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ORIGINAL PAPER

Profit-Driven Corporate Social Responsibility as a Bayesian Real Option in Green Computing

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Abstract The idea that socially responsible investments can be viewed in terms of real options is relatively new. We expand on this notion by demonstrating how real option theory, within a Bayesian decision-making framework, can be used by managers to help when making green technology investment decisions. The Bayesian decision framework provides a more flexible approach to investment decision making because it adjusts for new information. Responding to a call for multidisciplinary and multifaceted research in environmental sustainability, this paper integrates ethics, finance, and information technology by viewing investments in environmentally friendly technology as a profit-driven CSR real option. Our model provides managers with the analytic tool needed to make the business case for CSR initiatives providing an opportunity for firms to create economic, social, and ecological solutions that benefit all stakeholders. The practical applicability of our model is demonstrated in an illustrative case scenario based on real data.

Keywords Corporate social responsibility · Green computing · Investment decisions · Real options, Bayesian decision framework

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Introduction

The relationship between corporate social responsibility (CSR) and financial performance has been hotly debated, but without resolution (Chand and Fraser 2006; Griffin and Mahon 1997; McWilliams and Siegel 2001; Orlitzky et al. 2003; Waddock and Graves 1997). Husted and Allen (2007) argue that this could be due to a methodological problem. Financial performance is a function of a multitude of factors, some of which may include social activities and initiatives. Unfortunately, it is impossible to clearly identify the impact of these nonmarket activities. Consequently, instead of viewing them as expenses that may contribute to financial performance, Husted and Allen (2007) suggest that CSR initiatives should be seen as strategic investments that are designed to create value and competitive advantage. "In practical terms, strategic management of non-market social activities turns an expense into an investment with a measurable return" (Husted and Allen 2007, p. 595).

A similar argument is proposed by van Marrewijk (2003), who argues sustainability initiatives have positive social consequences while helping the environment. He contends that firms can combine social and environmental perspectives into a profit-driven sustainability strategy. Such a strategy integrates "social, ethical and ecological aspects into

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business operations and decision-making, provided it contributes to the financial bottom line" (van Marrewijk 2003, p. 595). In other words, a firm will invest in environmental and social initiatives when the firm thinks that those investments will create value for the firm.

We combine these two lines of thought and argue that an environmental sustainability initiative may be both a proactive CSR strategy and a profit-driven investment. Environmental sustainability is a nonmarket activity that will create value for the firm and society. Furthermore, the impact of these profit-driven environmental initiatives can be measured using a Bayesian real options model.

One such area of environmental sustainability consideration is organizational computing. Today's organizations cannot possibly survive without using computers to carry out their operations. However, technology usage is confronted with a variety of environmental issues that include consumption of significant amounts of electricity, which places a heavy burden on our electric grids and adds to greenhouse gas emissions, as well as the production and subsequent disposal of hazardous hardware and software components (Murugesan 2008). A personal computer, for example, can generate about a ton of carbon dioxide (CO_2) every year (Carbonrally.com 2010; Murugesan 2008).

Global warming caused by CO_2 emissions is one of the biggest challenges facing the environment. According to the U.S. Energy Information Administration, over 90% of CO_2 emissions are caused by energy consumption. Consequently, the commitment to decrease environmental impact and power consumption has become critical for many organizations. Environmentally sustainable information technology (IT) infrastructure design has become a new norm of proactive corporate social responsibility (CSR) in computing (Bansal and Roth 2000; Buchholz 1991, 1993). Focusing on environmental sustainability as part of CSR has emerged as a strategic key factor affecting businesses (Zarrella 2008). Organizations are increasing their expectations for corporate social and environmental responsibility for their own organizations and for their business partners (Babin and Nicholson 2009). A 2009 Boston Consulting Group report remarks that senior managers "consider the economic, social, and even political impacts of sustainability-related changes in the business landscape" (Berns et al. 2009). According to a survey of managers conducted by IBM, CSR is no longer viewed as just a regulatory or discretionary cost, but as an investment that brings financial returns (Pohle and Hittner 2008).

Consequently, organizations need to consider both the cost of energy consumption and the environmental impact of CO_2 emissions in their evaluation of green (i.e., ecologically friendly) computing opportunities (Chheda et al. 2008; Watson et al. 2010; Dao et al. 2011; Brooks et al. 2012; vom Brocke et al. 2013). Because of the conventional view that green initiatives represent costs to the firm, perhaps due to costlier infrastructure components, the positive linkage between green performance and firm performance is neither universally accepted nor often considered in capital budgeting decisions (Husted 2005; Sharfman and Fernando 2008). Many have argued for initiating and expanding information systems (IS) research related to green computing and sustainability (Melville 2010; Malhotra et al. 2013; Sarkis et al. 2013). However, the research that includes quantitative models on how organizations can justify green IT initiatives is rather sparse. Hence, one of the objectives of this article is to fill this research gap in the green computing literature.

Managers need the analytical tools to make the case for CSR investments (Godfrey and Hatch 2007). Husted (2005) was the first to propose the notion of environmental CSR investments in terms of real option theory.[1] He notes that using a traditional net present value methodology ignores strategic flexibility. Instead, a CSR real option approach provides a way for a firm to minimize its downside financial risk when planning whether or not to make a CSR investment.[2] Cassimon et al. (2016) extend Husted's (2005) idea by focusing on the time during which the option can be exercised. They calculate the opportunity cost of waiting versus immediately undertaking a CSR investment using the Black–Scholes model. Waiting has a value, because it can help avoid making a bad investment decision, since once the investment is made, the firm loses its strategic flexibility.

We leverage Cassimon et al. (2016) and Husted (2005) by suggesting that an investment in an environmentally sustainable computer infrastructure design can be viewed as holding a CSR option. The environmental impact of a sustainable infrastructure design is often ignored in the traditional net present value approach to investing. Consequently, treating green computing as a CSR investment and modeling it as a real option allows capturing the economic upside potential of the investment, which enables managers to make the case for a CSR investment. The second objective of this article is to extend the work of Cassimon et al. (2016) and Husted (2005) by valuing CSR options using a Bayesian decision-making model. This Bayesian approach is more versatile, especially when data about cash flows are unavailable or uncertain. When there is uncertainty, it is important to consider the trade-off between (a) immediately undertaking a CSR investment and (b) the value of waiting until more information becomes known in the future and combining this new information with the old information to avoid

[1] A real option is a contract for the purchase of a physical asset, as opposed to a stock option, such as a put or a call, which trades on a stock exchange.

[2] For simplicity, henceforth a CSR real option will be referred to as a CSR option.

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making a bad investment decision. The issue of obtaining more information to resolve uncertainty can be investigated by integrating a Bayesian analysis into the CSR option valuation model. The model contributes to the CSR literature by providing an information-based methodology for valuing profit-driven environmental sustainability initiatives.

Our article makes several contributions to the literature on evaluating CSR investments in green computing. First, we develop a Bayesian decision framework for evaluating environmentally friendly investments. To the best of our knowledge, this is the first article to integrate the Bayesian decision framework with environmental uncertainty and to model the impact of green computing alternatives. Second, this article contributes to filling the literature gap noted in Cassimon et al. (2016) and Husted (2005) with regard to CSR, risk management, and the valuing of CSR investments as real options. Finally, we contribute to business practice by conceptualizing, developing, and illustrating a CSR investment model that focuses on energy reduction, energy efficiency, and the total costs of ownership of green computing initiatives. This article aligns with the energy informatics paradigm articulated in Watson et al. (2010) by providing an approach to quantify the value of a CSR option on green computing that can be used to integrate environmental sustainability into information systems. It also addresses the call by Gardiner (2004) and Elliot (2011) that environmental sustainability requires a multidisciplinary and multifaceted approach that cuts across different academic disciplines. This article attempts to integrate ethics, finance, IT, and statistical concepts and tools to model environmental issues in IT infrastructure design.

The rest of the article is organized as follows. In the next section, we review the ethical dimension of green computing as it pertains to CSR. We discuss green computing and CSR investments as real options with a review of prior literature. Then we explain the Bayesian approach to valuing CSR investments and illustrate the methodology with an example of the decisions by a small university to change its computer server configuration. Next, we discuss limitations, opportunities for future research, and practical implications. The final section presents concluding remarks.

Background Literature

Corporate Social Responsibility and the Environment

Businesses have an interpenetrating relationship with society; each influences and is influenced by the other (Preston and Post 1975). The realization that businesses and society are tightly interwoven gave rise to the concept of corporate social responsibility (CSR) (Wood 1991). Corporate social responsibility is a well-researched area. In a rich literature review based on 588 journal articles and 102 books and book chapters, Aguinis and Glavas (2012) provide a synthesis of the literature at institutional, organizational, and individual levels of analysis. The authors define CSR as "context-specific organizational actions and policies that take into account stakeholders' expectations and the triple bottom line of economic, social, and environmental performance" (Aguinis and Glavas 2012, p. 933). CSR is "the firm's consideration of, and response to, issues beyond the narrow economic, technical, and legal requirements of the firm" (Davis 1973, p. 312).

The furthering of goals beyond the interests of the firm can include both social objectives (McWilliams and Siegel 2001) and environmental ones (Buchholz 1991, 1993; Frederick 1998; van Marrewijk 2003). Much of the CSR literature has focused on social consequences. (See Moura-Leite and Padgett 2011 for a historical review of the CSR literature.) Instead, we concentrate on the environmental aspects of CSR. van Marrewijk (2003) argues that social and environmental concerns are two sides of the same coin. Firms interested in sustainability must combine both aspects into their operations and decision-making routines. He refers to this as profit-driven sustainability. Husted and Allen (2007) argue that socially responsible investments go beyond the narrow bounds of those activities required by the law. These CSR activities are strategic investments that can create value for the firm. We combine both of these notions to argue that environmentally friendly expenditures are strategic CSR investments designed to create value for the firm while also helping to save the planet.

We define environmental CSR as ecologically friendly actions and activities that may go beyond those required by law and the narrow financial interests of the firm. Our definition is in the spirit of Carroll (1979), who argues that business decision makers must take into account the public consequences of their decisions. These public consequences can include the effect that their decisions have on the natural environment in which businesses and society both exist. The theoretical basis for this position is the principle of sustainability that the environmental decisions of businesses have impacts on the ability of the planet to provide for the needs of current as well as future generations (World Commission on Environment and Development UN 1987). Consequently, firms have an ethical responsibility to act in an environmentally friendly manner by not contributing to the degradation of the planet's air, land, and water. In order to achieve sustainability, businesses must behave in an economically, socially, and ecologically responsible manner (van Marrewijk 2003).

Bansal and Roth (2000) identify three reasons why firms will be ecologically responsive. The first is economic self-interest. If there is a competitive advantage to going green, then firms will do so. The competitive advantage could be

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simply reducing production costs (Porter and Van der Linde 1995) or adopting a differentiated "green" marketing strategy (Menon and Menon 1997). Firms also want to appear to be legitimate in the eyes of external stakeholders (DiMaggio and Powell 1983), and so they adhere to society's norms, values, and beliefs of what are seen as appropriate business behaviors (Suchman 1995) including regulatory compliance. Finally, firms engage in environmental CSR because it is the "right thing to do" (Wood 1991) consistent with the firm's corporate values (Buchholz 1993) or with the manager's attitudes and norms about pollution prevention (Cordano and Frieze 2000). Our analysis of green CSR focuses on the first motivation: economics.

Researchers find that environmental management is positively related to financial performance (Klassen and McLaughlin 1996; Menguc and Ozanne 2005; Russo and Fouts 1997). In other words, it pays to go green. But the reality is that not all CSR investments pay off; there is risk associated with investments. Consequently, firms must manage their investment risk in order to maximize their investment returns. Real option theory acknowledges that managers are able to delay, expand, contract, learn, and even abandon an investment opportunity (Copeland and Antikarov 2001; Dixit and Pindyck 1994; Hayes and Garvin 1982; Luehrman 1997; Trigeorgis 1996). Cassimon et al. (2016) and Husted (2005) point out that real option theory can also be applied to environmental CSR investment decisions. We adopt their real option model and add a Bayesian analysis to better explain how managers make environmentally friendly investment decisions in green computing.

Green Computing

With the rapid growth in worldwide computer and Internet usage, computing has directly impacted the environment. A variety of environmental issues arise with extensive use of technology, including significant electricity consumption, which places a heavy burden on power grids; greenhouse gas emissions; and the production and disposal of hazardous IT hardware components (Murugesan 2008). With the recognition of our obligation to reduce the negative environmental impact of technology and to create a more sustainable environment, green computing, or green IT—in which businesses make their IT products "green," that is, make their applications, services, and practices more environmentally friendly—has legal, ethical, and social appeal (Murugesan 2008; Zarrella 2008). Sustainable IT has emerged as a strategic key factor affecting businesses today (Zarrella 2008). Sustainability essentially refers to the "conservation, deployment, and reuse of resources in responsible ways" (Malhotra et al. 2013, p. 1265).

The terms "green IT," "green technology," "green computing," "environmentally sustainable IT," and "green IS" have been discussed and debated.[3] Some researchers focus on technology rather than IT applications, while others define it in terms of people, processes, and software components (Curtis 2008; Francis and Richardson 2009; Harmon and Auseklis 2009; Jindal and Gupta 2012; Murugesan 2008; Zarrella 2008). We follow Elliot's (2011) definition: "activities to minimize the negative impacts and maximize the positive impacts of human behavior on the environment through the design, production, application, operation, and disposal of IT and IT-enabled products and services throughout their life cycle."

Watson et al. (2010) indicate that the IS academic community has been relatively slow in recognizing environmental sustainability as an urgent problem. In a review of the literature appearing in five leading research journals in the IS and operations area over an eight-year period from 2000 to 2007, Melville (2010) finds that the majority of the articles appeared in the operations area with only one article in a leading IS journal that addressed Watson et al.'s (2010) concerns. Subsequent editorials (Malhotra et al. 2013; Sarkis et al. 2013) and panel reports (Seidel et al. 2017; vom Brocke et al. 2013) have called for more research in IS-related environmental sustainability. These recent articles also reviewed the literature in information systems journals to indicate that research in this area is in a relatively nascent stage.

Watson et al. (2010) advocate a research agenda for energy informatics dealing with the analysis, design, and implementation of IS to increase the efficiency of energy demand and supply systems. In one of the earlier papers in this area, Chen et al. (2008) argue that while technology may be partly responsible for environmental deterioration, IS can help minimize pollution by reducing energy needs through efficiency and productivity improvements in organizations. Using institutional theory, Chen et al. (2008) discuss how IS can be leveraged to achieve the three milestones of ecological sustainability, that is, eco-efficiency, eco-equity, and eco-effectiveness. Watson et al. (2011) further argue that organizations can develop innovative solutions to focus on eco-effectiveness rather than eco-efficiency. While eco-efficiency is characterized as minimizing the ecological

[3] Watson et al. (2010), in defining the term "green IS," argue that while much of the practitioner literature has devoted attention to "green IT" with exclusive focus on technologies, they prefer "green IS," which refers to an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals. This definition includes green IT and allows for a greater variety of possible initiatives to support sustainable business processes. Elliot (2011) argues that the term "green IT" focuses attention on technology rather than IT applications and is often associated with reducing energy use in data centers. He emphasizes that the term "environmental sustainability of IT" is also often used in a narrow sense which ignores its multifaceted nature.

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footprint of existing solutions, eco-effectiveness focuses on solutions that are sustainable (Watson et al. 2011).

Brooks et al. (2012) identify several eco-goals that are relevant to green IS initiatives: eco-capacity, eco-efficiency, eco-effectiveness, and eco-collaboration. Using a resource-based approach, Dao et al. (2011) propose a sustainability framework that integrates human and supply chain considerations. They argue that contributions of IT to sustainability go beyond reducing energy consumption in IT. Similarly, Ba and Nault's (2017) review of the literature finds that sustainability is an important theme in the economics and management of technology. These important articles set an interesting agenda with research questions and issues. However, the majority of these articles are conceptual. More specifically, while most of these researchers have urged green computing and sustainability initiatives, this literature has not modeled how organizations can make the business case for green computing. Our article aims to fill this gap in the literature.

vom Brocke et al. (2013) state that green IS offers the promise to make a significant contribution to reducing greenhouse gas emissions and mitigating the effects of global climate change and other environmental problems. Green computing encompasses efficient and ecologically friendly computing practices by organizations with the objective of achieving reduced IT costs. Environmentally sustainable infrastructure design focuses on both traditional IT business goals and environmental resource constraints (Curtis 2008). Further savings can be achieved through the strategic configuration of hardware servers (Francis and Richardson 2009). Broadly, these practices include minimizing the environmental footprint by: the proper disposal of e-waste; the use of virtualization, cloud computing, and other computer architectures (hardware and software) that focus on efficiency; reducing energy consumption; and engaging in futuristic initiatives such as carbon-free computing, solar computing, lead-free computing, and nanotechnology (Harmon and Auseklis 2009; Jindal and Gupta 2012; Murugesan 2008). Brooks et al. (2012) identify data center reengineering, CO_2 emission measurement, equipment recycling and refurbishment, and server virtualization as eco-efficiency measures.

In a conceptual paper, using virtualization as the context, Bose and Luo (2011) develop a model based on three IS theories, namely technology–organization–environment, process virtualization, and diffusion of innovation, to assess the potential for undertaking green IT initiatives. In Dao et al.'s (2011) conceptualization, virtualization falls in quadrant I (Internal-Today), where organizations focus on optimizing their internal operations to deliver sustainability value by energy conservation and emission control, among others. Virtualization may also fall in quadrant III (Internal-Tomorrow), where a flexible IT infrastructure needs to be carefully planned to provide a base for future initiatives in anticipation of scalable or changing business needs. Our model focuses on energy reduction through more efficient infrastructure design using virtualization to support environment sustainability.

Organizations have an opportunity to address environmental issues while improving their productivity, reducing costs, and enhancing benefits, but achieving this organizational-level win–win goal is not easy (Sarkis et al. 2013). Based on a study of 143 organizations in Australia and New Zealand, Molla et al. (2009) found that cost was the biggest disincentive to adopting green IT, followed by unclear business value. Gholami et al. (2013) surveyed 508 managers in Malaysia and found that coercive pressures experienced through regulations, suppliers, and customers influenced managerial attitudes toward green IS adoption. Although it is perceived to be a challenge to balance sustainability initiatives with profit-driven development, a case study of China Mobile indicates that it may be achievable (Du et al. 2013). This aligns with the profit-driven CSR argument.

Watson et al. (2010) argue that green computing involves recognizing the role that technology can play in reducing energy consumption and thus CO_2 emissions. Watson et al. (2010) point out that there is an economic motive to reduce energy consumption because using less energy contributes to higher profits and lower CO_2 emissions. Firms also need to comply with government regulations on CO_2 emission limits, which are increasingly likely to be applied as governments address global warming. Because of the interpenetrating relationship between businesses and society (Preston and Post 1975), government intervention and regulation often influence firms' behavior toward socially desirable environmental practices. While regulation has been found to influence managerial decisions (Gholami et al. 2013), there is uncertainty as to both the level of carbon tax that will be imposed and the degree to which the carbon tax will be enforced as a result of political and industry pressure. This uncertainty makes green computing decisions problematic, especially when the costs of government compliance put the firm at a competitive disadvantage. Sarkis et al. (2013) identify that one way in which green IS and green IT can add business value is by reducing costs and inefficiencies, although additional business value can come from risk mitigation. In this article, we provide a methodology to manage risk by incorporating new information before making a decision.

Conceptualizing Green Computing as a Profit-Driven CSR Option with Bayesian Revisions

Arguing for abandoning a "one solution fits all" definition for corporate social responsibility (CSR) and corporate sustainability (CS), van Marrewijk (2003) explains the reasons for ethical decision making by organizations as a set of

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individual or combined organizational positions. For example, the organization may choose a position of compliance-driven CS/CSR, which is forced by regulations to provide welfare to society; profit-driven CS/CSR, which is motivated by the business case to increase profits; holistic CS/CSR, which is embedded in every aspect of the organization; caring CS/CSR, which consists of balancing economic, social, and ecological concerns beyond legal compliance and profit consideration; and synergistic CS/CSR, which is aimed at creating economic, social, or ecological value through well-balanced functional solutions in a synergetic win-together approach. Incorporating sustainability into the analysis is an example of a profit-driven CSR business approach that integrates social, ethical, and ecological aspects into business decision making (van Marrewijk 2003). Our model falls in the profit-driven CS/CSR category. The reduction in energy consumption and the external impact of the application architecture design provide the organization with an opportunity to make CSR investments in green computing. That is, an organization can choose to invest, at an appropriate time, in a more energy-efficient application architecture that will reduce not only the energy consumption cost but also the firm's environmental impact.

CSR investments provide a way to minimize the downside business risk for organizations. However, justifying CSR investments using a traditional net present value or cost–benefit approach ignores strategic flexibility (Epstein and Roy 2003; Husted 2005). Consequently, Husted (2005) rejects the traditional approaches and instead explains the Johnson & Johnson Tylenol recall, the *Exxon Valdez* oil spill, and the development of the First Community Bank by Fleet Boston Financial Corporation in terms of real option value drivers. Adapting the traditional stock option model, Husted (2005) argues that the value of a CSR option is a function of five factors: the value of the asset, the exercise price of the option, the time during which the option can be exercised, the risk-free interest rate, and the volatility of the price of the asset. Expanding upon his work, Cassimon et al. (2016) make a valuable contribution to the pricing of CSR options by considering the optimal timing in which to invest in CSR. The authors consider the opportunity cost of waiting versus investing immediately in CSR using the Black–Scholes model with dividend payouts. Through a case application, the authors showed that in the absence of any opportunity cost of waiting, firms tend to delay CSR investments.

From a capital budgeting point of view, it is often more difficult to make the business case for CSR investment when the benefits are environmental as compared with economic, especially when other investments compete for limited financial resources (Gordon et al. 2016). The reason is that capital markets push stock prices higher when revenue-producing projects are publicly announced as compared with an announcement of a CSR investment in green computing. The monetary quantification of an environmentally friendly CSR investment using a real options framework facilitates making the business case for a CSR investment, because the value of the project is enhanced by adding the option value to the net present value of the investment. The underlying idea is to determine the economic value of the reduced energy consumption arising from a green computing alternative (traditional net present value analysis) and the value of the real option to exploit the economic upside by resolving uncertainty.

The main uncertainty with respect to current green investment decisions concerns taxation. The rising costs of energy consumption as a result of diminishing finite scarce natural resources combined with the emergence of worldwide concerns about sustainability have led governments to impose (or consider imposing) carbon taxes. In Canada, British Columbia has imposed a carbon tax, while Quebec has a cap-and-trade system for CO_2 emissions, and the federal government is thinking about a nationwide carbon tax (McCarthy and Leblanc 2016). In the USA, California has a cap-and-trade policy, but there are no state or federal carbon taxes, although there is a strong lobby to have them implemented (Elias 2014). Furthermore, when carbon taxes are proposed by governments, businesses often resist those tax proposals. For example, in 2016 both the energy and auto sectors raised red flags over Ontario's plan to address climate change (Morrow and Keenan 2016), and the Ontario Chamber of Commerce urged the provincial government to delay for 1 year the implementation of the $7 billion Climate Change Action Plan, which was scheduled for release in June 2016 (Jones 2016). Consequently, there is a high degree of uncertainty concerning the level of taxation (if any), the degree to which the government will enforce the carbon tax, and whether all businesses will have to comply or only certain industry sectors.

Our argument is that the real option to delay a CSR investment in green computing primarily concerns the resolution of uncertainty regarding the level of carbon taxation and the degree of enforcement of the carbon tax. The resolution of uncertainty through the Bayesian revision procedure changes the prior probabilities associated with the distribution of the carbon tax and thus changes the real option value (the economic dimension). The real option value enhances the net present value to make the business case for an investment in green computing.

Description of the Bayesian Approach to Revising Probabilities

Traditional real option theory considers the managerial flexibility of postponing an irreversible investment and exercising the investment option to exploit its upside financial potential. Cassimon et al. (2016) considered CSR investments as real

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options. The idea is that if the asset price might increase during the wait-and-see period, there is an opportunity cost to investing in CSR today. For many capital investment decisions, there also may be a benefit if the project generates cash flows immediately or if the firm gains a first-mover advantage. In this traditional real option setting, the costs and benefits of waiting are compared and a decision is made.

Bayesian real option models (Galli et al. 2004; Grenadier and Malenko 2010; Herath and Herath 2009; Herath and Park 2001) extend the concept of waiting to include learning more about the nature of uncertainty. In these models, uncertainty is no longer constant as in the traditional real option models, but is driven by Bayesian updating or learning. Grenadier and Malenko (2010) argue that there are two real options in the Bayesian model: the traditional "waiting" real option and the "learning" real option.

The learning real option can be considered an opportunity to acquire additional information before making an irreversible investment decision (Galli et al. 2004; Herath and Park 2001). There are numerous ways in which additional information can be obtained in capital budgeting. For example, a decision may be delayed so that more information on uncertain cash flow parameters can be obtained through surveys or from expert sources. In energy exploration and production, new seismic wells can be drilled to resolve uncertainty regarding energy reserves before undertaking production and refining (Galli et al. 2004). Capital investments can be undertaken in stages if projects can be replicated to acquire more information on potential cash flows (Herath and Park 2001). A retail chain, such as Walmart, might open superstores in a number of locations and, based on this sample, decide whether or not subsequently to invest in other locations. The idea is to avoid poor investment decisions due to insufficient data and to evaluate whether or not it is worth acquiring new information (Galli et al. 2004). Simply put, if additional information can be obtained, then Bayesian analysis can be combined with real option theory to better manage project risk. CSR investments in green computing fall into this category of real options.

Conceptually, real options are as follows. Consider an investment with uncertain project payoffs. The net present value of the payoffs is the asset price (V). The investment cost (I) or exercise price is X. The net present value of the overall investment is $NPV = V - I$. In the traditional waiting option model, an investment is deferred until time T so uncertainty regarding V can be resolved with new information that arrives with the passage of time (Copeland and Antikarov 2001). The delay adds value by allowing the firm to avoid investing if the payoff (V) is less than the investment cost (X) (see Cassimon et al. 2016). More specifically, the firm exploits the upside potential of the investment, which creates an extra value greater than the NPV, and the two components combined are termed the strategic net present value ($SNPV$). In computing the NPV, however, both the upside potential of the payoff and the downside payoff risk are considered as a result of averaging. On the other hand, in computing the $SNPV$ with the real option to defer the investment, only the upside potential is considered because an option is worthless when the payoff is less than the investment cost. Using $\boldsymbol{\Phi}$ as a general probability operator, $SNPV = \boldsymbol{\Phi}\max[V - X, 0] = NPV + \Omega$, where the option value to defer the investment can be rewritten as $\Omega = SNPV - NPV$. As a result of the exploitation of the upside potential, a real option can also have a positive value at the current time, which is termed the intrinsic value of an option. This is the case in the proposed CSR option on green computing, since there is an immediate upside potential in uncertain payoff because of the carbon tax savings that result from the new server system emitting less CO_2.

A main feature of a traditional real option deferred investment model is that the probabilities remain constant and there is no revision of the probabilities. The probability values represented by $\boldsymbol{\Phi}$ are the same at time zero and at time period 1 (i.e., $\boldsymbol{\Phi}_0 = \boldsymbol{\Phi}_1$). If delay allows obtaining additional information, then the probabilities can be updated (revised) with new information. These new probabilities are the conditional probabilities obtained via Bayes' theorem. The updating of probabilities allows the firm to learn more about the nature of uncertainty and incorporate them into the real options model. The Bayesian analysis combined with traditional real option theory allows firms to modify investment behavior through active risk management by proactively obtaining additional information rather than passively resolving uncertainty through deferral alone.

With respect to green computing, the major sources of uncertainty are both the amount of future carbon taxes and the degree of enforcement of those taxes by the government. The Bayesian approach incorporates this uncertainty into the analysis of the CSR investment in green computing and thus influences firm investment behavior. If the real option value with the Bayesian updated probabilities is larger than the real option value based on the original probabilities, then acquiring additional information has value. Otherwise, it is worthless.

In the traditional "waiting" CSR option of Cassimon et al. (2016), uncertainty is passively resolved over time. In our model, a firm may actively obtain additional information during the deferral period to resolve uncertainty. For example, if there are no prior data on the carbon tax, uncertainty regarding the proposed carbon tax is subjectively assessed at time zero, with incomplete information. If there is additional uncertainty with regard to the degree of enforcement of the carbon tax, an estimation of the joint probabilities of the carbon tax and the degree of enforcement would be useful from the perspective of CSR investment risk management. The Bayesian CSR option proposed in this article

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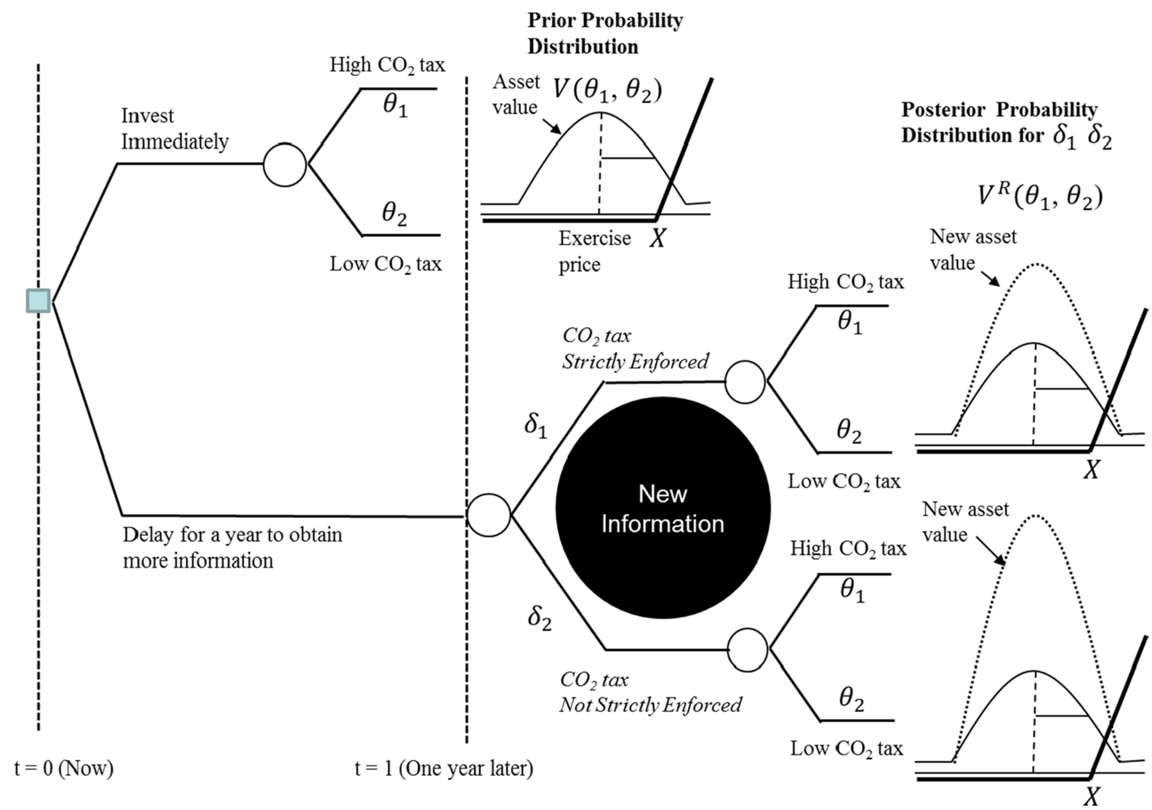

Fig. 1 CSR real option on green computing: Bayesian approach

allows assessing these joint probabilities and thereafter revising the initial beliefs of the carbon tax with the new information on the degree of enforcement in order to obtain the posterior probabilities. These revised posterior probabilities (Φ_1^R) reflect the new information pertinent to the CSR investment decision. The strategic net present value at time period 1 with the Bayesian resolution of uncertainty is $SNPV^R = \Phi_1^R \max[V - X, 0] = NPV + \Omega^R$, and the real option value with Bayesian revision information can be computed as $\Omega^R = SNPV^R - NPV$. We illustrate the basic idea in Fig. 1.

Advantages and Disadvantages of the Bayesian CSR Option Model

There are several notable advantages of the Bayesian real option model compared with the traditional real option model. First, the Bayesian model allows for proactively incorporating additional information regarding uncertainty. More specifically, because of the Bayesian updating of the parameters, the uncertainty is no longer constant, which is more realistic because uncertainty can change during the life of an option. Second, the Bayesian approach allows uncertainty to be modeled without invoking the strict assumptions of risk-free arbitrage that most financial and real option models are based on. Finally, in the CSR investment in green computing, imperfect information is typically the norm rather than the exception because the incremental benefits (cash flows) are functions of the reduction in CO_2 emissions and energy consumption, which require subjective assessment of parameter uncertainties. In such settings, where market data are unavailable or where assets are not traded, refining the initial probability assessments with additional information obtained during the delay period via Bayesian analysis is immensely valuable in order to properly ascertain project risk and its impact on explaining a firm's investment behavior.

A major limitation of the Bayesian approach to real option analyses is the degree of complexity when modeling in continuous time. When the payoffs are modeled as continuous-time stochastic processes, integrating Bayesian analysis may become extremely difficult. Also, if the prior and likelihood functions are modeled by continuous probability distributions, then to avoid computational intractability, conjugate distribution assumptions have to be made. Conjugate distributions are those where the prior and the posterior will be of the same type of a continuous probability distribution. (In the following illustrative case scenario, this limitation was avoided by using discrete probability distributions and decision tree analysis for modeling asset dynamics and Bayesian

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revisions.) Another limitation of Bayesian analysis is the use of subjective probability assessments. But when data are available, objective probabilities by fitting distributions can be used as prior probability distributions. Despite these limitations, Bayesian analysis methods are general and applicable to both discrete-time and continuous-time modeling. Details of the Bayesian CSR real option model for green computing are provided in Online Appendix 1.

Illustrative Case Scenario: Server Consolidation

We now illustrate how a firm's decision to make an environmentally friendly investment can be seen in terms of a CSR option. Our example concerns a small North American University that has a proactive environmental policy on IT and energy consumption.[4] IT includes the various components that use power, such as a central processing unit, hard drives, graphics cards, and monitors. The faculty and staff combined operate 1450 computers on campus. The university's green computing initiative involved upgrading its current data center to reap operating cost savings and to reduce the center's environmental impact.

In order to evaluate the green architecture design alternative, we perform an incremental cost analysis. That is, we compute the discounted operational cost savings of migrating from the existing computer system (System A) to a more energy-efficient one (System B). In this example, there is a high degree of certainty about the costs of making the investment in the energy-efficient system. Similarly, the incremental operating cost savings associated with moving to a more energy-efficient system are also known. What is unknown is the carbon tax. There is a high degree of uncertainty about the level of this tax and uncertainty as to how strictly the government will enforce the new carbon tax. Consequently, the Bayesian analysis will only pertain to the level of the new carbon tax and degree of enforcement of the carbon tax.

We define the net present value of a CSR investment as the discounted cash flows (DCF) associated with the investment less the investment cost. (See Online Appendix 2 for the detailed assumptions, data, and computations of this server consolidation example.) The total incremental annual discounted operating cost savings of moving to System B are $1,172,594. The capital cost of the new computer system is $915,480. So the net present value (*NPV*) of the CSR investment is $257,114 ($1,172,594–$915,480). This is the value to the university of moving to a more energy-efficient computer technology.

Because the *NPV* of this CSR investment in green technology is positive, the simplistic analysis would be that the university should make the CSR investment immediately. However, that conclusion does not capture the strategic importance of delaying the investment until the university determines the level of carbon tax that will be imposed and how strictly the tax will be enforced. Such determination requires a Bayesian analysis.

Assume that there is a 0.5 probability that the carbon tax will be $52 per short ton of CO_2 emissions, and a 0.5 probability that it will be $26 per short ton. The present value of the expected carbon tax savings by moving to the more energy-efficient system is $25,843. We define the strategic value (*SNPV*) of the CSR investment as the value that includes the carbon tax savings. The total incremental annual discounted operating cost savings of moving to System B are still $1,172,594, and the capital expenditure of the new computer system remains $915,480. Consequently, the strategic value of the CSR investment (*SNPV*) is $282,957. The value of the CSR option is the difference between the strategic value of the CSR investment ($282,957) and the present value of the CSR investment ($257,114). The value of the CSR option is $25,843, the difference between the two values. This represents the value to the university of making the investment in green technology immediately. This real option is considered to be valuable because the dollar value is positive.

Similarly, the university does not know how strictly the government will enforce the new carbon tax regulations. The university may wish to wait for additional information that will reduce the level of uncertainty about the degree of enforcement. Assume that at the high tax level, there is a 0.9 probability that the carbon tax will be strictly enforced and a 0.1 probability that it will not. At the low tax level, there is a 0.2 probability that the carbon tax will be strictly enforced and a 0.8 probability that it will not (see Table 3 in Online Appendix 2). Using Bayes' theorem, the initial probabilities are revised with the additional information (see Table 4 in Online Appendix 2). If the university postpones the decision to invest in green technology and the carbon tax is strictly enforced, then the CSR option has a value of $17,590. On the other hand, if the carbon tax is not strictly enforced, then the CSR option decreases to $5988. Either way, the CSR option is valuable because both of these values are positive. This would seem to suggest that regardless of how strictly the carbon tax is enforced, there is an opportunity savings to delaying the investment. However, these two values are both less than the immediate value of the CSR option ($25,843). This means that there is no value

[4] The technical and cost data for the servers are obtained from a publicly available test report prepared by Principled Technologies (2012), available at http://www.principledtechnologies.com/Dell/R720_vs%20_R710_0312.pdf. We label the servers Server A and Server B to avoid favoring one model over the other. Data are scaled to accommodate the computing requirements of a small North American university. Just for estimation purposes, we use the data available from a report available at https://www.trentu.ca/eab/energy_computer.php.

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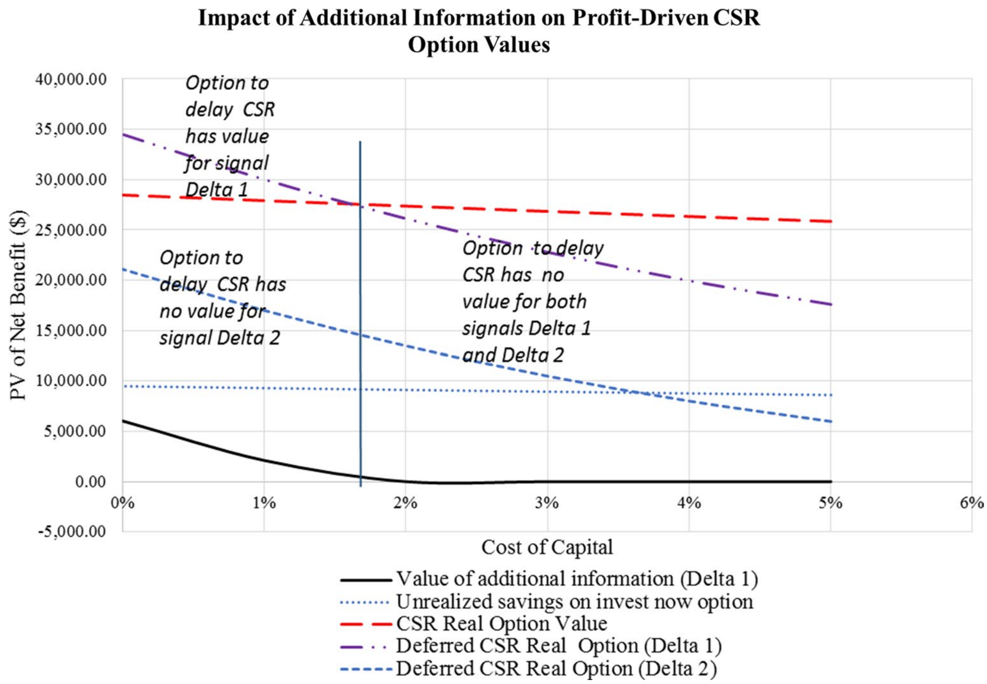
Fig. 2 Sensitivity of real option price to cost of capital



in waiting. Consequently, based on this Bayesian analysis, the university should replace its existing computer system with the new environmentally friendlier computer system immediately.

Sensitivity Analyses

We conduct two sensitivity analyses: one on the cost of capital and the other on the volatility of the level of the carbon tax.

Over the past few years, interest rates in North America have been at historic lows, making the cost of capital quite inexpensive. Hence, we carry out a sensitivity analysis of the CSR option with respect to changes in interest rates. We vary the interest rate from 0 to 5%. As shown in Fig. 2, for low interest rates (up to 1.75%), the value of the CSR option to delay the investment is greater than the value of the CSR option to immediately invest in the green initiative if the carbon tax is strictly enforced. But the CSR option has no value if the carbon tax is not strictly enforced. On the other hand, when interest rates exceed 1.75%, the CSR option to delay the investment has no value over an immediate investment in the green technology regardless of whether or not the carbon tax is strictly enforced. Consequently, there is a value of gathering information of up to 1.75% of cost of capital, but there is a cost of postponing because of higher discount rates.

One of the key option price value levers is volatility. Therefore, we vary the size of the carbon tax, while keeping the discount rate fixed at 5%. We also keep the low carbon tax rate fixed at $11 per short ton while varying the high carbon tax rate from $17 per short ton to a maximum of $112 per short ton in $5 increments. Using the same probabilities of 0.5 for high carbon tax rate and 0.5 for low carbon tax rate, the CSR option price volatility is estimated for each pair of the high and low carbon tax rates. The sensitivity results are presented in Fig. 3. The results indicate that the value of the CSR option increases as the volatility of the carbon tax increases. When the high carbon tax rate is below $77, while the low carbon tax is $11, the university should undertake the CSR investment immediately. On the other hand, when the high carbon tax rate is greater than $77 per short ton and the low carbon tax rate is $11, there is merit in postponing the CSR investment only when the carbon tax will be strictly enforced, and not when the carbon tax will be loosely enforced.

Discussion

Researchers in other disciplines have argued that climate change is fundamentally an ethics issue, although moral philosophers have not taken it up seriously (Gardiner 2004). The author attributes this slow uptake to the interdisciplinary nature of the subject of climate change encompassing science, economics, law, and international relations (among other fields). It is well known that the main reason for climate change is the unprecedented increase in the concentration of CO_2 in the atmosphere due to human action. From an ethics perspective, the moral issue is that the climate problem is ultimately one of human and societal values, and not efficiency or economics (Jamieson 1992). How CO_2

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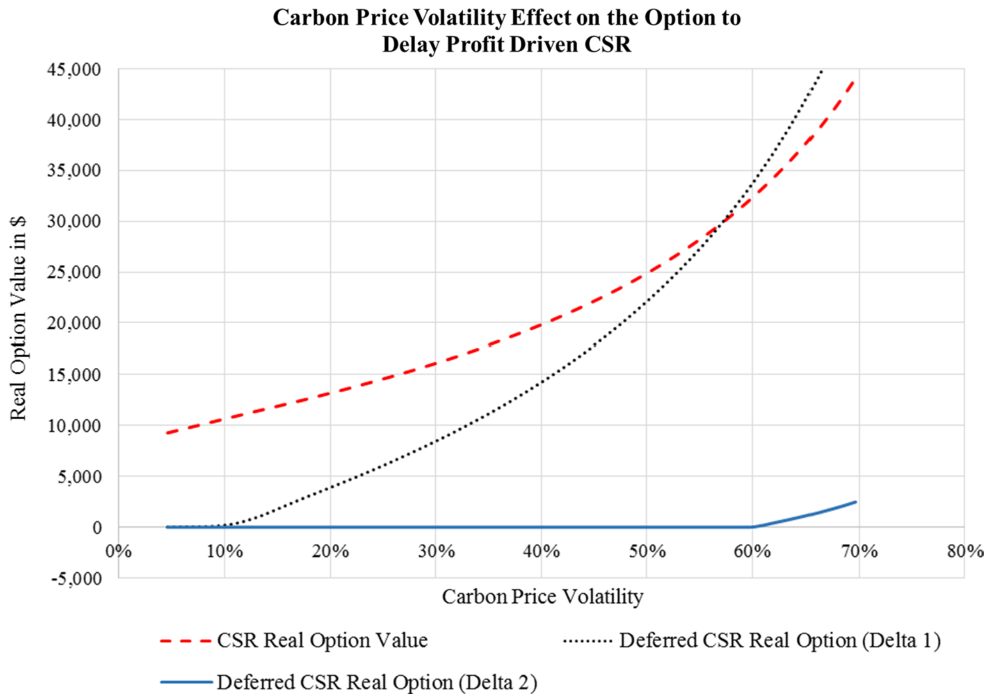
Fig. 3 Real option price sensitivity to CO_2 price volatility



emissions relate to ethics is twofold: (1) curbing CO_2 is an issue of twenty-first-century values such as humanity, courage, and moderation, among others; and (2) it is the moral issue of subjecting future generations to the risk of harm (Jamieson 1992; Gardiner 2004). A reasonable precautionary approach to climate change is reducing energy consumption. Such a precautionary approach entailing changes to energy consumption and low-cost emission-savings measures would have a benefit from a societal point but may be perceived as a cost by organizations if it involves additional capital expenditures and resources. Our model relates to business ethics by showing how organizations can justify CSR initiatives based on a profit-driven approach when a moral, altruistic basis alone cannot make the business case.

While the positive impacts of CSR are documented in the empirical literature (Buchholz 1991, 1993; Frederick 1998; McWilliams and Siegel 2001; Moura-Leite and Padgett 2011; van Marrewijk 2003; Wood 1991), organizations may be reluctant to make these investments due to their inability to see the strategic benefits of these investments. Many have argued that relying on a traditional net present value approach ignores the strategic nature of investments (Cassimon et al. 2016; Husted 2005; Sanchez 1993). Applying a real options framework, strategy views CSR investments as opportunities but not as obligations to make investments when the upside financial potentials can be realized. As Husted (2005) emphasizes, considering the strategic nature of CSR investments entails looking at real options as a risk management tool, which is a much-needed approach because these CSR investments involve corporate decisions to allocate resources.

van Marrewijk (2003) argues that profit-driven sustainability involves both social and environmental initiatives. Husted and Allen (2007) argue that social initiatives are strategic investments that lead to competitive advantage and thereby contribute to firm value. We build on these two perspectives to argue that profit-driven environmental initiatives are strategic investments that can be measured by using a Bayesian real option approach. Our model is consistent with the CSR real options of Husted (2005) and Cassimon et al. (2016) and further supports the argument that CSR initiatives are win–win strategies that can create value for the firm and society. Furthermore, we show that the value of these profit-driven strategic investments can be measured. This furthers our understanding of the strategic importance of CSR activities and contributes to the CSR–financial performance debate (Chand and Fraser 2006; Griffin and Mahon 1997; McWilliams and Siegel 2001; Orlitzky, Schmidt, and Rynes 2003; Waddock and Graves 1997) by showing that environmental strategies can be beneficial to both the firm and society.

We use an illustrative case of an environmentally sustainable infrastructure design at a small university. We use this setting to illustrate the application of the Bayesian CSR option model. The proposed model provides evidence that waiting may not always be beneficial, especially when uncertainty can be resolved by obtaining additional information. Our model demonstrates that the option to delay may

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have value depending on the additional information gathered by the firm.

When a carbon tax is not strictly imposed, we find that waiting for additional information is not worthwhile given that the real option to undertake CSR investment is positive. If an option has value, then exercising the option immediately is worth more than holding it. However, when a carbon tax is strictly imposed, we find that waiting for additional information is worthwhile even if the real option to undertake CSR investment is positive, but only if the cost of capital is low. In this latter situation, there is value to postponing the CSR investment while the manager gathers more information. The value of this additional information is a useful benchmark because it provides an upper bound on the dollar amount that an organization should pay to obtain the additional information, which allows the organization to resolve uncertainty.

The Bayesian framework, which uses reliability probabilities obtained from an expert source and the manager's own prior probabilities, determines the posterior probabilities. This Bayesian analysis provides valuable insight into the decision to invest in green initiatives given uncertainties uncertainty in carbon taxes and enforcement of carbon tax. Thus, the decision maker has the best information available to minimize risk. The concept of a decision tree analysis-based option, proposed by Arrow and Fisher (1974) and Henry (1974), considers the value of gaining more information before making an irreversible decision.

In practice, however, there are scenarios where an organization may go ahead with a green computing alternative even if there is no carbon tax in place or where the probability of a carbon tax being imposed is zero. One such example is the Green Data Center (GDC) at Syracuse University constructed in 2010.[5] GDC was built based on green building principles, where 99% of the construction waste was recycled; the center is powered by a unique tri-generation power plant that uses water-chilled racks that increase power and cooling efficiencies; heat emitted in generating power is used by two chillers to cool the equipment, the GDC building, and the adjacent campus buildings; and the center includes a robust virtual private cloud and sensors to maximize efficiency (Syracuse University 2017). Such scenarios are examples where organizations have implemented green investment as an ethical decision rather than delay the investment for opportunistic financial reasons. The organization may choose to embed CSR and sustainability into every aspect of the organization, or the firm may intentionally include economic, social, and ecological concerns beyond legal compliance and profitability considerations, or the organization might be attempting to create economic, social, or ecological value through well-balanced functional solutions in a synergetic win-together approach (van Marrewijk 2003).

Alternatively, an organization may be able to make the business case to immediately implement a green investment, regardless of carbon tax considerations, if the net present value of the investment is positive, as illustrated in the case scenario in our article. In our example, the positive benefit of the project arose primarily from energy and other cost savings and not from the environmental impact due to quantifying the carbon tax savings.

Extensions and Limitations of the Model

Our model has several limitations that lend opportunities for future research. One main limitation of the proposed model is its narrow focus on reducing energy consumption and impact on the environment by replacing an existing server system. Hence, this narrow focus does not apply directly to the Syracuse data center case discussed above, which is a multifaceted effort to reduce energy consumption and promote sustainability using low-cost, clean-energy-sourced power generation; efficient use of cooling systems; and sharing of resources similar to Microsoft and Google's data centers (Kurp 2008). If an opportunity to resolve uncertainty and to delay a large-scale, multifaceted, green IT investment such as the Syracuse data center exists, then the generic Bayesian approach exemplified in this article is still applicable but would require extensive modeling of the benefits and costs, such as in-house power generation, use of renewable energy, and a multifaceted approach to using cooling systems and resources efficiently along with pertinent sources of uncertainty. We leave that for future research. Future research may also investigate relaxing some of the assumptions in the current model that limit the scope of the model. For example, model, the uncertainty in the electricity prices and staff hours, which were assumed to be constant. Future research may also relax the assumption of independence between the two sources of uncertainty (server cost and carbon tax) and consider the dependent case with correlated uncertainty.

Several other limitations also provide avenues for future research. First, often quantitative analysis is not the only component, and a decision maker must also use personal expertise and experience in interpreting and analyzing results. Second, in the current model, Bayesian analysis is incorporated into real options using discrete distributions modeled by probability trees. One extension of this work would be to model uncertainty pertaining to a carbon tax and uncertainty in server costs as continuous-time distributions and incorporate them in the Bayesian real option valuation framework using Monte Carlo simulation. The Monte Carlo

[5] http://researchcomputing.syr.edu/resources/green-data-center/. We wish to thank an anonymous reviewer for pointing out this scenario.

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methodology is a numerical approach that allows several parameters to be treated as random variables simultaneously and can handle more complex Bayesian problems. Third, the Bayesian revision procedure could be made robust by permitting multiple parameter revisions. For example, the organization could obtain data several times and revise the priors and posteriors over time to reduce the bias that may arise if just one round of additional information is obtained. Under this approach, the posterior in the first round of revisions becomes the priors in the second round and so forth. This results in a finer set of probability distributions.

Practical Implications

The proposed model can be applied to both large and medium-sized universities, where a large number of personal computers (PCs) are used by faculty, staff, and students. In addition, legacy infrastructure, administrative computing needs due to recurring annual student enrollments, data privacy requirements, research data storage, and computing demands may require maintaining an in-house data center, which would facilitate applicability of the model. On the other hand, the model would not apply equally to all businesses as it would depend on the in-house data storage requirements and the number of computers used by an organization. Also, a business may not have the financial resources or IT staff to manage a data center. More importantly, not all businesses may be able to justify a data center based on the high cost of servers, energy cost savings due to a smaller number of users, and processing needs. The model, however, is more applicable to large-scale business organizations with in-house data storage needs and personal computer use.

Green computing principles of environmental responsibility through eco-friendly use of computers and their resources, however, would still apply. Consequently, perhaps it may entail other cost-effective alternatives such as streamlining IT infrastructure and using software as a service through cloud computing. Furthermore, businesses may not have legacy infrastructure that allows them to build into cloud computing with greater efficiency (Griffy-Brown and Palanisamy 2009). Finally, businesses may not require one personal computer per employee. Businesses can use the excess power of one PC and share it with several employees, thereby reducing energy consumption and cooling needs and minimizing e-waste and thus the energy footprint of the business, which has to be treated as the benefit in making the business case for green computing.

The Green Data Center project at Syracuse University shows that there are additional benefits of using green building principles in designing data centers. Therefore, wherever possible, green computing initiatives should focus on the broader perspective of how energy consumption and CO_2 emissions can be reduced, not only in the data center but also in the adjoining buildings, through new ideas to reduce power loss, increase efficiency, and reuse waste energy. Consequently, in line with Watson et al. (2010), who focus on the broader issue of green IS, which combines people, processes, software, and IT, we suggest that the evaluation of comprehensive green computing should use a modular approach in estimating costs and benefits of green computing CSR initiatives. The modular approach is a sequential approach that allows, for example, making the business case in stages in new innovations, smarter technologies, and in-house power generation because of high costs compared with the smaller investment cost to replace an existing server system as the proposed model.

Conclusion

The idea of modeling CSR investments as real options is relatively new (Cassimon et al. 2016; Husted 2005). We add to the sparse literature by demonstrating how a real options framework can be used to make green computing CSR investments by utilizing a Bayesian decision-making framework. Using publicly available data, we illustrate the model's application. As demonstrated, the model provides a practically useful approach to making the business case for CSR, given that more and more organizations are emphasizing green computing.

This paper adds to the ecological literature by responding to a call for multidisciplinary and multifaceted research in environmental sustainability (Elliot 2011; Gardiner 2004) by integrating ethics, finance, and IT. While CSR is sometimes associated with going above and beyond the narrow economic or legal requirements of the firm, many have argued, for varying reasons, for organizational engagement in these activities. This article provides a generic and flexible approach for managers to consider CSR initiatives according to their goals.

Businesses operate within society and consequently have social obligations (Carroll 1979; Preston and Post 1975). One of these obligations is sustainability, both for businesses and for the planet. Investing in green computer technology can be a win–win scenario, with positive economic rewards for businesses and reduced negative environmental impact for society. The acknowledgment of sustainability needs and CSR concerns provides an opportunity for firms to create economic, social, and ecological solutions that benefit all stakeholders (van Marrewijk 2003). Our model of viewing investments in environmentally friendly technology as real options provides managers with the analytic tool to make the business case for CSR initiatives.

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Compliance with Ethical Standards

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