

IMPACT OF PRESSURE FOR ENVIRONMENTAL SUSTAINABILITY ON GRID ASSIMILATION – EMPIRICAL RESULTS FROM THE FINANCIAL SERVICES INDUSTRY

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ABSTRACT

Due to the significant increase in IT-related power consumption and the resulting higher CO₂ emissions, Green IT has gained considerable attention in industry and society in recent years. Green IT as an engineering paradigm encompasses the multi-faceted, global effort to reduce power consumption and the promotion of environmental sustainability. Due to several similarities between Green IT objectives and the environmental benefits of Grid technology, this article provides empirical evidence from the financial services industry emphasizing that Grid technology is capable of reducing the environmental impact of IT hardware. Furthermore, the article analyzes the extent to which pressure for environmental sustainability as well as different types of institutional forces impact on the intention of enterprises to use Grid technology as a means to reduce energy consumption of IT hardware, which is one of the key Green IT objectives.

INTRODUCTION

During the last few years, the acceptance that CO₂ emissions are a major cause of global warming and changes of weather patterns has grown steadily. Therefore, enterprises, governments, and society at large are beginning to consider environmental issues in the process of technology adoption, leading to increased application of environmentally sound (“Green”) practices (Murugesan 2007). The adoption of such Green practices is mainly influenced by economic forces (i.e., rising energy costs), environmental regulations imposed by governments or inter-governmental organizations that allow or prohibit certain practices, and social pressure that stems from the need to meet social obligations and enforces moral governance (Molla et al. 2009b).

One of the most important Green practices is the reduction of electric power consumption of IT hardware that needs significant amounts of electricity (Murugesan 2008). According to a report provided by the U.S. Environmental Protection Agency (2007), data centers were estimated to have used 1.5 percent of all electricity in the United States in 2006, and their power demand is projected to grow 12 percent per year through 2011. In addition, the cooling and air-conditioning problems caused by global warming or energy supply difficulties, especially in over-populated areas, further enhance ecological pressure on IT-intensive industries. Consequently, the concepts of environmental sustainability have been among the most important themes in industry to emerge over the last decade

(Petrini & Pozzebon 2009) and the key objective is to reduce the environmental impact of IT and to facilitate the emergence of a more sustainable environment (e.g., by reducing CO₂ emissions).

In order to meet this goal, the IT industry increasingly considers Green IT as a way to address environmental issues of IT and envisions environmentally sustainable IT as the key to future success, as suggested by several industry research reports (e.g., Gartner 2008; IDC 2008). Accordingly, Ryan (2008) and Porter and van der Linde (1999) state that enterprises exhibiting the technology and vision to provide products and services that address environmental issues are likely to achieve sustained competitive advantage. Another driver of Green IT initiatives is that IT investors and consumers are beginning to look at the carbon footprint of an IT company and its products. In this context, a carbon footprint is a measure of the total set of greenhouse gas emissions caused directly and indirectly by an individual, an organization, a process, or a product (Kurp 2008). As a result, IT companies increasingly advertise their environmental credentials and disclose their carbon emissions in order to be recognized as being an environmentally responsible enterprise. Moreover, besides social pressures, recent research suggests that mimetic and coercive pressures significantly drive Green IT adoption (Chen et al. 2009). This means that organizations are motivated to adopt a given Green practice because of the favourable results achieved by other adopters (mimetic pressure) and because of governmental regulations, laws, and industry standards (coercive pressure).

Since especially IT-intensive industries are increasingly exposed to pressure for environmental sustainability in the technology assimilation process, more and more enterprises are searching for ways to reduce IT-related energy consumption without huge investments in new, energy-efficient hardware. As will be shown in this article, Grid technology is capable of reducing the environmental impact of IT hardware while at the same time providing enterprises with large computing and storage capacity. Although the extant literature on Grid computing suggests that Grid technology is capable of minimizing the number of IT hardware by automatically adjusting the provision of hardware resources according to the demand, Grid-based IT infrastructures have not yet been considered to be an implementation of Green IT concepts. Therefore, the research objective is to provide first empirical evidence for the analogies between Green IT objectives and the characteristics of Grid technology by depicting the results of a questionnaire-based field study conducted in the financial services industry. To the best of our knowledge, there is only little empirical evidence of the environmental impact of Grid technology in prior literature, wherefore this research is one of the first quantitative studies on this topic and thereby contributes to both theory and practice. The field study analyzes the relationship between perceived pressure exercised on financial institutions for environmental sustainability and their motivation to use Grid technology to respond to this pressure by reducing IT-related energy consumption. Furthermore, the role of different types of institutional pressures (mimetic, coercive, and normative pressure) is analyzed in the context of Grid assimilation as a means to reduce environmental impact of IT hardware. Although the term "Green IT" is multi-faceted and encompasses the manufacturing and purchasing of energy-efficient IT equipment, the efficient operation and utilization of hardware devices, as well as its proper disposal (Murugesan 2008), this article mainly focuses on the minimization of energy consumption of IT equipment as the key Green IT objective.

Other Green practices include the design and manufacturing of environmentally sound and energy-efficient IT equipment, which can be achieved by adopting new techniques and materials that are both environmentally friendly and economically advantageous. Prominent examples are the move from 65 to 45 nanometer chips that have increased energy efficiency and an improved performance per watt ratio (Allarey et al. 2008) or the implementation of new power management features as well as the production of recyclable materials (Kurp 2008). Moreover, Green practices include the reuse, refurbishing, and recycling of old IT equipment in environmentally sound ways (Murugesan 2008).

The remainder of this article is organized as follows. First, the article emphasizes the need for Green IT infrastructures in order to reduce the power consumption in data centers and provides an introduction into Grid technology that is expected to be an effective and efficient implementation of Green IT. Subsequently, the theoretical background of the research is illustrated and an introduction into the research model that is used in the survey is provided. The following sections depict the research model and the hypotheses derived from literature and describe the empirical study conducted to validate the model. The results of the empirical study are presented and discussed subsequently. Finally, the article concludes with a summary and limitations of the findings and an outlook to further research.

NEED FOR GREEN IT INFRASTRUCTURE

Due to the increasing competition in the industry and the current market dynamics, enterprises are forced to adopt high-performance computing (HPC) technology in order to stay competitive. According to a study by Joseph et al. (2004), 97 percent of the U.S. businesses surveyed could not exist, or could not compete effectively, without the use of HPC technology. Although data centers achieve economies of scale in management and power supply, they consume large amounts of energy and have high carbon emissions. Due to the high cost of power consumption and cooling, enterprises are facing a dual challenge of adopting more HPC technology to meet dynamically changing business needs while at the same time delivering such capabilities cost effectively as well as power-efficient (Scaramella & Healey 2007). As already outlined, Green IT can support enterprises to use IT equipment in an environmentally friendly way by reducing the power consumption of IT hardware.

Although the benefits of Green IT solutions are numerous and the rate of Green IT adoption is increasing, Biros et al. (2008) and Olson (2008) state that most Green IT efforts take too long since many enterprises cannot afford a short-term replacement of their existing systems with newer ones. Here, Grid technology provides a remedy to this problem by giving enterprises the opportunity to build up a powerful Green IT infrastructure by connecting existing IT hardware into a Grid without the necessity to invest in new hardware. Enterprise Grid computing (Strong 2005) provides users and applications with immediate access to large computing power and storage capacity, such as server clusters, servers, desktop computers, storage systems and databases that can be accessed as a unified resource across an industry, enterprise, or workgroup (Foster & Kesselman 1999). Grid technology in combination with virtualization technology automatically handles fluctuating workloads and peak demands by adding IT resources to or removing them from the Grid without affecting the resilience and stability of the Grid infrastructure (Vykoukal et al. 2009). Enterprises thereby benefit from a "breathing" IT infrastructure with constantly high resource utilization and reduced power consumption due to minimal hardware utilization. This is especially important because of the fact that in typical data centers, resource utilization is only 20-30 percent on average (Bohrer et al. 2002). Therefore, the goal is to minimize the number of under-utilized or idle IT resources that still consume significant amounts of energy. Hence, Grid virtualization and minimized hardware use are a key strategy to reduce IT-related energy consumption. Additionally, simulation results provided by Beck et al. (2008) indicate that virtualization of Grid resources can significantly reduce the number of IT resources and thus produce a cost reduction of about 40 percent compared to dedicated servers.

Another benefit of Grid technology is that it allows IT service providers to interconnect a large number of IT resources into a Grid and to offer these Grid-based IT resources to their customers over the Internet on a use-on-demand, pay-per-use basis. In extant literature this concept of on-demand computing is often associated with Cloud computing (Foster et al. 2008). Since most of the external service providers have already invested in Green IT initiatives, they can offer Grid resources that are more energy and cooling efficient, leading to reduced carbon emissions. In addition, Grid providers

increasingly adopt energy-efficient servers, apply virtualization technology to maximize the utilization of hardware, and build new data centers at locations with a cool climate (e.g., Iceland or Siberia). By using cold outside air for cooling of the data center, there is lesser need for power to operate mechanical chillers to produce cool air, thus reducing overall energy consumption. For example, Microsoft, that offers Grid resources on-demand to customers, has built a large data center in Ireland which is, due to the moderate climate in Ireland, air cooled and therefore 50 percent more energy-efficient than other comparably sized data centers (Kulp 2008).

Consequently, Grid technology is shown to be suitable for the implementation of Green IT concepts and the development of a Green IT infrastructure.

RESEARCH MODEL AND HYPOTHESES

In order to empirically validate the impact of ecological pressure and institutional pressure on the assimilation of Grid technology, the research model depicted in Figure 1 was developed. The research model draws on institutional theory (DiMaggio & Powell 1983; Meyer & Rowan 1977) and analyzes the extent of institutional pressure for Grid assimilation. The model also incorporates a newly developed construct that measures the pressure for environmental sustainability in the industry domain. Lastly, the model analyzes the impact of these different types of pressures (institutional pressure for Grid assimilation and pressure for environmental sustainability) on the motivation of enterprises to use Grid technology to respond to this pressure. The constructs, their relationships, and the resulting hypotheses are discussed in the following subsections.

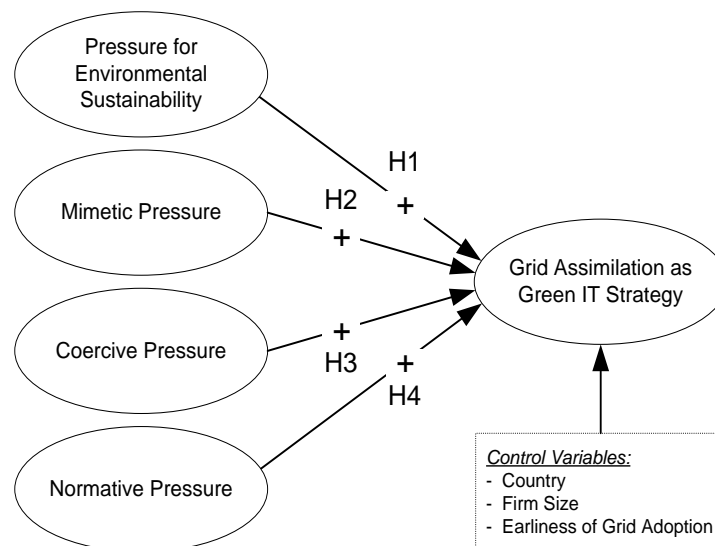


Figure 1: Research model

Pressure for Environmental Sustainability

During recent years, especially IT-intensive industries, (e.g., financial services, manufacturing, and retail industry) have identified environmental sustainability as a way to proactively address and handle environmental issues of IT. Huang (2009) states that one possible reason for the former lack of environmental concerns in industry is that IT has been too progressive and too successful for enterprises to worry about being efficient. However, today, the efforts on Green IT initiatives in industry are increasing and environmental sustainability is becoming a critical topic for IS research

(Elliot 2007). The maturing literature in this research field suggests mainly three types of pressure for environmental sustainability in the industry domain: (1) economic, (2) political and governmental, and (3) social pressure for environmental sustainability. *Economic pressure* mainly stems from rising energy costs, leading to the need for enterprises to reduce power consumption of IT hardware. Lowering energy costs is often associated with the aim to achieve competitive advantage (Hendry & Vesilind 2005; Kuo & Dick 2009; Porter & van der Linde 1999; Ryan 2008). *Political and governmental pressure* for Green IT mainly stems from various forms of environmental standards and regulations imposed by governments around the world (Chen 2001; Chen et al. 2009; Clemens & Douglas 2006; Hendry & Vesilind 2005; Kurp 2008; Molla 2009; Rugman & Verbeke 1998). *Social pressure* is exerted by the increasing customer demand for Green IT solutions (Chen 2001; Molla et al. 2009a) and the increased positive public perception of Green IT initiatives (Daly & Butler 2009; Unhelkar & Dickens 2008). By changing the IT strategy towards an increased assimilation of Green technology, organizations accommodate the ecological demand and increase their resilience to ecology-driven shocks while reducing their vulnerability at the same time. Adaptation due to perceived ecological pressure can be regarded as adjustments in social-ecological systems in response to actual, perceived, or expected ecological changes (Janssen & Ostrom 2006). Due to the aforementioned pressures for environmental sustainability and since Grid technology is likely to have the potential to reduce energy consumption of IT, we propose:

Hypothesis 1: Enterprises that are exposed to a higher level of pressure for environmental sustainability are more likely to assimilate Grid technology as an implementation of Green IT.

Institutional Pressure for Grid Assimilation

Institutional theory in general posits that structural and behavioural changes in firms are rather driven by an inherent organizational need for legitimacy than sole considerations of competitive advantages and hidden efficiency potentials (DiMaggio & Powell 1983; Meyer & Rowan 1977). This continuous search for organizational legitimacy eventually facilitates the process of institutionalization and organizational isomorphism especially against the background of an uncertain and turbulent environment. Due to DiMaggio and Powell (1983) basically three different types of institutional pressure can be distinguished: mimetic, coercive, and normative pressure.

Mimetic pressure reflects the pressure to imitate structurally equivalent successful organizations in the same industry without necessarily considering the firm-specific context (DiMaggio & Powell 1983). These so-called “bandwagon phenomena” can be induced by competitors in the same industry having already successfully adopted Grid technology that resulted in a reduction of IT-related power consumption and a positive perception of the adopting enterprise and the technology. Due to this, Swanson and Ramiller (2004) suggest that most enterprises “borrow” mindfulness from peers that have successfully introduced a new technology for their business processes and achieved significant benefits. This pressure can even be enforced by rising energy costs and increased customer demand for Green IT solutions. With these (perceived) ecological benefits of Grid technology, mimetic pressure is supposed to positively impact the intention of enterprises to assimilate Grid technology for the purpose of reducing energy consumption of IT hardware. This is in line with the findings by Chen et al. (2009) that found a positive impact of mimetic pressure on the adoption of Green practices (pollution prevention, sustainable development practices, and product stewardship). Thus, we hypothesize:

Hypothesis 2: Enterprises that are exposed to a higher level of mimetic pressure are more likely to assimilate Grid technology as an implementation of Green IT

Coercive pressure is defined by the pressure grounded in societal expectations and dependencies towards other enterprises (Bela & Venkatesh 2007; DiMaggio & Powell 1983). Furthermore, various government and industry regulations exert coercive pressure on enterprises and decisively drive the

assimilation of new technologies (Ang & Cummings 1997; Zhu et al. 2006). With regard to the increased governmental pressure for sustainability, Grid technology is an effective implementation of Green IT since it can be used to reduce the environmental impact of IT by providing large storage and computing capacity in a power efficient way (Scaramella & Healey 2007). Due to this, Grid technology provides enterprises with the opportunity to encounter coercive pressure imposed by government and industry regulations. The empirical findings provided by Chen et al. (2009) as well as Clemens and Douglas (2006) indicate that coercive forces encourage organizations to focus on Green practices, which reflects the effectiveness of regulatory efforts in guiding Green behaviours across organizations. Hence, we propose:

Hypothesis 3: Enterprises that are exposed to a higher level of coercive pressure are more likely to assimilate Grid technology as an implementation of Green IT

Pressure that is rooted in the ongoing process of professionalization is encompassed by *normative pressure* (DiMaggio & Powell 1983). This pressure arises from the exchange of best practices among business partners, suppliers, and the government. This ongoing information exchange within the value chain provides enterprises with guidelines how to assimilate Grid technology efficiently and provides them with access to first-hand experience with Grid technology and its ecological and economic benefits. In line with this, Molla (2009) indicates that Green practices are driven by normative pressure in terms of pressure for eco-effectiveness and eco-legitimacy. Thus, we hypothesize:

Hypothesis 4: Enterprises that are exposed to a higher level of normative pressure are more likely to assimilate Grid technology as an implementation of Green IT

Grid Assimilation as Green IT Strategy

To the best of our knowledge, the environmental impact of Grid technology has never been empirically analyzed. Due to this, the dependent variable of the research model incorporates the suggested potential of Grid technology to reduce IT-related power consumption, which can be interpreted as a Green IT strategy. The environmental benefits of Grid technology are especially provided by (1) the application of virtualization technology to the Grid and (2) the purchase of IT resources from external Grid resource providers. As already outlined, Grid virtualization technology is able to automatically handle fluctuating workloads and peak demands by adding resources to the Grid infrastructure or by removing them from the Grid. This self-reconfiguration capability of a virtualized Grid infrastructure leads to a reduction of redundant hardware components and hence maximizes hardware utilization and minimizes energy consumption (Pernici et al. 2008). Furthermore, computational workloads can be shifted to more energy-efficient resources so that less energy-efficient resources can be powered down (Patel et al. 2003). Additionally, since third-party Grid resource providers (also called Cloud computing providers) increasingly expand their network of massive data centers with hundreds of thousands of servers, petabytes of data, and hundreds of megawatts of power, they tend to be more conscious concerning power consumption than enterprises that utilize less IT resources. Due to the exploitation of economies of scale in provisioning, powering, cooling, and recycling of IT equipment, Grid service providers are able to invest in energy-efficient practices and technologies, leading to reduced power consumption compared to traditional data centers (Kulp 2008). This leads to the suggestion that Grid technology is an effective way to implement the concepts of a Green IT infrastructure with reduced power consumption, thereby enhancing environmental sustainability.

EMPIRICAL STUDY

Because our research in the domain of Green IT is in its early stages and profound theoretical background as well as empirical work is scarcely available, the nature of this research is exploratory.

The research model depicted in the previous section was operationalized as a structural equation model (SEM). The SEM approach is a methodology of multivariate data analysis that allows for modeling complex cause-effect relationships involving unobservable latent variables (constructs, factors) and observable variables (measurement items, indicators). These models seek to analyze the underlying causal process that is assumed to generate some phenomenon of interest. As will be explained in the subsequent section, two different SEM methods can be distinguished: covariance-based and component-based SEM methods. For our research, the components-based SEM approach, i.e., the partial least squares (PLS) method was applied. The following subsections provide details on the measures used for the empirical field study, and on the data collection as well as the sample profile.

Measures

As depicted in Table 1, each construct of the research model is represented by a set of two to three measurement items. The operationalization of the measurement items is provided in Table 5 in the Appendix.

Construct	Abbreviation	Item	Source	Scale
Pressure for Environmental Sustainability (<i>reflective measures</i>)	SUST	SUST1	based on Porter and van der Linde (1999)	7-point Likert
		SUST2	based on Chen et al. (2009)	
		SUST3	based on Chen (2001)	
Mimetic Pressure (<i>reflective measures</i>)	MP	MP1-3	adapted from Liang et al. (2007)	7-point Likert
Coercive Pressure (<i>reflective measures</i>)	CP	CP1-3	adapted from Liang et al. (2007)	7-point Likert
Normative Pressure (<i>reflective measures</i>)	NP	NP1-3	adapted from Liang et al. (2007)	7-point Likert
Grid Assimilation as Green IT Strategy (<i>reflective measures</i>)	ASSM	ASSM1	based on Pernici et al. (2008)	7-point Likert
		ASSM2	based on Kurp (2008)	

Table 1: Set of constructs and measurement items

In PLS analyses, the lack of emphasis on the measurement properties of the constructs makes it more amenable to the use of constructs with fewer items than are required for covariance-based SEM (Hair et al. 2010). Generally, each construct should be measured by at least two items so that both measurement reliability and construct validity can be assessed (Gerbing & Anderson 1988; Nunnally 1978). However, measurement models in which factors are defined by only two items per construct can be problematic so that more items (MacCallum et al. 1999) or larger samples are required to obtain a converged and proper solution (Anderson & Gerbing 1988). Due to our sample consisting of 359 responses we deemed the use of only two items for the construct ASSM as appropriate for our study.

Whenever possible, existing measures from prior empirical studies were adopted as was the case for the three institutional pressures (mimetic, coercive, and normative pressure). These measures were informed by existing measures in the literature (i.e., Liang et al. 2007) and adapted to our context. In case of the SUST and ASSM constructs, our new operationalizations were deductively informed by extant literature on Green IT (i.e., Chen 2001; Chen et al. 2009; Porter & van der Linde 1999) and Grid technology (i.e., Kurp 2008; Pernici et al. 2008). In doing so, the nature of causality between the (unobservable) latent constructs and their (observable) measurement items was assessed since two different types of relationship between constructs and their measures can be distinguished: reflective and formative. *Reflective relationships* indicate that the measurement items are a reflection of the construct (reflective measurement), whereas in *formative relationships*, the items describe and define the construct (formative measurement) rather than vice versa (Petter et al. 2007).

A fundamental characteristic of reflective measurement models is that a change in the latent construct causes variation in all measures simultaneously. Furthermore, all measures in a reflective model must be positively inter-correlated (Diamantopoulos et al. 2008). In formative measurement models, the indicators characterize a set of distinct causes which are not interchangeable as each indicator captures a specific aspect of the construct's domain (Jarvis et al. 2003). Thus, omitting an indicator potentially alters the nature of the construct (Bollen & Lennox 1991). Moreover, in formative models, there are no specific expectations about patterns or magnitude of inter-correlations between the indicators (Diamantopoulos et al. 2008).

In our study, all constructs were modelled using reflective indicators (measured on a fully anchored 7-point Likert scale, ranging from "strongly agree" to "strongly disagree") since the items used were designed to tap into the same concept or phenomenon and have the tendency to move in the same direction. In detail, the items of "mimetic pressure", "coercive pressure", and "normative pressure" are reflective indicators, which is consistent with previous literature (e.g., Liang et al 2007).

The items of the SUST construct are also operationalized in a reflective manner since high pressure for sustainability exerted on organizations is reflected by high energy cost awareness, increased environmental regulation, and increased positive public perception of Green practices. Furthermore, we assessed the inter-item correlations. Our results suggest high correlations among the three indicators, ranging from $R=0.59$ to $R=0.70$, which supports our hypothesis of reflective indicators.

Moreover, both items of the ASSM construct were modeled as reflective indicators. Both indicators are inter-related since they reflect the capability of Grid technology to reduce IT-related power consumption. In this context, it is irrelevant whether the Grid-based resources are provisioned in-house or by an external Grid resource provider. The inter-item correlation between both indicators is high ($R=0.62$) and further supports our hypothesis of reflective indicators.

To ensure content validity of the measures drawn from the literature on Green IT and Grid technology, several expert interviews were conducted and the survey instrument was provided to a panel of judges of both practitioners and academics to refine the wording of the measures.

DATA COLLECTION AND SAMPLE PROFILE

In order to validate the research model presented in Figure 1 and the aforementioned hypotheses, a questionnaire-based, large-scale field study was conducted. The study aimed at IT decision makers that work for a financial institution with more than 1000 employees. Moreover, the financial institution had to be a Grid adopter in order to ask the study participants for their experience with Grid technology. The decision to conduct the field study in the financial services industry was driven by the fact that this industry is one of the most promising application domains of Grid technology because of its information-driven business processes and its high computational demands (Schwind et

al. 2007). In addition, the financial services industry is the largest user of IT among industry sectors, which is reflected in the fact that the annual IT spending in the financial services industry is twice as high as in other industries (Zhu et al. 2004). In essence, the Grid adoption rate is likely to be higher than in other industries. Thus, we deemed the financial services industry an appropriate test bed for our research model. From an empirical perspective, focussing on a single industry also allows to control for extraneous industry factors that could otherwise confound the analysis, thereby enhancing internal validity (Zhu et al. 2004). Since the field study was conducted internationally, the back-translation method proposed by Brislin (1986) was used to translate the questionnaire into different target languages. In doing so, first, professionals translated the questionnaire, originally written in English, into German, French, and Dutch. In a second step, different bilinguals translated the questionnaires back into English allowing for a comparison of the original and the back-translated questionnaire and a re-translation of discrepant passages.

In August 2009, 3096 potential study participants were selected by a large market research company that runs several expert panels (e.g., IT business panel). The research company applied the criteria defined by the authors (IT decision maker in a financial institution with more than 1000 employees) for the selection of the panel members and invited them (on behalf of the authors) to respond to the survey by sending an email invitation. The email contained an embedded, individualized URL link to the online questionnaire to ensure that each respondent completed the survey only once. Moreover, it allowed the research company to track all study participants so that they could send an email reminder to all non-respondents after one week. However, information about the respondent's profile (name, email address, etc.) was kept confidential and was not disclosed to the authors. The potential participants were asked to completely fill-out the questionnaire to avoid missing values that can cause bias due to systematic differences between observed and unobserved data. As an incentive for their participation, the respondents that completely filled-out the questionnaire received airline or hotel discount vouchers. In total, 855 responses were returned, indicating a response rate of 27.6 percent.

Since the study aimed at Grid adopters, the study participants were asked at the beginning of the questionnaire to indicate whether they have already adopted Grid technology or not. In the latter case, the non-Grid adopters were directly excluded from taking part in the survey. 393 responses from non-Grid adopters and 103 responses that exhibited missing values were removed, leading to a final sample of 359 valid responses. The key characteristics of the sample are shown in Table 2.

Country			Number of employees (firm size):	
	<i>invited</i>	<i>responded</i>		
U.S.	2034 (65.7%)	211 (58.8%)	1,001 - 5,000	48 (13.4%)
U.K.	788 (25.5%)	111 (30.9%)	5,001 - 10,000	47 (13.1%)
Germany	132 (4.3%)	13 (3.6%)	10,001 - 50,000	92 (25.6%)
Canada	44 (1.4%)	11 (3.1%)	50,000+	172 (47.9%)
France	78 (2.5%)	3 (0.8%)		
Netherlands	20 (0.6%)	10 (2.8%)		
Respondent's position:			Year of first Grid adoption:	
CTO COO CIO		53 (14.8%)	< 2000	21 (5.8%)
Chief Systems Architect		16 (4.6%)	2000 - 2001	22 (6.1%)
Other IT decision maker		290 (80.8%)	2002 - 2003	20 (5.6%)
			2004 - 2005	46 (12.8%)
			2006 - 2007	112 (31.2%)
			2008 - 2009	138 (38.4%)

Table 2: Sample characteristics

DATA ANALYSIS AND RESULTS

To validate the research model, two main approaches can be considered (Tenenhaus 2008): covariance-based SEM methods and components-based SEM methods. *Covariance-based* SEM methods involve various constraints regarding the distributional properties, e.g., multivariate normality (Fornell & Bookstein 1982) and are mainly applied to test whether the hypothesized relationships among the latent variables and between the latent variables and the measurement items are consistent with the empirical data (Diamantopoulos & Siguaw 2000). Covariance-based SEM methods are usually employed when prior theory is strong and further theory testing and development is the goal. In this case, covariance-based estimation methods, e.g., the maximum likelihood (ML) or the unweighted least squares (ULS) method, are more appropriate to validate a research model (Chin et al. 2003). In contrast, *components-based* SEM approaches, i.e., the PLS method, require fewer distributional assumptions about the data (Cassel et al. 1999). Especially in new areas of applied research and in early stages of measurement instrument development, little is known about distributional characteristics of observed variables. Although PLS can be used for theory confirmation, it can also be used to suggest where relationships might or might not exist and to suggest propositions for later testing (Chin et al. 2003). Therefore, the PLS method is a prediction-oriented approach (Chin 1998) that not only supports confirmatory but also exploratory research (Gefen et al. 2000). This can be seen as an advantage since theory construction is as important as theory verification (Deshpande 1983). Due to these facts, we deemed the PLS method appropriate for the validation of our research model since our research is still at an early stage and the proposed research model (i.e., that contains two newly-developed constructs SUST and ASSM) has not been tested in the literature.

In the data collection stage, we aimed at gathering a large number of responses to address the criticism raised by Marcoulides and Saunders (2006) of insufficient sample sizes in PLS studies. The authors note that even moderate non-normality of data requires a sufficiently large sample size, even if the indicators are highly reliable. In line with this, Hui and Wold (1982) found, in a simulation study, that the average absolute error rates of PLS estimates diminish as sample size increases. Thus, the larger the sample, the more reliable the PLS estimates. Although the appropriate sample size depends on many factors (Marcoulides & Saunders 2006), Chin et al. (2003) state that large sample sizes are needed for unbiased parameter estimates. Thus, our data sample of 359 valid responses seems to be sufficiently large to validate our research model.

For the data analysis, the software implementation SmartPLS (Version 2.0 M3) was used, which is a components-based path modeling software application based on the PLS method. SmartPLS (Ringle et al. 2005) is comparable to PLS-Graph (Chin 2001) since it is based on the same method.

To estimate the parameters in the measurement and the structural model, we used PLS path modeling with a path weighting scheme for the inside approximation (Chin 1998; Tenenhaus et al. 2005). Because PLS does not directly provide significance tests, the non-parametric bootstrap (Davison & Hinkley 2003; Efron & Tibshirani 1993) re-sampling method was conducted to provide confidence intervals for all parameter estimates, building the basis for statistical inference. With this method, the performance of an estimator of interest is judged by studying its parameter and standard error bias relative to repeated random samples drawn with replacement from the original observed sample data (Marcoulides & Saunders 2006). We pre-specified the number of 500 bootstrap samples and conducted the bootstrap procedure with construct level changes pre-processing to test the significance of the path estimates and factor loadings. The default number of bootstrap samples is 100 but a higher number may lead to more reasonable standard errors of the estimates (Tenenhaus et al. 2005).

In the following subsections, the results of the PLS analysis are discussed in detail.

VALIDATION OF THE MEASUREMENT MODEL

Since the research model contains only reflective constructs, the validity of all constructs was assessed in terms of convergent validity and discriminant validity (Campbell & Fiske 1959), which will be presented in the following.

Assessment of Convergent Validity

Convergent validity signifies that a set of indicators represents one and the same underlying construct (Henseler et al. 2009) and is examined by the magnitude of correlation between the indicators of a construct (Gefen 2003). Convergent validity is demonstrated by (1) indicator reliability and (2) construct reliability.

Indicator reliability is a measure for the degree to which the variance of an item can be explained by the underlying construct and can be assessed by the indicator loadings. As can be seen in Table 3 (bold numbers), all loadings of the reflective constructs are above the recommended threshold of 0.707 (Barclay et al. 1995; Chin 1998), indicating that there exists more shared variance between the construct and its indicators than error variance (Hair et al. 2010) and that the measurement items used were adequate for measuring each construct.

Construct reliability measures the degree to which items are free from random error, and therefore yield consistent results. Construct reliability was assessed by using the average variance extracted (AVE), the composite reliability, and the Cronbach's alpha.

The AVE measures the amount of variance that a construct captures from its indicators relative to the amount due to measurement error (Chin 1998). It is used to assess how well a theoretical latent construct explains the variance of a set of items that are supposed to measure this construct. As indicated in Table 4, the AVE of each construct is above the recommended threshold of 0.5 (Fornell & Larcker 1981), meaning that at least 50 percent of measurement variance is captured by the construct.

The composite reliability (Werts et al. 1974) is an aggregate measure of the degree of inter-correlation or internal consistency among measurement items of the same construct and indicates how reliably the construct is represented by the indicators (Chin 1998; Fornell & Larcker 1981). Table 4 shows that the composite reliability scores of the constructs is above the recommended threshold of 0.7 (Straub 1989) providing evidence for sufficient reliability.

Cronbach's alpha (Cronbach 1951) is an alternative measure for estimating internal consistency and assumes equal weights of all the items of a construct and is influenced by the number of items. In contrast to this, composite reliability relies on actual loadings to compute the factor scores and thus provides a better indicator for measuring internal consistency (Henseler et al. 2009; Teo et al. 2009). However, as presented in Table 4, the Cronbach's alpha values were computed and exceed the critical value of 0.7 (Nunnally 1978) providing further indication of internal consistency among the measurement items.

Assessment of Discriminant Validity

Discriminant validity measures the degree to which the specified constructs differ even though they are correlated (Hair et al. 2010) and was assessed by analyzing (1) the cross-loadings and (2) the Fornell-Larcker criterion.

The first criterion of discriminant validity requires that the loading of each indicator exceeds all of its cross-loadings (Chin 1998) and thereby ensures the appropriateness of the measurement model (Henseler et al. 2009). The cross-loadings shown in Table 3 reveal that each indicator loading is much

higher on its assigned construct than on the other constructs, providing evidence for sufficient discriminant validity on the indicator level.

The Fornell-Larcker criterion (Fornell & Larcker 1981) posits that a construct shares more variance with its assigned indicators than with any other construct and is assessed by the relationships between the inter-construct correlations and the square root of AVEs. In statistical terms, the square root of the AVE for each construct should exceed the correlations involving the construct (Fornell & Larcker 1981; Gefen et al. 2000). Table 4 shows that the square roots of all the AVEs (i.e., the numbers on the diagonal) are greater than the correlations among constructs (i.e., the off-diagonal numbers), indicating satisfactory discriminant validity of all constructs.

Consequently, the results demonstrated that all constructs in the model were indeed different from each other.

	SUST	MP	CP	NP	ASSM
SUST1	0.84	0.00	0.15	0.12	0.39
SUST2	0.87	0.10	0.20	0.16	0.38
SUST3	0.90	0.08	0.18	0.12	0.44
MP1	0.06	0.88	0.48	0.33	0.20
MP2	0.08	0.94	0.48	0.38	0.21
MP3	0.06	0.93	0.50	0.37	0.24
CP1	0.15	0.42	0.80	0.52	0.32
CP2	0.19	0.43	0.89	0.51	0.37
CP3	0.17	0.50	0.88	0.48	0.41
NP1	0.17	0.31	0.50	0.89	0.35
NP2	0.09	0.39	0.50	0.90	0.31
NP3	0.12	0.30	0.50	0.73	0.20
ASSM1	0.46	0.20	0.42	0.31	0.92
ASSM2	0.37	0.23	0.36	0.33	0.89

Table 3: Loadings and cross-loadings for measurement items. Bold numbers indicate indicator loadings on the assigned constructs.

	Mean	SD	AVE	CR	Alpha	SUST	MP	CP	NP	ASSM
SUST	4.76	1.57	0.76	0.90	0.84	0.87				
MP	4.62	1.22	0.85	0.94	0.91	0.07	0.92			
CP	4.83	1.46	0.74	0.89	0.82	0.20*	0.53*	0.86		
NP	4.47	1.44	0.71	0.88	0.80	0.15*	0.39*	0.58*	0.84	
ASSM	5.01	1.29	0.81	0.90	0.77	0.47*	0.24*	0.43*	0.35*	0.90

Table 4: Means, standard deviations, average variances extracted (AVE), composite reliabilities (CR), Cronbach's alphas, and correlations among constructs; Diagonal elements represent the square root of AVE; * $p < 0.01$ (two-tailed).

VALIDATION OF THE STRUCTURAL MODEL

Since all constructs showed convergent validity and discriminant validity and all indicators satisfied various reliability and validity criteria they were used to test the structural model and the proposed hypotheses. In doing so, the hypothesized relationships between the constructs were tested by estimating the path coefficients and the R² value. Path coefficients indicate the strengths of the relationships between the independent and dependent variables, whereas the R² value is a measure of the predictive power of a model for the dependent variables (Chin 1998).

As can be seen in Figure 2, three of the four path coefficients are above the threshold of 0.1 (Sellin 1994) at a significance level of at least 0.05 (two-tailed). Therefore, three hypotheses H1, H3, and H4 are supported by the survey data, whereas hypothesis H2 is not supported by the survey data due to the insignificant path coefficient. The explanatory power of the structural model is measured by the squared multiple correlations (R²) of the dependent variable. The R² value of 0.354 indicates that, according to Chin (1998), the model explains a moderate amount of variance for the dependent variable.

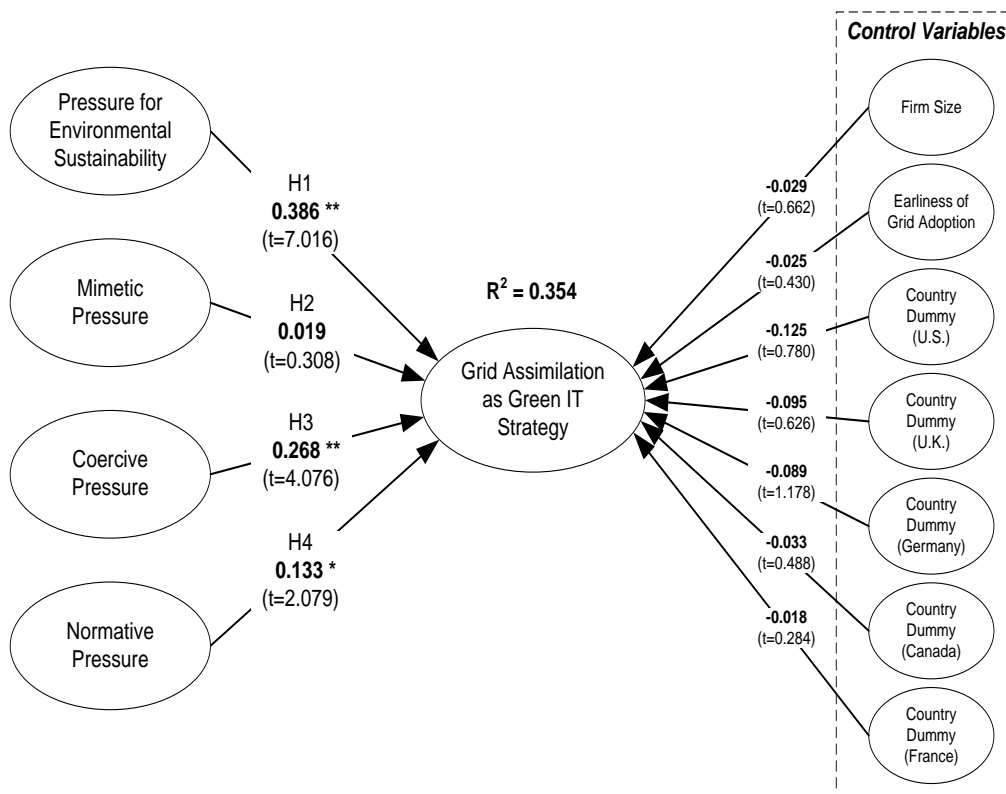


Figure 2: Structural model with results; ** p < 0.01, * p < 0.05 (two-tailed); Netherlands sample served as reference group for five country dummy variables.

Effect of Control Variables

In order to account for differences among the financial institutions, three control variables “firm size” (Zhu et al. 2006), “earliness of Grid adoption” (Fichman 2001), measured as the number of years since first Grid adoption, and “country” (Zhu & Kraemer 2005) were included in the model. Rogers (1995), Tornatzky and Fleischer (1990), as well as Slade and van Akkeren (2002) suggest that firm size may be positively related to innovation adoption since large firms are more likely to exhibit slack resources. In contrast to this, Nord and Tucker (1987) argue that smaller firm size can also be expected to facilitate innovation assimilation since small firms require less communication, less coordination, and less influence to gather support. The second control variable “earliness of Grid adoption” captures the fact that firms that initiated Grid implementation activities earlier will have had more time to reach later stages of assimilation, leading to different magnitudes of IT-related energy consumption. Therefore, it is likely that this measure involves some degree of commingling of behaviours across different assimilation stages (Fichman 2001). The third control variable “country” accounts for country-specific characteristics and differences in the survey data. Due to the categorical nature of this control variable, it was formed into five dummy variables (Aiken & West 1991; Cohen & Cohen 1983). The responses from the Netherlands were used as the reference group and the responses from the remaining five countries were dummy-coded with a “1” on the respective country dummy variable. Thus, the dummy coding for the Netherlands sample served as a comparison group against which the samples drawn from the other countries are contrasted.

For the data analysis, we estimated the model parameters with each of the control variables as well as with all control variables. However, the analysis reveals that none of the control variables is significantly related to the decision of enterprises to assimilate Grid technology as Green IT strategy (see Figure 2). This means that the survey data does not support the hypothesis that large firms are more (or less) innovative than small firms in terms of the use of Grid technology for the purpose of reducing the environmental impact of IT hardware. Moreover, the hypothesis that firms that have more experience in the use and utilization of Grid technology are more likely to use this technology for reducing IT-related energy consumption is not supported by the survey data. Lastly, country-specific characteristics and differences between the six surveyed countries do not show significant effects on the survey results.

Common Method Bias Analysis

Method biases are one of the main sources of measurement error and most researchers agree that common method variance is a potential problem in behavioural research (Podsakoff et al. 2003). In this context, common method variance refers to the variance that is attributable to the measurement method rather than to the constructs the measures are supposed to represent. A common method bias, which is a subset of method bias (Burton-Jones 2009), can occur if the same individual is asked to assess both the independent and dependent variables in a field-based study. This research design flaw is a frequently encountered problem especially with survey studies and constitutes a major threat to the validity for reported empirical findings (Henderson & Lee 1992).

To test for common method bias, the statistical approach described by Podsakoff et al. (2003), Liang et al. (2007), and Williams et al. (2003) was employed. In doing so, a common method construct whose indicators included all the indicators used in the empirical research model was included in the PLS model. Then, the variances explained by the common method construct relative to that explained by the substantive constructs were assessed. As depicted in Table 6 in the Appendix, the average explained variance by the substantive constructs is 0.772 while the average variance explained by the common method construct is 0.001. Given the low and in all cases insignificant method variance values, it can be concluded that common method bias did not impact the results.

DISCUSSION

The results of the data analyses suggest that three of the four proposed hypotheses (H1, H3, H4) are supported by the survey data. The R^2 value of the dependent variable is satisfactorily high, indicating a high degree of explanatory power of its predecessors. The results suggest that pressure for environmental sustainability as well as coercive and normative pressure positively impact Grid assimilation of enterprises for the purpose of reducing energy consumption. Unfortunately, due to the insignificant path coefficient, it cannot be concluded that mimetic pressure drives Grid assimilation for the purpose of reducing the environmental impact of IT hardware.

The analysis of the newly developed construct SUST and its measurement items leads to the conclusion that the financial services industry is facing economic, political/governmental, and social pressure for environmental sustainability. Due to this, the construct SUST and its highly significant indicators are shown to be suitable for measuring the pressure for environmental sustainability and can therefore be used in future empirical studies on Green IT adoption. The analysis of the first hypothesis leads to the conclusion that pressure for environmental sustainability positively affects Grid assimilation as a means to decrease the environmental impact of IT usage. This finding is supported by the fact that when dropping (or adding) the SUST construct from the research model, the change in R^2 is 0.14, which further emphasizes the strong ecological pressure (financial) institutions are facing. This is reasonable due to the fact that the rising energy costs, governmental regulations, and the increasing positive public perception for Green IT initiatives force enterprises to implement environmentally sound IT infrastructures. Since Grid technology supports enterprises in developing Green infrastructures relatively fast, it is likely that pressure for environmental sustainability significantly drives Grid assimilation.

In addition, the study results indicate that coercive pressure drives the assimilation of Grid technology in the industry domain for the purpose of reducing energy consumption of IT hardware. Since enterprises are forced to meet the regulatory requirements for environmental protection and due to the capability of Grid technology to effectively implement a powerful and at the same time an energy-efficient IT infrastructure, coercive pressure positively impacts Grid assimilation. This is consistent with extant literature that hypothesizes that government and industry regulations exert coercive pressure on enterprises and decisively drive the assimilation of new technologies (Ang & Cummings 1997; Zhu et al. 2006). Moreover, our study results support the empirical findings by Chen et al. (2009) as well as Clemens and Douglas (2006) that coercive forces encourage organizations to focus on Green practices, which reflects the effectiveness of regulatory efforts in guiding Green behaviours across organizations.

Furthermore, the survey data emphasizes that normative pressure positively affects Grid assimilation. This can be explained by the fact that, due to the competitive conditions in the industry, the demand for more storage and computing capacity rises. This leads to the need of enterprises to build up a scalable IT infrastructure that thereby contributes to the reduction of IT-related energy consumption. Grid technology is a relatively new technology but the number of Grid adopters is rising rapidly, as is evidenced by the sample characteristics depicted in Table 2. Due to this, the move to a Grid infrastructure can be seen as a process of professionalization that is encompassed by normative pressure. The finding that normative pressure positively impacts on the adoption of Green practices is consistent with the empirical results provided by Molla (2009) indicating that Green practices are driven by normative pressure in terms of pressure for eco-effectiveness and eco-legitimacy.

Unfortunately, the hypothesis that mimetic pressure positively affects Grid assimilation as a means to reduce the environmental impact of IT hardware is not supported by the survey data. This might be explained by the fact that the ecological benefits of Grid technology are not well known or not even

discussed in the industry and in scientific literature. Due to this lack of knowledge about the ecological benefits of Grid technology and the relatively small but increasing number of Grid adopters, the so-called “bandwagon phenomena” are currently not induced by competitors. This result is not consistent with the findings provided by Chen et al. (2009) that found a positive impact of mimetic pressure on the adoption of Green practices (pollution prevention, sustainable development practices, and product stewardship).

Regarding the newly developed construct ASSM and its highly significant indicators, the results of the analysis support the hypothesis that Grid technology is capable of reducing energy consumption of IT hardware components. Due to this, the construct ASSM and its measurement items are shown to be suitable for measuring the motivation of enterprises to use Grid technology as an implementation of Green IT infrastructure and can therefore be used in future empirical studies.

CONCLUSION AND FURTHER RESEARCH

As will be presented in the following subsections, the results of our study provide some interesting contributions to theory and practice, but also contain some limitations. Finally, opportunities for further research are discussed.

Theoretical and Practical Contribution

Prior literature mainly emphasized the benefits of Grid technology with regard to increased computing and storage capacity although the results of the study show that there are also benefits of Grid technology towards environmental sustainability. Therefore, the reduced environmental impact of Grid technology in contrast to non-Grid IT environments should be promoted as another central benefit of Grid computing in the extant literature.

The results of the empirical field study provide a valuable contribution to both theory and practice. Since little empirical research has been conducted on Green IT so far, this article provides empirical evidence on the relationship between Green IT and Grid technology. Moreover, this article is one of the first empirical researches conducted to analyze the role of institutional pressure as well as pressure for environmental sustainability in the context of Grid assimilation. The main theoretical contribution of the article is the analysis of the pressure for environmental sustainability in the context of IT assimilation. The results indicate that this kind of environmental pressure complements institutional pressures, which, to the best of our knowledge, has not been analyzed in the prior literature.

Besides the theoretical contribution, the results are of interest for enterprises that are planning to reduce power consumption of their IT systems while not cutting back on compute and storage capacity for their departments. Grid technology has shown to be suitable for the implementation of Green IT concepts leading to increased competitiveness of the assimilating enterprise. Most Green IT efforts take too long since many enterprises cannot afford a short-term replacement of their existing systems with newer ones. Our empirical results indicate that Grid technology provides a remedy to this problem by giving enterprises the opportunity to build up an energy-efficient IT infrastructure with large computing and storage capacity by connecting existing IT hardware without the necessity to invest in new hardware.

Limitations and Further Research

Despite rich implications, this exploratory study has some limitations to acknowledge.

Although Gerbing and Anderson (1988) as well as Nunnally (1978) state that each construct should be measured by at least two items so that both measurement reliability and construct validity can be assessed, the average number of indicators used in IS literature is three (Chin et al. 2003), which is equal

to the minimum recommended indicators per construct in the SEM literature (Bollen 1989). Therefore, future studies may employ additional items to adequately assess the newly developed ASSM construct that was measured using two items.

Another limitation is that our study results do not support our hypothesis that mimetic pressure positively impacts on the adoption of Green practices (as, e.g., indicated by Chen et al. 2009). Although the measures were adapted from well established literature (i.e., Liang et al. 2007, Teo et al. 2003), future research is needed to analyze whether the measurement instrument items are appropriate for measuring mimetic pressure in the context of Grid assimilation in the financial services industry. Moreover, it has to be analyzed if there are mediating agencies that are involved in the causal relationship between mimetic pressure and Grid assimilation, such as, e.g., top management support. Empirical results provided by Liang et al. (2007) in the context of ERP assimilation indicate that top management serves as main human agency for absorbing and conversing institutional pressure arising from the environment to operational course of action. Therefore, the inclusion of top management support as mediator between mimetic pressure (as well as the other three pressures analyzed in our study) and Grid assimilation might provide more insights about the motivation of (financial) institutions to adopt Grid technology for the purpose of reducing the environmental impact of their IT systems. Moreover, to refine the current research model, further research will be performed to incorporate additional predecessors of Green technology assimilation in the model and to identify mediating or moderating factors.

Since the study was conducted in the financial services industry, the results are only indicative for other industries and limited to a specific technology (i.e., Grid technology). Further research is needed to analyze if the different types of pressures exert the same impact on Grid technology assimilation in other industries compared to the financial services industry. Moreover, future studies may analyze other technologies that are useful in reducing the environmental impact of IT equipment.

Lastly, further research is needed to establish a research model that analyzes the predecessors of Green IT practices in general, thereby extending the recent empirical work on Green IT adoption provided by, e.g., Chen et al. (2009) and Molla (2009).

Although the study has some limitations, the findings provide the basis for future research to further investigate the environmental impact of Grid technology or IT in general.

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APPENDIX

Pressure for Environmental Sustainability (1 = strongly disagree; 7 = strongly agree)	
SUST1	Rising energy costs force our IT departments to reduce IT-related power consumption
SUST2	Political pressure and governmental regulation force our IT departments to reduce IT-related power consumption
SUST3	Social pressure and positive public perception of Green IT initiatives force our IT departments to reduce IT-related power consumption
Mimetic Pressure (1 = strongly disagree; 7 = strongly agree)	
MP1	Our main competitors who have adopted Grid technology have greatly benefited
MP2	Our main competitors who have adopted Grid technology are favourably perceived by others in the same industry
MP3	Our main competitors who have adopted Grid technology are favourably perceived by their suppliers and customers
Coercive Pressure (1 = strongly disagree; 7 = strongly agree)	
CP1	The increasing regulatory pressure requires our firm to use Grid technology
CP2	The increasing customer demand requires our firm to use Grid technology
CP3	The competitive conditions require our firm to use Grid technology
Normative Pressure (1 = strongly disagree; 7 = strongly agree)	
NP1	Our firm's IT service providers have already adopted Grid technology
NP2	Our firm's business partners have already adopted Grid technology
NP3	The government's promotion of IT influences our firm to use Grid technology
Grid Assimilation as Green IT Strategy (1 = strongly disagree; 7 = strongly agree)	
ASSM1	With a virtualized Grid environment, IT-related power consumption of my firm could significantly be reduced
ASSM2	By on-demand purchasing IT resources from external Cloud computing providers, IT-related power consumption of my firm could significantly be reduced

Table 5: Measurement items and scales

Construct	Indicator	Substantive Factor Loading (R1)	R1²	Method Factor Loading (R2)	R2²
Pressure for Environmental Sustainability (SUST)	SUST1	0.862*	0.743	-0.046	0.002
	SUST2	0.861*	0.741	0.040	0.002
	SUST3	0.891*	0.794	0.004	0.000
Mimetic Pressure (MP)	MP1	0.903*	0.815	-0.016	0.000
	MP2	0.951*	0.904	-0.009	0.000
	MP3	0.907*	0.823	0.025	0.001
Coercive Pressure (CP)	CP1	0.780*	0.608	0.039	0.002
	CP2	0.948*	0.899	-0.068	0.005
	CP3	0.841*	0.707	0.034	0.001
Normative Pressure (NP)	NP1	0.846*	0.716	0.010	0.000
	NP2	0.903*	0.815	-0.011	0.000
	NP3	0.783*	0.613	0.002	0.000
Grid Assimilation as Green IT Strategy (ASSM)	ASSM1	0.895*	0.801	0.015	0.000
	ASSM2	0.908*	0.824	-0.015	0.000
Average			0.772		0.001

Table 6: Common method bias assessment; * p < 0.01 (two-tailed)