Evaluation and Program Planning 31 (2008) 284–298

Contents lists available at ScienceDirect

Evaluation and Program Planning

journal homepage: www.elsevier.com/locate/evalprogplan

# Data and the measurement of R&D program impacts

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ARTICLE INFO

*Article history:*
Received 24 May 2007
Received in revised form
7 February 2008
Accepted 30 March 2008

*Keywords:*
Government R&D programs
Innovation
Economic impact

ABSTRACT

The purpose of this paper is to propose a research agenda for the measurement of economic impacts of Canadian government R&D support programs. Different methodologies and indicators used to assess benefits from government support programs/agencies for R&D are discussed first. Using available information on major business-related R&D federal programs, the paper will assess which indicators and methodologies can be implemented. The specific programs/agencies under investigation include: Technology Partnerships Canada sponsored by Industry Canada, Industrial Research Assistance Program sponsored by National Research Council, Atlantic Innovation Fund sponsored by Atlantic Canada Opportunities Agency, Canadian Space Agency and National Defence.



## 1. Introduction

There have been a number of recent papers in this journal that investigated the effects of government R&D programs on innovation and economic growth (Feller, Ailes, & Roessner, 2002; Kostoff, 1995; Luukkonen, 1995; Martin, 1998). While there appears to be general consensus as to what sorts of evaluations are theoretically possible, there is little agreement on what is possible practically. The current Conservative federal government in Canada is interested in value for money in terms of their expenditures on R&D programs. This paper represents an early stage investigation to help inform the government of what is possible. The problem of measurement, however, is a difficult one. From my experience with Canadian program evaluation the main problem is a lack of data on outputs from R&D programs. The aims of this paper are to reiterate the reasons for government R&D support programs, to summarize five existing Canadian programs, and to propose a method for analyzing the socio-economic impact of these programs.[2]

Technology policy stems from the neoclassical belief that because of knowledge and technical spillovers there will be a market failure in the research and development conducted by private firms. The government's answer to this dilemma is technology policy. What is Canadian technology policy? It can be viewed as a set of institutions designed to increase the rate of technological change. Increasing technological change occurs when the rate of product and process innovations increases, when the rate of adoption/diffusion of new technology increases or some combination of the two. The federal government is quite dedicated to "innovation" as is evidenced by their presence on the Internet at (www.innovation.gc.ca). In 2005/2006 the federal government's expenditure on science and technology (S&T) is expected to be $9.1 billion. Approximately $5.8 billion of that will be on research and development (R&D) and the remainder on associated activities. The federal government is directly responsible for conducting approximately $2.1 billion worth of R&D; the remaining $3.7 billion worth of research is conducted in private firms, universities and non-governmental labs (Statistics Canada, 2005).

The structure of the paper is as follows: Section 2 gives a short introduction as to why governments intervene in the markets for research and development and innovation; Section 3 discusses the nature of five Canadian government programs; Section 4 details the current data situation for each program. Since the situation is not optimal for the measurement and evaluation of the programs, Section 5 asks "Where to Go From Here?". Finally, Section 6 concludes the paper.

## 2. Rationale for government intervention in research and development

This section is a brief summary of the economic rationale for government intervention in the market for research and development. In an influential paper Schmookler (1959) argued that private firms engage in too little research and development from

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[1] The views expressed in this paper are solely those of the author and do not represent the views of the Government of Canada and/or Industry Canada.

[2] An earlier version of this paper was completed under contract to Industry Canada in 2006. Industry Canada provided direction as to what programs were to be included in the analysis.

0149-7189/$ - see front matter 
doi:10.1016/j.evalprogplan.2008.03.004

**Table 1**
Characteristics of R&D/Innovation

| Characteristic | Explanation | Example |
| --- | --- | --- |
| Uncertainty | Innovation involves the generation of new ideas, and the development of new markets. The probability of a "success" is therefore low. | When Xerox first invented the photocopier, it did not sell well. The market did not understand its novel uses. |
| Path-dependency | Technology evolves according to specific paths; the choice of one path may block or delay access to another; this constitutes a risk to the innovator. | MS Windows dominates the desktop operating systems market (over Mac OS and Linux) because it gained an early lead and was able to exploit it. It would be very difficult for another operating system to displace Windows. |
| Cumulativeness | There is a cumulative property to learning in general. This characteristic is related to absorptive capacity. | Computer programming has advanced because new programming languages build on their predecessors. |
| Irreversibility | The choice of one technological path often precludes the later choice of alternate paths. This constitutes a risk to the innovator. | VHS vs. Betamax, steam vs. diesel power. An open vs. a closed standard such as Linux vs. Windows |
| Technological inter-relatedness | Technology is often embedded in systems, with one type of technology dependent on another. This characteristic is related to absorptive capacity. | Computer networks constitute a complex relationship between hardware and software components which must be compatible with one another. |
| Tacitness | Knowledge is difficult to express clearly and thus, hard to transfer. This characteristic is related to absorptive capacity. | Consulting methodology is hard to codify. Because this knowledge is so tacit, it is expensive and difficult to replicate. |
| Inappropriability | Environmental factors affect the innovator's ability to capture the profits from the innovation. This constitutes a risk to the innovator. | Pharmaceutical firms can appropriate the returns from drug innovations because patents are effective. Most industries do not obtain the same protection from patents as their products are not as well defined (i.e. by a chemical formula). |

*Source*: Adapted from Teece (1996) and Cohen and Levinthal (1990).

a socially optimal standpoint. His arguments for government intervention included—high costs, prospective returns are too distant and uncertain and that appropriability is weak (Nelson, 1959). Firms will under-invest in research in a competitive economy because the returns cannot be fully captured (due to spillovers). Economic theory predicts that spillovers will distort firms' investment behaviour and thus R&D investment will be suboptimal (Dixit and Stiglitz, 1977; Hall, 1986; Stoneman, 1987).

Yet, the spillover of information is just one facet of the R&D/innovation process. Teece (1996) listed the following additional characteristics in addition to spillovers (inappropriablility): uncertainty, path dependency, cumulativeness, irreversibilities, technological inter-relatedness, tacitness. By its very definition, innovation is uncertain, since it involves the generation of new ideas, and the development of new markets. The three types of uncertainty related to innovation are 'primary', due to randomness; 'secondary', due to communication; 'behavioural', due to opportunism. Primary uncertainty is due to nature and so is not controllable. Secondary uncertainty can be controlled through organizational form. Behavioural uncertainty cannot be controlled per se, but can be mitigated when the proper incentives for management and legal restrictions for competitors are put in place; Path dependency relates to technological trajectories, meaning that technology evolves according to where it has been (the cumulative nature of innovation is tied to the cumulative property of learning in general). Choosing one technology may block or delay access to alternate paths. Furthermore, when a path is taken it generates its own inertia causing 'lock-in effects'. This leads to irreversibility since the choice of one path often precludes the later choice of alternate paths.

Technological inter-relatedness refers to the fact that technology is often involved in systems, with one type of technology often dependent on another. For instance, an 'autonomous innovation' fits into existing systems—a faster microprocessor using the same Intel x86 architecture. On the other hand, a 'systemic innovation' requires that the whole system changes—the replacement of portable CD players with portable mp3 players. Complementary assets are another example of how technological inter-relatedness affects innovation. Complementary assets can be either generic (assets which do not need to be tailored), specialized (unilateral dependence between the innovation and the assets) or co-specialized (bilateral dependence between the innovation and the assets) (Teece, 1986). Tacitness characterizes the knowledge used to develop innovations. Such knowledge is difficult to express clearly and, thus, hard to transfer. The inappropriability characteristic defines the extent to which "environmental factors, excluding firm and market structure, govern the innovator's ability to capture the profits generated by an innovation" (Teece, 1986). All the foregoing is summarized in Table 1.

*Uncertainty*: The uncertain nature of the innovation process manifests itself in many ways and presents many different hazards to potential innovating firms. Firms are uncertain as to whether they are duplicating the efforts of other innovating firms; let alone the uncertain nature of the innovation process itself (in terms of time lags, cost over runs, loss of key scientific personnel, and outright failure). Either way, the sunk costs of R&D are borne by the losing firms when another wins the race to be first. This presents financial risks for the firm, and managers must determine if the firm can avoid bankruptcy if the outcome is not favourable. Government intervention in the market for R&D is advisable under these circumstances.

*Path dependence/cumulativeness/irreversibility and technological inter-relatedness*: Path dependency, the cumulative nature of knowledge and irreversibility of historical decision-making help to funnel innovations into an industry-wide standard. Standards are normally viewed as a good thing in an industry, but they also serve to protect the status quo. There are substantial risks to the innovator who deviates from the locked-in design. Witness the 100 year dominance of the internal combustion engine fuelled with gasoline. Thus government intervention is warranted under these circumstances.

An autonomous innovation is easier to market because it fits in an already extant system. A systemic innovation is harder to develop and market because the whole system embodying it is different. Thus systemic innovations are more risky and less likely to be pursued by firms. Government intervention through R&D programs can help to mitigate the risks associated with systemic innovations. Path dependence is associated with first-mover advantage in an imperfect market with imperfect agents (Mueller, 1997), while technological inter-relatedness is an invitation to first-mover advantage by inventing a new widget to fit into the system.