ARTICLE IN PRESS

Technovation ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at SciVerse ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

Real option valuation of public sector R&D investments with a down-and-out barrier option

Roger D. van Zee [a], Stefan Spinler [b,*]

[a] National Institute of Standards & Technology, 100 Bureau Drive, Gaithersburg, MD 20899, USA
[b] Kuehne Foundation Endowed Chair of Logistics Management, WHU, Otto Beisheim School of Management, Burgplatz 2, 56179 Vallendar, Germany

ARTICLE INFO

Keywords:
Down-and-out barrier
Publically funded R&D
Real options
Risk management
Stretched trinomial lattice

ABSTRACT

This paper presents a real options approach for valuing public-sector research and development projects, using a down-and-out barrier option. Specifically, it considers the potential savings to the tax payer for investing in technology to be purchased by a national government. The valuation is performed with stretched trinomial lattices. Government-driven demand for this technology is equated with the underlying asset, and valuation measured in terms of potential government savings. Two variables, volatility of demand for the technology and unit cost, are treated as uncertain. A Monte Carlo simulation is performed to understand the effects of these variables on the valuation. Other variables are estimated, and a parametric analysis is performed to understand the effects of these variables. To illustrate how this approach could be used, the development of a new sensor, to be used in large networks that track greenhouse gas fluxes, is considered as an example.

1. Introduction

For firms that rely on cutting-edge research and development (R&D) to drive growth, managers balance controlling near-term costs against maintaining long-term competitiveness through R&D. Within the public sector, science and technology program managers increasingly face similar decisions. At mission-driven agencies, such as the U.S. Department of Defense or the U.S. Environmental Protection Agency (EPA), program managers fund a wide range of basic and applied research related to meeting the anticipated future technology needs of the agency. Typically, the Broad Agency Announcement procedure (Broad Agency Announcements, 48 Code of Federal Regulations 35.106), which invites proposals from companies and universities to perform research that will advance the state-of-the-art in targeted technology areas, is used in this process. Most announcements draw numerous proposals, of which only a handful can be funded. Managers usually select the winners through technical expert review, a process that tends to emphasize intellectual merit, over economic impact or technological potential. During periods of national urgency, program managers are allocated enough resources to fund a range of projects, increasing the odds that some of the funded research will result in discovery and development that will ultimately spur the desired innovation. During periods of tight funding, program managers must be more selective. Moreover, governments increasingly expect science and technology programs to demonstrate economic impact. Even the U.S. National Science Foundation (NSF), which historically has funded curiosity-driven research, now considers the broader impacts of research proposals, including potential economic impacts, when making awards. In fact, the NSF recently initiated an "Innovation Corps" program (NSF, 2011) to increase the basic research community's awareness of innovation opportunities and strengthen links between publicly funded researchers and privately held technology companies.

This paper presents a tool for assessing the value of publically funded R&D projects. The paper is structured as follows: In Section 2, we provide a short overview of the literature related to new product development and real options with particular focus on risk management applications. In Section 3, we describe a greenhouse gas sensor, which serves as an example of a publically funded research project whose value is to be determined. Section 4 presents the valuation model based on a down-and-out barrier option, and the following section contains key findings and a sensitivity analysis. We conclude with theoretical and managerial implications and an outlook to future research.

2. The real options and new product development literature

Drawn from the financial sector, real options analyses have proved to be useful in guiding corporate decisions regarding investments in R&D and other capital investments that may not have a positive discounted cash flow. The term real option captures the fact that many investment decisions provide the right, but not the obligation to proceed with a certain course of action. Hence, real

* Corresponding author. Tel.: +49 261 6509 430; fax: +49 261 6509 439.
E-mail addresses: roger.vanzee@nist.gov (R.D. van Zee), sspinler@whu.edu (S. Spinler).

0166-4972/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.technovation.2013.06.005

options valuation allows decision makers to quantify managerial flexibility. In environments where uncertainty is high, this additional value can be significant. Examples of real options applications include patent valuations (Schwartz, 2004), oil field valuations (Smith and McCardle, 1999), software platform selections (Taudes et al., 2000), pharmaceutical R&D opportunities (Demirer et al., 2007; Jacob and Kwak, 2003), multiphase projects within the telecommunications industry (Cassimon et al., 2011), and investments in renewable energy (e.g. Reuter et al., 2012). In contrast, real options methods have not yet found their way into public sector decision making, and application of these methods to public sector projects has received only limited attention in the literature (Gray et al., 2005; Shishko et al., 2004). Nevertheless, national governments invest heavily in new technology development, and in the process are exposed to many of the same risks as those faced by a firm. Specifically, new product development activities are exposed to multiple sources of risk, such as market-size uncertainty, technology availability or maturity (Ulrich and Eppinger, 2008), supply chain disruptions (Tang and Zimmerman, 2009), and organizational risk (Doering and Parayre, 2000). Verdu et al. (2012) find a positive relationship between real options, guiding management's actions in an intuitive manner, and the ability to create technological innovation. The typical risk management process involves risk identification, risk assessment, and risk control (Hull, 2009). Wu and Olson (2008) stress the importance that risk should be quantified through appropriate models. Validation and vetting of these models are important but can pose a challenge in practice, A stylized real options model has been proposed for valuation of R&D projects, which allows for the incorporation of performance risk, market pay-off risk, and budget risk (Huchzermeier and Loch, 2001). It has also been shown that risk management activities targeted at technological and organizational risk enhance the likelihood of new product development success (Mu et al., 2009). When combined with decision trees and Monte Carlo simulations, real options have been shown to provide a useful tool for project assessment in the context of a portfolio of projects, and can be especially effective when relevant data are available (Doctor et al., 2001). Wu et al. (2010b) discuss the issue of risk-based decision making and identify drivers of technological risk: uncertainties of technology, market, innovation benefits, and institutional environment. In addition, they posit that decision making under risk is influenced by three factors: risk perception, value perception, and risk preference. In our paper, by contrast, risk perception as well as value perception, are based on objective measures such as probability distributions. This is the strength of the real options approach which replaces, to the extent possible, subjective by objective factors. Our valuation is done in a setting where either risk-neutrality or risk-aversion can be implemented. Wu et al. (2010a) illustrates causal relationships among different types of risks in a new product development context. Of particular relevance for our paper is the link between regulatory changes that affect market size, technical risk impacting instrument performance and schedule, and cost risk.

In this paper, we build on and extend the existing literature in the following ways: First, we consider the specifics of a publically funded development project and the associated risk management issues pertaining to the stages of risk identification and risk assessment. Second, we model the requirement of achieving a minimum market size by means of a barrier option, which, to the best of our knowledge, is new to the real options literature. Third, by means of a case example, we illustrate how the valuation parameters can be derived from available data and thus the method be utilized in real-life settings.

2.1. Societal background

Most climate scientists agree that average global temperatures are increasing and link this change, in part, to anthropogenic emission of greenhouse gases, most notably carbon dioxide (IPCC, 2007). Because of this linkage, an interest in monitoring the flow of carbon dioxide across large land areas has developed, with the objective of better understanding atmospheric transport of greenhouse gases and identifing sources and sinks, that is, areas that are net emitters and absorbers, respectively, of carbon dioxide. For example, in 2011 the Scripps Insitution of Oceanography in collaboration with Earth Neworks announced plans to set up a network of one-hundred carbon dioxide monitoring stations across the continental U.S (Scripps, 2011). In another example, the National Institute of Standards and Technology in collaboration with the Pennsylvania State and Purdue Universities is establishing a network of a dozen greenhouse gas monitoring sites around the city of Indianapolis, Indiana U.S.A. to better understand transport of these gases around a metropoliatan area (Rella et al., 2012). It should be noted that these networks are, essentially, large scale experiments aimed at determining whether this technology coupled with sophisticated modeling can provide relevant information about movement of carbon dioxide through a large area.

Parallel to a growing scientific interest in monitoring greenhouse gas emissions and understanding their transport characteristics, emission data are gathered and reported by, for instance, the EPA (2013) and all twenty-seven member states in the European Union as part of the emission trading system (EC, 2013). If extensive regulation of greenhouse gas emissions were to be implemented, the demand for accurate and precise carbon dioxide sensors could be significant—many tens of thousands units would be needed in the U.S. alone. Absent such regulation, demand for such technology will exist, albeit at significantly lower levels, driven primarily by the climate science community. In summary, considerable uncertainty exists.

2.2. Technology background

Two existing technologies are capable of making carbon dioxide flux measurements at the targeted levels of quantification (1×10^{-7} parts of an atmosphere). Nondispersive infrared (NDIR) sensors are comparatively cheap ($6k), but are unstable and thus require frequent calibrations (as often as every 4 h) with expensive standards ($10k of consumables per year per sensor) (Zhao et al., 1997). Cavity ring-down spectrometers (CRDS) are an alternative (Crosson, 2008), but these instruments are expensive ($50–$100k), fragile, and still require calibration—though much less frequently (once or twice a year, $2k of consumable per year). The expert intervention required to perform calibrations on either instrument is a further expense that impedes deployment of greenhouse gas monitoring networks. Interestingly, however, the ten-year cost of ownership is approximately the same for both sensors (cf. Table 1). To be competitive, an alternative technology must have either lower base cost or lower maintenance costs.

Considerable effort has been invested in research directed at developing new sensors for monitoring greenhouse gases, including a technique referred to as photoacoustic sensing. The photoacoustic

Table 1
Ten year cost of ownership (k$).

	Year									
NDIR	0	1	2	3	4	5	6	7	8	9
Instrument costs	6.0									
Calibration gas	9.0	9.5	9.9	10.4	10.9	11.5	12.1	12.7	13.3	14.0
Ten-year cost	96.0									
CRDS										
Instrument costs	75.0									
Calibration gas	9.0					11.5				
Ten-year cost	93.0									

Please cite this article as: van Zee, R.D., Spinler, S., Real option valuation of public sector R&D investments with a down-and-out barrier option. Technovation (2013), http://dx.doi.org/10.1016/j.technovation.2013.06.005