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RATIONALES FOR GOVERNMENT INTERVENTION IN THE COMMERCIALIZATION OF NEW TECHNOLOGIES

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1. Introduction

The role of science and technology (S&T) policies in fostering economic growth has received increasing attention by economists, policy-makers, and practitioners (e.g. NBER, 1962; Freeman and Soete, 1997). The ways to conceptualize innovation have evolved from unidirectional 'science-push' models towards more complex models that account for interactions between science, technology and markets (e.g. Kline and Rosenberg, 1986). Also, institutional structures to support innovation processes have received attention in comparative analyses, as exemplified by the adoption of the concept of a national innovation system both in theoretical and empirical research (e.g. Nelson, 1993).

In spite of conceptual advances, econometric models, and illustrative case studies there are still no straightforward answers to the question of what elements an innovation policy should include, or how such policies should be implemented (e.g. Pavitt and Walker, 1976; Mowery, 1995; OECD, 1998a). Innovation policies can emphasize basic research and technology development (e.g. public funding of basic research), exploitation of research infrastructure (e.g. university-industry collaboration), support of industrial technology development (e.g. tax subsidies for R&D), technology adoption, and technical standardization, for instance. Some of these policies are best implemented through legislation, while others call for active participation of civil servants in government agencies, or collaboration with the private sector.

One of the difficulties in policy design is that while one policy may mitigate an identified market failure, other government or systemic failures may remain or, at worst, be created (Andersson, 1998). Mowery (1995) defined 'technology policy' as "policies that are intended to influence the decisions of firms to develop, commercialize or adopt new technologies" (p. 514). For the purposes of this paper, 'innovation policy' refers to policies that are intended to influence the decisions of firms and both public and private organizations to develop and commercialize new technologies. Thus, aspects of technology adoption are excluded, while policies which seek to influence non-firm organizations (e.g. universities, research institutes) are included. More specifically, 'government intervention' is used to refer to the mechanisms through which the government participates in the resource allocation decisions in the commercialization of new technologies.

In part, this paper is motivated by recent structural changes in national innovation systems and, specifically, by the shifting roles of both private and public actors in promoting innovative activities. In some regions, such as Silicon Valley, the development and commercialization of new technologies is supported by the existence of a vibrant venture capital industry. In some other regions, such as Israel and Finland, government interventions have preceded the rise of private venture capital industry. Governmental funding agencies, both in these and other countries where the promotion of innovative activities is one of the policy priorities, share objectives that are similar or comparable objectives to those of the private venture capital industry.

In this paper, we examine rationales relevant to the evolving roles of private venture capital industry and government intervention in the commercialization of new technologies. The motivation for explicating these rationales and their implications for innovation policy is that this may help set policy measures which realize potential complementarities while minimizing unwarranted interventions. At this juncture, the comments of Max Weber in *Bureaucracy* (Gerth & Mills, 1946: p. 235)

> "Only the expert knowledge of private economic interest groups in the field of 'business' is superior to the expert knowledge of the bureaucracy. ... Very frequently the measures of the state in the field of capitalism take unforeseen and unintended courses, or they are made illusory by the superior expert knowledge of interest groups."

suggest a normative bias in favor of private venture capital. However, the R&D processes include interactions and feedback loops that are of limited interest to the private venture capital industry. Public support to the aspects ignored by the private venture capital industry could enhance the performance of innovation systems.

More specifically, we outline analytical perspectives – termed as rationales – for examining the role of government agencies in comparison with, or as a complement to, private venture capital[1]. The first two rationales, *market* and *systemic failure*, take the institutional structure of the R&D system as a given and attribute the production of non-optimal outputs to problems of appropriability and coordination, respectively. The third rationale, *structural rigidities*, examines the structure of the innovation system as a variable that is under limited control by policy-makers. Thus, changes in the innovation system initiated by policy-makers may have effects that persist after the intervention due to the institutionalization of new practices. The fourth rationale, *anticipatory myopia*, proposes that without intervention individuals and organizations may underinvest in the generation and assimilation of information which contributes to the parties' ability to act with foresight. Here, the role of the intervention is to promote search for new long-term opportunities.

The remainder of this paper is structured as follows. Section 2 discusses the emergence of venture capital industry and the roles of funding agencies in the commercialization of new technologies. Section 3 outlines alternative rationales for government intervention. Section 4 discusses some inherent problems in the government–agency –relationship, and the role of policy evaluation in mitigating these problems. Section 5 takes initial steps towards integrating the theoretical discussion into practice by examining innovation policies in two case counties, Finland and Israel. Section 6 concludes the paper.

2. Background

2.a Innovation systems

Technological change has been widely recognized as a key driver of economic development (Freeman and Soete, 1997). To a considerable extent, economic development has been driven by the scientific and engineering efforts in the public and private sector. Furthermore, the very institutional structure of techno-economic interaction has changed considerably. This structure is best depicted as a complex system which consists of universities, governmental research laboratories, legislative framework on governing competition and cooperation among firms, and intellectual property protection, among others. These institutional structures have evolved in distinctive ways in different countries, as characterized by the growing literature on 'national innovation systems' (e.g. Nelson, 1993).

While the systems that encourage or inhibit innovation are highly complex, stylized models of innovation help in the analysis of specific institutions. Early on, Schumpeter (1934) divided economic activities into two broad categories.

1. First, during the circular flow of economic life "the economic system will not change capriciously on its own initiative but will be at all times connected with the preceding state of affairs" (p. 9). The activities are based on previous experience, and the autonomous actors are coordinated by a price mechanism (Hayek, 1945). The system may achieve incremental economic growth by the small adjustments taken at the margins, although the routines employed by firms remain the same. More radical changes (or 'development' as Schumpeter defined it), require that established rules are ignored and replaced by new combinations of activities.
2. Second, there are spontaneous and discontinuous changes in the economic system. As a result, the materials and forces used in the production process are combined in different ways. Some new combinations are enabled by technological development (e.g. an introduction of a new production method), whereas others are of a more socio-economic character (e.g. organizational restructuring to break up a monopoly position). Often, these new combinations are not introduced by established firms but by new ones (Schumpeter, 1934: p. 66). Individuals who seek these new combinations are called 'entrepreneurs', who, if successful, create entrepreneurial profits "to which no liability corresponds" (p. 132).

Entrepreneurial profits are temporary. New businesses emerge to gain a share of the profit opportunity, until what was new becomes routine and embedded in the industry equilibrium. Extraordinary profits are thus a result of successful change, suggesting that continuous extraordinary profits call for processes of continuous change – something quite unusual considering the proposed routine nature of the circular flow of economic activities. Established firms seek to enable these processes through industrial R&D, while venture capitalists bear some of the financial risks that are inextricably linked to new entrepreneurial activities.

Industrial R&D activities acquired a formal organizational form when the multidivisional, centrally coordinated manufacturing firms, such as DuPont and General Electric, rose into dominant industry positions in the early twentieth century. The increasing coordination power of headquarters was associated with the establishment of corporate research centers (Mowery, 1990). The corporate research centers had a dual role in internal inventive and external monitoring activities.

In the 1980s, however, especially US corporations perceived increasing competitive pressures, and consequently 'externalized' some of their R&D operations (Mowery, 1998). Research joint ventures, strategic alliances, and research consortia were widely established, making it possible to spread the costs of R&D, to gain access to complementary capabilities, and to facilitate technology transfer. These changes were – and still are – particularly manifest in certain high-technology industries, for example biotechnology, where the locus of innovation has gradually moved from individual firms and research institutes to networks of innovators (Powell *et al.*, 1996). Nevertheless, most industrial R&D activities emphasized development rather than research, which caused policy concerns over the long-term rate of technological development (Nelson and Romer, 1996; OECD, 1998b).

2.b Venture capital

The first independent venture capital fund, American Research and Development, was established in 1946. In the late 1960s, many large corporations established venture divisions that emulated venture capital practices (Fast, 1978). However, most of these early corporate venture capital initiatives were terminated after a few years, especially if the parent company met financial difficulties. Also, the total commitments to the venture capital industry consisting of independent funds remained small compared to the volume of industrial R&D. In 1979, the US regulations controlling pension fund investing were relaxed, and the venture capital industry started a rapid, although somewhat cyclical, growth. In the 1990s, several governments took policy actions to encourage the development of the private venture capital industry (OECD, 1996).

In private venture capital industry, the venture capitalist provides financial resources to an entrepreneur and, in exchange, receives an equity share of the firm. Typically, instead of receiving any interest for the investment, the economic rewards are realized only when the venture capitalist exits from the business. The preferred exit mechanism is through initial public offering (IPO) of the stock while acquisition by another firm is a common alternative. Unfortunately, many of the start-ups fail. However, a few major successes in the portfolio of a fund can recover the costs of the non-successful investments. Historically the amount of new venture capital investments has correlated with strong IPO performance, reinforcing the cyclical nature of the industry (Gompers and Lerner, 1999b).

Venture capital investments are typically staged according to the maturity of the business (Barry, 1994). Seed and start-up investments are relatively small investments that are used to demonstrate the business concept, develop prototypes, or initiate customer relations. Expansion investments are used to finance ongoing R&D efforts, establish distribution channels, ramp up production, or develop international operations of a growing firm. Venture capital can also contribute to the rejuvenation of mature firms by financing management buy-outs or buy-ins.

Typically, the size of successive rounds of venture capital investment rises sharply. The seed investments are often made by individual investors, so-called "business angels", and can range around 100 000 USD. In the following start-up and early expansion rounds, organized venture capital funds invest in stages in the range of 1 – 10 MUSD. The expansion stages are often syndicated by several venture capital funds, which in turn have raised the financial resources from investment banks, pension funds, and other institutional sources (Gompers and Lerner, 1999a). After an initial public offering, the firms are better able to raise financial resources from the capital market through, for instance, secondary public offerings.

In the business press venture capital is often referred to as "smart money". Venture capitalists receive business plans for evaluation from potential entrepreneurs. Based on their business and technological expertise, the venture capitalists select the most promising plans for in-depth consideration, or "due diligence". They are active investors who advice entrepreneurs on finance, strategic management, human resources, and other management issues. Moreover, venture capitalists monitor the entrepreneurs' activities, often by serving on the board of directors. In the late 1990s, some venture capital firms launched "incubators" by offering a full range of services, including human resource and information technology, to the firms they invested in (Hansen *et al.*, 2000).

Although professional skills and techniques used in the selection and management of innovation projects have demonstrated some progress (OECD, 1996: p. 20), the process of identifying break-through business opportunities relies largely on personal judgment and tacit expertise. The structure of venture capital industry supports the development of expertise both at the individual and organizational level. Individual venture capitalists monitor and provide advice to several ventures, and are thus able to synthesize the potentially complementary experiences. The syndication of expansion stage financing rounds creates incentives for collaboration across venture funds. At both levels, reputation is important. Individual entrepreneurs are likely to seek financial resources and advice from sources that have proven their expertise in the specific field of their venture. Thus a venture capitalist with specific expertise is well positioned to obtain a portfolio of related ventures which constantly update her special expertise. At organizational level, the venture capital funds' track record on previous IPOs is crucial for their ability to raise money from institutional investors for later investments (Gompers and Lerner, 1999b). As firms going public have typically received funding from several venture capital funds in several stages, the best performing funds have incentives to collaborate with other successful funds.

The structure of venture partnerships constrains the learning activities general partners can undertake. Due to the tacit nature of monitoring and advising activities, limited partners (i.e., institutional investors) cannot directly monitor the quality of the services general partners (the individuals performing the investment decisions, i.e. the venture capitalists) provide. It is therefore commonplace that partnership agreements specify numerous covenants that restrict the activities of general partners, including restrictions on fundraising and addition of new general partners (Gompers and Lerner, 1996). The restrictions on fundraising, as well as more general restrictions on general partners' outside activities, focus the general partners' attention on the fund they are currently managing. The restrictions on the addition of new general partners contribute to the quality of the oversight, as new partners would presumably have less experience.

In the history of the venture capital industry, institutional investors have increased their venture capital commitments in sudden bursts, perhaps as a response to highly visible successful IPOs (Gompers and Lerner, 1999b). Yet, the partnerships that are established may not be able to develop new areas of expertise in a timely manner. As a result, the industry may overinvest myopically in a few select technological areas (Sahlman and Stevenson, 1985).

2.c Funding agencies for new technology development and commercialization

Industrial R&D is "the heart of capitalist engine" (Nelson, 1996) which drives techno-economic development and contributes to societal well-being. Venture capital industry is a part of the innovation system specialized in the commercialization of new technologies via start-up firms. Some countries have established agencies or initiatives with tasks comparable to those of the private venture capital. Examples include Small Business Innovation Research Program[2] in the US, Sitra and National Technology Agency[3] in Finland, and Anvar[4] in France.

In order to reap economic and social benefits from technological progress, governments have taken policy measures to promote innovative activities (OECD, 1997b). One such measure is the establishment of agencies that provide selective funding for R&D efforts in private firms, universities, and research institutes[5]. The provision of such funding is typically justified on the grounds that free market financing of R&D is not socially optimal (e.g. TAFTIE, 1997). Most of the agencies provide funding on a per project basis, whereby the costs due to R&D efforts are fully or partially subsidized.

In the next section, we discuss the above 'market failure' rationale, as well as other rationales, for government intervention in the commercialization of new technologies. In addition to providing selective funding for R&D, the funding agencies may carry out other functions as well, for example, offer incubating services to small firms, distribute technological or market information, or activate firms to utilize the services of local research institutes. In general, however, the cost of these complementary services is rather small compared to the costs of providing financial support to even a moderate share of industrial R&D efforts at the national scale. For the sake of analytical tractability, the discussion of government intervention in the commercialization of new technologies is limited to situations where the government takes an active part in the allocation of resources to R&D.

3. Rationales for government intervention

3.a Underinvestment in R&D – Market failure

Arrow (1970) showed that markets for information have several uncomfortable properties. If there is no intellectual property protection, it is not feasible to sell information in the open market, as any buyer could reproduce it for reselling with insignificant cost. Moreover, a potential purchaser can determine the value of a piece of information only after receiving it, after which he has little need to pay for the information.

The information generated by R&D can be appropriated by a single firm only to a limited extent. Thus, in the absence of effective markets for information, profit-seeking firms are likely to invest in R&D less than what would be socially optimal, and market failure occurs (Nelson, 1959). To remedy the situation, government can provide support for R&D activities, especially for basic research in universities, research institutes and firms.

Firms conduct R&D if they expect to benefit from the results via, for example, sales of new products or savings accruing from more effective production processes. Provided that there are no serious capital market imperfections, firms should be able to raise funds to perform R&D projects that they perceive as economically optimal. However, the results of R&D projects may also benefit other firms or the society at large. *Market failure* refers to the conditions under which the amount of funding allocated to R&D by market forces is less than socially optimal (e.g. Arrow, 1970).

R&D activities can be viewed as a cumulative learning process where the assimilation of new knowledge is facilitated by previous complementary experiences (Polanyi, 1958). Thus, by undertaking R&D firms not only produce new information but enhance their ability to recognize and utilize the information that spills from the R&D activities of other firms, universities, and research institutes (Cohen and Levinthal, 1990). The value of this absorptive capacity encourages firms to invest in research, especially in industries in which scientific or technological change is rapid (Cohen and Levinthal, 1989). This race to learn and invent might produce a socially optimal level of R&D (or even exceed it), and the government support would be most justified at the basic research end of the research-development continuum, where the potential spill-overs are most significant.

The market failure rationale is the foundation of several instruments of innovation policy, such as tax credits based on R&D expenses (e.g. Hall and Van Reenen, 2000). However, the rationale as such does not necessitate active governmental participation in the process of allocating resources to R&D. Indeed, active participation is costly and also influences the behavior of those who conduct R&D. Thus instruments involving active governmental participation should induce desired changes in the behavior to offset the costs of intervention. Such changes could include, for instance, elements of quality control achieved via peer review, an aspect especially relevant for basic research[6]. In the commercialization of new technologies, however, the nature of the desired changes is more more subtle, because in their profit-seeking activities firms are presumably already doing their best, while the governments' track record in guiding commercialization efforts is rather mixed (e.g. Nelson, 1990).

3.b Coordination problems among R&D participants – Systemic failure

Innovation systems can be viewed as a a set of institutions whose interactions influence the innovative performance of the actors involved in R&D (Nelson, 1996: p. 276). These actors include universities with basic research agendas, research institutes and corporate research centers conducting applied research, as well as firms which are active in product development and commercialization of new technologies. The working practices, incentives, and priorities of these organizations support their primary tasks. If the practices, incentives, and priorities are optimal at the level of individual organizations, while the overall innovative performance of the system is sub-optimal, *a systemic failure* is present (cf. Andersson, 1998).

A linear view of the innovation process (in which scientific research, technological development, and commercialization are regarded as sequential phases), ignores the complex feedback mechanisms that connect these parallel aspects of techno-economic development (Kline and Rosenberg, 1986). That is, innovation is not only driven by research findings, but new promising research directions are often identified during the later phases of product development and commercialization. Thus, the effectiveness of the innovation system depends on the interactions between firms, government laboratories, and universities (Metcalfe and Georghiou, 1998). These institutions, and the individuals employed, have distinctly different priorities which may inhibit collaboration. If the differences in priorities are significant enough to diminish the long-term performance of the innovation system, a systemic failure occurs. The government can intervene by creating incentives which facilitate knowledge transfer between organizations in the different phases of innovation process, thus mitigating systemic failures with regard to commercialization of new technologies.

In many countries, technology programmes are one policy instrument to partially correct the systemic failure[7]. In these programmes public and private participants pursue joint R&D efforts (OECD, 1998c). Thus neither academic peer review (which would exclude the priorities of industry), nor unselective tax incentives (which would exclude the priorities of academia), are used as the primary resource allocation mechanisms. For example, in the technology programmes of the National Technology Agency in Finland, administrative rules favor collaborative project proposals: for instance, projects proposed by universities are funded on condition that there is a participating industrial partnerfor, and large firms can receive more government support for projects that involve subcontracting from small firms or research institutes.

The proposed benefits of these collaborative efforts include harmonization of incentive structures (in the sense that the academics are rewarded for industrially relevant work, and the industry is encouraged to take part in R&D activities at universities), joint prioritization of R&D goals, and more intense interaction between the research and development ends of the R&D continuum (cf. Buisseret *et al.*, 1995). The attainment of these benefits involves several challenges, as technology programmes have been criticized for rigid structures, premature selection of technological options, and consensus-seeking decision-making mechanisms (Luukkonen, 1998).

Systemic considerations do not fully explain how technology programmes contribute to new schumpeterian innovations, which require 'creative destruction' of established industry practices (e.g. use of biotechnology in pharmaceutical R&D, or the transition from mainframes to personal computers). That is, if the emergence of new industries is associated with conflicts with established firms, closer university-industry collaboration may inhibit rather than promote R&D activities that threaten the technological or market positions of legitimate industrial sponsors (cf. Aldrich and Fiol, 1994). Consequently, the mechanisms of resource allocation should balance the interests of existing and potentially emerging firms and industries. To some extent, the latter may be disadvantaged, as established industries have more political lobbying power and are better positioned to trade favors with government officials. Owing to the discretion provided by civil servants, the interests of emerging industries may be represented by technology agencies, provided that their prevalent norms emphasize the exploration of frontiers in technological and industrial development. Yet, to what extent the civil servants perceive and comply with such norms has received little empirical scrutiny.

3.c Inertia within innovation systems – Structural rigidities

Institutions, as well as of technological expertise, develop through path-dependent processes (North, 1990). Institutional change is based predominately on continuous marginal adjustments, while external stimuli may lead to less gradual development paths. Insofar as the development of innovation systems is constrained by path-dependencies at the level of institutions or organizations, government interventions may stimulate new development paths. That is, innovation policies may seek to create variation and flexibility in the system to overcome potential *structural rigidities*.

The institutions in an innovation systems are highly interdependent. For example, the venture capital industry in the Silicon Valley area in the US relies on specialized firms delivering legal services, close collaboration with local universities, and cultural norms supporting the mobility of work force (Saxenian, 1991). As a consequence, if changes in one institution call for complementary changes in other institutions, the development of the system as a whole may be hampered even if only some of the institutions become rigid. New configurations in the evolutionary innovation system, as envisioned by Metcalfe (1995), are unlikely to emerge without external stimuli. Thus a government may launch experiments (support initiatives, or even direct organizational or institutional changes) to overcome structural rigidities. Moreover, if some experimental practices institutionalize and diffuse in the innovation system, the interventions can have significant long-term effects.

In the context of venture capital, governments have identified and initiated numerous policy measures, including direct supply of capital, financial incentives, and investor regulations, to support the growth of the private venture capital industry (OECD, 1997a). For example, in 1990 there were only two private venture capital funds in Israel; but in 1993 the Israeli Government invested USD 100 million in a venture capital fund with a focus on high-technology start-up firms. By 1996, when the government sold its share of this fund, there were some 40 private venture capital funds specializing in technology-based firms. It is plausible that the Government's intervention (temporary support of novel means to commercialize new technologies) contributed to the development of an institutional environment in which the private venture capital industry could prosper on its own.

Technological progress often follows 'paradigms' (Dosi, 1982), and organizations accrue specialized expertise relevant to these major development paths. The stock of expertise limits the set of feasible future R&D project options. If there is a certain minimum 'critical mass' for activities that aim to develop new areas of expertise, instruments such as technology programmes may help subsidize part of the set-up costs and activate other potential participants. Thus, active government participation in the allocation of resources for R&D would be concentrated on emerging technologies. Arguably, such interventions would contribute to the renewal of expertise pools in R&D organizations, which would expand the number of directions the innovation system could pursue on its own. From this perspective, a government intervention would be motivated as a temporary measure to reconfigure the innovation system. If reconfigurations are typical to successful innovation policies, then the government's ability to identify and initiate new policy experiments would be important (Ormala, 1998).

3.d Anticipatory myopia

Successful interventions based on the preceding rationale, structural rigidities, require that policy makers have a good understanding of what kinds of experiments and policy measures are called for and what the impacts thereof are likely to be. However, to the extent that the actors in the innovation system do not either attempt to foresee beneficial intervention opportunities, or do not act on the insights they possess, the development of the innovation system may suffer from *anticipatory myopia*. Here, anticipatory myopia is not limited to governmental agencies, as both public and private organizations may adopt a reactive rather than proactive stance vis-à-vis future opportunities (cf. Salo, 2001). This is all the more so, because none of the actors in the innovation system alone may able to change conditions that apply across organizational or institutional boundaries. In practice, responses to anticipatory myopia are likely to call for interventions to abolish identified structural rigidities.

There are several dimensions to anticipatory myopia. First, information about future opportunities is expensive to acquire and hard to trade or appropriate. Thus, analogously to the market failure situation with R&D efforts as such, actors may underinvest in foresight activities (for examples of formal foresight exercises, see e.g. Martin, 1996; for discussion of foresight activities embedded in technology programs, see Salo and Salmenkaita, 2001). Second, the actors that have information of future opportunities may not be the ones to act on it. Thus, in the absence of incentives that support collaboration across organizational boundaries, even foresight information that is otherwise be actionable may remain unused; this parallels the systemic failure. Third, even if an actor possesses actionable foresight information, the implementation of an experiment may require collaboration with other organizations or complementary institutional changes. Thus, structural inertia may inhibit experimentation.

Funding agencies and private venture capital industry may have complementary roles in the commercialization of new technologies. However, public and private organizations differ in several key dimensions, including incentive intensity, administrative controls, and adaptation characteristics (Williamson, 1999). Because these differences are likely to affect the behavior of public and private organizations, both forms should be promoted in performing tasks in which they have comparative efficiency advantage.

More often than not, the incentives of civil servants are not strongly dependent on the outcome of the R&D projects that they choose to fund. In contrast, the general partners of private venture capital funds typically receive 15-25 percent of the capital gains generated by their fund (Gompers and Lerner, 1999b). Thus, other things being equal, it is plausible that private venture capitalists have stronger incentives to spend more time and effort in the initial decision making and later monitoring of ventures. However, the close scrutiny of R&D projects by venture capitalists might not be applicable to situations in which the projects mitigate systemic failures (e.g. university-industry collaboration with compromise goals) or structural rigidities (e.g. development of new expertise pools of uncertain commercial appropriability). That is, while the venture capitalists have strong incentives to maximize the economic success of the R&D projects they fund and monitor, any other concerns of systemic failures or structural rigidities are secondary and likely to receive little attention.

For example, Lerner (1996) found that the Small Business Innovation Research (SBIR) program, a major US public venture capital initiative, had a strong positive impact only on those firms which operated in geographic areas with active private venture capital, and the beneficial effect was greatest for firms in industries which did not frequently attract funding from sources of private venture capital. This suggests that civil servants are able to select firms with growth potential in a wide variety of industries, yet private venture capital, or associated business infrastructure, is needed to realize that potential. The explanation concurs with the stylized fact that the private venture capital industry tends to focus on select 'hot' technologies. To mitigate anticipatory myopia, technology agencies could fund a broad variety of start-up firms, whereas the private venture capital would commit to the most promising opportunities and ensure that they receive resources for expansion.

3.e Summary of rationales

The four rationales for intervention are summarized in Table 1. In addition to examples and diagnoses, corresponding challenges for evaluation are also emphasized. Specifically, to correct market failure, resources are provided to achieve a desired quality and quantity of R&D outputs, whereby the mechanisms of priority setting and the productivity of the R&D process can be scrutinized. The rationale of systemic failure, on the other hand, calls for measures that are geared towards the promotion of collaboration networks. If the intervention seeks to change the structure of the innovation system by overcoming some structural inertia, evaluation of the degree of success involves comparison to the counterfactual development of the system without intervention. That is, taking into account the uniqueness of innovation systems, it is not possible to make a direct comparison between a system that has been subjected to an intervention and a system that has developed gradually. Intervention to mitigate anticipatory myopia relies, at least implicitly, on distinguishing activities of varying levels of forward-looking explorativeness. Alternatively, the intervention could aim to facilitate processes which are presumed to generate foresight (cf. Salo and Salmenkaita, 2001). Given these challenges, it is plausible that the effectiveness of 'higher-order' interventions is rather equivocal. The next section discusses problems related to the ambiguous goals and performance criteria of technology agencies.

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4. Perspectives on normative rationales for intervention

If the benefits associated with interventions called for by the four rationales are to be realized, a funding agency must be capable of constantly reinventing itself. Information asymmetries in the political system may foster policy interventions even in situations where this does not engender social welfare benefits. In this section, we discusses some associated requirements of competence and information acquisition. These concerns are synthesized in a framework that highlights the different roles of policy evaluation as an adaptable control instrument.

4.a Policy capture

Innovation is a complex and uncertain process, affected by the institutional environment, national policies, and firm-specific characteristics. Despite the challenges in the identification of effective policy measures, political actors may be rewarded for being perceived as 'pro-innovation'. Thus, due to bounded rationality considerations, policy experiments can be undertaken even in the absence of a clear causal rationale (Lindblom, 1965). The experiments provide new information that can be used to gradually refine the policies. A funding agency can therefore be seen as an enabler of policy experiments, or an organization which facilitates control, accumulation of experience, and even accountability.

Organizations, however, tend to develop purposes of their own (Selznick, 1957). To exist, they require an inflow of resources which maintains the internal incentive equilibrium (Barnard, 1938), and to receive the resources, the organization has to respond to external demands. A funding agency, for example, receives financial resources from the government and allocates them to the universities, research institutes, and firms. From this perspective, the agency fulfills politicians demand for 'pro-innovativeness' is fulfilled ed if the agency (and thus indirectly the politicians), receives public credit and recognition from universities, research institutes, and firms. From the viewpoint of recipients, public credit and recognition is a relatively low cost way to enhance the likelihood of receiving more financial support in the future. As a result, the agency can be captured in a reinforcing process of political recognition, where the allocation of resources may be unduly influenced by the desire to enhance public recognition as a step towards the reception of further financial resources. Such a process may become problematic, if the quest for public recognition deserves undue attention as a motive for resource allocation.

Political recognition is sustainable only if stakeholder groups are not able to collect verifiable information on the relative ineffectiveness of the activities of the agency (Figueiredo *et al.*, 1999). In the case of public support for private R&D, factors such as confidentiality concerns, time lags and ambiguous performance criteria make the collection of verifiable information a challenging task. Moreover, if the agency has considerable autonomy in designing its activities, it is difficult to impose procedural rules to ensure multiple interest group participation (McCubbins *et al.*, 1987). In the extreme, if the agency is fully autonomous in designing its operations, it may control its own evaluation procedures, thus being able to selectively provide information on the effectiveness of its operations. Thus positive feedback and recognition is ensured, and the polity remains content. To overcome the risk of policy capture, the agencies can deploy transparent evaluation procedures, as well as methods for exposition of various stakeholders' viewpoints (e.g. multicriteria mapping).

4.b Neutral competence requirements

Successful agency operations require a high level of expertise. The alternative tasks – determination of socially optimal levels of investment in R&D in various fields, correction of incentive mismatches between R&D organizations, design of policy initiatives for the reconfiguration of the national innovation system, and identification of R&D opportunities that enable new industries to emerge – stretch the limits of bounded rationality even under the most favorable conditions. At the minimum, these tasks require 'neutral competence', experienced civil servants with professional careers (Moe and Caldwell, 1994).

Funding agencies are controlled by public authority. By its very nature, public authority is coercive, as winning political coalitions impose their will on others (Moe, 1991). The structure of public institutions reflects political uncertainty, compromise, and protection against unanticipated exercise of authority, which may undermine the agency's performance in its core tasks. Legislation and procedural rules can be used to define the mandate of the agency, the extent and mode of interest group participation, and attendant activities of an agency, thereby increasing political control over it. Such restrictions partly constrain the agency's ability to solve complex problems by internal coalition formation (Cyert and March, 1963), and to accumulate organizational knowledge generated through new activity patterns (Teece *et al.*, 1997).

In view of the above, governments are faced with a control–effectiveness trade-off in the authorization and management of funding agencies. If the primary goal is to achieve effectiveness in executing operational tasks, the agency should be a politically insulated, autonomous entity, able to reconfigure its activities according to accumulating experience. Then, however, information asymmetries between the government and agency tend to increase while control decreases – conditions in which activities in 'policy capture' mode, with little or no connection to actual effectiveness, could flourish. In practice, the control and neutral competence requirements must be balanced, so that the agencies themselves have an interest to propose new solutions.

4.c Embeddedness requirements

The tasks outlined for technology agencies require a wide variety of information of the state-of-the-art in science and technology, market development, and the capabilities of local R&D organizations. The primary sources of information are the very organizations that the agency is funding – universities, research institutes, and private firms. By being tightly embedded in the local innovation system the agency is able to gather information (including informal opinions of technological and market trends) that is relevant to its decision making processes. Embeddedness, however, may lead to the loss of impartiality, or eventual collusion, between the agency and other organizations in the local innovation system (Granovetter, 1985). Thus embeddedness, and the use of informal information in decision making, increases both the agency's decision making capabilities and the risk of operating in the 'policy capture' mode.

If the agency controls its own agenda, embeddedness will have an effect on the initiatives that it chooses to undertake. Ocasio (1997) has presented a synthesis of the mechanisms controlling attention in organizations, identifying how the decision making outcomes depend on the decision-making environment. The underlying theme is that information is equivocal, and that same information can lead to different actions due to decision makers' selective attention and contextual differences (Weick, 1995). The agency's collaborative relations, and associated information sources, thus frame how new opportunities and courses of action are perceived. At worst, these biases can be harmful if the agency is expected to represent both existing and emerging areas of R&D activity in its resource allocation decisions.

Thus, governments authorizing technology agencies face a trade-off between information richness and biasedness. If the primary goal is to utilize wide sources of information in the agency's decision making processes, the agency should be embedded in the national innovation system. But then, information asymmetries between the government and the agency, as well as the risk of collusion increase, giving rise to conditions that are favorable to the ‘policy capture’ mode of operation.

4.d Role of evaluation as an adaptable control instrument

The above trade-offs between 1) control and effectiveness, and 2) information richness and biasedness, call for practices that mitigate information asymmetries while preserving the autonomy required to carry out reconfigurations to support organizational learning. In the area of technology policy, evaluation of policy measures has received increasing attention (e.g. Meyer-Krahmer and Reiss, 1992; Georghiou and Roessner, 2000). The usual definition of evaluation – "the analysis and assessment of technology policy goals, instruments, and impacts" (Meyer-Krahmer and Reiss, 1992: p. 47) – implies that evaluations cover both the rationales for action and the chains of events caused by the intervention. However, comprehensive evaluations may be unfeasible if the rationales remain equivocal or the causal chains are exceedingly complex.

By distinguishing different types of evaluation, it is possible to outline realistic aims for each. *Ex ante* evaluations explicate rationales for government intervention; *constructive* evaluations aim to enhance ongoing interventions by synthesising perspective from the different stakeholders; and *ex post* evaluations are often analytic exercises that trace the impacts of past interventions.

Even though these three types of evaluation are concerned with policy goals, instruments, and impacts, the learning mode in each is different. By combining the three types of evaluation into a sequence, the government can mitigate the risk of activities in ‘policy capture’ mode while letting the agency operate in an autonomous and embedded manner.

Ex ante evaluations provide insight into intervention alternatives. The rationale for intervention is explicated, alternative actions are considered, relevant performance indicators are identified, and baseline data is collected. If an agency is found to possess neutral competence to initiate interventions in the innovation system, ex ante evaluation formalizes the beginning of the intervention process. Ideally, the early identification of performance indicators and baseline data prevents retrospective rationalization of activities, and reduces the agency's ability to selectively provide information on positive effects only. Ex ante evaluations are anticipatory, as milestones, scenarios, or roadmaps can be used to provide structure to the cognitive exercise (Bunn and Salo, 1993). Overall, the goal is to develop and communicate a story of what should be undertaken in order to prepare for the future.

From the perspective of neutral competence, the agency itself is capable to carry out ex ante evaluations. The competence to identify promising paths of action resides within the networks between the agency and stakeholders from industry and universities. Ex ante evaluation reflects some stakeholders' desired future state, whereby the role of government is to provide boundary conditions for policy interventions and to set priorities for interventions. Evaluation initiates these policy discussions, and in this sense serve the 'future-orientedness' that has been also credited to technology foresight exercises (Martin, 1995). Evaluation professionals can support ex ante evaluations by providing examples of suitable performance metrics (e.g. impact-weighted publications in specific scientific area, or ratio of start-up firms to public R&D spending).

Constructive evaluations are reviews of on-going interventions. They may include both outward and inward-looking elements. The intervention can be compared to similar interventions in other contexts, thus identifying either emerging best practices or complementary activities. Specifically, constructive evaluations can synthesize both actual and potential (or excluded) stakeholders' perspectives on the intervention. Thus the agency is less able to control information of the effectiveness of its activities, and 'policy capture' mode activities can be identified. For this purpose the performance metrics and baseline data defined in ex ante evaluations provide essential background.

Professional evaluators have a critical role in constructive evaluations. They should be perceived as neutral by the government, the agency, and other stakeholders. The evaluations should be commissioned in a way that facilitates impartiality. Nevertheless, close collaboration with the agency may be warranted to provide direct operational feedback to the agency.

Ex post evaluations are reviews of the impacts of past interventions. Micro-economic research may be useful in this role, although a specific evaluation can be justified if the evaluation is to produce policy guidelines beyond the scope of academic research. The evaluators may also help the agency to produce a more objective 'lessons learned' analysis for the agency's internal use.

The ex ante, constructive, and ex post evaluations form a continuum in time. The evaluators, agency, government, and academics have different roles in the different evaluations. Overall, ex ante evaluations have to be performed where the competencies are, constructive evaluations benefit from neutral third party evaluators, and ex post analysis should follow the research practices of relevant disciplines, e.g. microeconomics and innovation studies. These differences are summarized in Table 2.

INSERT TABLE 2 AROUND HERE

5. Empirical observations

To illustrate the practical ramifications of the above considerations, this section elaborates on some key innovation policy instruments deployed in two case countries, Finland (e.g. Salo and Salmenkaita, 2001; Tuomaala *et al.*, 2001) and Israel (e.g. Trajtenberg, 2000; Trajtenberg, 2001). Specifically, technology programmes of Tekes in Finland and programs of the Office of Chief Scientist (OCS) in Israel are discussed. Both countries adopted a proactive stance towards innovation policy in the 1990s, and provided ample public support to R&D activities via a number of instruments. In both countries, positive economic development, for example as quantified by exports in high-technology industries or patent statistics, has apparently benefited from public support. Also, in both cases public initiatives preceded the substantial rise of private venture capital. Thus, albeit one should be cautioned against drawing strong conclusions from mere stylized facts regarding the specific development of two innovation systems, such considerations illustrate the areas from which more general lessons can be learned.

In both countries, the bulk of support is provided via matched grants for project-specific R&D expenses in companies. In Israel, the selection of supported projects does not involve prioritization between fields, as per the neutrality principle adopted by the OCS (Trajtenberg, 2001). In Finland, projects that fit into national technology programs have an advantage in receiving support, although such a fit is not a strict requirement. Thus, in neither case the intervention is strongly aligned with mission-oriented research purposes or attempts to set priorities among technological fields, but rather correction of a *market failure* in general. Even in the case of technology programmes in Finland, the process of priority-setting is best be described as that of facilitating discussions among public and private actors to identify common areas of joint R&D efforts, rather than that of setting strict boundaries on areas that are eligible for support (cf. Salo and Salmenkaita, 2001).

With regard to *systemic failure*, the practices in the two countries differ. In Finland, systemic considerations are integrated directly into the technology programmes. That is, research institutes and universities can apply with research projects to the technology programmes on condition that one or more industrial sponsor is participating in the projects. Also, firms are encouraged to establish subcontracts with universities in their research projects. In Israel, a separate initiative, the “Magnet” program, supports the formation of consortia made of both industrial firms and academic institutions.

Of interventions that aim to correct a *structural rigidity*, the Israeli “Yozma” initiative to jump-start the venture capital market is noteworthy. The initiative was timely and designed with fixed life expectancy, i.e. the intervention was implemented to serve a transitory role in the innovation system. In Finland, technology programmes also have limited life-spans of (typically three to five years). Thus, although the institutional changes pursued in the programmes are less drastic than in Yozma (i.e. the goals typically involve strengthening of collaboration clusters across organizations), the programmes nevertheless intended to serve temporary reconfigurations in the innovation system.

Trajtenberg (2001) summarized the Israeli experience by proposing that "if the institutional setting does not allow for a speedy process of adaptation and innovation in policy design, it may be better not to intervene to begin with" (p. 47). Salo and Salmenkaita (2001) argued that the Finnish technology programmes have elements that provide "embedded foresight". Indeed, it seems plausible that the organizational conditions provided by OCS and Tekes have reduced *anticipatory myopia* in the innovation systems. As an example, the technology experts (civil servants) of Finnish National Technology Agency review tens of project proposals by firms, research institutes, and universities in a given technology area per year. In the process of following approved projects they develop long-term ties to the R&D groups in the field. Senior technology experts also have an important facilitative role in the preparation of new technology programmes.

In principle, conditions of 'embeddeness' can create control problems between the government and the agency, even to the extent that 'policy capture' mode of operations could flourish. Evaluations, as explicated in the previous section, can partially mitigate such problems of control. In Finland, for example, public evaluations of technology programmes have became a routine aspect of innovation policy practice (Oksanen, 2000).

To reiterate, active government participation in the allocation of resources for R&D should not be viewed narrowly as task of establishing priorities for projects or technological fields. Rather, there is a need for participatory activities which allow the government to recognize different rationales for its intervention and to take systemic considerations into account. Here, there are close parallels to technology foresight which, as an instrument, raises the civil servants' awareness of new opportunities and suggests measures reducing counterproductive inertia through innovative policy instruments.

6. Conclusions

In this paper, we have investigated alternative reasons, and related challenges, for policy intervention in the commercialization of new technologies. In particular, four rationales for government intervention in commercialization processes were identified and analyzed.

1. Private markets may invest less than is socially optimal in R&D due to appropriability problems; however, this rationale is not congruent with the expert assessment rather than peer review –based decision-making

mechanisms used by the technology agencies, nor does it necessitate support for R&D conducted by firms instead of universities.
2. Public intervention (selective subsidies) may create incentives that encourage collaboration between universities, research institutes, and firms. Based on this rationale, public interventions may favor R&D activities in established instead of emerging industries.
3. Public intervention may be a temporary measure to encourage re-configuration of the innovation system, thus fostering development of new self-sustaining patterns of activity, including new areas of expertise within R&D organizations.
4. Technology agencies and private venture capital may have complementary roles due to differences in incentives, information sources, and propensity to behave opportunistically. Public intervention may aim to foster foresight in the innovation system via public-private joint activities.

A technology agency, even if established as a policy experiment, may continue to receive resources due to the high information asymmetries related to the effectiveness of its activities. This mode was referred to as ‘policy capture’. To succeed in its operations, presuming the agency is not in the ‘policy capture’ mode, the agency requires internal expertise and access to a wide variety of information. Autonomy would benefit the development of expertise, but decrease the government’s ability to detect ‘policy capture’ mode activities. Embeddedness in the innovation system would benefit information acquisition, but increase the risk of collusion in ‘policy capture’ mode activities. Different kinds of policy evaluation – ex ante, constructive, and ex post – can be used to mitigate these perplexing dilemmas.

The above considerations were set into practical context by examining some aspects of innovation policy instruments adopted in Finland and Israel. Admittedly, strong conclusions cannot be inferred from the existing scant empirical evidence. Case studies of funding agencies should uncover the relative importance of the outlined rationales (and yet other rationales ignored in this paper). Quantitative studies, following the examples set by Lerner (1996) and Kortum and Lerner (1998), should analyze the comparative effectiveness of private and public solutions, if the goals indeed are competing or complementary. At this stage, we believe that the various forms of evaluation provide helpful tools for the consideration of alternative policy measures.

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Table 1. Summary of policy rationales

	Examples of intervention	***Diagnosis***	***Evaluation challenge***
Market failure	Support university research in specific fields	Technological / scientific fields critical for future competitiveness do not receive adequate resources	Appropriate level of resources for different fields (priority setting); Quality and quantity of R&D (outputs)
Systemic failure	Support university-industry collaborative projects	Existing R&D capabilities are not utilized effectively	Quantification of benefits and drawbacks related to collaboration networks
Structural inertia	Provide public venture capital when private VC is non-existent; Create a system of 'centers of excellence' to both renew and strengthen collaboration clusters	Pursuit of new opportunities is seriously constrained by status quo	Comparison between counterfactual development of the system without intervention
Anticipatory myopia	Create joint decision-making situations among government, industry, and university representatives	Insights are not acted upon; Experimentation follows herd behavior	Quantification of explorativeness of actions; Understanding of processes that generate foresight

Table 2. Role of evaluation in policy development

	Ex ante	***Constructive***	***Ex post***
(1) Rationale – GOAL	Explicate the rationale for intervention *(agency / government)*	Compare to other similar interventions *(evaluator)*	Generalize results into policy guidelines *(government / evaluator / academics)*
(2) Implementation – INSTRUMENT	Compare proposed actions to other feasible ones *(agency)*	Initiate complementary actions *(evaluator / government)*	Compare the impacts to those of competing instruments *(evaluator / academics)*
(3) Performance measures - IMPACT	Identify performance metrics and collect baseline data *(agency / evaluator)*	Review performance metrics, ensure data collection, and provide operational feedback *(evaluator / agency)*	Analyze the effectiveness of actions *(evaluator / academics)*
Learning mode	Anticipatory: Outline milestones, scenarios, or roadmaps to achieve goals *(agency)*	Synthetic: Compare stakeholders' perspectives *(evaluator)*	Analytic: Perform lessons learned –analysis *(agency / evaluator)*

[1] One might stylize governments as intervening more or less extensively in the new technology commercialization process, which thus creates a dichotomy of 'free-market – government intervention' policies, for example, US vs. European style (cf. Giesecke, 2000). However, the actual policy practices are much more complicated: Lerner (1996: p. 31-32), for example, identified 25 *public* US venture capital initiatives, including at least 43 state venture funds.

[2] http://www.sba.gov/SBIR/sbir.html

[3] http://www.sitra.fi/; http://www.tekes.fi/

[4] http://www.anvar.fr/

[5] For European agencies, see http://www.taftie.org/. Small Business Innovation Research (SBIR) Program, http://www.sba.gov/SBIR/sbir.html, has a somewhat similar role in the US.

[6] For example, in the Finnish context the resource allocation decisions by National Technology Agency, http://www.tekes.fi/, are based on selective expert (government civil servant) assessment, whereas the Academy of Finland, http://www.aka.fi/, primarily uses peer review.

[7] For example, European Union Fifth Framework Programme (FP5), http://www.cordis.lu/fp5/home.html.

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