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Review

Determinants of Green ICT Adoption in Organizations: A Theoretical Perspective

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Abstract: Information and communication technologies (ICT) are present in almost all fields of human activity. The expansion of their use should be balanced by the results of the studies on the negative effects on the environment. The relationship between these technologies and the environment is relatively new. The application of environmental criteria is commonly referred to as green ICT or green computing. Awareness of the importance of the ecosystem has led to increased interest in its protection both in production and in consumption. Green ICT should be a major concern not only for the hardware and software producers but also for the users. They could stimulate the demand for less harmful products for the environment with an essential role in the after-sales stages. Companies can contribute to this process by resource efficiency, dematerialization, and minimizing e-waste, increasing recycling, and producing fewer CO_2 emissions. The decision to adopt green ICT depends on the expected benefits and investments. This decision depends on costs, competitiveness, financial support, managers and employees' characteristics and skills, legal regulations, supply, and demand. The contributions of the paper cover identifying, analysing and classifying general and specific determinants of green ICT adoption in organizations based on the literature in this field.

Keywords: green information and communication technologies; green ICT; determinants; environment protection; motivations; sustainable; legal regulations

1. Introduction

The interest of research and industry, both in the public and private sectors, in environmental problems is not new. Theories regarding the concept of green and sustainability started to influence the market and consumers' preferences ever since the 1970s; first in United States as "societal marketing" [1]. During that period, organizations interested in environmental protection managed to persuade the consumers to be more eco-friendly in some actions and decisions. After a flurry of conceptual papers to initiate the field of study, research now focuses on resource efficiency, dematerialization, and reduction of e-waste and emissions, leading to improved environmental performance and/or reduced environmental impact [2]. Concepts such as eco-innovation, sustainable development, and environmental friendliness have had great success in research and in practice, partly due to the strengthening of environmental regulatory restrictions. The success of concepts such as these has become a major social phenomenon, supported by national and international non-governmental organizations dedicated to environmental protection and by regulatory agencies.

Thus, environmental concerns have influenced the field of green information and communication technologies (ICT), which is considered the most innovative at present. Its evolution through eco-innovations is a natural result of progress over the last decades. The ubiquity of ICTs leads to increased energy consumption and CO_2 emissions with considerable negative effects on the environment in terms of sustainable development [3–8]. This ubiquity also leads to increasing the volume of e-waste [9–12]. However, the relationship between ICTs and the environment is complex.

ICTs can play a positive role as well, through dematerialization and online delivery, transport and travel substitution, a host of monitoring and management applications, greater energy efficiency in production and use, and product stewardship and recycling [13,14]. The favourable effects mentioned above and the development of environmentally friendly ICT products and services, defined in the following section, lead to diminishing the negative influences on the environment, thereby stimulating the use of eco-friendly ICT in a wide variety of activities. Based on these reflections, we consider very important factors that influence organizations to select ICT products and services with minimal negative environmental influences, also known as green ICT.

This study attempts to identify the research trends and emerging areas in determinants influencing the adoption of green ICT and to identify any gaps in the literature for future research. The absence of a theoretical framework is still a major gap in green ICT literature [15–17]. While most studies focus on green ICT implementation results, this paper identifies, analyses and classifies the determinants of green ICT adoption in the pre-implementation stage. Furthermore, this paper contributes the identification of specific determinants of the adoption of green ICT in organizations to research on green ICT. While previous research analyses, theoretically and empirically, the general motivations of green ICT adoption, similar to EMP motivations, our study identifies and classifies specific motivations of green ICT adoption in organizations and highlights the differences between implementing actions of green ICT and other EMPs. Thus, this paper provides an overview of the current research on the general and specific determinants that influence the adoption of green ICT in organizations.

2. Definition of the Topic

In the case of ICT, environment protection involves the development of hardware and software with minimal influence on the environment (radical innovation) or improving the existing ones (incremental innovation), and using ICT for diagnosing and solving environmental problems. Concepts such as green information technologies (IT) or green ICT—especially targeted to reduce the negative effects of ICT usage on the environment and IT for green, ecological informatics, environmental informatics, and computational sustainability—for development and usage of applications dedicated to environmental protection were introduced after the mentioned concerns in literature and practice. Table 1 presents some representative definitions for green ICT/IT.

Table 1. Definitions of green information and communication technologies (ICT).

Author	Green information technology (IT)/ICT is ...
[18]	... how "hardware and other infrastructure [...] can be better managed and designed from an environmental perspective."
[19]	... "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems—such as monitors, printers, storage devices, and networking and communications systems—efficiently and effectively with minimal or no impact on the environment. Green IT also strives to achieve economic viability and improved system performance and use, while abiding by our social and ethical responsibilities."
[20]	... "mainly focused on energy efficiency and equipment utilization."
[21]	... "an organization's ability to systematically apply environmental sustainability criteria (such as pollution prevention, product stewardship, use of clean technologies) to the design, production, sourcing, use and disposal of the IT technical infrastructure as well as within the human and managerial components of the IT infrastructure."
[22]	... "design technique, construction technique, the function of the information diffusion technique to achieve optimal environmental governance, and the approach is also about optimization and improvement of the organization's operational processes without hindering its progress in use of technology."

The terminology "Green IT/ICT" became popular after the publication of a Gartner report in 2007 [23] and was later joined by "Green Computing", "Green Software", "Green Software Engineering" and "Green Information Systems" [24]. Green ICT addressed developers' and ICT users' concerns for solving environmental problems. The direct benefits, manifesting mainly in savings from reduced energy consumption, which lead to CO_2 reduction, are the base for attracting interest. Bachour and Chasteen believe that the adoption of green ICT in organizations means using technology efficiently while taking into account the triple bottom line: "economic viability, social responsibility, and environmental impact" [25].

The effects of green ICT, which have the potential to be substantial, can be direct by reducing negative ICT impacts on the environment or indirect by using information systems to support other business initiatives in reducing their negative environmental impacts [26]. Concepts such as "green by ICT" and "green in ICT", "green by software" and "green in software", "green by hardware" and "green in hardware" refer to specific subdomains or various levels of involvement in environmental protection through ICT [27]. Table 2 presents their definitions and descriptions based on literature in the field.

Table 2. Green IT: green software and green hardware.

Concept	Definition	Concept	Description
green by IT	"the impact of IT on the environmental productivity of other sectors" [27]	green by hardware	Equipment and installation to help monitor and protect the environment; The use and disposal of hardware with minimum negative influences on the environment.
		green by software	Software dedicated exclusively to environmental protection and monitoring; Software that provides efficient resources management for other applications.
green in IT	"the IT sector's own activity and its impact on environmental efficiency" [27]	green in hardware	All ICT industry initiatives to reduce the consumption of non-renewable resources, pollution and waste efficient management.
		green in software	Minimizing negative influences of software development on the environment and supporting the complete life cycle of sustainable software system engineering.

These distinctions highlight the particularities of green ICT. They also highlight how an organization can contribute to environmental protection through ICT development and adoption. The most important feature of the ICT industry, which distinguishes it from other industries, is its double role: on the one hand, it supports environmental protection, and on the other hand, it contributes to the degradation of the environment, both by through the hardware and software dedicated to its monitoring and protection. An important vector for promoting the importance of green ICT adoption is the increasing ubiquity of ICT at all levels (individual, organizational and societal) and their important contributions to economic and social progress. They are strategic technologies because they have an essential role in the redesign of business and production processes through green information systems, in order to decrease the CO_2 emissions of organizations [28]. The ICT contribution to environmental protection can become manifest in the reduction of energy consumption, in the development and use of hardware and software (e.g., replacing desktop PCs with thin clients), in virtualization, in the reduction of energy consumption in data centres, in the reduction of emissions from transport by promoting communication in the virtual environment, in recycling and reuse, and in the increased access to information. From "enabling a carbon footprint analysis, monitoring and reporting capability through supplanting eco-unfriendly business practices, to deploying computerized models to increase energy efficiency and reduce greenhouse gas emissions," [29] hardware and software make green ICT essential and unique.

Nevertheless, the environmental concerns were introduced into organizations by environmental management practices (EMPs). These practices include environmental audits, total quality management, pollution prevention plans, environmental training for employees, total cost accounting, life cycle analysis, research and development (R&D), environmental standards for suppliers, and employee incentive programs for environmental suggestions [30]. Green ICTs have some particularities that differentiate them from other EMPs. They offer the necessary tools to implement some important EMPs in organizations but also extend the application of these practices on ICTs through their recycling and reuse, proactive cost reduction, and surveillance of the market for environmental issues as well. Below, we present some specific determinants of the adoption of green ICTs to highlight these differences.

Current green IT trends are characterized by the efforts of IT management, primarily to use IT resources more efficiently and effectively and to reduce the environmental impact [31]. The direct or indirect benefits influence the involvement in green ICT development and implementation in organizations or their usage by individuals. The following sections analyse the main general and specific determinants influencing the adoption of green ICT identified in the literature.

3. Research Methodology

3.1. Research Questions

The goal of this work is to identify the main factors influencing the adoption of green ICT. We will answer the following two important questions:

Q.1: What are the general and specific motivations in the adoption of green ICT?
Q.2: How can the motivations in the adoption of green ICT be classified?

While previous research focused on the effects of green ICT adoption [32–36], this paper addresses the pre-adoption phase of green ICT.

3.2. Research Method

The first step for analysing the determinants of green IT in organizations was to conduct a comprehensive review of the current literature. We used content analysis for this research. This methodology has become popular in social sciences in recent years, especially thanks to technological advances. According to Kassarjian, this is "a phase of information-processing in which communications content is transformed, through objective and systematic application of categorization rules, into data that can be summarized and compared" [37]. Krippendorff offers a conceptual framework for content analysis with six components: (1) "a body of text, the data that a content analyst has available to begin an analytical effort"; (2) "a research question that the analyst seeks to answer by examining the body of text"; (3) "a context of the analyst's choice within which to make sense of the body of text"; (4) "an analytical construct that operationalizes what the analyst knows about the context"; (5) " inferences that are intended to answer the research question"; and (6) "validating evidence , which is the ultimate justification of the content analysis" [38] (pp. 29–30). Below, we address all these components.

We searched in several academic databases and search engines, such as ACM Digital Library, Web of Science, Science Direct, and IEEE Xplore Digital Library. The keyword used was "green ICT". Through these searches, we identified 435 papers focused on green ICT and/or green IT. For the following steps, we used EndNote to eliminate redundancies and to explore the scope of the articles. Titles and abstracts were analysed to identify the articles related to determinants of green ICT from a business perspective. This process led to a final number of 70 articles that we considered for further analysis. The timeframe for our review was the period in between the years 2008 to 2015. We chose 2008 as the starting point, since the concept of green ICT has only become significant and attracted the attention of researchers since 2008 as a reaction to the Gartner report, which estimated the global ICT industry to account for approximately 2 percent of global carbon dioxide (CO_2) [23].

4. Analysis, Findings and Discussion

4.1. Publications by Year

The interest in studying the relationship between ICT and the environment in literature began to increase as of 2008. Table 3 shows the number of papers published from 2008 to 2015 in some representative international databases.

Table 3. Amount of papers in international databases found with the keywords "green ICT"/"green IT".

Database	2008	2009	2010	2011	2012	2013	2014	2015	Total
ACM Digital Library	-	3	5	6	8	8	7	5	42
Web of Science	1	8	6	9	21	19	18	13	95
Science Direct	-	-	2	3	23	16	15	31	90
IEEE Explorer	-	6	4	10	19	47	9	113	208
Total	1	17	17	28	71	90	49	126	435

Researchers' interest regarding the relationship between ICT and the environment appears to be increasing. Organizations and individuals are increasingly concerned about their study and their use in the current activity. There is a lot of discussion about theory and practice but few real-world implementations—the suspicion being that there are not many to examine and that, as pointed out by researchers, the metrics are difficult to quantify and measure [39].

4.2. Overview of Factors Influencing the Adoption of Green ICT in Literature

A mix of both pragmatic (e.g., financial and legal) and idealist (e.g., moral and ethical) factors influence managers' decisions to adopt green ICT according to Lampe et al. [40]. There are general motivations, applied to all EMPs, and specific motivations applied only to the ICT field (Figure 1). In this section, we have selected and reviewed articles addressing all sets of determinants.

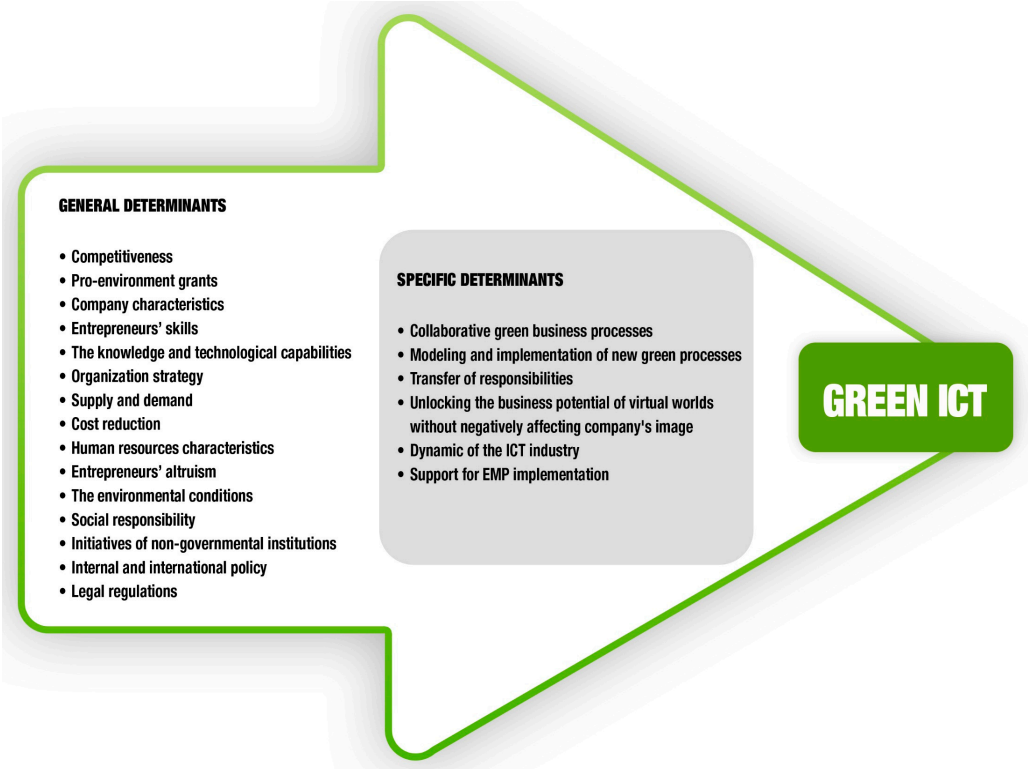

Figure 1. The determinants of green information and communication technologies (ICT) adoption.

Figure 1 presents, on the left, general determinants of green ICT adoption as identified in the literature. The specific determinants, presented in the right side of the figure, reflect our opinion about the motivations of green ICT adoption in organisations. We consider that the first category of determinants provides general framework for green ICT adoption and the second category represents effective exploitation of green ICT opportunities.

There are vast amounts of literature on the main motivations of the adoption of EMPs. The reason is that the costs of environmental irresponsibility have become much clearer because of global and regional problems, such as global warming, ozone depletion, deforestation, and loss of biodiversity [41,42]. The introduction of the ISO 14000 standards family [43] plays the most important role in taking initiatives for the environment's protection inside organizations. The researchers identified the following determinants in this case: environmental legislation, incident prevention, improving corporate image and ethics, costs, human resources, customers and suppliers, and the technological, organizational, and environmental context [42,44,45]. This section analyses the general motivations of the adoption of EMPs inside organizations, identified in the literature, on the particular case of green ICT. In the second part of this section, we identify a series of specific determinants of the adoption of ICT in organizations.

From a theoretical perspective, the motivations that influence companies to engage in technological innovation development for the protection of the ecosystem or its adoption are the planet's problems which are reflected in global warming, the reduction of non-renewable resources and pollution. They are listed by Gärling et al. [46] and refer to: (1) air pollution (outdoor and indoor); (2) solid waste disposal; (3) topsoil erosion; (4) ozone layer depletion; (5) population growth; (6) marine and freshwater pollution; (7) toxic waste accumulation and disposal; (8) reduction in biodiversity; (9) wetlands destruction; (10) deforestation; and (11) climate modification. Some authors linked these reasons with the theory of organizational motivation [47–51]. They rely on civic sense and social responsibility within companies.

The application of the theory of organizational motivation to ICT and eco-sustainability implies that an organization's belief and value system associated with eco-sustainability as well as the influence of external institutions can drive organizational actions to green ICT [47,52]. In reality, in most cases, the involvement in environmental protection is constrained through legal regulations [53,54]. Regulations targeting results (not processes) make companies redesign technologies in order to increase the efficiency of the activity by reducing costs and increasing product quality and develop less polluting goods [55–57]. In the European Union, green ICT is one of the ICT4Society pillars [58]. Different directives support and sometimes impose, directly or indirectly, the adoption of green ICT in organizations. For example, e-waste management (including that from the ICT field) is a priority. Directive 2012/19/EU [59] of the European Parliament and of the Council from 4 July 2012 regulates this problem. The objective is to promote reuse, recycling and other forms of recovery of e-waste to reduce the disposal of waste. It is based on a take-back system: the authority is given to the manufacturers for managing e-waste properly because the consumers can return the used products free of charge. This directive supports the adoption of the green by hardware concept inside the organizations by replacing ICT with others that are more environmentally friendly. *A Digital Single Market Strategy for Europe* [60] displays another way through which the European Commission supports green ICT Digital, by contributing to increasing access to information, transparency, and competition. The *Good Practices* collection in *Green Public Procurement* [61] promotes the adoption of green ICT in public institutions with the selection of hardware. Regarding ICT manufacturers, one of the most important regulations and the first law in the world that limits the use of hazardous substances in electrical and electronic equipment is the Restriction of the use of certain hazardous Substances in Electrical and Electronic equipment (RoHS) Directive [62]. It was updated in 2011 by the RoHS Recast Directive (RoHS 2). The restricted substances list was modified for the last time in 2015 [62]. These regulations sustain the green hardware concept. These are just some of the regulations adopted by the European Union that support green ICT, involving both users and developers.

Responsiveness to the regulatory changes focused towards environmental protection, as well as their anticipation, can provide the advantage of a temporary monopoly for the organizations, such as all technological innovations, especially in the field of ICT, considered being extremely dynamic. Due to the regulations, market-based mechanisms to address climate change increase, businesses will focus on environmental sustainability and some buyers in the field are asking their suppliers to take measures to "green up" their products and their manufacturing processes, including those from the ICT field [63]. According to Bose and Luo [64], the primary drivers of green IT are reducing costs due to budget cuts (cost), complying with the local law (legislation) and reducing consumption due to resource restrictions (environment).

Molla et al. [29] mention the following factors of green ICT adoption in organizations, in order of their importance: reducing the cost of IT, corporate strategy, environmental consideration, social acceptance, the maturity of the green IT industry, government regulations, government incentives, clients/consumers' pressure, green IT uptake by more organizations, industry associations, competitors' actions, and vendors' pressure.

The negative effects have been analysed at each stage of the life cycle, from manufacturing to usage and disposal [65]. In these circumstances, if the motivations of ICT adoption and implementation are clear, their correlation with the environmental issues is relatively new. Chen et al. [53] identified three eco-motivations:

- Eco-efficiency refers to a business's desire to deliver "competitively priced goods and services [. . .] while progressively reducing ecological impacts".
- Eco-equity focuses on "equal rights of people to environmental resources" and a business's "social responsibility for the future generations".
- Eco-effectiveness "aims to stop contamination and depletion [. . .] by directing individual and organizational attention to the underlying and fundamental factors of environmental problems [. . .] through a fundamental redesign of the system".

Starting from the motivations proposed by Chen et al., Molla and Abareshi [47] identified and analysed the following reasons for the adoption of green ICT in organizations, relative to the theory of organizational motivation, which involves a combination of ecological and operational performance considerations: eco-efficiency motives, eco-effectiveness motives, eco-responsive motives and eco-legitimacy motives. The study conducted on a sample of 176 companies from various business areas showed that the first two reasons mentioned (eco-efficiency and eco-effectiveness) have the greatest influence in the adoption of green ICT.

Oltra [66] classified the determinants into three main categories: regulation and policy determinants, supply-side determinants and demand-side determinants. In the first category, the author mentions:

- implementation of environmental policy instruments: economic and regulatory;
- existence and anticipation of environmental regulations;
- regulatory design.

The second category refers to:

- cost savings and productivity improvements;
- organizational innovations;
- R&D activities;
- industrial relationships, supply chain pressure and networking activities.

Finally, the last category of determinants includes:

- environmental consciousness and consumers' preferences for ecological products;
- expected increase in market share or penetration of new market segments.

Kuo [67] identified three categories of determinants that make companies interested in green ICT: motivational determinants (competitiveness, legitimacy and social responsibility), organizational determinants (related to the internal environment of organizations such as human resources and capabilities), and technological constraints (related to ICT available on the market that can significantly limit the field of green ICT initiatives). These factors are found in other approaches as well, as we will present below.

Competitiveness [68,69] is an important determinant of the adoption of green ICT favoured by the market evolution. The advantages obtained by companies are essential both internally and in their relations with the external environment, providing a competitive market position [70] (pp. 6–11). Competitiveness between ICT manufacturers in terms of pro-environment characteristics is quite large, and their popularization has become commonplace for each sub-sector, with larger companies competing for supremacy, according to studies published by Green Peace [71]. Bansal and Roth also mention this factor [72]. They identify two additional determinants: stakeholders' pressure and ethical motivations. The stakeholders can be external (regulators, community, suppliers) or internal (employees, management, and shareholders). The ethical motivations are the desire to "do well" for the environment out of a sense of social obligation. The study was conducted on a sample of 53 companies in the UK and Japan and emphasised that these motivations were influenced by three contextual conditions: field cohesion, issue salience, and individual concern.

Changes or initiatives stimulated at national and international levels by grants represent another category of factors [73–75]. It is very important for green ICT if we consider that many of the priority axes are closely linked to it. Relevant at the European level is the Europe 2020 strategy, called suggestively a "European strategy for smart, sustainable and inclusive growth" [76]. Wide environmental priorities set by the European Union in this strategy are highlighted in the following objectives: investing 3% of gross domestic product in research and development, a 20% reduction in emissions of greenhouse gases (even 30% if the conditions are favourable), a 20% increase in the percentage of renewable energies and increasing energy efficiency by 20% [77].

Some components of green ICT involve major investment. This makes the financial strength of the company another important factor for the use of ICT consistent with the company's environmental footprint. Large companies are more willing to invest in ICT than small ones [78]. As a consequence, their ability to replace equipment and applications with eco-friendly ones is higher or, more appropriately, opportunities to invest in innovation in green ICT are bigger.

Organization characteristics [54,79,80] as an important determinant of green ICT adoption are highlighted by Ashford [80] as desire, exploitation of opportunities and the ability to innovate. Desire is influenced by the attitude in relation to the industry in general, by the comprehension of possible options and solutions and the ability to evaluate alternatives. The exploitation of opportunities refers to supply and demand in the company's activity field. The offer is considering possible gaps between existing technologies in the company and in the industry and the pressures arising from relationships with partners that could stimulate investment in innovation. Potential savings may motivate the demand of requesting greener products by pressures from the consumers and employees. The last determinant, considered the most important by Ashford and Hall [56] the company's "capacity to innovate", is reflected in the company's desire to be involved in the innovative process, but also in the existence of the necessary skills and collaboration with the external environment.

Green ICTs have specific determinants as well. These make this field different from the other EMPs. One of these is the transfer of the responsibilities. It is facilitated by cloud computing. This is a new model that integrates existing technologies and models, in order to optimize the use of physical and logical resources. In the case of cloud computing, the responsibility for software updates,

security, disaster recovery and storage of information falls to the cloud services provider. Practically, the environmental benefits of cloud computing are better strategies for reduced energy consumption, a smaller volume of required equipment [81] (pp. 29–31) and consequently of necessary resources for their production as well as decreased waste after discharge.

Another important determinant in favour of the adoption of green ICT is the dynamics of the ICT industry: the high technology industry has been one of the fastest-growing industries in the world that increasingly leads to technological innovations and global economic developments, while there are concerns regarding the sustainability of the industrial energy consumption and CO_2 emissions [82]. It enforces companies in the rapid adoption of next-generation technologies, particularly where they form the basis for the design and production processes. In many industries, the adoption of green ICT is a condition for eco-design rules and directives and for cleaner technologies. They have the goal of eliminating the least performing products from the market, significantly contributing to the energy efficiency objective.

The support for the implementation of EMPs is another specific determinant of adopting green ICT. Green ICT is the basis for green information systems. It can have different sophistication, can be used at different levels and provides support to the business to implement EMP and its environment strategies [83] (pp. 219–220). Green ICT can be used for measuring, monitoring and performance-checking of the various emissions generated by the devices employed in the organization's activities. However, green ICT is not limited to the information system of a single organization. It provides the necessary tools for comparing the performance in reducing carbon emissions across organizations and multiple industry sectors and facilitates the understanding of the economic advantage of green initiatives among competing organizations [83] (pp. 219–220).

Green ICT also refers to communication with customers, suppliers, public institutions and communication and interaction among employees or members of an organization. The implementation of some collaborative green business processes, based on green web services, is conditioned by the adoption of green ICT and constitutes the base of the corporate environmental strategy. The situation is similar for modelling and implementation of new green processes which is impossible to achieve without adoption of green ICT, and, at a broader level, without implementing a green information system.

Finally, the last determinant specific to the adoption of green ICT that we have identified is harnessing the potential of the presence in the virtual environment without adversely affecting the company's image. As we have previously mentioned, ICT consumes resources and causes pollution. Mainly, the dimensions of these negative effects constitute the difference between ICT and green ICT. The use of virtual environments that promote environmental protection (such as green cloud computing, green web, green social networks, etc.) helps to maximize the benefits of the presence in the virtual environment and to minimize its influences on the ecosystem.

4.3. Classifications of the Determinants Influencing Green IT Adoption

Above, we identified the main determinants of adopting green ICT. Some of these determinants are general and some are specific to the field analysed in this paper. Now, we classify the identified determinants in three categories, based on literature [50]: economic, ethical and regulatory. Starting from these three categories, we have classified general determinants as shown in Table 4.

The specific determinants are important for the adoption of green ICT as well. They are the next level of green ICT adoption when general determinants are known, understood and accepted by managers and employees. We have classified specific determinants in the same categories as general determinants, economic, ethical and regulatory, as shown in Table 5.

Table 4. General determinants of green ICT adoption.

Economic	Ethical	Regulatory
Competitiveness [40,44,67–69,72]	—	—
—	Social responsibility [44,49,53,65,67]	—
—	—	Initiatives of non-governmental institutions [71,84]
—	The environmental conditions: pollution, diminishing of exhaustible resources, global warming, etc. [40,46,47,66]	—
Pro-environment grants [70,73–77]	—	Pro-environment grants [70,73–77]
Company characteristics [25,54,56,79,80]	Company characteristics [25,54,56,79,80]	—
—	—	Internal and international policy [61,62,66,70,77]
Entrepreneurs' skills [67,80,84]	Entrepreneurs' skills [67,80,84]	—
—	Entrepreneurs' altruism [21,52,72,84]	—
The knowledge and technological capabilities [67,80,84]	—	—
Organization strategy: eco-efficiency, eco-equity, eco-effectiveness [49,53]	Organization strategy: eco-efficiency, eco-equity, eco-effectiveness [49,53]	—
—	—	Legal regulations [11,40,44,53–57,63,64,66,67,84]
Supply and demand [29,44,66]	—	—
Cost reduction [29,42,44,45,55–57,64,66,72]	—	—
Human resources characteristics [42,44,67]	Human resources characteristics [42,44,67]	—

Table 5. Specific determinants of green ICT adoption.

Economic	Ethical	Regulatory
Collaborative green business processes	—	Collaborative green business processes
Harnessing the potential of the presence in the virtual environment, without adversely affecting the company's image	Harnessing the potential of the presence in the virtual environment, without adversely affecting the company's image	—
Modelling and implementation of new green processes	—	—
The transfer of responsibilities	The transfer of responsibilities	—
The dynamic of the ICT industry	The dynamic of the ICT industry	The dynamic of the ICT industry
The support for implementation of EMPs	The support for implementation of EMPs	The support for implementation of EMPs

Green ICT is a complex concept. It involves placing environmental concerns at all stages of a product's life, from design to disposal. The product development factor involves the greening of the existing product (e.g., using recycled content, using biodegradable materials or using alternative sources of fuels and materials) and developing new green sustainable products (e.g., reverse logistics, design for disassembly, use of renewable resources, and use of biodegradable materials) [85].

5. Conclusions

This paper set out to examine the determinants that positively influence green ICT adoption in organizations. The general contribution of the article is that it proposes the general and specific determinants that motivate managers and employees to engage in pro-environmental actions through green ICT adoption. The general motivations for the adoption of EMP practices in organizations have often been described. We have summarized these motivations in the particular case of green ICT and we have classified them in three categories identified in the literature: economic, ethical and regulatory. This classification may guide companies' managers towards a particular environmental strategy according to their priorities, resources, industry, and vision. The main contribution of this paper is the identification of the specific determinants of green ICT adoption: transfer of the responsibilities, dynamics of the ICT industry, support for the implementation of EMPs, collaborative green business processes, harnessing the potential of the presence in the virtual environment without adversely affecting the company's image, and modelling and implementation of new green processes. These motivations are related to the specific characteristics of different technologies. They create a technological context for green ICT adoption that improves the environmental performance of the organization. The specific determinants are the next level of green ICT adoption after the awareness and appropriate evaluation of general determinants.

This paper is not without limitations: The first limitation is that the paper is a theoretical piece and it has not been tested empirically. Future research should be focused on the empirical evaluation of the specific determinants for the case of green ICT adoption. Second, the general determinants and the specific determinants have been analysed separately. We have not examined the interrelationship between them. Future research ought to explore this relationship as well, because the general determinants are the basis for the specific determinants.

From the technical perspective, green ICT is a broad concept, which includes numerous technologies, such as e-commerce, virtualization, Internet of Things, telecommuting, supercomputers, smart grids and cloud computing. Future research should expand and customize the determinants of green ICT adoption on each technology. The specific characteristics of these should be considered as

potential motivations for its adoption in practice. Accordingly, the results of this study can be used by academics as a roadmap for future research. This paper is useful to practitioners as well: Managers can use the specific determinants identified with the objectives and strategies of the organization to adopt decisions on the implementation of green ICT according to technical requirements. Hardware and software engineers can use the specific determinants to establish the order of the adoption of green ICT depending on the priorities of the organization or society (in the case of ICT manufacturers or providers). Regulatory agencies are interested in these changes, as indicated in Section 3 of this paper. They can use specific determinants for setting the future directions of public funding and regulations.

Furthermore, regulations that apply to ICT products and internal and external politics specific to the green ICT field are further important problems not entirely clarified. The main measures by which regulatory organizations can get involved in environmental protection are adopting some strict regulations in this field and grants dedicated to eco-innovations in ICT. There are great differences between the regulations adopted in different countries, determined mainly by the level of economic development and education. The less developed countries have a very low level of adoption of regulations on environmental protection. Contextual differences such as these could also well be the focus of future research in green ICT.

Finally, it is important to note that the results of green ICT adoption are not immediate, both financial and those relating to environmental benefits. Therefore, beyond the rational and pragmatic factors, values and altruistic motivations of organizations' managers are very important in adopting green ICT. The study of these aspects, based on specific determinants, will be the subject of future research.

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References

1. Peattie, K. Green Consumption: Behavior and Norms. *Annu. Rev. Environ. Resour.* **2010**, *35*, 195–228. [CrossRef]
2. Pujari, D. Eco-innovation and new product development: Understanding the influences on market performance. *Technovation* **2006**, *26*, 76–85. [CrossRef]
3. Berkhout, F.; Hertin, J. *Impacts of Information and Communication Technologies on Environmental Sustainability: Speculations and Evidence*; Report to the OECD; OECD Publishing: Brighton, UK, 2001; Available online: http://www.oecd.org/sti/inno/1897156.pdf (accessed on 21 July 2015).
4. Guster, D.; Hemminger, C.; Krzenski, S. Using Virtualization to Reduce Data Center Infrastructure and Promote Green Computing. *Int. J. Bus. Res.* **2009**, *9*, 133–139.
5. Fuchs, C. The Implications of New Information and Communication Technologies for Sustainability Environment. *Environ. Dev. Sustain.* **2008**, *10*, 291–309. [CrossRef]
6. Ruth, S. Green It More Than a Three Percent Solution? *Internet Comput.* **2009**, *13*, 74–78. [CrossRef]
7. Börjesson Rivera, M.; Håkansson, C.; Svenfelt, T.; Finnveden, G. Including second order effects in environmental assessments of ICT. *Environ. Model. Softw.* **2014**, *56*, 105–115.
8. Lungu, I.; Bara, A.; Popeangă, J. Measuring and Improving Energy Efficiency Indicators for a Greener Romania. *Econ. Comput. Econ. Cybern. Stud. Res.* **2014**, *48*, 1–14.
9. Saravana Kumar, P. E-Waste in India—The Dark Side of Information Technology. *J. Nanosci. Nanotechnol.* **2014**, *2*, 148–151.
10. Li, J.H.; Tian, B.G.; Liu, T.Z. Status quo of e-waste management in mainland China. *J. Mater. Cycles Waste Manag.* **2006**, *8*, 13–20. [CrossRef]
11. Hanne, F.Z. Green IT—Why Developing Countries Should Care? *Int. J. Comput. Sci.* **2011**, *8*, 424–427.
12. Krikke, J. Recycling E-Waste: The Sky is the Limit. *IT Prof.* **2008**, *10*, 50–55. [CrossRef]
13. Houghton, W.J. ICT and the Environment in Developing Countries: A Review of Opportunities and Developments. In *What Kind of Information Society? Governance, Virtually, Surveillance, Sustainability, Resilience*; Berleur, J.J., Hercheui, M.D., Hilty, L.M., Eds.; (IFIP Advances in Information and Communication Technology); Springer: Berlin, Germany, 2010; Volume 328, pp. 236–247.

14. Ishida, H. The effect of ICT development on economic growth and energy consumption in Japan. *Telemat. Inform.* **2015**, *32*, 79–88. [CrossRef]
15. Rahim, R.E.A.; Rahman, A. Resource-based framework of green it capability toward firms' competitive advantage. In Proceedings of the 17th Pacific Asia Conference on Information System, Jeju Island, Korea, 18–22 June 2013. Paper 280.
16. Nanath, K.; Pillai, R.R. Green Information Technology: Literature Review and Research Domains. *J. Manag. Syst.* **2014**, *24*, 57–79.
17. Tushi, B.T.; Sedera, D.; Recker, J. Green IT Segment Analysis: An Academic Literature Review. In *Smart Sustainability: The Information Systems Opportunity*, Proceedings of the 12th Americas Conference on Information Systems, Savannah, GA, USA, 7–9 August 2014; Association for Information Systems: Atlanta, GA, USA, 2014; pp. 2566–2580.
18. Sarkis, J.; Koo, C.; Watson, R. Green information systems & technologies—This generation and beyond: Introduction to the special issue. *Inf. Syst. Front.* **2013**, *15*, 1–10.
19. Murugesan, S. Harnessing Green IT: Principles and Practices. *IT Prof.* **2008**, *10*, 24–33. [CrossRef]
20. Boudreau, M.C.; Chen, A.; Huber, M. Green Is: Building Sustainable Business Practices. In *Information Systems: A Global Text*; Watson, T.R., Ed.; Global Text Project: Athens, Greece, 2008; pp. 1–17. Available online: http://www.ceport.com/files/file/Green%20IS%20CePORT%20Article.pdf (accessed on 15 May 2015).
21. Molla, A. Organisational Motivations for Green IT: Exploring Green IT Matrix and Motivation Models. In Proceedings of the 13th Pacific Asia Conference on Information Systems, Hyderabad, India, 10–12 July 2009. Paper 13.
22. Andreopoulou, Z. Green Informatics: ICT for Green and Sustainability. *J. Agric. Inform.* **2012**, *2*, 1–8. [CrossRef]
23. Mingay, S. Green IT: The New Industry Shock Wave, 2007. Available online: http://www.ictliteracy.info/rf.pdf/Gartner_on_Green_IT.pdf (accessed on 21 October 2015).
24. Hilty, L.M.; Aebischer, B. ICT for Sustainability: An Emerging Research Field. In *ICT Innovations for Sustainability. Advances in Intelligent Systems and Computing*; Hilty, L.M., Aebischer, B., Eds.; Springer International Publishing: Berlin, Germany, 2014; Volume 310, pp. 3–36.
25. Bachour, N.; Chasteen, L. Optimizing the Value of Green IT Projects within Organisations. In Proceedings of the Green Technologies Conference, Grapevine, TX, USA, 15–16 April 2010; Institute of Electrical and Electronics Engineers: New York, NY, USA, 2010; pp. 82–91.
26. Jenkin, A.T.; Webster, J.; McShane, L. An agenda for Green information technology and systems research. *Inf. Organ.* **2011**, *21*, 17–40. [CrossRef]
27. Calero, C.; Piattini, M. Introduction to Green in Software Engineering. In *Green in Software Engineering*; Calero, C., Piattini, M., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 3–27.
28. Watson, R.T.; Boudreau, M.C.; Chen, A.J. Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community. *MIS Quart.* **2010**, *34*, 23–38.
29. Molla, A.; Pittayachawan, S.; Corbitt, B.; Deng, H. An International Comparison of Green IT Diffusion. *Int. J. e-Bus. Manag.* **2009**, *3*, 3–23. [CrossRef]
30. Yang, J.; Han, Q.; Zhou, J.; Yuan, C. The Influence of Environmental Management Practices and Supply Chain Integration on Technological Innovation Performance—Evidence from China's Manufacturing Industry. *Sustainability* **2015**, *7*, 15342–15361. [CrossRef]
31. Unhelkar, B. Green IT: The Next Five Years. *IT Prof.* **2011**, *13*, 56–59. [CrossRef]
32. Nishant, R.; Thompson, T.; Goh, M. Sustainable Information Systems: Does It Matter? In Proceedings of the 17th Pacific Asia Conference on Information Systems, Jeju Island, Korea, 18–22 June 2013. Paper 88.
33. Hankel, A. Understanding Higher Order Impacts of Green ICT. In Proceedings of 2nd International Conference of ICT for Sustainability, Stockholm, Sweden, 24–27 August 2014; Höjer, M., Lago, P., Wangel, J., Eds.; Atlantis Press: Amsterdam, The Netherlands, 2014; pp. 385–391.
34. Nanath, K.; Pillai, R.R. A Sustainability Model of Green IT Initiatives. In Proceedings of 33rd International Conference on Information Systems, Orlando, FL, USA, 16–19 December 2012; pp. 1–22. Available online: http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1064&context=icis2012 (accessed on 10 July 2016).
35. Nishant, R. Green Is and Organizational Performance. An Empirical Examination. In Proceedings of the 16th Pacific Asia Conference on Information Systems, Hochiminh City, Vietnam, 11–15 July 2012. Paper 185.

36. Nedbal, D.; Wetzlinger, W.; Auinger, A.; Wagner, G. Sustainable Is Initialization through Outsourcing: A Theory-Based Approach. In Proceedings of 17th Americas Conference Information Systems, Detroit, MI, USA, 4–8 August 2011; Association for Information Systems: Atlanta, GA, USA, 2011; pp. 2282–2291.
37. Kassarjian, H.H. Content Analysis in Consumer Research. *J. Consum. Res.* **1977**, *4*, 8–18. [CrossRef]
38. Krippendorff, K. *Content Analysis: An. Introduction to Its Methodology*, 2nd ed.; Sage: Thousand Oaks, CA, USA, 2004.
39. Albertao, F. Sustainable Software Development. In *Harnessing Green It: Principles and Practices*; Murugesan, S., Gangadharan, G.R., Eds.; John Wiley & Sons, Ltd.: Chichester, UK, 2012; pp. 63–83.
40. Chen, J.A.; Watson, T.R.; Boudreau, M.C.; Karahanna, E. An Institutional Perspective on the Adoption of Green IS & IT. *Australas. J. Inf. Syst.* **2011**, *17*, 5–27.
41. Khanna, M.; Speir, C. Motivations for Proactive Environmental Management. *Sustainability* **2013**, *5*, 2664–2692. [CrossRef]
42. Dooley, R.S.; Fryxell, G.E. Are conglomerates less environmentally responsible? An empirical examination of diversification strategy and subsidiary pollution in the U.S. chemical industry. *J. Bus. Ethics* **1999**, *21*, 1–14. [CrossRef]
43. International Organization for Standardization. ISO 14000–Environmental Management, 2015. Available online: http://www.iso.org/iso/iso14000 (accessed on 10 June 2016).
44. Weng, H.H.; Chen, J.S.; Chen, P.C. Effects of Green Innovation on Environmental and Corporate Performance: A Stakeholder Perspective. *Sustainability* **2015**, *7*, 4997–5026. [CrossRef]
45. Chen, C. Design for the environment: A quality-based model for green product development. *Manag. Sci.* **2001**, *47*, 250–263. [CrossRef]
46. Gärling, T.; Fujii, S.; Gärling, A.; Jakobsson, C. Moderating effects of social value orientation on determinants of proenvironmental behavior intention. *J. Environ. Psychol.* **2003**, *23*, 1–9. [CrossRef]
47. Molla, A.; Abareshi, A. Green IT Adoption: A Motivational Perspective. In Proceedings of the 15th Pacific Asia Conference on Information Systems, Brisbane, Queensland, Australia, 7–11 July 2011. Paper 137.
48. Mishra, D.; Akman, I.; Mishra, A. Theory of Reasoned Action Application for Green Information Technology Acceptance. *Comput. Hum. Behav.* **2014**, *36*, 29–40. [CrossRef]
49. Molla, A.; Abareshi, A. Organisational Green Motivations for Information Technology: Empirical Study. *J. Comput. Inf. Syst.* **2012**, *52*, 92–102.
50. Molla, A. GITAM: A Model for the Adoption of Green IT. In Proceedings of the 19th Australasian Conference on Information Systems, Christchurch, New Zealand, 3–5 December 2008. Paper 64.
51. Koo, C.; Chung, N.; Lee, Y.C. The Influential Motivations of Green It Device Use and the Role of Reference Group Perspective. In Proceedings of the 17th Pacific Asia Conference on Information Systems, Jeju Island, Korea, 18–22 June 2013. Paper 90.
52. Molla, A.; Abareshi, A.; Cooper, V. Green IT beliefs and pro-environmental IT practices among IT professionals. *Inf. Technol. People* **2014**, *27*, 129–154. [CrossRef]
53. Chen, A.J.; Boudreau, M.C.; Watson, R.T. Information systems and ecological sustainability. *J. Syst. Inform. Tech.* **2008**, *3*, 186–201.
54. Zailani, S.; Govindan, K.; Iranmanesh, M.; Shaharudin, M.R. Green Innovation Adoption in Automotive Supply Chain: The Malaysian case. *J. Clean. Prod.* **2015**, *108*, 1115–1122. [CrossRef]
55. Porter, M.E. Towards a Dynamic Theory of Strategy. *Strateg. Manag. J.* **1991**, *12*, 95–117. [CrossRef]
56. Ashford, N.A.; Hall, P.R. The Importance of Regulation-Induced Innovation for Sustainable Development. *Sustainability* **2011**, *3*, 270–292. [CrossRef]
57. Van Osch, W.; Avital, M. From Green IT to Sustainable Innovation. In Proceedings of the 16th Americas Conference on Information Systems, Lima, Peru, 12–15 August 2010; Association for Information Systems: Atlanta, GA, USA, 2011; pp. 3737–3746.
58. European Commission. For a Socially Responsible European ICT Sector, 2016. Available online: https://ec.europa.eu/digital-single-market/en/ict4society-multi-stakeholder-platform (accessed on 2 June 2016).
59. European Commission. Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE), 2016. Available online: http://ec.europa.eu/environment/waste/weee/index_en.htm (accessed on 15 June 2016).
60. European Commission. A Digital Single Market for Europe: Commission sets out 16 Initiatives to Make it Happen, 2015. Available online: http://europa.eu/rapid/press-release_IP-15-4919_en.htm (accessed on 21 June 2016).

61. European Commission. Green Public Procurement a Collection of Good Practices, 2012. Available online: http://ec.europa.eu/environment/gpp/pdf/GPP_Good_Practices_Brochure.pdf (accessed on 18 June 2016).
62. European Commission. Directive 2002/95/EC on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment, 2015. Available online: http://ec.europa.eu/environment/waste/rohs_eee/legis_en.htm (accessed on 5 June 2016).
63. Ozturk, A.; Umit, K.; Medeni, I.T.; Ucuncu, B.; Caylan, M.; Akba, F.; Medeni, T.D. Green ICT (Information and Communication Technologies): A Review of Academic and Practitioner Perspectives. *Int. J. e-Bus. e-Government Stud.* **2011**, *3*, 1–16.
64. Bose, R.; Luo, X. Integrative Framework for Assessing Firms' Potential to Undertake Green It Initiatives via Virtualization–a Theoretical Perspective. *J. Strateg. Inf. Syst.* **2011**, *20*, 38–54. [CrossRef]
65. Elliot, S.; Binney, D. Environmentally sustainable ICT: Developing Corporate Capabilities and an Industry-Relevant IS Research Agenda. In Proceedings of the 12th Pacific Asia Conference on Information Systems, Suzhou, China, 3–7 July 2008. Paper 209.
66. Oltra, V. Environmental Innovation and Industrial Dynamics: The Contributions of Evolutionary Economics. In Paper presented at the 1st DIME (Dynamics of Institutions and Markets in Europe) Scientific Conference on Knowledge in space and time: economic and policy implications of the Knowledge-based economy, Strasbourg, France, 7–9 April 2008; Available online: http://www.dime-eu.org/files/active/0/DIME_WP_n7_oltra.pdf (accessed on 17 June 2015).
67. Kuo, N.B. Organizational Green IT: It seems the bottom line rules. In Proceedings of the 16th Americas Conference on Information Systems, Lima, Peru, 12–15 August 2010; Association for Information Systems: Atlanta, GA, USA, 2011; pp. 2716–2725.
68. Loeser, F.; Erek, K.; Zarnekow, R.; Schmidt, N.H.; Kolbe, L.M. Aligning Green IT with Environmental Strategies: Development of a Conceptual Framework that Leverages Sustainability and Firm Competitiveness. In Proceedings of 17th Americas Conference Information Systems, Detroit, MI, USA, 4–8 August 2011; Association for Information Systems: Atlanta, GA, USA, 2011; pp. 1991–1999.
69. Dao, V.; Langella, I.; Carbo, J. From green to sustainability: Information Technology and an integrated sustainability framework. *J. Strateg. Inf. Syst.* **2011**, *20*, 63–79. [CrossRef]
70. European Commission. *Monitoring industrial research: The 2010 EU Industrial R&D Investment SCOREBOARD*; Publications Office of the European Union, Luxembourg; Publications Office of the European Union: Luxembourg City, Luxembourg, 2010.
71. Green Peace. Make IT Green Cloud Computing and its Contribution to Climate Change, 2010. Available online: http://www.greenpeace.org/international/Global/international/planet-2/report/2010/3/make-it-green-cloud-computing.pdf (accessed on 27 February 2016).
72. Bansal, P.; Roth, K. Why companies go green: A model of ecological responsiveness. *Acad. Manag. J.* **2000**, *13*, 717–736. [CrossRef]
73. European Commission. Funding Opportunities, 2016. Available online: http://ec.europa.eu/environment/funding/intro_en.htm (accessed on 8 June 2016).
74. Gu, Q.; Lago, P.; Bozzelli, P. A Decision-Making Model for Adopting Green ICT Strategies. In *Green in Software Engineering*; Calero, C., Piattini, M., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 285–300.
75. Caia, F.; Năstase, P. Modeling a Business Intelligence System for Investment Projects. *Econ. Comput. Econ. Cybern.* **2015**, *2*, 1–24.
76. European Commission. EUROPE 2020. A Strategy for Smart, Sustainable and Inclusive Growth, 2010. Available online: http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52010DC2020 (accessed on 5 June 2016).
77. European Commission. Europe 2020 Indicators—Climate Change and Energy, 2016. Available online: http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_climate_change_and_energy (accessed on 18 July 2015).
78. Bayo-Morionesa, A.; Lera-Lópezb, F. A firm-level analysis of determinants of ICT adoption in Spain. *Technovation* **2007**, *27*, 352–366. [CrossRef]

79. Howard, G.R.; Lubbe, S. Synthesis of Green IS Frameworks for Achieving Strong Environmental Sustainability in Organisations. In Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference, Pretoria, South Africa, 1–3 October 2012; Machanick, P., Tsietsi, M., Eds.; ACM: New York, USA, 2013; pp. 306–315.
80. Ashford, N.A. An innovation-based strategy for a sustainable environment. In *Innovation-Oriented Environmental Regulation: Theoretical Approach and Empirical Analysis*; Hemmelskamp, J., Rennings, K., Leone, F., Eds.; Physica-Verlag Heidelberg: New York, NY, USA, 2000; pp. 67–107.
81. Linthicum, D.S. *Cloud Computing and SOA Convergence in Your Enterprise: A Step-by-Step Guide*; Addison-Wesley Professional: Boston, MA, USA, 2009.
82. Yan, M.R.; Chien, K.M.; Yang, T.N. Green Component Procurement Collaboration for Improving Supply Chain Management in the High Technology Industries: A Case Study from the Systems Perspective. *Sustainability* **2016**, *8*, 105. [CrossRef]
83. Unhelkar, B. *Green IT Strategies and Applications: Using Environmental Intelligence (Advanced & Emerging Communications Technologies)*; CRC Press: Boca Raton, FL, USA, 2011.
84. Deng, Q.; Ji, S. Organizational Green IT Adoption: Concept and Evidence. *Sustainability* **2015**, *7*, 16737–16755. [CrossRef]
85. Hassini, E.; Surti, C.; Searcy, C. A literature review and a case study of sustainable supply chains with a focus on metrics, *Int. J. Prod. Econ.* **2012**, *140*, 69–82. [CrossRef]