Available online at www.sciencedirect.com
ScienceDirect
European Journal of Operational Research 177 (2007) 1105–1112
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

Stochastics and Statistics

Optimal decision indices for R&D project evaluation in the pharmaceutical industry: Pearson index versus Gittins index

Michael A. Talias

School of Humanities and Social Sciences, International University Bremen, P.O. Box 750561, 28725 Bremen, Germany

Received 11 February 2004; accepted 8 January 2006
Available online 10 March 2006

Abstract

This paper examines issues related to various decision-based analytic approaches to sequential choice of projects, with special motivation from and application in the pharmaceutical industry. In particular, the Pearson index and Gittins index are considered as key strategic decision-making tools for the selection of R&D projects. It presents a proof of optimality of the Pearson index based on the Neyman–Pearson lemma. Emphasis is also given to how a project manager may differentiate between the two indices based on concepts from statistical decision theory. This work demonstrates and justifies the correct use of the Pearson index.

Keywords: Gittins index; Pearson index; Project prioritization; Research and development in pharmaceutical industry; Statistical decision theory

1. Introduction

This paper addresses the problem of evaluating research and development (R&D) projects in the pharmaceutical industry by using appropriate indices for determining priorities between potential R&D drugs within the Bayesian decision framework.

An R&D process is divided into a number of distinct phases that must be implemented sequentially (in a fixed order) and all succeed before a drug is marketed to yield any financial benefits. The phases and sequence of a research project's stages are explained by Gittins (1996, 1997). Typically, a project is characterized by the exploratory research stage in pharmaceutical laboratory, which is followed by the development and the marketing stages. There are several important features of the R&D process: It is considered a very uncertain process, it needs at least 15–30 years from the time the research starts until a drug is marketed, and the initial investment is large. Towards the end of each stage the results from the current stage will become known and a decision should be made regarding the fate of the project.

E-mail address: m.talias@iu-bremen.de

0377-2217/$ - see front matter
doi:10.1016/j.ejor.2006.01.011

A project manager must continually make decisions concerning the treatment of projects. This means that the existing resources should be allocated on the basis of the available information concerning each project. For example, the project manager has to decide which new projects should be funded and which existing projects should be continued or abandoned. However, information is gained at considerable cost and decisions must be made under uncertainty. Thus, a continued corrective action based on new information is at the heart of the successful R&D management. For all these reasons, a statistician may recommend a Bayesian decision approach.

R&D project selection models have a history of more than 50 years. The definition of the problem is not unique and is largely dependent on methods that were fashionable at various times in the past. These range from classical methods, such as profiles, checklists, scoring models, and economic indices, to decision theory or analysis models. Models based on mathematical techniques, such as linear programming, non-linear programming and dynamic programming, were developed in the past. A more recent technique is the application of the real option pricing analysis. A summary of R&D selection methods as applied in the pharmaceutical industry may be found in chapter 4 in Bergman and Gittins (1985).

In this paper, we consider profitability indices which can be viewed as a solution to decision problems related to the valuation of research and development projects. A profitability index is given by Pearson (1972) who suggested that the sequential characteristics of decision analysis must be incorporated into a profitability index as follows: Consider a project with k stages with fixed order. Each stage of the project is denoted by the index j for $j = 1, \ldots, k$, with associated cost c_j, conditional probability of success given success at the previous stages p_j, and final reward R to be gained when the last stage is completed successfully. Assuming that the reward R and costs c_j for all j are discounted figures at some interest rate, then the Pearson index is defined as

$$\frac{\text{Expected net value}}{\text{Expected cost}} = \frac{R\prod_{j=1}^{k} p_j - \sum_{j=1}^{k} c_j \prod_{r=0}^{j-1} p_r}{\sum_{j=1}^{k} c_j \prod_{r=0}^{j-1} p_r}, \tag{1}$$

where $p_0 = 1$.

To set up a portfolio of projects using a profitability index, the index value of a project is calculated on the basis of the available information concerning the project. Projects are then ranked in decreasing order of their index values. The projects to be included in the portfolio must have a greater index value than those projects that may possibly be rejected: Such a criterion may help us to achieve the highest possible income for a given expenditure expressed in terms of the total expected cost.

Pearson defined his index as the ratio of expected net present value of the reward of an R&D project to its expected development cost without making any reference either to the pharmaceutical industry or to the R&D manager's objectives. When the manager's goal is to maximize the net present value of the expected profit stream from any project undertaken, it is not clear why one should try to maximize the ratio of expected reward to the expected cost, and not, for example, to seek maximization of their long-run difference.

The history of this index is not long. Gittins (1996, 1997) reconsidered this index when he developed a stochastic model to investigate how many scientist should be allocated at each successive stage to maximize profitability. Senn (1996, 1997, 1998), too, discussed its merits, the relation of the index with games, and whether some option value is captured by the index. Regan and Senn (1997) accounted for the use of the Pearson index as the main approach in project evaluation in drug development from a pharmaceutical company perspective. Zipfel (2003) discussed how to model the probability-cost-profitability architecture of portfolio management in the pharmaceutical industry using the Pearson index.

The objectives of this paper are twofold: first, to develop a way of looking at the Pearson index as an optimal decision rule in the project selection process, and second, to compare the Pearson index with Gittins' index (Gittins, 1979) as a means of evaluating R&D projects to indicate how the two selection methods differ.

The paper is organized as follows: In Section 2 notation is given and the problems of parallel and sequential selection are defined. Parallel selection is approached in Section 3. Optimality of the Pearson index is justified using the Neyman–Pearson lemma in Section 4. Section 5 deals with the applications of sequential analysis in project prioritization. The multi-armed bandit problem is introduced and the Gittins index is studied. Concluding remarks are discussed in Section 6.