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# Stochastic internal rate of return on investments in sustainable assets generating carbon credits

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ABSTRACT

Internal rate of return (IRR) is a widely used tool in ranking capital budgeting projects and eventual accept or reject decisions. In this paper, we consider an investment decision involving a sustainable, energy efficient, greenhouse gases (GHG) reducing asset and incorporate the value of carbon emission allowances for the investing company. These allowances create cash flows that may be characterized by significant volatility and uncertainty. The methodology developed in this paper allows decision makers to integrate their knowledge of carbon trading markets and the cash flows that result from sale of emissions credits. The novel methodology utilizes a Bayesian model for IRR that uses Gibbs sampler. Analysis of the results shows that IRR is influenced by volatility and uncertainty of carbon credit cash flows. Ignoring those uncertainty characteristics and simply using the expected values of cash flows can result in significantly inaccurate investment rate of returns. When compared to deterministic IRR calculations, the results show that the occurrence of very high and very low cash flows affects IRR positively, whereas higher variability of cash flow distribution affects IRR of GHG-reducing asset negatively. In other words, frequent large or small cash flows are preferred over fluctuating cash flows. The results may also provide a rationale for the existence of an anomalous consumer behavior known as the energy efficiency gap.



## 1. Introduction

Organizations are facing many stakeholder pressures to improve their performance on climate change and other sustainability issues (Kassinis and Vefeas, 2006; Sarkis et al., 2010). The concerns have been increasing over the past three decades as global climate change has become a major concern for governments and communities. To help mitigate climate change concerns, governments and regulators have introduced various regulatory schemes to internalize the environmental externalities that lead to climate change. This internalization of environmental costs may come through taxes, permits, and market-based trading mechanisms, to name a few (Choi, 2013; Thi et al., 2016). The implications of these environmental costs can be quite profound as to how companies make investment decisions in a wide array of environmentally supportive organizational projects.

Many types of capital investments can be used to help address various environmental issues. For climate change mitigation and greenhouse gas (GHG) emission reductions, a number of potential capital investments can be made (Lee, 2013). For example, renewable energy production, alternative fuels usage, and improved energy efficiency and conservation are all such possible investments. Energy efficiency investments are part of sustainable development initiative and provide valuable alternatives because they have environmental, social and economic benefits (Apostolos et al., 2013; Boukherroub et al., 2015). Yet, appraisal and justification of these investments is not always a trivial task given various uncertainties and potential benefits associated with operational, strategic, and even external regulatory dimensions.

The uncertainties involved in some of these relatively complex investments require some reconsideration of traditional investment appraisal approaches such as payback, net present value (NPV), internal rate of return (IRR) and return on investment (ROI). Some of the most popular financial justification tools are the discounted cash flow (DCF) approaches of NPV and IRR. These related techniques require a number of user estimates on various parameters in order to be useful in practice. Cash flows from investments over time are central to both these approaches and may contain significant uncertainties and assumptions. When it comes to internalizing environmental externalities, modeling of cash flows that result from governmental regulations and tax policy are crucial. Use of risk management and forecasting tools with these techniques

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provides significant managerial and investment insight based on sensitivity of IRR and NPV. Issues related to these tools for environmentally oriented decision making and managerial acceptance of their results has been addressed in the literature (McMohan, 2001; National Center for Environmental Economics, 2010; Gillingham and Palmer, 2014). They do warn, however, about concerns regarding uncertainties associated with cash flows in these techniques. The carbon trading market adds additional uncertainties to these investments.

Managers have used discounted cash flow models for at least past 80 years. The net present value and internal rate return have gained in popularity as capital budgeting techniques based on solid mathematical and rational foundations.

In this paper, to fully address uncertainties in the trading markets for carbon emission permits and to portray various cash flows for a discounted cash flow approach such as IRR, a Bayesian analysis approach is introduced. A cash flow model that incorporates carbon market characteristics related to energy efficiency investments in manufacturing equipment is presented as an example. The model is used to evaluate the IRR results under various uncertainty scenarios. It can handle any standard or non-standard, continuous or discrete, or any categorical distributions involving any complex statistical relationship. The results show that uncertainty attributes of cash flows influence the IRR. Higher standard deviations and/or kurtosis characteristics of cash flows from carbon trading markets result in lower IRRs for investments when compared to deterministic assumptions. A number of policy and practical managerial implications from these findings are also discussed.

Our contributions to the research literature include integration of Bayesian information and analysis into the standard IRR approach. Furthermore, uncertainties are introduced through assumptions surrounding carbon markets thus advancing knowledge and perspective of the influences of external environmental sustainability policy initiatives on the internal organizational investment decisions.

The uncertainties in cash flows resulting from trading of carbon permits are due to many factors. The carbon markets are still in the process of being structured, the rules for them are being formulated or changed as sustainability policies promulgated by the regulatory bodies evolve. New technology, such as cracking of rock formations to extract natural gas (fracking), and spread of alternate sources of energy such as wind and solar farms can have significant effect on the prices of carbon permits because they allow the companies to switch to a less polluting fuel thereby reducing the need for purchase of permits. Prices of fossil fuel have fluctuated significantly, but have generally decreased over the past few years. The use of coal, which has a high GHG footprint, has decreased, which adds to volatility to prices of carbon permits because it affects their demand in unforeseen ways. It is expected that permit prices will have a long-term upward trend, but it is not clear how steep it will be or how many short-term dips it will experience because of the lack of a world-wide consensus on curtailment of GHG emissions.

Additional investigations related to probability and uncertainty characteristics provide theoretical results that identify further avenues of research. We use an illustrative example based on a real-world data and energy/environmental efficiency factors to evaluate the nuances of the IRR model.

The illustrative example developed by Dhavale and Sarkis (2015) is based on NPV. The model in this paper uses IRR, which requires a completely different approach in Bayesian framework since solution is based on trial and error approach resulting in a complex linking function. Furthermore, in this paper we delve into the two different sources of improbability, the uncertainty and the volatility and obtain important insights to deal with them. Because in practice users tend to use both these techniques concurrently, we have used same variable names, as much as feasible, as in the illustrative example used in Dhavale and Sarkis (2015) to facilitate comparison and ease in implementation.

Our focus in the paper is clearly on environmental sustainability; although social sustainability and responsibility is not covered, it has potential as future research direction in the context of this paper.

We first provide some background and position this paper within the capital investment and justification literature, especially focusing on environmentally oriented investments. We then provide insights into the Bayesian methodology that will help derive the data to be utilized within an IRR analysis. Various scenarios in the illustrative example provide insights. Practical, managerial, policy, and theoretical insights are identified. A summary of the results and conclusions are then presented with future research avenues identified.

## 2. Background

Making the business case for environmentally oriented investments has been a concern for decades (Presley and Sarkis, 1994). Yet, the traditional tools and models for investment that utilize discounted cash flows have come under increasing scrutiny (McDermott et al., 2002). Criticisms associated with standard discounted cash flow (DCF) techniques include issues of providing a poor picture of actual cash flows and being myopic in its outlook. Myopic refers to the fact that it is harder to objectively and correctly quantify soft benefits of long-term, strategically-important investments in terms of cash flows alone, which unintentionally results in acceptance of short-term, routine, and predictable investments (Presley et al., 2007; Liesen et al., 2013). Of primary concern with the use of discounted cash flow approaches such as NPV and IRR are the uncertainties of the cash flows in situations entailing complexity, intangibility, behavioral issues, and external market forces (Chang, 2013). In this backdrop, we set the stage for how DCF has been previously utilized for environmental investment appraisal, and its limitations; and how we seek to investigate one technique, IRR, which can be advanced to address this investment situation.

### *2.1. Environmental sustainability investment appraisal and discounted cash flow techniques*

Environmental sustainability oriented investment appraisal has not received significant scrutiny because it is presumed that traditional approaches for investment appraisal will be utilized by organizations. Some work on expanding the investment appraisal literature focusing on strategic investment analysis has been proposed to address many of the concerns with myopic investment appraisal approaches (e.g. Presley and Sarkis, 1994; Presley et al., 2007; Lefley and Sarkis, 2013; Bai et al., 2016). The strategic analysis is required to make a business case for difficult-to-measure and complex investments. Significant research integrating difficult-to-measure and intangible metrics of environmental sustainability investments has occurred (e.g., Bai and Sarkis, 2013; Bai et al., 2016). Organizations still rely on the tangible dimensions of investment appraisal and the application of DCF and other more traditional approaches (Bennouna et al., 2010).

The primary investment appraisal dimensions remain financial, costs and profits. The economic and financial elements of making the business case continue to be central to the justification and adoption of environmental sustainability investments. The use of these traditional approaches is common in various strategic justification investment appraisal approaches and decision support systems (e.g. Presley et al., 2007, 2016)