ELSEVIER

Int. J. Production Economics 74 (2001) 213–224

international journal of
production
economics

www.elsevier.com/locate/dsw

Manufacturing flexibility and real options: A review☆

Jens Bengtsson*

Department of Production Economics, IMIE, Linköping Institute of Technology, S-581 83, Linköping, Sweden

Abstract

This paper considers manufacturing flexibility and real options from an industrial engineering/production management perspective. Real options papers are related to different types of manufacturing flexibility in order to show which types that are considered and in what way they are considered. Flexibility types not valued with real options and real options without any corresponding manufacturing flexibility type are identified and discussed.

Keywords: Real options; Manufacturing flexibility; Capital budgeting; Production management

1. Introduction

What is flexibility worth to a company? Many managers in the manufacturing industry ask this question, since the investment cost in flexible manufacturing equipment mostly exceeds the investment cost of dedicated equipment. A flexible system gives numerous options to management and these could for example be constituted by the ability to increase or decrease capacity, switch between products and switch between input material. Hence, flexibility gives the management some degrees of freedom to take advantage of outcomes better than expected and simultaneously provide an ability to reduce losses. Such options must of course have a value to companies.

Traditionally, in capital budgeting, expected future cash flows have been discounted with a risk-adjusted discount rate. The risk-adjusted rate has for example been estimated with Sharpe-Lintner-Mossin's Capital Asset Pricing Model (CAPM) to handle the effects of the systematic risk in an appropriate way. Other models can also be used to estimate a discount rate but these have the same shortcoming as the CAPM, in that they can not value projects containing flexibility. Thus, other methods have to be used to find the appropriate value of flexibility and one of these is to use option pricing theory. Some big advantages of using option pricing theory are that the complex risk structure of a flexible project is handled more appropriate than in the traditional method mentioned above and that the problem of estimating a risk-adjusted rate is avoided in the most cases. It also gives the possibility to model so-called American options, i.e. options that can be exercised at any point in time during the lifetime of the option, and has thereby another advantage over the traditional method.

☆The research is supported by grants from the Swedish Foundation for Strategic Research and Swedish National Board for Industrial and Technical Development.

* Corresponding author. Tel.: +46-13281538; fax: +46-13288975.

E-mail address: jens.bengtsson@ipe.liu.se (J. Bengtsson).

0925-5273/01/$ - see front matter
PII: S0925-5273(01)00128-1

Since Black and Scholes [1] and Merton [2] presented their work on option pricing theory a lot of application areas, e.g. valuing complex financial securities and valuing companies, have been found. Capital budgeting is another area where option pricing theory has become more and more used, at least by academics. Many authors, see e.g. Trigeorgis [3], have used this theory to deal with features and problems associated with valuation of projects containing flexibility which have resulted in a number of papers concerning valuation of so-called real options.

This paper will review some of the literature on option pricing theory applied on valuation of manufacturing flexibility, or real options in manufacturing. The paper will relate the real options literature to manufacturing flexibility from an industrial engineering/production management (IE/PM) perspective. As a point of departure from the IE/PM perspective, Sethi and Sethi's [4] survey on manufacturing flexibility is used. Sethi and Sethi proceed from Brown et al. [5] but a number of flexibility types are added and the view of Sethi and Sethi occasionally deviates from that of Browne et al. Gupta and Goyal [6] claim that the definitions of flexibility in Browne et al. are the most comprehensive and use their framework in a survey to classify the literature on manufacturing flexibility. Olhager and West [7] refer to Sethi and Sethi as a literature review on manufacturing flexibility, which covers and systematise the flexibility types linked to flexible manufacturing systems. Hence, the Sethi and Sethi framework based on Browne et al. should be appropriate as a point of departure for a review on and classification of manufacturing flexibility and real options.

Using the definitions of Sethi and Sethi, we will consider the value of flexibility

- at the basic level, i.e. flexibility of the machine level,
- at the system level, i.e. the flexibility of a production system,
- at the aggregate level, i.e. the flexibility of a whole manufacturing plant.

Sethi and Sethi define a number of flexibility types at each level and these will be used in this paper. Some of the definitions are quite wide and can therefore be interpreted in somewhat different ways.

This paper will be structured in the following way. First, a short introduction to option pricing and real options is given. Second, we look at the different levels of flexibility using the Sethi and Sethi framework. Here, we also map the different kinds of flexibility treated in the real option literature to the different types of flexibility as Sethi and Sethi define them. This analysis will highlight the following:

(i) The types of flexibility that are treated in the real option literature can be distinguished and clarified.
(ii) The flexibility types that have not been treated as real options are identified, and can be subject to further research.
(iii) The applications of real options may indicate that there are other flexibility types relevant to manufacturing that have not yet been identified by the literature on manufacturing flexibility.

This may also be illustrated as in Fig. 1 where the section of the two sets represents the set of real options literature, which can be mapped to flexibility types defined by Sethi and Sethi. The other two sets represent the literature, which cannot be mapped to each other. The literature will be reviewed from an application point of view. Thus, the underlying assumptions and how these affect the solution and impose limitations on the result will be analysed.

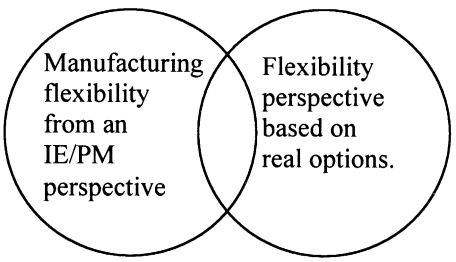

Fig. 1. Sets representing different types of flexibility related literature.