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Options in technology investment games: The real world TFT-LCD industry case

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ABSTRACT

The Thin Film Transistor-Liquid Crystal Display (TFT-LCD) industry has demonstrated that the investment of huge amounts of capital in new plants is a key factor for success. Decisions about investing in the latest generation of plant involve billions of dollars and a great deal of uncertainty. Moreover, the industry shows distinct oligopolistic characteristics, so the first mover's reactions must be considered when making capital decisions in such competitive environments. The traditional net present value (NPV) rule is a 'now-or-never' concept that fails to capture the need for managerial flexibility, which is especially important when investments are irreversible and involve a great deal of uncertainty. In this paper, we use a combination of real options and game theory to analyze the investment strategies of a case company in the TFT-LCD industry. The results show that real options reveal the value of flexibility, which NPV fails to consider. In addition, we apply game theory analysis to different investment strategies to demonstrate the decision-making processes used by competing companies.

1. Introduction

In the uncertain and fiercely competitive high-tech industry, some of the most important decisions relate to investments in capital intensive equipment [1]. The TFT-LCD (Thin Film Transistor Liquid Crystal Display) industry in particular is characterized by intense technological and market competition [2–5]. Companies must make huge capital investments with a corresponding high degree of risk to expand their manufacturing capacity, because falling behind competitors means dropping out of the game. Hence, as the size of LCD panels increases, a major inflow of capital for investment is needed; for example, it costs more than US$1 billion to build a fifth-generation TFT-LCD plant [6]. Rapid responses to competition and improvements in yield stability are critical to success in this industry. This rush to get the latest-generation production facilities in the TFT-LCD industry is akin to an arms race, and therefore, continuing capital investment is critical to the continued success of firms [6,7].

A disadvantage of these huge investments and hyper competition in production is the likelihood of resulting price wars. The traditional Net Present Value (NPV) rule is a static concept that fails to capture the need for managerial flexibility, which is especially important when investments are irreversible and involve a great deal of uncertainty. Moreover, the competition that characterizes the TFT-LCD industry requires a more comprehensive analysis of players' market strategies.

Among academics and practitioners, technology investment decisions constitute an important topic. Our own survey of the literature on technology investment decisions reveals two common trends. First, few studies use a combination of options theory

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and game theory to analyze uncertainty and competition. Second, to date, few studies have considered real-world cases to improve our knowledge of real-world applications.

In response to these gaps within the existing literature, this paper employs the options game evaluation framework developed by Smit and Trigeorgis [8] to study a company in the TFT-LCD industry in 2004, the AU Optronics Corporation. The dilemma for AUO was whether to invest in fifth-generation or sixth-generation facilities. The study demonstrates the dynamic decision making process for investments in the TFT-LCD industry under conditions of uncertainty and intense competition.

The research process is comprised of four stages. First, we calculate the value of projects with the traditional NPV rule. Second, we calculate the value of projects with the real options method. Third, we use game theory to analyze different scenarios and explain the calculated values. Finally, we provide a comprehensive analysis of the dynamic decision making process under uncertainty and competition.

The remainder of this paper is organized as follows. The next section contains a review of related works. In Section 3, we describe the background of the case company. In Section 4, we provide a comprehensive analysis of the case. Then, in Section 5, we summarize our conclusions, discuss the implications of our findings, and consider avenues for future research.

2. Previous work

Investment decisions are usually analyzed in terms of the net present value (NPV) rule [9–11]. The NPV of an investment is calculated from the discounted cash flow of its future earnings, which are known at the time of the calculation. A negative NPV suggests that the costs of a project outweigh its benefits, and management should therefore terminate it. In contrast, a positive NPV indicates that the benefits outweigh the costs. Despite its simplicity, the NPV rule has a number of shortcomings, which are well documented within existing research. For example, the rule assumes that investments are reversible, and non-deferrable; however, in the real world, technology investments are irreversible, deferrable, and undertaken in conditions of uncertainty [63–65]. The rule also ignores the strategic value embedded in technology investments [12]. Moreover, in highly uncertain environments, flexibility cannot be properly quantified. NPV works when future volatility is trivial. There is also a problem with discounting in NPV, which is not risk-adjusted. For example, Linstone [13] notes that when discounting in the case of planning, this method fails for any situation where the measurement values are compounded over time; thus it does make a difference whether money spent or earned in a given year affects performance in later years.

Technology investments have unique characteristics, and NPV analysis does not capture the complete picture for several reasons. First, investing in technology is a high-risk process that requires significant capital investment, and uncertainty plays a key role in decision-making. Moreover, the most serious problem in applying the NPV rule to technology investment is the implicit static worldview of the NPV metric; it denies the benefits that could accrue from active management involvement in technology investment [14–17]. Pinpoint 'now-or-never' decision-making based on the NPV rule can result in huge costs in terms of lost opportunities because, once the course of an implementation process veers from the original plan, management has no way to respond appropriately to the resulting uncertainties.

In contrast to NPV, options theory [66–68] is based on the premise that the option holder has the right, but not the obligation, to exercise an option. Myers [67] was the first to suggest that option-pricing theory could be applied to real assets and non-financial investments. As real options are derived from financial options, the initial phase of an investment project is implicitly equivalent to buying an option. Myers observed that investment opportunities, such as growth options, can capture a project's real value and provide a better way to deal with uncertainties than NPV. Fundamentally, options theory (OT) offers a new and more realistic means of evaluating strategic opportunities and risks that traditional valuation methods, such as the NPV approach, do not consider. Myers (1974), Kester [18], and Dixit [19] suggested using option-based techniques to value the managerial flexibility implicit in investment opportunities. They stressed the importance of the irreversibility of most investment decisions, and the ongoing uncertainty about the environment in which those decisions are made. Kulatilaka et al. [20] also considered the strategic value of managerial flexibility and its option-like properties, while Trigeorgis [21] used OT to deal with the features of, and the problems associated with, the valuation of projects.

Many studies have stressed the importance of capturing the essence of managerial flexibility when uncertainty and irreversibility are high, and have thus investigated the applicability of options theory to technology investments. For example, Dos Santos [22] and Kumar [23] suggested that the theory could be applied to information technology investments to hedge project risks. Some researchers have employed specific OT formulas to guide information technology investments. For example, Benaroch and Kauffman [24,25] used the Black and Scholes [61] option pricing formula to evaluate the value of deferring investments related to the expansion of electronic banking networks; and Taudes [26] applied the Margrabe [27] formula to assess the growth opportunities of a software platform implementation.

More recently, Kumar [28] used the switching options approach to evaluate the benefits that accrue if a company adopts a computer-aided software engineering tool to accelerate the development of a software project. The study stressed that the value of managerial flexibility should be included in the value of technology investments. Fichman [29] used options to value IT platform options and manage IT platform implementation and risks. Benaroch [30] and Benaroch et al. [31] explored multiple options in Internet sales channel investments. Kauffman and Li [32] considered the investment timing strategy for a firm that must decide between two incompatible and competing technologies in light of expectations associated with future technology competition. Toshimori and Kobayashi [33] developed a real options model to determine the optimal timing strategy for project evaluation and implementation. D'Halluin et al. [34] studied the investment decision timing of adding new capacity to a wireless network. Bardhan et al. [35] developed a nested options model to examine a large U.S.-based energy firm that was considering an