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How to improve a technology evaluation model: A data-driven approach

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ABSTRACT

Academic research suggests a number of technology evaluation models. To ensure effective use, models need to be improved in accordance with changing internal and external environments. However, a majority of previous studies focus on model development, while a few emphasize their implementation or improvement. To fill this research gap, this study suggests a systematic approach to examining the validity of technology evaluation models and improving them. We consider three propositions as criteria for improvement: 1) the coherence of the evaluation results with the evaluation purpose, 2) the appropriateness of the evaluation methods, and 3) the concreteness of the evaluation model. Rather than using expert opinions, this study takes a data-driven approach, wherein we analyze actual evaluation results and determine whether the model produces the intended results. A case study of 291 technology evaluation results, all made by the South Korean government in support of technology-based small and medium-sized enterprises, is conducted to verify the suggested approach's applicability. This is one of the few studies to address issues regarding improvements to a technology evaluation model. Its approach can help to develop and continuously improve a valid technology evaluation model, thus leading to more effective practice.

1. Introduction

Technology evaluation has long received considerable attention, in both industry and academia (Cho and Lee, 2013; Hsu et al., 2015; Kim et al., 2011; Perkmann et al., 2011); accordingly, to date, a number of technology evaluation models have been suggested and are currently in use. Existing efforts towards the use of a technology evaluation model can be divided largely into two categories, namely, model development and implementation. *Development* relates to activities for deciding "what and how" to evaluate technologies, in order to achieve the evaluation purpose in a given context (*ex-ante* efforts). Meanwhile, ***implementation*** refers to the application of the model developed in practice, and it includes activities for investigating the evaluation process and results, in an attempt to improve the model (*ex-post* efforts). The development category is foremost, since without a valid model, any remaining work may not be meaningful. Quite naturally, mainstream research in South Korea, the United States, and Europe has also focused on this first category of activities (Lee et al., 1996). However, once a valid model has been developed, it needs to be implemented with the necessary commitment of resources and a customized application to a real context. The same evaluation model can produce different performance results, depending on differences in resource commitments (Bremser and Barsky, 2004) and project profiles (Loch and Tapper, 2002). Thus, if an evaluation model is to be used effectively, continuous efforts need to be made, so that the model may be implemented and further improved.

Regarding development and implementation, Kaplan and Norton (1996, p. 99), who developed a balanced scorecard as a strategic management tool concerning measures to achieve strategic goals, highlight the continuous adaptation of strategy, arguing that "measurement has consequences far beyond reporting on the past. Measurement creates focus for the future." This implies that implementation, in particular continuous improvement, also requires careful analysis and consideration. Implementing a technology evaluation model can be a management challenge, producing unexpected results, even when the model was reasonably developed on a basis of scientific literature and data. In practice, unexpected barriers (e.g., objection to model use, or a lack of experts involved in the evaluation process) may be encountered in a model's actual application, which can in turn hinder the reception of anticipated results. Sometimes, when developing the model, incorrect cause-and-effect relationships can be hypothesized (e.g., evaluation criteria irrelevant to the construct of interest). Internal or external environments may also change, and this can affect the model's validity (e.g., changes in corporate innovation policy, or in government policy and funding programs). Hence, the validity of the model needs to be tested, and on the basis of that validity, its

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improvement strategy needs to be developed.

These problems are observed not only in the technology evaluation context, but also in other contexts such as decision support systems and knowledge management. Borenstein (1998) insists that little attention has been given to validate decision support systems that have been developed and put into practice. More recently, Park et al. (2010) argue that a majority of the studies, in a knowledge management context, tend to concentrate on evaluation model development, but that insufficient efforts have been made to improve the evaluation models. The current study recognizes this research gap and aims to develop an approach by which to improve technology evaluation models, while focusing especially on models that look to predict future impacts (i.e., outcomes). Of course, improvement strategies can target various elements such as people (evaluator) and processes (evaluation procedure), while this study emphasizes the significance of tools (evaluation model).

The effectiveness of this particular tool—an evaluation model—depends on its ability to discriminate high-performance technologies from low-performance ones. The validity of the model can be tested by comparing predicted performance to actual performance. In any case, it is not easy to measure R & D performance, on account of unobservable effort levels, uncertain project success, and time lags between investment and performance (Loch and Tapper, 2002). Thus, comparison analysis between predicted and actual performance can cover only limited aspects of model validity. Therefore, in this study, we reviewed the literature on validity theory, based on three propositions that we consider valuable guidelines in improving model validity: 1) the *coherence* of the evaluation results with the evaluation purpose, 2) the *appropriateness* of the evaluation methods, and 3) the *concreteness* of the evaluation model (mutually exclusive and collectively exhaustive (MECE) nature of indicators as evaluation criteria). In particular, we suggest a data-driven approach, where evaluation results are used to determine model validity; this allows the data to directly express the characteristics of the model, and thus the current approach can complement an expert-based approach in advancing the model.

To verify the applicability of the propositions, we adopted a technology evaluation model that has been used since 2002 by a South Korean government agency. The agency is one of the most representative institutes in charge of supporting South Korean small and medium-sized enterprises (SMEs). SMEs with great potential to successfully commercialize their technologies in the future have been identified and then involved in the national-level SME development program by the agency. For this purpose, the agency has used the model to assess the potential of the technology a firm possesses. Although the agency recognized the significance of ex-post activities in model implementation, it has focused mainly on program implementation and maintenance. The model has evolved through several stages, but has been based mainly on experts' insights, even as the necessity of employing more systematic approaches that use evaluation results was raised within the agency. Therefore, the agency was selected as a case study, and its technology evaluation data—which were gathered during the 2008–2013 period—were provided as a major analytical source. Theoretically, the current study is one of the few to address how to improve a technology evaluation model that has already been developed and is being implemented. The approach also can be practically helpful by improving the validity of both the development and use of a technology evaluation model.

The remainder of this paper is structured as follows. Section 2 describes various types of technology evaluation models and the requirements for building a valid evaluation model. Section 3 then suggests three propositions to test model validity and introduces suitable statistical methods for the test. The study's results are addressed in Section 4, and discussions are presented in Section 5. Finally, contributions and limitations are discussed in Section 6.

2. Literature review

2.1. Technology evaluation models

Since the early 1960s, technology assessment has received consistent attention from both academia and industry (Azzone and Manzini, 2008; Linstone, 2011). Technology is defined as "… the practical application of knowledge to achieve particular tasks that employs both technical artefacts (hardware, equipment) and (social) information (software, know-how for production and use of artefacts)" (IPCC, 2007). As the nature of technology depends on the tasks to be achieved, technology is diverse in its application, and technological innovation can also be observed in different ways (OECD, 2005). This indicates that technology evaluation can be conducted in various ways, according to the purpose of a given evaluation. This study uses the term "technology evaluation" in a broad sense, so as to include the evaluation, assessment, and measurement of technology or R & D-related factors. Diverse types of technology evaluation, in this context, need to be reviewed to achieve the aim of this study—namely, the development of a framework by which to improve technology evaluation models. We adopt two basic elements to recap the existing approaches to technology evaluation: 1) what to evaluate, and 2) how to evaluate. These can be considered the core of an evaluation model.

First, "what to evaluate" relates to an evaluation target. Different technology evaluation purposes require different perspectives with respect to technology. Specifically, as technology has long served as a springboard or a source of innovation (Danneels, 2004; Kang and Park, 2012), key technology evaluation areas include not only technological features, but also technology-based organizational capabilities and technological impacts on markets, since all these factors work together to determine the value of a technology. According to Roure and Keeley (1990), three perspectives—namely, management, environment, and the firm—have been suggested in evaluating the technologies in a venture. The management perspective relates to organizational or individual capabilities that make a firm's technology or R & D-related activities effective and efficient. This perspective has been a particular focus of recent studies that look to assess organizational technology capabilities (e.g., Cheng and Lin, 2012; Kim et al., 2011; Mohammadi et al., 2017; Sobanke et al., 2014; Van Wyk, 2010). The environment perspective is used to predict the successful diffusion of these capabilities in a market and the benefits that can be expected from corresponding R & D investments. Therefore, a number of researchers have incorporated this perspective into their technology evaluation models (e.g., Abbassi et al., 2014; Jolly, 2012; Santiago et al., 2015). Finally, the firm perspective deals with the advantages of technology itself, as a resource, and as a corporate strategic choice with respect to technologies (e.g., Chiu and Chen, 2007; Kim et al., 2011; Rocha et al., 2014; Shen et al., 2010). Here, it should be noted that although the three perspectives are valuable in capturing the value of technology, they need not always be considered simultaneously when evaluating a technology; the choice of perspective in evaluating a technology should instead depend upon the evaluation purposes at hand.

Second, "how to evaluate" is linked to evaluation methods, which can in turn be largely classified as qualitative, quantitative, or a combination thereof. Technology assessments, in spite of their well-known limitations in terms of reliability and validity (Yin, 2013), have been conducted in a qualitative manner, given the ease of capturing through this method all the softer aspects of technology-related factors (Azzone and Manzini, 2008; Facey et al., 2010). Qualitative methods include interviews with experts, or a focus group study. On the contrary, quantitative approaches offer hard data and provide numerical clarification. Such inherent advantages make them attractive for use in technology evaluation (Daim et al., 2009; Kalbar et al., 2012; Wang et al., 2015). Quantitative data, or a set of quantified soft data, have been generally applied to the purely quantitative approach in this case, because doing so can facilitate a more realistic evaluation process