infrastructure	3	1879	0.585*	0.355	0.749	0.000
Perceived direct benefits	2	719	0.591*	0.541	0.636	0.000
Organizational factors – Green IT adoption						
H5: Top management support	11	2029	0.511*	0.389	0.615	0.000
Environmental factors – Green IT adoption						
H7: Competitive pressure (Industry characteristics)	16	7286	0.548*	0.404	0.666	0.000
Moderate						
Technological factors – Green IT adoption						
H2: Compatibility	8	2062	0.401*	0.142	0.142	0.003
Technological readiness	6	1466	0.406*	0.362	0.448	0.000
Perceived indirect benefits	2	719	0.303*	0.019	0.542	0.000
Organizational factors – Green IT adoption						
H4: Knowledge (Human resources)	2	1917	0.403*	0.207	0.567	0.000
H6: Organizational size	12	5280	0.429*	0.227	0.596	0.000
Attitudes towards innovation	2	1161	0.424*	0.117	0.657	0.008
Learning culture	2	372	0.482*	0.400	0.557	0.000
Environmental factors – Green IT adoption						
H7: Pressure from trading partner (Industry characteristics)	3	607	0.300*	0.078	0.495	0.009
H8: Regulatory support	9	4118	0.342*	0.184	0.483	0.000
Weak						
Technological factors – Green IT adoption						
H1: Relative advantage	8	2090	0.255*	0.133	0.370	0.000
H3: Complexity	9	2184	-0.099*	-0.185	-0.011	0.027
Perceived risks	2	1194	-0.254*	-0.306	-0.200	0.000
Organizational factors – Green IT adoption						
Information sharing culture	2	376	0.153*	0.052	0.250	0.003

Table 4: Magnitude of relationships

Overall, given the original hypotheses, as well as the additional factors coded from the prior research were empirically supported. A model showing both the hypothesized factors and the additional factors is shown in Figure 3.

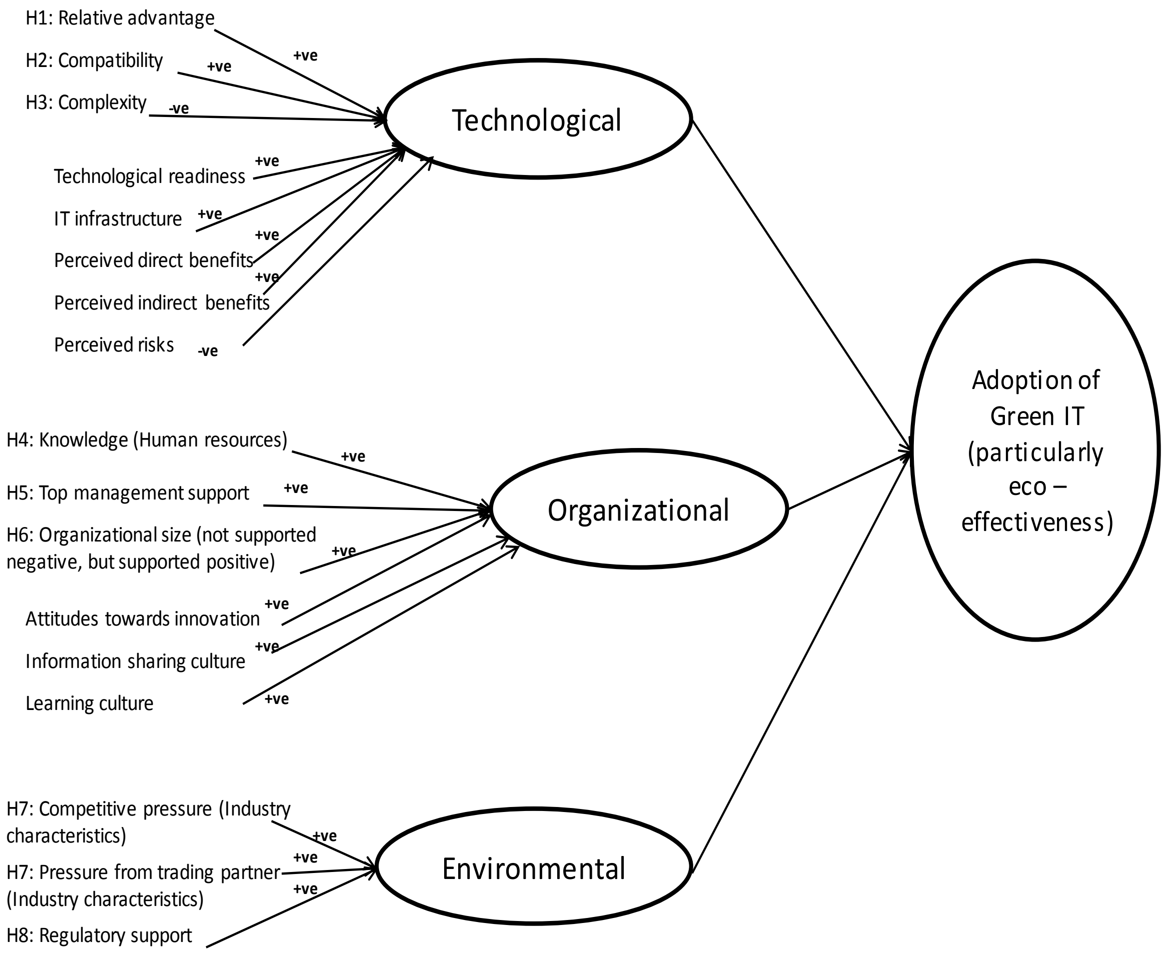

Figure 3: TOE model for adoption of Green IT particularly eco-effectiveness

Original studies have shown Green IT as a single technology or practice. Table 1 provided the types of Green IT and classified them as eco-efficient, eco-equity and eco-effectiveness. When we categorize the papers in this meta-analysis, all papers bar one fit in the eco-effectiveness category (refer to Table 5). Transcending this result into the Green IT context, when organizations making decisions about their IT/IS adoption, they are more conscious to implement technologies that restore and enhance the natural environment (Young and Tilley, 2006). A plausible reason why there is one paper in eco-equity category is that cloud computing research is still at an early stage thus it has many adoption issues (Jing et al., 2013). Also, it is costly to implement cloud computing as it needs a large-scale computing infrastructure (Lee et al., 2014). No papers were categorized in the eco-efficiency category.

Given the findings relate to the eco-effectiveness domain of Green IT we can show the model in Figure 3 using the hypothesis and the additional factors from the TOE model that have moderate and strong strength. The magnitude of relationships in Table 4 indicates our conceptual model in Figure 1 was not correct. Empirically factors that we had not hypothesized turned out to be important. The rationale for their importance also needs to be investigated in future research. Figure 3 shows that the conceptual model for adoption of Green IT (eco-effectiveness) is in reality closer to the general IT adoption model. It would be interesting to see if this is also found with eco-efficiency and eco-equity domains of Green IT.

	Papers in the meta-analysis classified by type of Green
Eco-efficiency	
Eco-equity	*Cloud computing* (Oliveira et al., 2014)
Eco-effectiveness	*Collaborative commerce* (Chong et al., 2009); *enterprise application* (Gu et al., 2010; Henderson et al., 2012; Ramdani et al., 2013); *electronic business* (Alawneh et al., 2010; Eze, 2008; Oliveira and Martins, 2010); *electronic commerce* (Ekong et al., 2012; Ghobakhloo et al., 2011; Ghobakhloo and Tang, 2011; Hong and Zhu, 2006; Le et al., 2012; Li et al., 2010; Sila, 2013), *electronic data interchange* (Kuan and Chau, 2001; Seyal et al., 2007); *electronic procurement* (Cui et al., 2008; Li, 2008; Soares-Aguiar and Palma-Dos-Reis, 2008; Teo et al., 2009); *enterprise resource planning* (Pan and Jang, 2008); *electronic supply chain management system* (Lin, 2014); *mobile business* (Picoto et al., 2014);*radio frequency identification* (Paydar and Endut, 2013; Thiesse et al., 2011; Wang et al., 2010; Wu and Subramaniam, 2011).

Table 5: Papers in meta-analysis classified by type of Green IT

The literature on Green IT has discussed the stages of Green IT adoption. In particular, the earlier papers raising awareness about environmental issues and particularly the relationships between information systems and sustainability (El Idrissi and Corbett, 2016). Next literature moved on to a firm's motivations and their readiness to adopt Green IT/IS (Deng et al., 2015). After this later papers moved onto ways to assess the antecedents of Green IT adoption and their level of adoption. This paper presents first attempt to identify empirically the important antecedents from all prior studies influencing the adoption of Green IT in particularly the area of eco-effectiveness. Originally, this was conceptualized as being different than the general IT adoption model, however, Figure 4 shows us that the Green IT adoption model for eco-effectiveness has emerged more like a general IT adoption model than a distinctive Green IT adoption model.

A limitation of this research is that the papers used in the meta-analysis only cover the eco-effectiveness area of Green IT. Future research into the TOE model would be interesting if additional papers were published on eco-equity and eco-efficiency areas that included sufficient information for them to be used in a meta-analysis and these areas constructs could be tested. Also, this paper concentrated on adoption of Green IT, if there were sufficient empirical papers other parts of the Green IT life cycle such as initiation, strategy and use could be investigated as well.

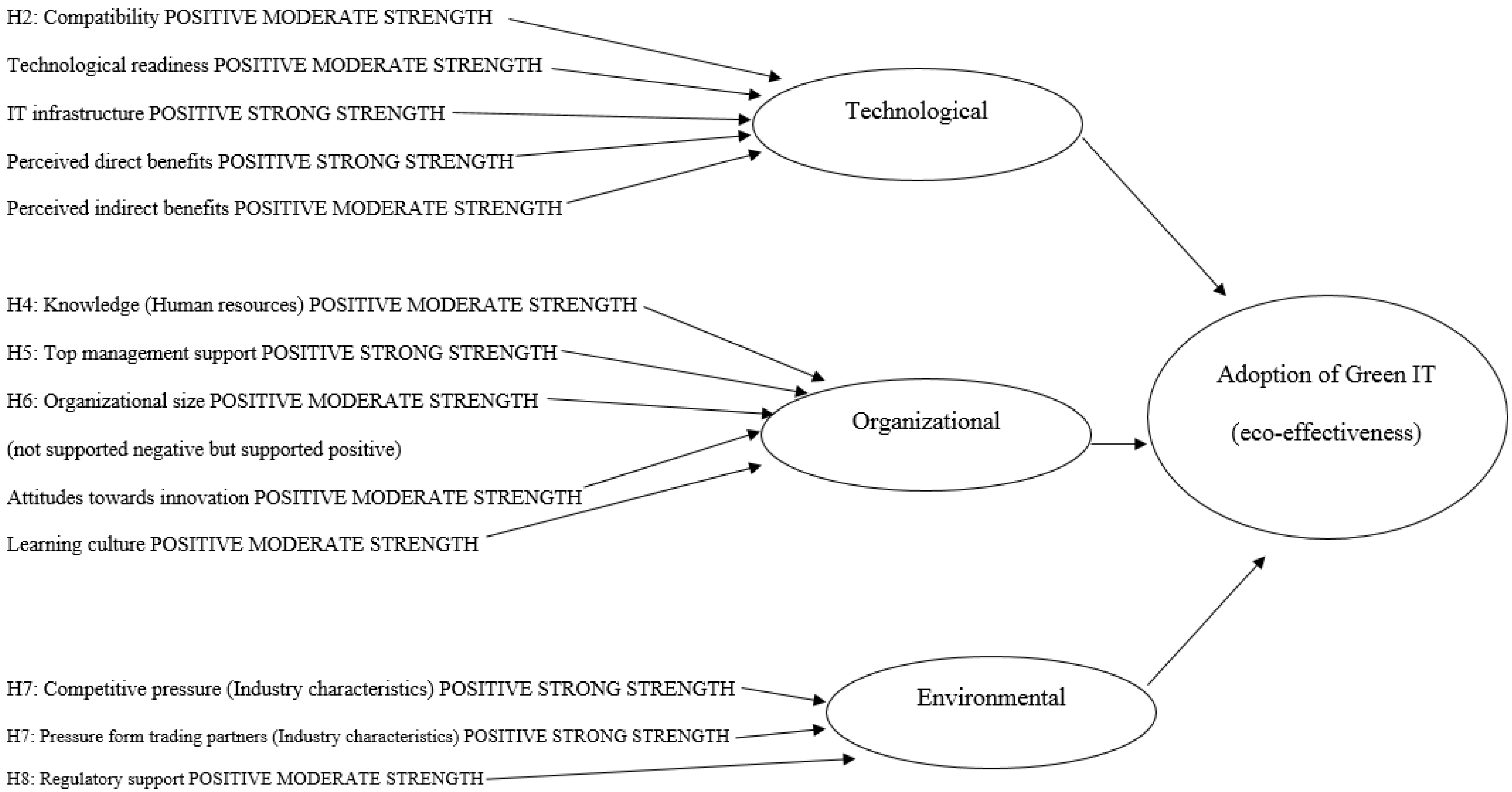

Figure 4: Final TOE model for adoption of Green IT particularly eco-effectiveness

7 Conclusion

The general literature on Green IT has been fragmented and not cohesive (Tushi et al., 2014; Wang et al., 2015a; Wang et al., 2015a). While past studies have looked at antecedents to Green IT – the frameworks used have been fragmented. However, the prior literature does include 28 studies that have explicitly examined antecedents of adoption of Green IT using the TOE framework. This is enables the comprehensive examination of environmental, technological and organizational factors using a consistent theory. Our work assesses the TOE framework for the adoption of Green IT. We have examined aspects of the TOE model – technological, organizational and environment that relate to Green IT adoption using meta-analysis. By using meta-analysis we have been able to get a clear understanding of the relative impact and strength of the antecedents of Green IT adoption. We found that the Green IT antecedents did not significantly differ from those of general IT adoption.

The findings of the meta-analysis allowed us to draw more definitive conclusions on the relationship between the TOE model and adoption of Green IT. We have empirically examined the relationships using meta-analysis and found the majority of the relationships to be supported. However, the empirical papers used in the meta-analysis did support the eco-effectiveness type of Green IT. This is particularly important as the current empirical papers cover the eco-effectiveness area bar one. This model is a significant contribution to the area of adoption of Green IT. However, some limitations have to be considered. We included only studies that performed correlation analysis. For some variables, the number of data sets available were not adequate to perform the meta-analysis. Similarly, the study did not evaluate the moderator factor effect for variables due to the lack of data. We used studies that provided correlation values for the relationship between TOE variables and Green IT adoption.

Our findings have considerable significance in understanding the determinants of Green IT adoption relating to eco-effectiveness. The study provides researchers and practitioners with a set of factors that affect the adoption of Green IT in organizations. We found strong support for IT infrastructure, perceived direct benefits, top management support, and competitive pressure. Moderate support for compatibility, technological readiness, perceived indirect benefits, knowledge (human resources), organizational size, attitudes towards innovation, learning culture, pressure from trade partners (industry characteristics) and regulatory support. Lastly, weak support was found for relative advantage, complexity, perceived risks and information learning culture. Only two dimensions, financial resources and environmental uncertainty failed to reach statistical significance. Organizations do not have a clear understanding of what factors are important in Green IT adoption. Managers need to consider these issues when embarking on Green IT adoption for eco-effectiveness. These may not be appropriate for eco-equity and eco-efficiency types of Green IT adoption. More empirical research is needed on these areas. We hope this framework will point researchers in useful directions in engaging in future studies with Green IT.

Future studies utilizing papers that cover Green IT from the eco-equity and eco-efficiency would be interesting to see if the same TOE model as developed in this article were supported for these other types of Green IT. Different models of Green IT adoption could be developed based on the type of Green IT this offers organizations more understanding of the issues related to Green IT adoption. Given the small number of studies currently, moderator analysis was not examined. However, future research with a larger number of empirical papers could provide analysis size, industry type, information system type and type of Green IT as moderators.

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Appendix 1 List of independent variables examined in technological adoption research

Independent variables	Definition	Expected association	Data sources
Relative advantage	The degree to which new technological adoption provides positive organizational performances and economic gains over existing technologies	Positive	Ekong et al. (2012); Eze (2008); Ghobakhloo et al. (2011); Henderson et al. (2012); Le et al. (2012); Li (2008); Li et al. (2010); Wang et al. (2010)
Compatibility	The degree to which new technological adoption is compatible with the existing IT infrastructure	Positive	Ekong et al. (2012); Ghobakhloo et al. (2011); Ghobakhloo and Tang (2011); Henderson et al. (2012); Le et al. (2012); Li (2008); Thiesse et al. (2011); Wang et al. (2010)
Complexity	The degree to which new technological innovation is perceived as difficult to use	Negative	Ekong et al. (2012); Gu et al. (2010); Henderson et al. (2012); Le et al. (2012); Li (2008); Sila, (2013); Thiesse et al (2011); Wang et al. (2010); Wu and Subramaniam (2011)
Technological readiness	Refers to an organization's capability in adopting new technologies. It can be assessed by an organization's available technological infrastructure and IT knowledge and skill to implement a specific new technology	Positive	Alawneh et al. (2010); Eze (2008); Li et al. (2010); Oliveira et al. (2014); Pan and Jang (2008); Picoto et al. (2014)
IT infrastructure	Refers to the number of IT hardware and software and the networked status	Positive	Cui et al. (2008); Pan and Jang (2008) Soares-Aguiar and Palma-Dos-Reis (2008)
Perceived direct benefits	Direct benefits include reduction in transaction errors and transaction costs, improved data accuracy and information quality, and faster application process	Positive	Kuan and Chau (2001); Teo et al. (2009)
Perceived indirect benefits	Indirect benefits include better customer services and improved relationship with business partners	Positive	Kuan and Chau (2001); Teo et al. (2009)
Perceived risks	Refers to the cost of implementing the specific new technology	Negative	Ghobakhloo and Tang (2011); Le et al. (2012)

Independent variables	**Definition**	**Expected association**	**Data sources**
Attitudes towards innovation	The degree to which top management's attitude towards a specific new technology adoption	Positive	Ghobakhloo and Tang (2011); Le et al. (2012)
Financial resources	Refers to financial resources to invest in the technological adoption	Positive	Alawneh et al. (2010); Kuan and Chau (2001); Li (2008)
Organizational size	Refers to an organization's annual revenue, total number of employees, number of IT staff, employees,	Positive	Alawneh et al. (2010); Ghobakhloo et al. (2011); Le et al. (2012); Lin (2014); Oliveira et al. (2014); Oliveira et al. (2010); Pan and Jang (2008); Picoto et al. (2014); Soares-Aguiar and Palma-Dos-Reis (2008); Teo et al. (2009); Thiesse et al. (2011); Wang et al. (2010)
Information sharing culture	Extent of information is being shared within the organization for the adoption process	Positive	Ghobakhloo et al. (2011); Teo et al., (2011)
Learning culture	The degree to which an organization's emphasis on learning about specific new technology adoption	Positive	Henderson et al. (2012); Li et al. (2010)
Top management support	Extent of top management's engagement, commitment and allocation of resources to support the specific new technology adoption	Positive	Ekong et al. (2012); Eze (2008); Li (2008); Lin (2014); Oliveira et al. (2014); Picoto et al. (2014); Seyal et al., 2007; Sila (2013); Teo et al. (2009); Thiesse et al (2011); Wang et al. (2010); Wu and Subramaniam (2011)
Knowledge	Refer to the requisite expertise to adopt the specific new technology	Positive	Henderson et al. (2012); Le et al. (2012)
Competitive pressure	The degree to which an organization is affected by competition in the market		Alawneh et al. (2010); Ekong et al. (2012); Eze (2008); Ghobakhloo et al. (2011); Gu et al. (2010); Hong and Zhu (2006); Oliveira et al. (2014); Oliveira et al. (2010); Le et al. (2012); Li (2008); Pan and Jang (2008); Picoto et al. (2014); Sila (2013); Soares-Aguiar and Palma-Dos-Reis (2008); Wang et al. (2010); Wu and Subramaniam (2011)

Independent variables	Definition	Expected association	Data sources
Environmental uncertainty	The degree to which an organization is affected by the behaviours of its suppliers, customers and competitors	Negative	Eze (2008); Li et al. (2010)
Regulatory support	Extent of support from the government	Positive	Alawneh et al. (2010); Cui et al. (2008); Eze 2008); Ghobakhloo and Tang (2011); Kuan and Chau (2001); Le et al. (2014); Oliveira et al. (2014); Pan and Jang (2008); Seyal et al. (2007)
Trading partner readiness	Refer to trading partners' readiness in adopting the specific new technology	Positive	Ghobakhloo and Tang (2011); Soares-Aguiar and Palma-Dos-Reis (2008); Wu and Subramaniam (2011)