Economics of basic research

Optimal Allocation of R&D Funds using the Real Options Approach - G.Rothwell

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How does the R&D manager maximize the probability of developing a commercially successful technology by a specific future date? One of the problems facing all R&D managers, whether for a single firm, a consortium, or a national program, is to determine the optimal number of technologies to support at each stage of research, development, demonstration, and deployment on the road to commercialization. Here, we propose applying the "Real Options" literature to answer the question of how long the R&D manager should (from a net present value optimization viewpoint) maintain development options on N different technologies when (1) there is a limited R&D budget, (2) the probability of eventual commercial success is correlated across technologies, and (3) there are dynamic, increasing returns to each technology, i.e., cost declines as a function of experience with a technology.

For example, consider the development of advanced energy or transportation technologies. Given budget constraints, R&D managers cannot fund the construction of prototypes for each of the candidate technologies, how many should be funded? Of course, selecting only one technology would reduce expenditures, but should the chosen technology prove uneconomic for commercial deployment, the goal of developing a commercially successful technology by a specific date might not be realized. On the other hand, choosing all possible technologies in the manager's portfolio for prototyping would increase the probability of successful deployment, but might exhaust the budget required for the construction of the first-of-a-kind commercial unit. Therefore, how long should the manager maintain development options on each technology?

During the last decade, literature has applied pioneering work on options theory (Black-Scholes) to real assets; see, for example, Dixit and Pindyck (1994). This approach was extended to the evaluation of R&D projects; see Faulkner (1996), Childs and Triantis (1999), Huchzermeier and Loch (2001), and Schwartz (2004). Recently, the real options approach has been applied to the value of public investments in renewable energy; see Davis and Owens (2003), Kumbaroglu, Madlener, and Demirel (2004), and Siddiqui, Marnay, and Wiser (2005).

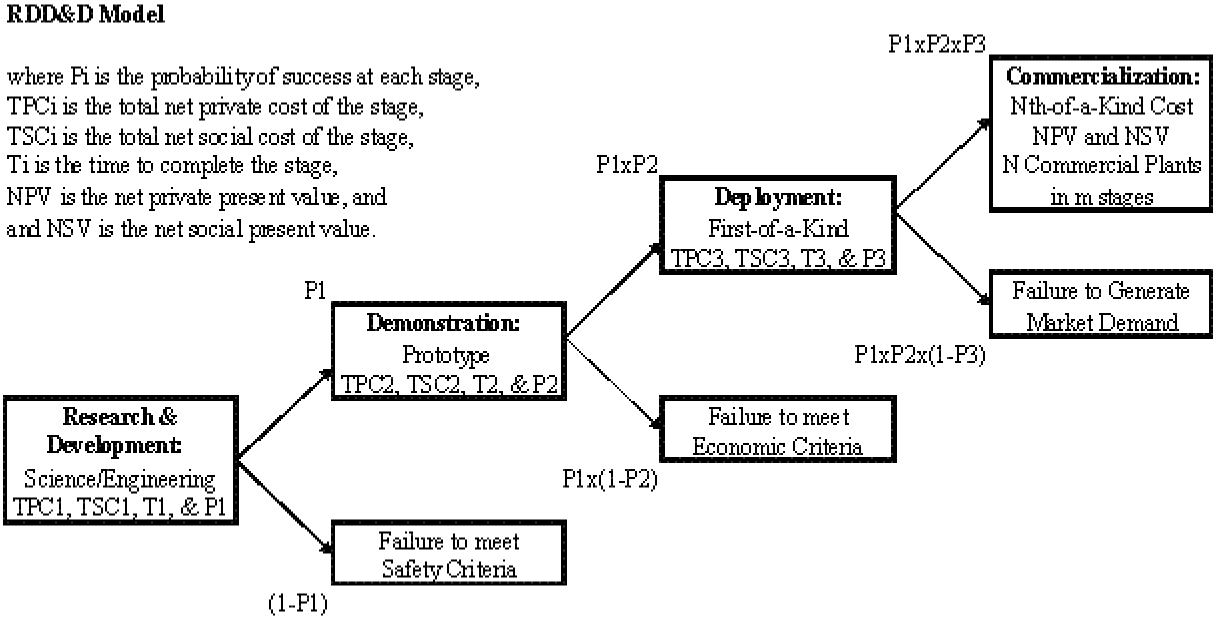
The real options literature points out that an investor can either begin a project or wait, and that waiting has value, e.g., waiting until market information becomes available. The real options literature provides a means for determining when the investor should optimally exercise the option of beginning a project (or ending one once the project has begun). For example, Rothwell (2004) calculates, as a function of price, cost, and output risks, when electricity generators should build new nuclear power plants (conclusion: when the price of construction drops to about $1200/kWe). The application of real options to nuclear power is also explored in Kiriyama and Suzuki (2004).

Figure 1 outlines the stages of a technology development program. Each stage (for each technology option) is characterized by a cost, a time to completion, and a probability of successful completion. The probability of completion could be correlated across technology options, i.e., research results for one technology could increase the probability of development of another option or the probability of commercial success for one option could decrease the probability of success of another option. Our research will parametrically characterize the net private cost, the net social cost, time, and probability of completion for N technology options and solve the problem of how many options should be funded at each stage given a limited budget. (A similar problem for 2 technologies is examined in Childs, Ott, and Triantis,1998).

The total net private present value (NPV) will be determined from the application of traditional discounted cash flow criteria. The net social present value (NSV) will be determined through the application of the sustainability criteria as described in Rothwell and van der Zwaan (2003), e.g., the prototype is built only if it can be shown that the technology is safe. These criteria are **(1) Non-Renewable Resource Depletion:** Does the energy system rely on fuels or materials that could be depleted within the foreseeable future at projected rates of consumption? **(2) Environmental Externalities:** Do emissions from the energy system accumulate faster than the absorption capacity of the environment? **(3) Social Externalities:** Does the energy system impose externalities on populations (current or future) that do not benefit from it? **(4) Economics:** Can the energy system maintain its capital stock?

Of course, the optimal allocation of R&DDD funding is easier to solve when applied to a real problem. We will begin by applying our model to nuclear fission and fusion technologies. Regarding fission technology development, during the last few years, the Generation IV nuclear power technology development project has taken shape. See U.S. DOE and GIF (2003). (The Generation IV International Forum includes Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, Switzerland, the United Kingdom, and the United States.) After extensive evaluation, six technologies were selected for research and development. As a member of the Generation IV Evaluation Methodology Group, technical director of the GenIV Economics Crosscut Group, and a current participant in the GIF Economic Modeling Working Group, Geoffrey Rothwell has access to the R&D plans for each of the technologies selected. We will apply our model to a portfolio of six technologies and attempt to determine an optimal R&D allocation given assumed probabilities of completion of each stage of technology development. (Alternatively, this model could be calibrated by applying it to earlier international models of nuclear power development, e.g., the "Atoms for Peace" program begun in 1953; see AEC-DOJ (1968) for a description of the U.S. R&D program for nuclear power development).

Figure 1: the RDD&D model



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