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INTERACTION BETWEEN THE PUBLIC SECTOR AND TECHNOLOGICAL INNOVATION: GOVERNMENT POLICY TOWARDS RESEARCH AND DEVELOPMENT

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Notes

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Abstract

This report analyzes the role of the state in supporting research and development (R&D), as part of state policies towards technological change. The report is a contribution to the ongoing work of the Division for Public Economic and Public Administration on the theme of evolving issues in economic governance.

Data for members of the Organization for Economic Corporation and Development (OECD), indicate that, after growing rapidly for at least three decades, total R&D spending expanded slowly in the first half of the 1990s. The decline in defence R&D, and slower growth in other areas of government R&D spending, were important contributions to this overall slowdown.

The economic rationale for a role for government in supporting R&D is derived from the contribution of R&D to economic growth, and the existence of substantial market failures in the private provision of R&D, leading to an under investment in R&D. The general rationale for government to support R&D, however, does not always contain specific guidelines for how, and to what extent, this support should occur.

There are numerous examples of government policies to foster R&D. The successes of some of these policies can provide guidelines for future initiatives, but work needs to be done to link the rationales more closely with the policies.

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Introduction

In the second half of the twentieth century, governments have assumed a significant role in shaping the nature of technological change in their societies. This is especially the case in the developed economies but governments in the economies in transition and in many developing economies, especially those considered as newly industrializing, have also accepted more responsibilities in the area of technological change.

This report focuses on one aspect of government's role in technological change, namely public policies towards research and development (R&D). The report describes recent trends in public expenditures on R&D and suggests some reasons for the observed trends. The report then focuses on the economic role of R&D and the rationales for a substantial government involvement in the R&D process, including why the rationales may be incomplete as a guide for policy formulation. The report also summarizes different policy mechanisms and closes with some suggestions for future research.

Recent trends in expenditures on research and development

Nature and source of data

Research and development expenditures are not generally captured either by systems of national income accounting or by data collected on financial flows. Similarly, government budgets do not always separate R&D from other government expenditures. The Organization for Economic Cooperation and Development (OECD) has established standards for measuring R&D expenditures that permits the collection and dissemination of comparative data for its member states (OECD, 1998). Since it appears that the vast bulk of expenditures on R&D are undertaken by firms, governments and not-for-profit institutions in the developed market economies, the OECD data is the closest approximation to a global total.

Data collected by the OECD for 25 of its member countries indicates that R&D spending for those countries totaled more than $536 billion dollars in the mid 1990s.[1] Approximately 60 per cent of the total, or $322 billion, was accounted for by the Group of Five (G-5) industrial countries, France, Germany, Japan, the United Kingdom and the United States. The United States alone accounted for 49% of the G-5 total and 30% of the OECD total. The remainder of the OECD total is accounted for by two large Pacific economies (Australia and New Zealand), the remaining countries of Western Europe except Luxembourg, and four additional economies, Greece, Mexico, the Republic of Korea and Turkey. Other developing economies and the economies in transition are missing from the list. Given the high concentration of R&D expenditures and the lack of data on a larger sample, the focus of much of the following discussion will be on the larger developed economies.

Governments and private firms finance more than 90 per cent of R&D in the OECD economies (OECD, 1997, p. 211). Although government funding has taken a large role in most OECD countries, the balance between government and private funding has shifted since the end of the 1980s. Private firms account for 60 per cent of total R&D funding in the OECD, based on data through the middle of the 1990s. Moreover, the shift towards private funding is most pronounced in the larger economies. A key question for policy analysis is whether this shift represents a temporary phenomenon, or is the result of long-run changes.

The rise in R&D prior to the 1990s

Research and development spending grew rapidly in the OECD economies from the 1960s through the 1980s, with annual growth rates generally exceeding that of gross domestic product (GDP). Spending on R&D grew particularly rapidly in the 1980s. As a result, the R&D intensity of output, measured by R&D as a share of GDP, also grew, from two per cent in 1981 to 2.4 per cent in 1990, before falling to 2.2 per cent in 1995-97 (OECD, 1999a, table 3.1). More recently, there are signs of renewed growth in the largest OECD economies (Payson, 1999; Stoneman, 1999).

The growth in R&D relative to economic output after World War II, and especially in the 1980s, can be attributed to a number of important changes. The transition to a "knowledge-based economy" (OECD, 1999b), or to "knowledge-societies" (Mansell and Wehn, 1998) is a widely accepted phenomenon in developed countries, and has become a target for developing and transitional economies. The growth in R&D intensity is often cited as one of the indicators of the emerging knowledge economy, but additional indicators, independent of R&D, also point in the same direction. There has been an increase in the knowledge content of production, especially in the developed economies, over time, skills have become more important in production and education levels have risen. Industries with a strong science base, such as chemicals, pharmaceuticals, electronics and aerospace, have grown in relative importance while other industries, such as automobile production, have incorporated more science-based elements. For example, computerized components have become prevalent in new automobiles. Thus, many economies have experienced a tendency for the portion of value added related to skills and knowledge applications to rise. And this implies a need for more R&D to pursue further advances in knowledge.

Second, there has been an increase in international competition over the course of the post-World War II period and this has stimulated investment in new technology as a competitive tool. Research and developed performed by businesses in OECD countries grew by an average of three per cent per year in the 1970s and five per cent in the 1980s (Guellec and Ioannidis, 1997, p. 124). Both exports and foreign direct investment (FDI) have grown more rapidly than GDP for the world economy as a whole, indicating a general tendency for the foreign content of domestic production to rise (UNCTAD, 1999). Exports and FDI are widely seen as a means by which technology is transferred internationally. The rapidly industrializing economies of East Asia, led by Japan, adapted new process and product technologies as a means of entering world markets. For example, the transistor was a product of R&D conducted in the United States but Japanese firms undertook the initial large scale applications to consumer products. Similarly, lean production techniques, which combined organizational and technical innovations, also originated in Japan but were partially drawn from production innovations developed elsewhere (Cusumanno, 1986). The economic success of these and other technological innovations, and continuing product and process innovations in both old and new industries, led firms throughout the world to expand their own technological efforts.

Third is a growth in government R&D activities. This is perhaps most visible in defense where the Cold War stimulated competition in military R&D. Both military production and the R&D intensity of military production reached levels that were higher than previously experienced outside of wartime. Governments also accepted a larger role in non-military R&D, in general science, health, transportation and other fields. This was partly an extension of the wartime experience, where war-related R&D contributed to civilian products such as computers, radar and jet aircraft, and partly to the expansion of government's role in fostering knowledge and combating poverty and inequality. There was a significant governmental presence in agricultural R&D in North America and some countries in Western Europe before 1940, and many countries had programmes supporting technical education and public health, but governmental R&D activities after 1945 were substantially larger and covered a wider range of issues.

The fourth factor may be labeled a measurement effect. Starting roughly in the 1920s and 1930s, and speeding up in recent decades, there has been a formalization of R&D. Whereas previously R&D occurred largely in the context of production, in the first half of the 20^{th} century firms, universities and governments began to treat R&D as a separate activity (Mowery and Rosenberg, 1999). Firms in such industries as chemicals established R&D departments (e.g., Hounshell and Smith, 1988), governments began funding R&D activities and supporting business-sector R&D with subsidies and tax credits, and universities increasingly trained R&D workers. This formalization, which expanded greatly in the second half of the century, undoubtedly led to activities being counted as R&D that previously would have been subsumed under production.

Why has R&D stagnated in the 1990s.

After expanding rapidly for more than three decades, R&D spending growth slowed markedly in the OCED economies during the first half of the 1990s. Spending on R&D grew more slowly than GDP, and in some countries R&D outlays actually fell in real terms. As a result, the share of R&D in total output fell for the OECD as a whole.

The most visible source of R&D stagnation in the 1990s is the drop in expenditures on military R&D. Data collected by the Stockholm International Peace Research Institute (SIPRI) indicates that real military R&D fell by 26 per cent between 1989 and 1995 (SIPRI, 1998). This substantial decline is largely due to the end of the Cold War and the sharp cutback in military appropriations in NATO countries and the member countries of the former Warsaw Treaty Organization (WTO). However, military R&D has not fallen as rapidly as overall military spending and the R&D intensity of military production remains high. Thus, if military production were to begin rising, military-related R&D will likely also grow.

In addition, government budget constraints limited public expenditure growth in many of the largest developed economies, as governments have sought to reduce or eliminate budget deficits. For some countries, such as the United Kingdom (van Reenen, 1997), this process began in the 1980s. It is often difficult to protect R&D from being a target of spending cuts. The benefits of R&D are far in the future so that the costs of making cuts in R&D programs will not be felt immediately.

Similarly, private sector cost-cutting may also restrict the growth of R&D. On top of the drop in R&D funded by governments, the growth of business funded R&D has been considerably lower in the first half of the 1990s than in the 1960s through the 1980s. Business-funded R&D grew by one per cent per year in the first half of the 1990s, compared with five per cent in the 1980s and three per cent in the 1970s (Guellac and Ionnidis, 1997, p. 124). Only three OECD countries saw their business sector R&D outlays grow more rapidly in the 1990s, Australia, Iceland and Ireland (Guellac and Ioannidis, 1997, pp. 124-5). As is the case in the public sector, firms under competitive pressures often cut those costs where the impacts will be felt furthest in the future. In addition, mergers and acquisitions of a horizontal nature can involve the consolidation of R&D, as the merged firms seek to leverage such activities. Thus, while increased international competition may push firms to utilize R&D to a greater extent, the cost-pressures that often result from competition can have the opposite effect.

Finally, firms may have experienced a decline in the rate of return from investment in R&D in the 1980s. A study of United States private sector R&D spending suggests such a phenomenon may have occurred (Hall, 1993). A decline in the rate of return to R&D suggests that R&D itself may have become less productive, possibly because R&D expanded faster than complementary productive inputs, thereby running into the law of diminishing returns.

Data since the mid-1990s and projections for the late 1990s indicates a significant recovery in R&D expenditures, largely the result of increased private sector outlays (OECD, 1999a, table 3.1; Payson, 1999). This recovery has been attributed to cyclical factors and suggests that, with government supplying a smaller share of total R&D funding, the time pattern of aggregate R&D spending may begin to resemble more closely other business investment outlays.

Economics of research and development

The economics of R&D is based upon the contribution of R&D to the level of productivity, and therefore to living standards, and its contribution to the rate of economic growth. In his empirical testing of the neo-classical theory of economic growth, Solow (1957) found that increases in the quantity of capital and labor explained only half of the economic in the United States. The remaining half, or the "residual" in Solow's estimating equation, was attributed to advances in the general state of knowledge. In the more than four decades following Solow's work, research in growth accounting has allocated some of this residual to specific factors, such as increases in education, improvements in efficiency, shifts in labor allocation from less productive to more productive activities, etc. The current consensus is about one-third of measured economic growth in developed economies can be attributed to improvements in knowledge (Cameron, 1996). Research and development also contributes to economic growth in developing economies (Birdsall and Rhee, 1993).

Research and development is an activity that contributes to advances in knowledge. As described by Nelson (1959, p. 299), "Scientific research may be defined as the human activity directed toward the advancement of knowledge," where that knowledge is both theoretical and empirical. Research and development encompasses a wide range of activities, including basic scientific research, research aimed at applying science to specific problems, and the development of specific products. Because of its role in the advancement of knowledge, and because aggregate data on R&D is thought to be better than alternative measures of knowledge, such as patents, diffusion indexes or international technology transfers, R&D has often been used as a measure to represent knowledge in empirical studies of economic growth. These studies have tended to conclude that R&D makes an important contribution to economic growth (Boskin and Lau, 1996; Cameron, 1996, Bayoumi, Coe and Helpman, 1998), although unresolved issues remain regarding the role of government, the relative importance of basic and applied R&D, and the mechanisms by which R&D is most effectively transmitted to economic growth (Cameron, 1996).

Why should government have a role in R&D?

The justification of a significant role for government in R&D is based upon the notion that private markets are unable to generate an optimal quantity of R&D. This failure of markets is thought to arise from three phenomena, the status of R&D as a public good, the presence of significant positive externalities in the production and distribution of R&D and the inability of capital markets to appropriately value the risk and information content of new ideas.

Public goods

The classic case supporting government expenditures on R&D is derived from the economic theory of public goods. A public good – which includes both goods and services – is one that will not be supplied by private, profit seeking firms and therefore can only be supplied by a governmental entity, a private not-for-profit institution, or a voluntary, private association. A public good has two essential properties (Stiglitz, 1999). One is that consumption of the good by a single user has no effect on the ability of any other user to simultaneously consume the good. The non-rivalrous character of a public good means that its marginal cost is zero, since no extra cost is involved in the production needed to satisfy the extra consumption. And since the well-known condition for economic efficiency is that marginal cost equals price, the most efficient price of a public good is zero. Private capital would not be attracted to a product with a zero price. Thus, the public sector or the private non-profit sector should either provide the capital, perhaps directly or via subsidies, or establish a system of incentives to stimulate private investment.

The second property of a public good is that no consumer can be excluded from its use, which means that no mechanism can be established to ration the good among potential users. A common example is national defense, where defense of a national territory cannot include only some residents and not others. In practical terms, this conditions means that the costs of establish a rationing mechanism is prohibitive in relation to the benefits. And if firms are not able to ration their output via price setting, they will not be able to appropriate profits. An example is the charging of tolls for the use of city streets. The direct costs of maintaining a system of toll booths and the indirect costs imposed upon users in terms of increased congestion make such a system economically infeasible. Perhaps in the future, with the development of low cost automobile recognition technology, such a system might be feasible, thereby creating the option of transforming a public good into a private good. Public goods are available to all, no individual can be excluded from their use and the consumption by one has no effect on the supply of the good to others. Another prominent example is knowledge, which also has the properties of being non-exclusionary and non-rivalrous. Because of these properties, private firms are unable to appropriate benefits from the production of knowledge, which means they have no incentive to allocate capital to this activity (Arrow, 1962). And since organized R&D is one of the means by which advances in knowledge occur, R&D is also thought to have public goods properties.

The examples mentioned above are illustrations of the concept of public goods but also of its limitations. While breathable air is a public good and a product of nature, its purity appears to be a function of how societies organize the technology of production. Polluted air is as much a public good as pure air. Some have employed the concept of a "public bad" to connote examples, such as that of polluted air, that detract from social welfare rather than add to it. National defense is an example of a product that is a public good on a national level but may not be on an international level (Gold, 1999). What one country does to enhance its national security may be perceived by another country as an aggressive act that reduces the national security of the second country. This is the familiar phenomenon of an arms race where, arguably, both sides are worse off as each takes independent actions to enhance its national security. Also, neighboring countries may benefit from the national defense posture of a large power without bearing the costs, known as the free-rider problem.

The application of the public goods concept to the production and dissemination of knowledge is also less than perfect. The ability to understand and apply advances in knowledge may require substantial prior investment in human and physical capital, as, for example, in scientific research, so that new knowledge is not available equally to all. These prior investments can be seen as a ticket of admission, permitting entrance to the arena of public goods. Thus, specific knowledge advances are more of a local public good, available to some but not all members of a society. Moreover, some knowledge can be priced and yield income, either alone or in conjunction with other goods. Books can be copyrighted and sold, providing a return to authors, publishers, distributors and retailers while at the same time the ideas contained in the books can be widely disseminated via libraries, classrooms, photocopied excerpts, the internet, etc. Advances in knowledge can be embedded in saleable products and thereby transformed into a private good. Thus, knowledge combines public goods and private goods properties. Knowledge should be thought of more generally as a class of activities in which the benefits tend to be greater than the costs since not all of the benefits can be appropriated by private firms. Thus, private firms will not produce knowledge up to the point where the marginal benefits equal the marginal costs, but will produce knowledge in a lesser amount. The tendency to underinvest in the production of knowledge can be attributed to the more general phenomena of externalities, of which public goods can be seen as a special case (Cornes and Sandler, 1996).

Externalities

An externality exists when some of the benefits (or costs) emanating from a transaction accrue to those who are not party to the transaction. Air, water and noise pollution that result from private production and consumption are common examples of negative externalities, or external costs. Air and water pollution are also examples of transnational negative externalities. Another example is over fishing in international waters, an illustration of the well-known “tragedy of the commons.”

Research and development provides numerous examples of external benefits, or positive externalities. (Not that R&D doesn’t also yield external costs; the tobacco industry would appear to provide examples of the latter). The research results in one firm frequently “spill over” and contribute to the knowledge base of other firms. Similarly, the knowledge generated by R&D can spill across industries and across countries. Evidence of positive externalities from R&D can be found in a wide range of empirical studies. Social rates of return to investment in R&D, that is, the annual rates of return experienced by industries, countries, or regions of the world economy resulting from investment by firms, are consistently higher than private rates of return, and often by a factor of two or more (Griliches, 1992; Nadiri, 1993; Fuglie et al, 1996; Hall, 1996; Jones and Williams, 1998). International spillovers are also important (Schimmelpfenning and Thirtle, 1999). One recent empirical study (Bayoumi, Coe and Helpman, 1998) found that a simulated increase in United States R&D expenditures had a substantial positive impact on GDP growth rates in other developed economies, and in developing countries. This came about both because of the spread of knowledge emanating from United States R&D, and because greater R&D efforts stimulated investment in physical and human capital.

Rates of return on government R&D investments are also thought to be high (Salter and Martin, 1999) but are varied, being substantial in some sectors, such as agriculture (Fuglie et al, 1996), and low or possibly even negative in others, such as defense (Guellec and van Pottelsberghe, 1997). A negative rate of return could occur if a government activity with low returns draws resources from private R&D with high returns. Government R&D will be undertaken with a variety of objectives, not just maximizing pecuniary returns; low measured returns to government R&D may be a consequence of the inability to fully measure the value of government output. In the case of defense R&D, there have been periods when such investment appears to have had substantial positive economic impacts. An important example is the computer industry in the 1940s and 1950s (Flamm, 1998).

Empirical research on the economic effects of R&D has tended to find that the private rate of return to investment in R&D is generally higher than the rate of return on investment in physical or human capital. The high rates of return to R&D investment relative to physical and human capital can be explained by two factors. The first is that R&D is generally a type of investment with greater risk and uncertainty than either physical or human capital investment. Research and development is, by definition, the exploration of the unknown, or at least "little-known", and this translates into a wider range of possible outcomes than for other types of investment. Investors will tend to gravitate towards R&D projects with higher expected returns, to compensate for the extra risk. The second factor is that firms will tend to underinvest in R&D because of the appropriability problem, that is, because firms cannot capture all of the potential revenues that would result from their R&D outlays. The excess of social returns to private returns is evidence of this under investment.

The rates of return to investment in R&D are average returns based upon past investments. Application of the law of diminishing returns suggests that additional investment in R&D relative to human and physical capital should produce lower returns than past investments, but data on average returns do not give information on how rapidly the returns would fall. Thus, they are an imperfect guide to how much additional R&D investment would be optimal. In addition, estimates of private and social returns are subject to a number of measurement problems that make it difficult to establish the quantitative dimensions of the relative externalities (Hall, 1996).

Moreover, while the gap between social and private returns suggests that additional investment would be optimal, it does not provide guidelines as to whether that investment should be undertaken by public agencies, or whether policies should be adopted to increase investment by private firms. If the latter, then account must be taken of the input-output relations in the economy. The fruits of R&D represent outputs for some firms and inputs for others. If a greater proportion of R&D is internalized, presumably a higher proportion of R&D would be subject to market pricing, thereby imposing higher costs on those firms using the results of R&D as inputs. Thus, the expansion of R&D by some firms may lead to a reduction in R&D by others. Information on the cross-elasticities of response would be needed to evaluate this effect.

Capital market failures

A third rationale for government intervention in R&D is derived from the idea that informational asymmetries make it difficult to finance R&D through private capital markets. Research and development is, by its definition, an exploration of uncertainty. The firm undertaking an R&D project is likely to have significantly more information about the project than either competitors or lenders. A firm seeking a loan must divulge that information, but to do so runs the risk of releasing it to potential competitors. Thus, firms tend to release less information than would be required to fully obtain needed capital. In addition, R&D projects tend to be riskier than other forms of investment and capital markets tend to undervalue risk. Finally, R&D projects tend to have longer pay-back periods than other forms of investment. Applying discount rates lowers the present of value of returns the farther into the future they occur. Yet many of the returns from R&D are long-lasting, suggesting a systematic tendency to undervalue the future.

Market institutions may be capable of segmenting capital markets to meet at least some of the needs of high-risk borrowers. In the United States, a venture capital industry specializes in funding start-up enterprises and is one of the reasons the United States has been successful in funding technologically innovative companies. However, such activities are not present in most countries, suggesting the existence of a substantial market failure and a continuing need for some governmental role. Also, in the United States context, there needs to be research on the effects of venture capital in the context of overall work on R&D.

Forms of government involvement

The failure of markets to optimally allocate R&D resources provides a general rationale for government actions. In addition, empirical research has reinforced the conceptual conclusions that societies underinvest in R&D. However, providing a rationale for government activity is not the same as determining either the size or form of governmental involvement. Governments have entered the R&D arena in a variety of ways. What follows is a brief description of three types of policies that have been tried.

Public spending on R&D

Governments are the second largest funders of R&D, behind private enterprise. Most government spending is in the form of contracts to private firms or to private not-for-profit institutions, such as universities, to perform specific R&D projects. One of the issues raised by government spending on R&D is how that spending can be most effective in its economic impact. Government spending is often thought to be most effective when it funds basic research, since basic research is general and can have a wide range of specific applications. Applied research and development is more specific. This is one of the reasons that defense and space R&D is thought to be less economically productive than government supported R&D that supports consumer-oriented industries, such as health care or pollution abatement. A similar point underlays the distinction between mission-oriented R&D and diffusion-oriented R&D (Ergas, 1988). While such distinctions appear to be useful, one difficulty is that the line between basic and applied research is not always clear. The progression from basic to applied is not necessarily un-directional, and there are numerous examples of basic research being fostered by work on applied problems.

Government spending can also affect R&D if the government provides a market for products, and firms engage in R&D as a means to serve this market (Flamm, 1998). As governments buy a wide variety of products, and, as in the case of health care, frequently underwrite private sector demand, this induced effect is undoubtedly significant.

Incentives

Governments also influence R&D by changing the incentives firms face. The market-based incentive system tends to produce sub-optimal outcomes because firms do not internalize enough of the returns to justify higher investments. Government actions can increase the internal returns for firms. One common and increasingly popular method of doing this is through the tax system. By tying reduced tax payments to the undertaking of R&D expenditures, the government effectively lowers the cost and increases the rate of return for private investment in R&D, giving firms an incentive to expand their R&D investments. Tax incentives appear to have produced a substantial positive impact on R&D investment (Hall and Van Reenen, 1999).

For many advocates, tax incentives have the advantage of allowing private firms to select R&D projects, giving a market-based outcome. It also means that firms have an incentive to classify a greater proportion of their activities as being eligible for the R&D tax credits. To the extent this happens, R&D spending is exaggerated and the effectiveness of tax incentives is weakened. In addition, the use of tax incentives leaves the choice of R&D projects with firms. This is seen a benefit in terms of allowing private markets to work, but could reduce the ability of governments to achieve some of their objectives.

Collaborative arrangements

Over the last several decades, firms throughout the OECD economies, and in many developing countries and economies in transition, have increasingly formed alliances with other firms, especially in technology-intensive industries (Narula and Hagedoorn, 1998; Hagedoorn and Sedaitis, 1998), and frequently focussed on R&D (Aldrich and Sasaki, 1995; Vonortas, 1997). These alliances have been formed in part due to the rapidly rising costs of developing new products and processes, and the shortening life cycles of new product. Trends such as these increase the risks to firms associated with product introduction, and lead firms to try and pool these risks through alliances. Alliances also supposedly enable firms to capture more of the external benefits of R&D, and make it easier to exploit economic of scale. In addition, alliance permit firms to achieve a global presence without having to place as much capital at risk.

Governments have come to support R&D alliances to a greater extent (Sakakibara, 1997). In some instances, for example the Eureka programme in Western Europe, Sematech in the United States and the activities of the Ministry of International Trade and Industry (MITI) in Japan, governments have been very active. Other government policies have been less active, but are still important such as allowing alliances to proceed in the presence of anti-monopoly policies. Government policies have also encouraged alliances between private firms and universities, and private firms and government operated R&D facilities (Mowery, 1998).

The social and economic benefits of R&D alliances are only beginning to be analyzed (Mowery, 1998), and many questions remain as to whether the institutional relationships are adequate to realize the potential benefits. One issue that has been raised is whether, and how, such alliances, since they frequently are transnational in nature, affect a national economy. The effects of alliance on the quantity and quality of transnational technology flows is only beginning to be studied.

One criticism of government’s role in fostering inter-firm collaborative R&D arrangements is that a government might favour certain firms on political rather than economic grounds. This is the notion of government capture, and is undoubtedly valid in many instances. The possibility of a policy apparatus being captured by the firms being regulated or subsidized is real enough that policy initiatives need to have safeguards built in that would make such outcomes more difficult to achieve.

Conclusions

This report has surveyed data on recent trends in R&D spending, the arguments for a governmental role in R&D and specific examples of government policy towards R&D. The basic conclusion is that the arguments and evidence support the existence of substantial market failures in the production and distribution of R&D. These market failures provide a rationale for formulating government policies to encourage R&D. There is also evidence supporting the existence of positive inter-relationships between government and private activities in R&D (Narin, Hamilton and Olivastro, 1997). At the same time, there are a number of aspects of government's effects on private R&D that need further research.

The evidence and arguments in support of government's role in R&D don't necessarily provide clear guidance as to how to formulate specific policies (Salter and Martin, 1999). Thus, another area where additional research is needed is in matching economic knowledge with ideas about policy formation.

Endnote

[1] The OECD data is collected in national currencies, converted to dollars using purchasing power parity exchange rates, and deflated using the United States GDP deflator. The figures cited in the text are obtained by cumulating individual country observations for 1994, 1995, or 1996, the latest data published. See OECD (1998a).

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