Why and How Governments Support R & D

Gordon Lenjosek and Mario Mansour*

PRÉCIS

Cet article comporte trois principaux volets. D'abord, il établit le bien-fondé économique de l'aide gouvernementale à la recherche et au développement (R & D), en examinant brièvement les théories économiques qui relient la R & D et la croissance économique, en identifiant l'échec du marché qui entraînerait par ailleurs des investissements insuffisants dans la R & D, et en présentant l'estimation de l'ampleur de l'échec du marché. Ensuite, les moyens pris par les gouvernements pour aider à la R & D sont examinés dans l'article, qui met l'accent sur la description et la comparaison des encouragements fiscaux à la R & D accordés dans les pays du G7 et en Australie et qui comprend une évaluation de l'intérêt relatif de ces mécanismes d'appui fondés sur la fiscalité. Finalement, il contient un bref commentaire sur l'efficacité des encouragements fiscaux à la R & D à stimuler des dépenses additionnelles en R & D, par dollar de recettes fiscales perdu, et à majorer le revenu réel.

ABSTRACT

This article has three main objectives. First, it establishes the economic rationale for governments to assist research and development (R & D) by briefly reviewing the economic theories that link R & D and economic growth, identifying the market failure that would otherwise lead to underinvestment in R & D, and reporting literature estimates of the size of that market failure. Second, the article considers ways in which governments assist R & D. In particular, it focuses on describing and comparing the income tax incentives for R & D available in the G7 countries and Australia, and provides a ranking of the relative attractiveness of those tax-based support mechanisms. Third, the article comments briefly on how well tax-based R & D incentives have been

* Of the Business Income Tax Division, Department of Finance, Ottawa. We wish to thank Donald MacDonald for his helpful suggestions. This article draws on information obtained through an evaluation of federal income tax incentives for R & D in Canada conducted by the Department of Finance and Revenue Canada. Others who contributed to the evaluation report, released in December 1997, include Louis Beauséjour, Jutta Elbe, Alan Forsythe, Gordon Hawkes, Karen Kirby, Cassaundra Iwankow, Clinton Lawrence-Whyte, André Paquin, and Munir Sheihk. The views expressed in this article are the responsibility of the authors alone.

found to perform in stimulating additional R & D spending per dollar of tax revenue forgone and in enhancing real income.

INTRODUCTION

Research and development (R & D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture, and society, and the use of this stock of knowledge to devise new applications. This work may take the form of basic research, applied research, or experimental development.[1]

R & D produces technology, a form of knowledge that is used to enhance the productivity of factors of production and economic growth and, ultimately, to improve living standards. Like other forms of capital, technology can be stored, be sold as a good or service, depreciate, and become obsolete. Technology can be used, in combination with other factors of production, to improve existing production processes or create new ones, and to increase the quality and variety of goods and services available for consumption.

The advancement of technology in production has long been recognized as an important factor underlying economic growth. However, the process by which technology is created and spread in an economy, the magnitude of its contribution to economic growth, and the role governments can play in its advancement are less well understood.

This article has three main sections. The first establishes the economic rationale for governments to assist R & D. It does this by briefly reviewing the economic theories that link R & D and economic growth, identifying the market failure that would otherwise lead to underinvestment in R & D, and reporting literature estimates of the size of that market failure. Following from the rationale for government support, the second section of the article considers alternative mechanisms used by governments to assist R & D. In particular, it focuses on comparing the income tax incentives for R & D available in the G7 countries and Australia, and provides a

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[1] Organisation for Economic Co-operation and Development, *Frascati Manual 1993—The Measurement of Scientific and Technological Activities: Proposed Standard Practice for Surveys of Research and Experimental Development* (Paris: OECD, 1994), 29-45. Chapter 1 of the manual discusses the distinction between R & D and other closely related activities that can be grouped more broadly under the headings of scientific and technological activities and scientific and technological innovation. Scientific and technological activities comprise systematic activities that are closely concerned with the generation, advancement, dissemination, and application of scientific and technical knowledge in all fields of science and technology. These include such activities as R & D, scientific and technical education and training, and scientific and technological services. Scientific and technological innovation may be considered as the transformation of an idea into a new or improved product introduced on the market or a new or improved operational process used in industry or commerce. Innovations involve a series of scientific, technological, organizational, financial, and commercial activities. R & D is only one of these activities and may be carried out at different phases of the innovation process.

ranking of the relative attractiveness of those tax-based support mechanisms. The third section comments briefly on how well tax-based R & D incentives have been found to perform in stimulating additional R & D spending per dollar of tax revenue forgone and in enhancing real income. An appendix to the article contains a more detailed description of the income tax support for R & D in the G7 countries and Australia.

THE NEED FOR GOVERNMENTS TO SUPPORT R & D

R & D and Economic Growth

Economic data show increases in real income per capita[2] for prolonged periods in many countries, and varying growth patterns in different historical periods both within particular countries and among countries. Empirical studies suggest that economic growth is not a random process. Rather, it is affected by a multitude of economic, social, and political variables. From a theoretical perspective, these facts need to be explained. This is the purpose of growth theories.

An economic growth theory can be defined as the identification and study of factors underlying the long-run growth of real income per capita. All theories depend on simplifying assumptions that may change over time and vary across economies, and there is no one theory that can fully explain growth. Existing models of economic growth can be classified into two main schools of thought: neoclassical growth theory and endogenous growth theory.[3]

Neoclassical Growth Theory

The neoclassical theory of economic growth, as first formalized by Solow,[4] is based on the accumulation of physical capital[5] as the key factor underlying growth in a perfectly competitive economy with constant returns to scale[6] and an exogenous savings rate assumed to be a constant fraction of

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[2] Real income per capita is obtained by dividing the total value of goods and services produced in a year (that is, gross domestic product) by an inflation index representing the average price of those goods and services, and then by population.

[3] Although the discussion focuses on research since the early 1950s, it should be noted that classical 19th-century economists such as Mill and Marx studied growth based on physical capital accumulation. One of their main conclusions was that, since resources are limited and the marginal return to capital decreases as the capital-labour ratio increases, the only way growth can be sustained is through improvements in production (that is, technological advancement). Both the neoclassical and endogenous growth theories build on these ideas to formally incorporate R & D in their models.

[4] Robert M. Solow, "A Contribution to the Theory of Economic Growth" (February 1956), 70 *Quarterly Journal of Economics* 65-94.

[5] Physical capital includes machinery, structures, and inventory, and differs from "R & D capital." The latter includes highly skilled, or very specialized, labour as well as physical capital for R & D.

[6] A production process is said to have constant returns to scale if the average cost of production remains constant as production changes. Increasing (decreasing) returns to

(The footnote is continued on the next page.)

total national income. The dynamics of the neoclassical theory in the absence of technological progress are as follows. The economy starts at a low capital-labour ratio. New capital (net of depreciation) is paid for out of aggregate savings. Because of diminishing marginal returns to capital, as the capital-labour ratio rises, the marginal product of capital falls and so does the incentive to invest in new capital. Therefore, each additional unit of capital generates less return and less savings, which in turn means that less income is available for capital accumulation. In the long run, the capital-labour ratio reaches a level where the return to capital equals its depreciation—savings are sufficient only to pay for the physical depreciation of capital and there is no incentive to invest in new capital. Capital accumulation and growth cease, and the economy is in a long-run steady-state equilibrium.

Technological progress enters neoclassical growth theory as an exogenous factor that grows at a constant rate and is essential to economic growth in the long run. The advancement of technology enhances the productivity of labour so that the marginal product of capital does not decline as the capital-labour ratio increases. In the long run, as there is no upper limit to the growth of technology and thus to the growth in labour productivity, the growth rate of real income per capita does not decrease to zero. Economic growth is therefore sustainable; the long-run growth rate is equal to the assumed constant growth rate of technological progress.[7]

The assumptions underlying the neoclassical theory imply that resources are allocated efficiently in the economy. This means that it is not possible to change that allocation and make one person better off without at the same time making at least one other person worse off. Therefore, there is no reason on efficiency grounds for government intervention in such an economy. Any policy that affected the allocation of resources would decrease total output and retard economic growth. However, government intervention could still be based on the criterion of equity. For example, a change in the distribution of income might be pursued to achieve a social policy objective. In this case, the relative merit of the intervention would be assessed by comparing the resulting loss in efficiency and gain in equity.

Criticisms of the Neoclassical Theory

Assumptions underlying neoclassical growth theory have been criticized as being unrealistic. Technological change is not always an exogenous factor outside the market and determined by an unknown process; many discoveries and technological improvements in production that significantly increased living standards in the 20th century were made in the commercial sector by firms seeking profits and not by governments or

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[6] Continued . . .
scale means that the average cost of production decreases (increases) as production increases (decreases).

[7] This discussion abstracts from population growth.

universities in which research is driven by non-market forces.[8] Markets are rarely perfectly competitive; they are often characterized by imperfect competition, increasing returns to scale, and asymmetric information. Moreover, not all desired goods and services can be produced by the private sector; some are public goods, and some produce externalities that benefit or cost other individuals in society. In all these cases, marginal-cost pricing, which is the key characteristic of perfect competition, is not feasible and markets fail to allocate resources efficiently.

Before proceeding to discuss how these criticisms are addressed in endogenous growth theory, it is important to describe briefly the concepts of asymmetric information, public goods, and externalities, given their implications for economic growth theories and the rationale for government intervention in a market economy.

Asymmetric information, also called the principal-agent problem, occurs when one party in a transaction has information that the other party does not possess or must incur a high cost to obtain. For example, a borrower may have information about his/her probability of defaulting on a loan that is not available to the lender. A car insurer may have several clients with different risk patterns; some of the clients may take specific actions to reduce the probability of having an accident while others do not. In such situations, it is possible that a market does not materialize because buyers and sellers cannot agree on a price and a quantity owing to the information gap. It is also possible that an incomplete market results in which the equilibrium quantity is lower than would be the case in a competitive equilibrium.

Public goods are characterized by non-rivalness and non-excludability. The first property means that the use of a public good by one individual or firm does not prevent other individuals from using it simultaneously, either partially or entirely. The latter means that it is impossible, or at least prohibitively costly, to prevent particular individuals from using such goods. Examples of public goods are radio waves and national defence.

Externalities (also called spillovers) arise when actions taken by one individual or firm affect (or spill over on), negatively or positively, the well-being of other individuals. Typically, externalities are not taken into account in the pricing of commodities because they do not affect the cost or revenue structure of the producer; society as a whole bears their effects. Air and water pollution are examples of negative externalities since they impose a cost on society. Spillover benefits associated with R & D are examples of positive externalities.

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[8] See, for example, "Innovation: The Machinery of Growth," *The Economist*, January 11, 1992, 17-19.

Endogenous Growth Theory

The endogenous growth theory relaxes many of the neoclassical assumptions to incorporate market imperfections such as those mentioned above.[9] However, as in the neoclassical models, long-run economic growth is driven by the accumulation of knowledge-based factors of production such as human capital, learning by doing, R & D, and innovation.[10] In the long run, it is the accumulation of these factors that causes factor productivity to continue to increase and prevents the marginal return to physical capital from falling below profitable levels.

Endogenous growth theory assumes that technological advancement is the result of R & D undertaken by profit-maximizing firms. R & D enters the production process as a factor of production and is used in conjunction with other inputs. As with any investment decision, R & D is not undertaken unless there is an opportunity for profit.[11]

The assumption that the determinants of long-run growth are endogenous to the decision-making process of the firm is a major departure from the neoclassical growth theory and has important policy implications. Indeed, if long-run growth is driven by knowledge-based factors of production that are part of the normal cost structure of the firm, then by changing the cost of those factors through, for example, direct subsidies, tax incentives, or trade policies, governments can influence long-run growth.[12]

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[9] Paul M. Romer, "The Origins of Endogenous Growth" (Winter 1994), 8 *The Journal of Economic Perspectives* 3-22, reviews the origins of the endogenous growth theory and discusses the theoretical and practical implications of the assumptions underlying neoclassical and endogenous growth models. Important contributions to endogenous growth theory include Paul M. Romer, "Increasing Returns and Long-Run Growth" (October 1986), 94 *The Journal of Political Economy* 1002-37; Paul M. Romer, "Endogenous Technological Change" (October 1990), 98 *The Journal of Political Economy* S71-102; Robert E. Lucas, "On the Mechanics of Economic Development" (July 1988), 22 *Journal of Monetary Economics* 3-42; Gene M. Grossman and Elhanan Helpman, *Innovation and Growth in the Global Economy* (Cambridge, Mass.: MIT Press, 1991); and Philippe Aghion and Peter Howitt, "A Model of Growth Through Creative Destruction" (March 1992), 60 *Econometrica* 323-51.

[10] Pierre Fortin and Elhanan Helpman, *Endogenous Innovation and Growth: Implications for Canada*, Occasional Paper no. 10 (Ottawa: Industry Canada, 1995), discuss these knowledge-based factors of production and their contributions to production and economic growth.

[11] In practice, R & D is financed and performed by both profit-seeking and public institutions. Statistics Canada reports that 48 percent of total R & D in Canada in 1996 was financed by the private sector and 62 percent was performed by it; the rest was financed (52 percent) and performed (38 percent) by governments, universities, and private non-profit institutions. See (August 1997), 21 *Science Statistics*, Statistics Canada catalogue no. 88-001-XPB.

[12] Government policies such as procurement policies may also target the products rather than the factors of production of R & D activities.

The Contribution of Technological Progress to Economic Growth

Economic growth theories provide a framework for analyzing growth and its determinants. Such a framework can also be used to study the impact of government policies on economic growth and investment in R & D. However, it does not allow for quantification of the contribution of R & D and other knowledge-based investments to economic growth. This is a complex measurement issue that is subject to data observability, availability, and quality.[13]

Unlike tangible capital, which has well-developed markets, the price of knowledge can rarely be determined with any degree of accuracy. In addition, knowledge is time cumulative and produces externalities that cannot be captured in market prices. Because of these difficulties, the contribution of knowledge-based investments to economic growth is not measurable. However, an indication of this contribution can be obtained by subtracting the growth in factors of production from the growth in gross domestic product (GDP); the remainder is termed the "Solow residual" and is a measure of total factor productivity (TFP).[14]

There is an abundant literature on the measurement of TFP and the contribution of R & D to economic growth.[15] For example, macroeconomic research has used TFP to investigate the reasons behind the decline in the growth of real income per capita in developed countries since 1974. One possible explanation for this phenomenon is a decline in the contribution of technological progress to growth in labour productivity, which in turn constitutes the largest component of growth in real income per capita. Fortin and Helpman[16] estimate that growth in labour productivity in Canada accounted for 60 percent of the growth in real income per capita over the period 1960 to 1993, and that approximately 50 percent of the growth in labour productivity over this period was due to technological progress.[17]

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[13] See, for example, Zvi Griliches, "Productivity, R&D, and the Data Constraint" (March 1994), 84 *The American Economic Review* 1-23.

[14] Griliches, ibid., and Grossman and Helpman, supra footnote 9, at chapter 1, discuss problems relating to the interpretation and measurement of TFP. TFP can be calculated for the entire economy, for specific sectors, and for industries.

[15] This literature is reviewed in Pierre A. Mohnen, *The Relationship Between R&D and Productivity Growth in Canada and Other Major Industrialized Countries*, a study commissioned by the Economic Council of Canada (Ottawa: Canada Communications Group, 1992).

[16] Supra footnote 10.

[17] Other components underlying the growth in real income per capita are the ratio between gross national income and gross domestic product (which accounts for payments to non-residents on their investments in Canada), the terms of trade or the ratio of export prices over import prices, the employment rate, the labour force participation rate, and the working-age ratio. In comparison with 60 percent for labour productivity, the contributions of these components to growth in real income per capita over the 1960-1993 period were approximately −2 percent, 5 percent, −7 percent, 21 percent, and 25 percent, respectively. For more detail, see Fortin and Helpman, supra footnote 10.

The authors also note that the dominance of labour productivity as a contributing factor to economic growth in Canada, and more generally in developed economies, is likely to become stronger relative to other factors whose growth either has come to a halt in the last decade or has been declining. Although empirical studies generally report positive estimates for the contribution of R & D to economic growth, debate about the level of such estimates is still ongoing among economists.[18]

Inappropriability and Market Imperfections

Economic theory and empirical evidence indicate that technological progress, through its impact on factors of production, is a key determinant of long-run economic growth; indeed, for some countries, it is the most important determinant. However, this does not in itself provide an economic justification for government intervention to reallocate resources in favour of R & D. Government intervention in a market economy is usually justified by the market's failure to provide an efficient or socially desirable allocation of resources. In the case of R & D investment, market failure is evidenced by the presence of externalities and market imperfections, the effects of which extend not only beyond individual firms but also beyond a country's borders.

Public finance theory classifies goods and services according to two criteria: rivalry and excludability. As noted earlier, a good is rival if its use by one individual prevents others from using it; it is excludable if it is possible to exclude others from using it. The two concepts of rivalry and excludability are not mutually exclusive. A rival good is excludable; a non-rival good may or may not be excludable depending on its nature and the cost that the owner must incur to exclude others from using it. If a good is non-rival and at least partially non-excludable, then it is inappropriable; that is, other individuals can benefit from the owner using that good at no cost to them.

Inappropriability of a good leads to its underproduction in a market economy. This is a result that flows directly from the microeconomics of the firm. A firm will not invest in a project if it knows it cannot appropriate the potential revenues. However, if some portion of the revenues is appropriable, then the firm will invest if that portion is sufficient to make the investment profitable. The quantity that is not produced depends on the degree of inappropriability. Other things equal, perfect inappropriability leads to the absence of production by private decision makers and perfect appropriability leads to efficient production.

Underproduction owing to inappropriability is a form of what is generally known as market failure; left alone, the market will not allocate an

[18] See, for example, Michael J. Boskin and Lawrence J. Lau, "Contributions of R&D to Economic Growth," in Bruce L.R. Smith and Claude E. Barfield, eds., *Technology, R&D and the Economy* (Washington, DC: Brookings Institution and American Enterprise Institute, 1996), 75-113, who argue that, depending on how one measures labour and capital, TFP estimates in the United States can be quite low.

efficient quantity of resources to the production of an inappropriable good. Market failure is a criterion used by economists and policy makers to justify government intervention in a market economy.

It is well known that technology, and knowledge in general, are not fully appropriable in a market economy;[19] once produced, at least part of it can be obtained at no cost. The price that buyers actually pay to acquire a technology is usually lower than the price that they would be willing to pay had the technology been fully appropriable by its developer. The difference between these two prices is called the spillover benefit (or spillover). Therefore, technology is not a pure private good; there is an incompatibility between its production, which may be based on private decision making, and its dissemination, an activity whose benefits extend beyond the producer to society as a whole.[20]

Asymmetric information and imperfect competition are other types of market imperfections that lead to underinvestment in R & D.[21] It has been argued that asymmetric information distorts an efficient functioning of capital markets; for example, it can lead to credit rationing, and to R & D investments in projects with a high probability of success being abandoned because of financing difficulties, while those in projects with a low probability of success are financed and carried on. Himmelberg and Peterson[22] show that R & D is funded primarily by internal sources because asymmetric information limits external financing.

Empirical Evidence on Spillovers

There have been many empirical studies on R & D spillovers (or the difference between private and social rates of return to R & D investment) especially since the mid-1980s. These studies, which focus mainly on manufacturing and high-tech industries, show that spillovers exist between different R & D projects within the same firm, between firms operating in the same industry, between different industries (intra- and interindustry spillovers), and between countries.

Generally, two types of econometric models are used to investigate R & D spillovers. The first involves estimating the parameters of production

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[19] An extreme example is a technology that is an idea. It is very difficult to prevent its dissemination; the marginal cost of reproducing it is zero; and others can use it without paying. The protection of intellectual property rights through, for example, the use of patents is only a partial remedy to the free rider problem caused by the inappropriability of technology.

[20] For more on inappropriability, see Romer, "Endogenous Technological Change," supra footnote 9.

[21] Don G. McFetridge, *Science and Technology: Perspectives for Public Policy*, Occasional Paper no. 9 (Ottawa: Industry Canada, 1995), reviews the literature on the various types of market failure and their potential impact on R & D investment.

[22] Charles P. Himmelberg and Bruce C. Peterson, "R&D and Internal Finance: A Panel Study of Small Firms in High Tech Industries" (February 1994), 76 *The Review of Economics and Statistics* 38-51.

functions that include not only labour and capital, but also R & D capital as an input. The second involves estimating cost functions in which the cost structure depends on variables such as output, factor prices, and R & D capital. Subject to data availability and quality, the parameters of these functions can be estimated using project, firm, industry, or economy-wide data. Once the spillover parameter has been estimated, social rates of return can be calculated; in the case of firm-level data, for example, this is done by adding to the private rate of return to an industry the marginal spillover benefits that accrue to all other industries.[23]

Econometric analyses of social versus private rates of return to R & D investments and R & D spillovers in manufacturing and high-tech industries yield the following general results:[24]

• Private rates of return to R & D investments are generally higher than those observed for other capital investments.

• Social rates of return to R & D investment can be up to five times higher than private rates of return; the size of the spillover benefits varies significantly.

• Social rates of return on basic R & D are higher than those on applied R & D.

• Public R & D yields lower rates of return than private R & D, but higher rates of return than public infrastructure capital.

• R & D spillovers reduce variable costs and enhance productivity; the magnitude of the results depends on whether the sample studied is at the firm level or the industry level. Similar qualitative results were found in project-level samples within firms.[25]

• R & D spillovers contribute to output expansion and to output price reduction.

• R & D spillovers are generally partial substitutes for labour and materials, but complements to capital (other than R & D capital). This means that spillovers reduce the demand for labour and material, and increase the demand for capital. Since the major component of R & D capital is skilled labour, the substitution effect that acts on the demand for labour should be seen, at least in part, as one that reduces the demand for unskilled labour in favour of that for skilled labour.

• R & D spillovers induce an increase in R & D capital investment in R & D capital-intensive firms but act as a substitute for R & D capital in

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[23] Jeffrey I. Bernstein, *International R&D Spillovers Between Industries in Canada and the United States*, Working Paper no. 3 (Ottawa: Industry Canada, 1994), reviews various functional forms estimated in the literature.

[24] Unless otherwise indicated, these results are based on the reviews by McFetridge, supra footnote 21, Bernstein, supra footnote 23, and Mohnen, supra footnote 15.

[25] Rebecca Henderson and Iain Cockburn, *Scale, Scope and Spillovers: The Determinants of Research Productivity in the Pharmaceutical Industry*, Working Paper no. 4466 (Cambridge, Mass.: National Bureau of Economic Research, September 1993).

firms where R & D capital investment forms a small portion of total investment. However, at the industry level, spillovers are generally a substitute for the R & D investment of the recipient industry.

- R & D spillovers in one country contribute to productivity gains in other countries. These international spillovers are a function of trade and other relations (for example, educational and cultural) that countries maintain with each other.[26] Moreover, the direction of productivity gains induced by international R & D spillovers is from large R & D-intensive economies to small open economies that are less intensive in R & D.[27] In other words, economies that spend a relatively low proportion of their GDP on R & D (such as Canada) benefit more, through cost reductions and productivity increases, from international spillovers than those that spend a relatively higher proportion (such as the United States and Japan).

McFetridge[28] reviews case studies of specific R & D projects, R & D processes, and new products that result from R & D investment. The results he reports on productivity gains and the gap between private and social rates of return to R & D investment are similar to those found in econometric studies.

HOW GOVERNMENTS SUPPORT R & D

As shown in the previous section, R & D produces technology, a form of knowledge that is used to enhance the productivity of factors of production. Economic theory indicates that technological progress, primarily through its impact on labour productivity, is a key determinant of the longer-term growth of an economy.

The economic rationale for governments to assist R & D is that the benefits of R & D spill over, or extend beyond the performers themselves, to other firms and sectors of the economy, and the value of these benefits is not fully appropriable by the R & D performer. These "spillover benefits" mean that, in the absence of government support, firms would perform less R & D than is desirable from the economy's point of view. Markets fail to allocate an efficient or socially optimal quantity of resources to the performance of R & D.

The empirical evidence shows that R & D spillovers exist among projects, firms, industries, and countries and that social rates of return to

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26 Grossman and Helpman, supra footnote 9, at chapter 9, discuss the implications of international interdependence for R & D investment and government policies.

27 See also Jeffrey I. Bernstein and Xiaoyi Yan, *International R&D Spillovers Between Canadian and Japanese Industries*, Working Paper no. 5401 (Cambridge, Mass.: National Bureau of Economic Research, December 1995); Jeffrey I. Bernstein and Pierre Mohnen, *International R&D Spillovers Between U.S. and Japanese R&D Intensive Sectors*, Working Paper no. 4682 (Cambridge, Mass.: National Bureau of Economic Research, March 1994); and David T. Coe and Elhanan Helpman, *International R&D Spillovers*, Working Paper no. 4444 (Cambridge, Mass.: National Bureau of Economic Research, August 1993).

28 Supra footnote 21.

R & D investments can be significantly higher than private rates of return. This confirms the non-excludability of technological progress and the failure of the market to allocate an efficient quantity of resources to R & D investment. From a policy perspective, the need for R & D incentives is clear; the issue for policy makers is to determine their magnitude and forms.

The governments of many countries provide support for R & D. This support takes a variety of forms. The decision as to which form to use depends on two elements: the nature of the market failure and the policy objectives pursued by particular countries. In most cases, market failure results from some combination of market imperfections such as inappropriability, imperfect competition, and asymmetric information. In most cases, the policy response to a market failure is some combination of regulatory and fiscal support.

This section does not address the question of the forms assistance for R & D should take, the appropriate balance between alternative forms of assistance, or whether assistance should be broadly based or targeted. Such questions are beyond the scope of this article. Rather, the discussion considers the general characteristics of alternative forms of government support, specific income tax mechanisms used internationally to support R & D, and the relative level of assistance provided by those tax-based support mechanisms.

Forms of Government Support

In terms of regulation, governments rely on patents and other measures to protect intellectual property rights as a partial remedy to the free rider problem caused by the inappropriability of technology, particularly for technologies that are specific to the production of a particular good or substitutes. Providing monopoly power to R & D performers reduces the effects of inappropriability and increases the costs of imitation. Intellectual property protection thereby facilitates the diffusion of technology while preserving the incentive to invest in R & D. However, technologies that are of general use are more difficult to appropriate by the use of patents and other measures.[29]

Complementary to patent protection are policy instruments that encourage investment in R & D or increase private rates of return to R & D investments to levels closer to social rates of return, without necessarily conferring monopoly power to R & D performers. Governments in Canada

[29] Richard C. Levin, Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter, "Appropriating the Returns from Industrial Research and Development" [1987], no. 3 *Brookings Papers on Economic Activity* 783-820, discuss various means that innovators use to protect themselves from imitators and minimize spillovers, and the limitations of patents. Edwin Mansfield, "The R&D Tax Credit and Other Technology Policy Issues" (May 1986), 76 *The American Economic Review* 190-94, and McFetridge, supra footnote 21, also discuss patents.

and other industrialized countries have implemented a number of such instruments to respond to the problems of market imperfections and their impacts on R & D investment and economic growth. They include

- government-sponsored R & D;
- government procurement of new technologies;
- direct subsidies, loans, and repayable contributions to businesses, universities, and non-profit organizations; and
- tax incentives.

McFetridge[30] reviews evaluations of government-sponsored R & D, procurement policies, direct subsidies, concessionary financing, and tax incentives for R & D in Canada. In the case of government-sponsored R & D, he finds that research projects with industry-wide applicability were characterized by high rates of return, while those that conferred proprietary advantages on individual firms were characterized by rent seeking and low rates of return.[31] This general finding also holds in the case of direct subsidies for R & D and extends to evaluations of R & D subsidies in the United States and the United Kingdom. Cost-effectiveness was highest in situations where such subsidies were aimed at solving industry-wide or multi-industry technological problems.[32] In the case of procurement policies, concessionary financing, and tax incentives, McFetridge finds that

- procurement policies have been effective in inducing or accelerating innovation in instances where government is a major customer for the products developed;[33]
- recent institutional changes in government lending may have improved the efficiency of financing innovation;[34] and
- "existing tax incentives are likely socially beneficial, but there is no compelling case for making them more generous."[35]

His overall conclusion on the cost-effectiveness of policy instruments for R & D is that

> the efficacy of policy instruments indicates that tax incentives and concessionary financing may be more effective than direct subsidies, although the empirical evidence is limited.[36]

Tax incentives and direct subsidies possess different characteristics and may be used to achieve alternative, but complementary, objectives. The main differences between these policy measures are as follows:

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30 Supra footnote 21.

31 Ibid., at 32.

32 Ibid., at 77.

33 Ibid., at 79.

34 Ibid., at 80.

35 Ibid., at 70.

36 Ibid., at ii.

- Direct subsidies involve discretionary government control over decision making; funds are selectively channelled to sectors, firms, or investments identified as having the greatest potential for growth or the most pressing need for assistance. With tax incentives, markets determine which investments will be undertaken; decision making remains with investors.

- Tax incentives are typically structured to deliver assistance to a broad range of sectors, firms, or investments. Direct subsidies are usually targeted to relatively small numbers of sectors, firms, or investments.

- It is generally the case that direct subsidies can be accessed by both tax-paying and non-tax-paying firms. However, tax incentives can also be designed to achieve this objective through the use of refundability or loss-transfer provisions.

- The revenue cost for direct subsidies is capped at the funding level made available to the granting authority in a year while the revenue cost of tax incentives is dependent on market-determined levels of investment.

- The tax system can be more effective in encouraging longer-term investments—firms can reasonably expect to receive ongoing benefits when multiyear projects are undertaken. Funding levels for direct subsidies are often established on an annual basis and may vary (sometimes significantly) from year to year.

- By making use of the existing tax administration structure, tax incentives can be less costly (in terms of both administration and compliance), easier to access, more timely, less uncertain, and less burdensome than direct subsidies.

Income Tax Assistance in the G7 Countries and Australia

Many countries use income tax incentives to encourage R & D to be performed by, or on behalf of, taxpayers. In general, the incentives focus on R & D undertaken within national boundaries for business purposes. While the definition of R & D adopted by the Organisation for Economic Cooperation and Development (OECD) is widely used as a standard, the definitions actually employed for tax purposes differ, sometimes significantly, from this benchmark in order to meet the policy objectives of particular countries. Some R & D tax incentives are structured to deliver broadly based support, others target specific types of R & D or companies (for example, new firms, smaller firms, or non-tax-paying firms), and still others focus on regional objectives. There are also significant international differences in the design and mix of the R & D tax incentives currently being employed to foster this type of investment.

This section compares the Canadian tax treatment for R & D with the treatment provided in Australia, France, Germany, Italy, Japan, the United Kingdom, and the United States. Table 1 summarizes key features of the income tax systems for R & D in these countries. R & D incentives take the form of accelerated deductions, bonus deductions, or incremental or non-incremental investment tax credits. The appendix to this article contains

Table 1 R & D Tax Treatment in the G7 Countries and Australia

Country	Income tax deduction	Income tax credit
Canada	Current expenditures: 100% Capital expenditures: 100%	Base: all expenditures Rates: 20% generally; 35% for certain small businesses; one-half normal rate for certain equipment used for both R & D and other purposes Refundability: certain businesses Carryover: 3 years back; 10 years forward Taxable: reduces base for deduction
Australia	Minimum expenditure threshold: A$20,000 Current expenditures: 125% Capital expenditures: 125% over three years on a straightline basis	Not applicable
France	Current expenditures: 100% Capital expenditures: straightline or declining balance; some acceleration for R & D	Base: R & D spending compared to previous two years; positive or negative Rate: 50% Refundability: new firms 3-year carryforward/refundability: other firms Tax credit use: annual limits
Germany	Current expenditures: 100% Capital expenditures: straightline or declining balance	Not applicable
Italy	Current expenditures: 100% (or over five years on a straightline basis) Capital expenditures: straightline generally; some acceleration for R & D	Not applicable
Japan	Current expenditures: 100% (or over five years) Capital expenditures: ordinary (straightline, declining balance, or any other approved method), initial or accelerated depreciation; some acceleration for R & D	Three R & D tax credits; one for incremental spending Base for incremental credit: R & D spending in a year in excess of largest annual R & D spending since 1966 Rates: 20% general credit (incremental); 7% basic technologies credit; 6% credit for small and medium-sized businesses Tax credit use: annual limit Carryover: none
United Kingdom	Current expenditures: 100% Capital expenditures: 100%	Not applicable

(The table is concluded on the next page.)

Table 1 Concluded

Country	Income tax deduction	Income tax credit
United States	Current expenditures: 100% (or over five years on a straightline basis) Capital expenditures: modified accelerated cost recovery system; some acceleration for R & D	Base: R & D current spending in excess of the product of the ratio of R & D current spending to gross receipts for the period 1984 to 1988 and the average of gross receipts for the four preceding years Rate: 20% Ability to earn tax credit: annual limit Carryover: 3 years back; 20 years forward Taxable: reduces base for current deduction

a more detailed description of R & D income tax support in the G7 countries and Australia. Key elements of these R & D tax systems include the definitions of eligible R & D and allowable expenditures, income tax deductions, and, where applicable, investment tax credits.

Income Tax Deductions

In each of the G7 countries, R & D current expenditures are fully deductible in the year they are incurred. Subject to meeting a minimum expenditure threshold, Australia offers a bonus deduction equal to 125 percent of R & D current expenditures.[37]

The rates at which capital expenditures can be depreciated for tax purposes vary considerably among the G7 countries and Australia. R & D capital expenditures are depreciated using a variety of methods, at various rates, and over differing periods of time. In general, some form of accelerated depreciation is available for R & D capital assets (other than buildings).

- Subject to the same minimum expenditure threshold applicable to R & D current expenditures, Australia allows 125 percent of the amount of R & D capital expenditures to be written off over three years on a straightline basis.
- In Canada and the United Kingdom, R & D capital expenditures are fully deductible from taxable income in the year they are incurred.
- In France and Germany, capital assets can generally be depreciated using either the straightline or declining-balance method. However, in France, declining-balance depreciation is optional for certain capital assets, including R & D machinery, material, and equipment, that have a useful life of at least three years. R & D capital expenditures are subject to the same treatment as other depreciable assets in Germany.

[37] In order to qualify for the 125 percent deduction, annual R & D current or capital expenditures must generally exceed A$20,000.

• In Italy, capital expenditures are generally depreciable on a straightline basis, but accelerated depreciation is also available in respect of R & D capital assets. Accelerated depreciation permits expenditures to be written off at the statutory rate for the first taxation year, at a rate that is up to double the statutory rate for the second and third taxation years, and on a straightline basis over the remaining life of the asset.

• In Japan, R & D capital expenditures may be subject to ordinary depreciation (using the straightline, declining-balance, or any other approved method), increased initial depreciation, or accelerated depreciation. Increased initial depreciation and accelerated depreciation are tax incentives available for certain types of machinery, plant, equipment, and buildings. Increased initial depreciation provides a rate of depreciation higher than the rate of ordinary depreciation otherwise available for the year in which the asset is first used. Accelerated depreciation provides a rate of depreciation in excess of the rate of ordinary depreciation otherwise available over a specified number of years.

• In the United States, tangible capital property is depreciated generally under the modified accelerated cost recovery system (MACRS). Under the general MACRS rules, depreciation methods are prescribed for each class of property and include the 200 percent declining-balance method, the 150 percent declining-balance method, and the straightline method.

Investment Tax Credits

The design and complexity of R & D tax credits also vary considerably among the G7 countries and Australia. Four of these countries provide such credits: Canada has a tax credit based on total R & D spending; the United States and France have tax credits based on incremental R & D spending; and Japan has three tax credits, one of which is based on incremental R & D spending and the other two, on total R & D spending. Methods for calculating incremental R & D spending differ in each of the countries that offer this form of tax credit. The definition of eligible R & D spending for tax credit purposes is different in each of the four countries. There are also certain limitations in some countries on the amount of tax credits that can be earned or used in a year. Germany, Italy, and the United Kingdom do not currently provide R & D tax credits.[38]

There are two rates of investment tax credit for R & D in Canada: a general rate of 20 percent and, for certain small businesses, an enhanced rate of 35 percent on up to $2 million of eligible current and capital expenditures. Expenditures on new equipment used primarily (more than 50 percent) for R & D may also qualify for an investment tax credit equal to one-half of the normal credit. The credits may be used to reduce federal income taxes otherwise payable, and unused credits may be carried

[38] In Italy, however, from 1991 to 1993, a regionally differentiated R & D tax credit was available for small and medium-sized enterprises. The appendix contains further details on this credit.

back 3 years or forward 10 years. In addition, small businesses eligible for the enhanced rate of tax credit and unincorporated businesses can obtain a refund of unused credits earned in a year. The general rate of refund is 40 percent of tax credits earned on both current and capital expenditures. However, a 100 percent refund is available for credits earned on current expenditures at the enhanced rate. Corporations can also assign expected tax credit refunds to lenders as security for bridge financing for their operations. The amount of tax credits claimed in a year reduces the amount of current and capital expenditures eligible for the income tax deduction.

In the United States, the tax credit is earned at a rate of 20 percent on the amount by which eligible R & D current spending in a year exceeds a base amount. The base amount is the product of the ratio of eligible R & D spending to gross receipts for the period 1984 to 1988 (termed the "fixed base percentage") and the average of the taxpayer's gross receipts for the four preceding years. This base amount is subject to two limitations. First, the fixed base percentage cannot exceed 16 percent. Second, the base amount cannot be less than 50 percent of the taxpayer's eligible R & D spending in the year. The credit may be used to reduce corporate income tax otherwise payable, and unused credits may be carried back 3 years or forward 20 years. The deduction for eligible R & D current expenditures is reduced by the amount of incremental credit claimed in a year.

The tax credit in France is 50 percent of eligible R & D spending (current expenditures and depreciation allowances) in a year in excess of the average level of R & D spending for the previous two years. Accordingly, the amount of this incremental tax credit can be positive or negative. There are limitations on the ability to use both types. A positive credit can be used to reduce corporate profit and income tax otherwise payable in the year to a maximum of FF40 million. For new firms, unused credits are fully refundable. In all other cases, unused credits can be carried forward for up to three years, at which time any remaining unused credits are fully refundable. The ability to deduct R & D expenditures is unaffected by the amount of incremental credit claimed in a year. A negative credit reduces positive tax credit amounts in subsequent years. However, the amount of negative credit carried forward cannot be larger than the sum of positive tax credits that a firm has previously received.

Japan provides three different R & D tax credits for corporations: a general 20 percent credit for incremental current expenditures and depreciation allowances for R & D machinery, equipment, and buildings; a 7 percent credit for expenditures on depreciable capital assets used for R & D in respect of certain basic technologies; and, for small and medium-sized businesses, a 6 percent credit for current expenditures and depreciation allowances for R & D machinery, equipment, and buildings. The base for the 20 percent credit is the amount by which R & D spending in a year exceeds the largest amount of R & D spending incurred by the company in any year since 1966. The 20 percent credit may be used to reduce corporation tax otherwise payable to a maximum of 10 percent of the company's annual tax liability, and unused incremental tax credits may not be carried over for use in other taxation years. The 7 percent basic technologies tax credit is additional to the 20 percent incremental R & D tax credit, but the combined amount of the two credits cannot exceed 15 percent of corporation tax otherwise payable. The 6 percent R & D tax credit for small and medium-sized businesses may be used only in lieu of the 20 percent incremental R & D tax credit but together with the 7 percent basic technologies tax credit, to a maximum of 15 percent of corporation tax otherwise payable. The ability to deduct R & D expenditures is unaffected by the amount of tax credits claimed in a year.

An International Comparison of Income Tax Support for R & D

A 1997 study performed for the OECD by the Conference Board of Canada compares the relative attractiveness of income tax support for R & D in OECD countries.[39] The R & D tax systems were ranked by comparing the minimum benefit-cost ratio at which an R & D investment becomes profitable given a country's income tax treatment for tax-paying corporations performing this work. The minimum benefit-cost ratio is the present value of before-tax income necessary to cover the cost of an initial R & D investment and to pay the applicable income taxes. The lower the ratio, the greater the incentive for these firms to invest in R & D. A ratio less than unity implies that R & D investments are subsidized by the income tax system.

The study shows that, after taking account of both federal and provincial incentives, Canada's income tax treatment for R & D investments is the most favourable among the G7 countries and Australia (and the second most favourable, after Spain, among OECD countries). Australia, which provides a bonus income tax deduction, is the second most favourable. Germany, which does not offer special incentives for R & D, is the least favourable. Each of the other G7 countries provides some form of income tax assistance for R & D. The results of this comparison, reported in terms of the income tax subsidy provided to R & D investments by large manufacturing firms, are provided in figure 1.

While the international comparison indicates very attractive income tax treatment for R & D investments in Canada, the share of business expenditures on R & D (BERD) to GDP in Canada is low by international standards. This is shown in figure 2, which compares BERD-to-GDP ratios for the G7 countries and Australia.

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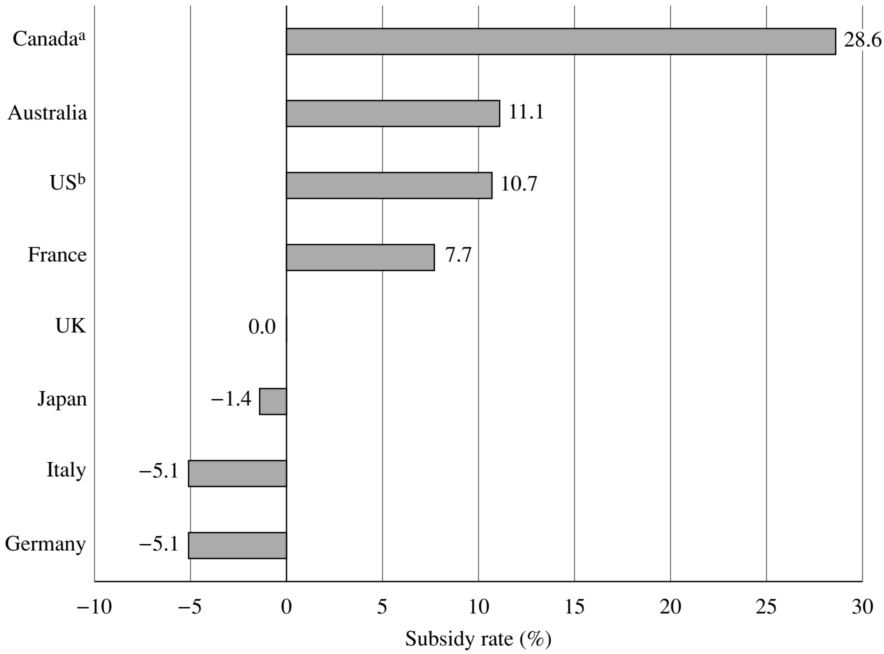
[39] Jacek P. Warda, *R&D Tax Incentives in OECD Countries: How Canada Compares*, Members Briefing 190-97 (Ottawa: Conference Board of Canada, January 1997); and Jacek P. Warda, *Fiscal Measures To Promote R&D and Innovation: An Overview of Policies in the OECD Countries* (Paris: Organisation for Economic Co-operation and Development, December 1997). The report includes a description of the income tax regimes for R & D in each of the countries and information on the methodology employed to compare them.

Figure 1 A Comparison of R & D Tax Support in the G-7 Countries and Australia



[a] For an R & D investment located in Quebec. [b] For an R & D investment located in California.

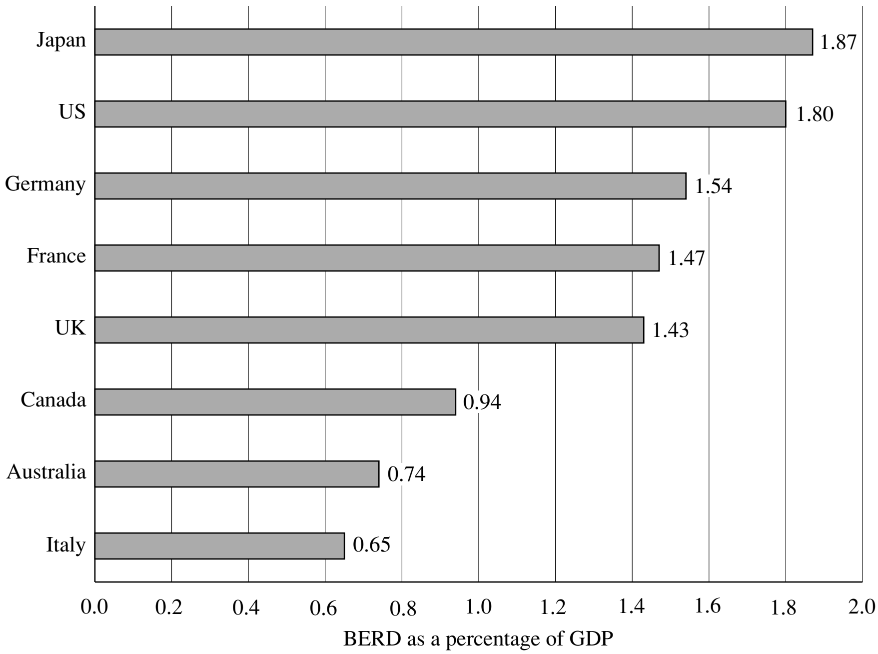
Source: Organisation for Economic Co-operation and Development (1997).

THE PERFORMANCE OF INCOME TAX INCENTIVES FOR R & D

The theoretical and empirical evidence that R & D, a key factor underlying economic growth, is subject to market failure provides a rationale for policy makers to intervene in markets to stimulate this type of investment. Most countries use some combination of both tax and non-tax incentives, the specific forms of government support for R & D depending on the nature of the market failure and the policy objectives being pursued. Tax and non-tax incentives possess different characteristics and may be used to achieve alternative, but complementary, objectives. In terms of their effectiveness, existing evidence seems to favour the use of tax incentives over direct subsidies such as grants.

Income tax provisions tend to focus on R & D undertaken within national boundaries for business purposes. However, definitions of R & D for income tax purposes differ, sometimes significantly, among countries, as do the purpose, design, and mix of R & D tax incentives and the level of assistance provided for R & D through the income tax system. This section briefly comments on how well the various types of instruments have been found to perform in stimulating additional R & D spending per

Figure 2 BERD-to-GDP Ratios in the G-7 Countries and Australia, 1994



Source: Organisation for Economic Co-operation and Development (1997).

dollar of tax revenue forgone, and in enhancing real income, by drawing on the available, limited evidence on this topic.

Income tax incentives for R & D are designed to stimulate R & D spending by firms and individuals, and by so doing, to increase the overall benefit to society as a whole. Cost-effectiveness provides a perspective on the ability of R & D tax incentives to achieve these goals. It does so by comparing the incremental change in R & D spending induced by the incentives to forgone government revenues. If one dollar of R & D incentives generates at least one dollar of R & D spending, then the incentives are said to be cost-effective. Stated alternatively, R & D tax incentives are cost-effective if the ratio of incremental R & D expenditures to tax revenues forgone is greater than or equal to unity. Underlying this methodology is the implicit assumption that cost-effective R & D tax incentives will be welfare enhancing.

Cost-effectiveness signals whether or not R & D tax incentives are having their intended effect of stimulating more R & D spending than it costs to provide the incentive. It does not account for all of the economic benefits and costs associated with R & D tax incentives. In the presence of market failure, an R & D tax incentive promotes a more efficient allocation of resources in an economy. However, it not only provides economic benefits (or spillovers) by correcting for the market failure associated with R & D, but also imposes economic costs since revenues must be raised to fund the incentive. Some other method is needed to capture the combined effects of the spillovers arising from the additional R & D induced by an R & D incentive and the costs associated with tax revenues needed to fund the incentive to determine whether the incentive can result in a net gain for an economy. Cost-effectiveness is relatively simpler to calculate than the alternative, and many studies provide empirical evidence on the cost-effectiveness of income tax incentives for R & D in Canada and other countries. Fewer attempts have been made to assess the potential net economic impacts of using an R & D tax incentive, funded through taxation, to stimulate investment in R & D by the private sector.

A 1997 evaluation undertaken jointly by the Department of Finance and Revenue Canada examined the performance of the current system of federal income tax incentives for R & D in Canada.[40] The evaluation found that the Canadian tax incentives

• have a substantial impact on the R & D spending behaviour of businesses—reported expenditures on R & D were found to be 32 percent higher as a result of the tax incentives;

• are cost-effective in meeting their policy objectives—the R & D tax incentives were found to induce an additional $1.38 in R & D spending for each dollar of federal tax revenues forgone; and

• are likely to benefit the Canadian economy—using a static computable general equilibrium model of the Canadian economy, the combined impacts of the spillover benefits from additional R & D and tax increases to fund the incentive were found to result in a potential net gain in real income ranging from, on average, $0.02 to $0.04 for every dollar of incentive.

Other studies on the cost-effectiveness of federal R & D tax incentives in Canada are relatively dated and apply to very different R & D tax incentives than those currently in place. However, it is noteworthy that the current system of federal R & D tax incentives was designed, in part, to respond to concerns that had been raised by businesses and academics about the cost-effectiveness of previous R & D tax incentives. One of the earlier studies found that R & D tax incentives in the early 1980s were not cost-effective in that they induced only $0.38 of additional R & D spending for every dollar of tax revenues forgone.[41] Another study undertaken

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[40] Canada, Department of Finance and Revenue Canada, *The Federal System of Income Tax Incentives for Scientific Research and Experimental Development: Evaluation Report* (Ottawa: Department of Finance, December 1997).

[41] Edwin Mansfield and Lorne Switzer, "The Effects of R and D Tax Credits and Allowances in Canada" (April 1985), 14 *Research Policy* 97-107; and Edwin Mansfield and Lorne Switzer, "How Effective Are Canada's Direct Tax Incentives for R and D?" (June 1985), 11 *Canadian Public Policy* 241-46. In part, this small cost-effectiveness

(The footnote is continued on the next page.)

at about the same time came to a different conclusion. It found that R & D expenditures increased by between $0.83 and $1.73 for every dollar of tax revenues forgone so that the incentives might have been cost-effective.[42] The smaller ratio assumes that economic output is unaffected by the increase in R & D spending. The larger ratio takes account of this secondary impact; that is, the additional R & D spending induced directly by the tax credit causes output to increase, which, in turn, increases R & D spending. The authors of the first study did not include the indirect impact on output in their analysis.

R & D tax incentives in other countries differ significantly among those countries and, in particular, differ from the incentives currently and formerly available in Canada. Researchers have attempted to ascertain the cost-effectiveness of these foreign incentives as they have existed at various points in time.[43] The results vary dramatically among countries and, in the case of the United States, among studies. Results for the incremental tax credit in the United States are mixed: some studies suggest that this incentive is cost-effective; others arrive at the opposite conclusion. Results for Australia, France, and Sweden indicate that the R & D tax incentives in those countries may not be cost-effective. The Australian study also attempted to establish whether its bonus deduction had a positive net contribution to economic welfare in Australia. The net economic impact was found to depend on underlying assumptions, and positive or negative results could be obtained.[44]

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41 Continued . . .
result was attributed to many firms not having sufficient taxable income to make full use of their tax credits.

42 Jeffrey I. Bernstein, "The Effect of Direct and Indirect Tax Incentives on Canadian Industrial R&D Expenditures" (September 1986), 12 *Canadian Public Policy* 438-48.

43 For Australia, see Bureau of Industry Economics, *R&D, Innovation and Competitiveness: An Evaluation of the Research and Development Tax Concession*, Research Report no. 50 (Canberra: Australian Government Publishing Service, 1993). For France, see Emmanuel Asmussen and Carole Berriot, "Le crédit d'impôt recherche, coût et effet incitatif," a study of the Ministère de l'Économie et des Finances (April 1993). For Sweden, see Edwin Mansfield, "Public Policy Toward Industrial Innovation: An International Study of Direct Tax Incentives for Research and Development," in Kim B. Clark, Robert H. Hayes, and Christopher Lorenz, eds., *The Uneasy Alliance: Managing the Productivity-Technology Dilemma* (Boston: Harvard Business School Press, 1985), 383-407; and Mansfield, supra footnote 29. For the United States, see Philip G. Berger, "Explicit and Implicit Tax Effects of the R&D Tax Credit" (Autumn 1993), 31 *Journal of Accounting Research* 131-71; Bronwyn H. Hall, "R&D Tax Policy During the 1980s: Success or Failure?" (1993), 7 *Tax Policy and the Economy* 1-35; Mansfield, "Public Policy Toward Industrial Innovation," supra, and supra footnote 29; William W. McCutchen, "Estimating the Impact of the R&D Tax Credit on Strategic Groups in the Pharmaceutical Industry" (August 1993), 22 *Research Policy* 337-51; and C.W. Swenson, "Some Tests of the Incentive Effects of the Research and Experimentation Tax Credit" (November 1992), 49 *Journal of Public Economics* 203-18.

44 Gordon J. Lenjosek, "Evaluating R & D Income Tax Incentives: Some Lessons from the Australian Experience," in *Competitive Industrial Development: The Role of Cooperation in the Technology Sector* (London: Routledge, forthcoming), discusses the Australian study (objectives, methodologies, results, and problems encountered) and draws some lessons from it.

APPENDIX: R & D TAX SUPPORT IN THE G-7 COUNTRIES AND AUSTRALIA

This appendix summarizes key elements of the existing income tax systems for R & D in the G-7 countries and Australia. In particular, deductions for current and capital expenditures and any additional incentives (for example, bonus deductions or investment tax credits) that are currently offered in these countries are described. Where applicable, special provisions relating, for example, to non-tax-paying companies, smaller firms, or regional incentives are included.

Australia

The R & D tax concession in Australia is an income tax deduction equal to 125 percent of eligible R & D expenditures.[1] An eligible taxpayer must be a company incorporated in Australia, a public trading trust, or a partner in a partnership of eligible companies.

The definition of eligible R & D is based generally on the OECD definition of R & D.[2] In order to be eligible, R & D requires either the presence of an appreciable element of novelty or the resolution of scientific or technical uncertainty through a program of systematic and investigative and experimental activities. In addition, the work must be based on principles of physical, biological, chemical, medical, engineering, or computer sciences. Furthermore, the R & D must satisfy certain "Australian content" rules relating to key personnel and major items of plant and

[1] The maximum rate of deduction was reduced from 150 percent to 125 percent in the Australian budget of August 20, 1996. Before July 24, 1996, two or more Australian companies could also form a syndicate to contract out or undertake R & D in Australia. Syndicated R & D was complementary to the then 150 percent R & D tax concession, and the two had similar requirements concerning eligible R & D expenditures. In addition, a syndicate had to incur more than A$500,000 in total R & D expenditures to qualify for a rate of deduction in excess of 100 percent. The policy intent of syndicated R & D was to allow a group of companies to undertake R & D projects that were beyond the resources of, or considered too risky for, a single company. One member of the syndicate was typically a smaller research company with tax losses that wished to undertake additional R & D on a pre-existing technology it possessed. Through syndication, this non-tax-paying research company could license its pre-existing technology and transfer the tax losses relating to the pre-existing technology to the tax-paying corporate investors in the syndicate to obtain funding for the additional R & D. Each corporate investor in the syndicate could deduct its proportionate share of eligible R & D expenditures in calculating its taxable income. The rate of deduction for expenditures relating to the pre-existing technology was 100 percent; the rate for additional R & D expenditures ranged between 100 percent and 150 percent, the higher rate being applicable to investments that were fully at risk. Claims could be made up to 13 months in advance of expenditures. Subject to grandfathering provisions for existing syndicates, the syndicated R & D program was terminated on July 23, 1996.

[2] There are, however, differences between the two. For example, in Australia, certain activities such as routine testing and data collection, and market research and sales promotion are eligible if they are directly related to an "eligible core activity." In addition, computer software development is eligible if the software is developed for sale, but not eligible where it is developed solely for in-house use.

equipment, and the results of the R & D must be exploited on normal commercial terms and for the benefit of the Australian economy.

An annual minimum threshold of A$20,000 must generally be met for R & D spending to qualify for the tax concession.[3] Eligible R & D expenditures include current costs and capital expenditures on plant and machinery and pilot plants that are used exclusively for R & D.[4] R & D current expenditures are deductible at a rate of 125 percent in the year incurred. R & D capital expenditures may be written off over three years on a straightline basis. Expenditures for R & D carried on outside Australia are also eligible if the amount of such expenditures does not exceed 10 percent of the eligible expenditures for the associated R & D project as a whole.

Canada

The federal income tax regime for R & D in Canada consists of income tax deductions and investment tax credits for eligible current and capital expenditures. An eligible taxpayer must be a business performing eligible R & D in Canada.

The definition of eligible R & D is consistent with the internationally accepted definition used by the OECD and includes basic research, applied research, and experimental development. Certain support work is also eligible where such work is commensurate with the needs, and directly in support, of basic research, applied research, or experimental development. There is also certain work that is excluded from the income tax definition of R & D—generally because it is not considered to be R & D in accordance with the OECD definition.[5]

Eligible current expenditures include salaries or wages of employees directly engaged in R & D; the cost of materials consumed in R & D; lease costs relating to machinery and equipment all or substantially all (90 percent or more) of which is used for R & D; expenditures incurred under various types of contracts; and overhead and administrative costs. Eligible

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[3] This threshold does not apply to contract payments made to a registered research agency. The use of these agencies allows taxpayers with smaller claims to access the 125 percent R & D tax concession.

[4] Capital expenditures on constructing or reconstructing buildings are generally deductible under the normal depreciation system over a period of 40 years on a straightline basis. Interest and expenditures made to acquire pre-existing technology for the purposes of the taxpayer's own R & D are deductible at a rate of 100 percent.

[5] Eligible support work consists of work in respect of engineering, design, operations research, mathematical analysis, computer programming, data collection, testing, and psychological research. Excluded work consists of market research or sales promotion; quality control or routine testing of materials, devices, products, or processes; research in the social sciences or the humanities; prospecting, exploring or drilling for, or producing minerals, petroleum, or natural gas; the commercial production of a new or improved material, device, or product or the commercial use of a new or improved process; style changes; or routine data collection.

capital expenditures generally consist of expenditures for machinery and equipment all or substantially all of which is used or consumed in the prosecution of R & D in Canada. However, not all current and capital expenditures are eligible expenditures. For example, capital expenditures for the acquisition of land or buildings (other than a highly specialized R & D building)[6] and current expenditures for related rental or leasehold payments are not allowable R & D expenditures. Also excluded are expenditures made to acquire rights in, or arising out of, R & D.

Eligible current and capital expenditures are fully deductible; expenditures that are not deducted in a year can be carried forward indefinitely. There are two rates of investment tax credit for R & D: a general rate of 20 percent and, for certain smaller businesses,[7] an enhanced rate of 35 percent on up to $2 million of eligible expenditures. Expenditures on new equipment used for both R & D and other purposes may also qualify for an investment tax credit equal to one-half of the normal credit.

Investment tax credits may be used to reduce federal income taxes otherwise payable. Tax credits that are not used in the year they are earned can be carried back 3 years or forward 10 years. In addition, smaller businesses eligible for the enhanced rate of tax credit and unincorporated businesses can obtain a refund of unused credits earned in a year. The general rate of refund is 40 percent for tax credits earned on both current and capital expenditures. However, a 100 percent refund is available for tax credits earned on current expenditures at the enhanced rate. Corporations can also assign expected refunds of tax credits to lenders as security for bridge financing for their operations. Such assignments, however, are not binding on the Crown.

France

R & D current expenditures are fully deductible in France. Straightline depreciation is the normal method of depreciation for capital assets and is prorated for the first taxation year. Rates of straightline depreciation are not set out in tax legislation and vary by asset type and the normal useful life of the asset according to the usages of each industry, commerce, or business. Straightline rates for machinery generally range from 10 percent to 20 percent; and for plant, from 10 percent to 15 percent. The straightline rate for patents, materials, and computer software is 20 percent.[8] Declining-balance depreciation is an optional method for certain capital assets, including R & D machinery, material, and equipment, that have a useful life of at least three years. Rates of declining-balance

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[6] Capital expenditures on buildings are generally deductible under the normal depreciation system at a rate of 4 percent per year on a declining-balance basis.

[7] Specifically, Canadian-controlled private corporations with prior-year taxable income under $400,000 and prior-year taxable capital employed in Canada under $15 million.

[8] In certain exceptional cases, computer software can be fully depreciated over 12 months.

depreciation equal 1.5 times the straightline rate for assets with a normal useful life of three to four years; 2 times the straightline rate for assets with a normal useful life of five to six years; and 2.5 times the straightline rate for assets with a normal useful life of over six years. Costs of industrial buildings are depreciable generally at a rate of 5 percent on a straightline basis.

France also provides an incremental tax credit for eligible R & D spending by corporations. The definition of eligible R & D is based largely on the OECD definition of R & D and includes basic research, applied research, and experimental development. Eligible expenditures include salaries and benefits, operating costs, certain contract payments, patent costs, and depreciation allowances in respect of capital property including buildings. The rate of incremental tax credit is 50 percent. The credit base is the amount by which a corporation's eligible R & D spending in a year exceeds its average level of eligible R & D spending, adjusted for inflation, for the previous two years. The amount of incremental tax credit can be positive or negative. A positive credit can be used to reduce corporate profit and income tax otherwise payable in the year to a maximum of FF40 million and is not taxable. For new firms, unused credits are fully refundable. In all other cases, unused credits can be carried forward for up to three years, at which time any remaining unused credits are fully refundable. A negative credit reduces positive tax credit amounts in subsequent years. However, the amount of negative credit carried forward cannot be larger than the sum of positive tax credits that a firm has previously received.

Germany

In Germany, R & D current expenditures are fully deductible in calculating taxable income. R & D capital expenditures are subject to the same treatment as other depreciable assets. Rates of depreciation vary by asset category, and capital assets can generally be depreciated using either the straightline or the declining-balance method. The statutory straightline rate of depreciation for machinery is 10 percent; for computers, 20 percent; and for patents, between 14 percent and 20 percent. The corresponding rates of declining-balance depreciation are up to three times the allowable straightline rate to a maximum of 30 percent per year. Costs of new buildings are depreciable only at a rate of 4 percent on a straightline basis.

There are no additional incentives available for firms performing R & D in Germany.

Italy

R & D current expenditures in Italy may be either fully deducted in the year incurred or amortized on a straightline basis over a maximum of five years. Capital expenditures are generally depreciable on a straightline basis, subject to a half-year rule, and rates of depreciation vary by asset category. Expenditures on machinery and equipment are generally depreciated over a period of 10 years; building costs, over 33 years. Companies may also claim accelerated depreciation in respect of R & D capital assets;

specifically, these expenditures are depreciable at the statutory rate for the first taxation year and at a rate that is up to double the statutory rate for the second and third taxation years. The undepreciated capital base may then be written off on a straightline basis over the remaining life of the asset.

Currently, there are no additional incentives available for firms performing R & D in Italy.[9]

Japan

In Japan, R & D current expenditures are fully deductible in the year incurred or may be amortized over a period of not less than five years. R & D capital expenditures may be subject to ordinary depreciation, increased initial depreciation, or accelerated depreciation. Expensing is allowed for capital assets costing less than 200,000 yen.

Ordinary depreciation is available for all tangible assets, other than land, and certain intangible assets such as patents, copyrights, and trademarks. It is based generally on the statutory useful life of an asset. Methods of calculating ordinary depreciation include the straightline method, the declining-balance method, or any other approved method. The amount of the allowance is prorated in the year the expenditures are incurred.[10]

Increased initial depreciation and accelerated depreciation are tax incentives available for certain types of machinery, plant, equipment, and buildings. These special depreciation measures are intended to help achieve a variety of policy objectives, including support for R & D undertaken in certain regions or by certain types of firms. Increased initial depreciation provides a rate of depreciation higher than the rate of ordinary depreciation otherwise available for the year in which the asset is first used.[11]

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[9] However, for the three-year period from 1991 to 1993, tax credits were available in respect of current and capital R & D expenditures incurred by small and medium-sized enterprises in Italy—that is, companies with fewer than 200 employees and operating capital of less than 20 billion lire. The credit rates were 30 percent generally and 45 percent for firms operating in depressed economic areas of the country. The amount of tax credit claimable by a particular company in a taxation year was also limited to a maximum of 500 million lire generally and 750 million lire for firms in depressed economic areas. The credit could be used to reduce income tax, local tax, or value-added tax otherwise payable. In addition, startup small and medium-sized enterprises in fields of "innovative technology" (for example, information technology, advanced materials, environment, and biotechnology) were allowed an identical tax credit for the first three years following startup, but in respect of general structural investment costs—that is, not necessarily costs relating only to R & D.

[10] The statutory useful life of, for example, reinforced concrete buildings (for office use) is 65 years; computers, 6 years; and patent rights, 8 years. The declining-balance method must be used for tangible assets where the corporation does not report the method it has chosen. Typical rates of depreciation are 18 percent for machinery on a declining-balance basis and between 1.5 percent and 2 percent for buildings on a straightline basis.

[11] For example, rates of increased initial depreciation for certain buildings and certain machinery and equipment used for R & D by small businesses are 8 percent and 30 percent, respectively. Certain machinery and equipment used for "high-technology businesses established in technopolis areas" are eligible for a 30 percent rate of increased initial depreciation.

Accelerated depreciation provides a rate of depreciation in excess of the rate of ordinary depreciation otherwise available over a specified number of years.

Japan provides three different corporate tax credits for R & D: a general 20 percent credit for incremental expenditures; a 7 percent credit for basic technologies; and a 6 percent credit for small and medium-sized businesses. None of the R & D tax credits are taxable.

To qualify for the 20 percent incremental tax credit, the R & D must be undertaken in order to manufacture products or to improve, design, or invent production techniques. Eligible expenditures consist of R & D current expenditures (that is, salaries and wages of employees engaged exclusively in R & D, cost of materials, and related expenditures) and depreciation allowances for R & D machinery, equipment, and buildings. The credit base equals the amount by which R & D spending in a year exceeds the largest amount of R & D spending incurred by the company in any year since 1966. The credit may be used to reduce corporation tax otherwise payable to a maximum of 10 percent of the company's annual tax liability. Unused incremental tax credits may not be carried over for use in other taxation years.

The 7 percent basic technologies tax credit is additional to the 20 percent incremental R & D tax credit, but the combined amount of the two credits cannot exceed 15 percent of corporation tax otherwise payable. The credit applies to expenditures on depreciable capital assets used for R & D in respect of certain basic technologies. The latter are advanced robots and machinery, advanced processes, advanced artificial conditions, advanced electronics, biotechnology, and new material technology.

The 6 percent R & D tax credit for small and medium-sized businesses may be used only in lieu of the 20 percent incremental R & D tax credit but together with the 7 percent basic technologies tax credit, to a maximum of 15 percent of corporation tax otherwise payable. Eligible expenditures are the same as those for the 20 percent incremental R & D tax credit. Small and medium-sized businesses are defined as those with capital of 100 million yen or less or fewer than 1,000 employees.

United Kingdom

The United Kingdom offers special tax incentives for scientific research. The definition of eligible R & D is based largely on the OECD definition of R & D.[12] R & D current expenditures are fully deductible from taxable income in the year they are incurred. R & D capital expenditures are also fully deductible if the scientific research is related specifically to trade or the moneys are paid to a scientific research association.[13] R & D capital

[12] For example, eligible R & D in the United Kingdom must include a substantial portion of innovation rather than just product development. However, the UK definition tends more toward pure and applied science, and excludes social sciences.

[13] Approved scientific research associations and bodies connected to universities are exempt from corporate taxes.

expenditures that are connected with trade, other than costs of acquiring land, may also be eligible for a 100 percent deduction.

United States

Under federal law,[14] certain current expenditures for R & D carried on by, or on behalf of, a taxpayer may be either fully deducted in the year incurred or amortized over a period of no less than 60 months beginning with the month in which the taxpayer first realizes benefits from the expenditures. To be eligible, the expenditures must be incurred in connection with a trade or business of the taxpayer and relate to R & D in the experimental or laboratory sense (that is, to activities intended to discover information that would eliminate uncertainty concerning the development or improvement of a product). Uncertainty exists if the information available to the taxpayer does not establish the capability or method for developing or improving the product or the appropriate design of the product. The term "product" includes any pilot model, process, formula, invention, technique, patent, or similar property. Spending in respect of several types of work is not eligible—specifically, expenditures in respect of quality control testing, efficiency surveys, management studies, consumer surveys, advertising or promotions, historical or literary research, and the acquisition of another's patent, model, production, or process. Also ineligible are expenditures for acquiring or improving land, oil or gas exploration, and depreciable or depletable property used in experimental work.

Tangible capital property is depreciated generally under the modified accelerated cost recovery system (MACRS). Under the general MACRS rules, depreciation methods are prescribed for each class of property and include the 200 percent declining-balance method, the 150 percent declining-balance method, and the straightline method. The number of years over which an asset can be depreciated is also prescribed for each property class. Averaging conventions (half-year, mid-quarter, or mid-month, as applicable) are used to calculate the MACRS deductions for the tax year in which the property is placed in service and the tax year of disposition.[15]

The federal government also provides a non-refundable 20 percent income tax credit for certain incremental R & D expenditures incurred in an existing trade or business of the taxpayer.[16] Eligible R & D is that eligible for the 100 percent deduction for current expenditures, undertaken for the

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[14] A number of US states also offer various forms of tax support for R & D, but these are not discussed here.

[15] Capital expenditures on R & D machinery and equipment are depreciated generally over 5 years using the 200 percent declining-balance method; building costs, over 39 years on a straightline basis.

[16] This credit is currently applicable to expenditures incurred between July 1, 1998 and June 30, 1999. Previous extensions of the credit have applied to expenditures incurred between June 1, 1997 and June 30, 1998, and between July 1, 1996 and May 31, 1997. There was no tax credit available for R & D expenditures incurred between July 1, 1995 and June 30, 1996. Various incremental tax credits were also available, each on a temporary basis and subject to different rates and rules, from July 1, 1981 to June 30, 1995.

purpose of discovering information that is technological in nature and intended to be useful in the development of a new or improved business component of the taxpayer, and substantially all of the activities of which constitute elements of a process of experimentation to achieve a new or improved function, performance, reliability, or quality. If the R & D relies fundamentally on principles of the physical or biological sciences, engineering, or computer science, the new information is deemed to be technological in nature.[17] The process of experimentation must involve evaluation of more than one alternative designed to achieve a result where the means of achieving that result is uncertain at the outset.

R & D and spending that are ineligible for the 100 percent deduction are also ineligible for the incremental tax credit. In addition, R & D does not qualify for the incremental tax credit if it is research performed outside the United States; research in the social sciences, arts, or humanities; research funded by another person or government entity by means of a grant or contract; research conducted after commercial production; or research conducted for the adaptation or duplication of an existing business component.

Eligible expenditures consist of wages for employees involved in the research activity, costs of supplies used in research, payments to others for the use of computer time in qualified research, 65 percent of the amount of contract payments for R & D performed on behalf of the taxpayer, and 75 percent of amounts paid to a qualified research consortium for R & D performed on behalf of the taxpayer and one or more unrelated taxpayers. The credit also applies to amounts paid or incurred by a corporation for basic research by colleges, universities, and other qualified organizations, to the extent that those amounts exceed certain base period amounts.

The base for the incremental tax credit is the amount by which eligible R & D spending in a year exceeds a base amount. The base amount is the product of the ratio of eligible R & D spending to gross receipts for the period 1984 to 1988 (that is, the "fixed base percentage") and the average of the taxpayer's gross receipts for the four preceding years.[18] However, the fixed base percentage cannot exceed 16 percent. In addition, the base amount cannot be less than 50 percent of the taxpayer's current year eligible R & D spending. The credit may be used to reduce corporate income taxes otherwise payable, and unused credits may be carried back 3 years or forward 20 years. The deduction for eligible R & D current expenditures is reduced by the amount of incremental credit claimed in a year.

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[17] Computer software development is eligible if it results in new or significantly improved programs or routines for computers. In addition, however, in-house computer software development must be used in eligible R & D performed by the taxpayer or a production process that meets the requirements for the credit. Further considerations in the case of in-house computer software development include whether the software is innovative and not commercially available, and whether the software development involves substantial economic risk.

[18] Special rules exist for startup firms. There are different rules for calculating the base period amount relating to basic research performed by universities and other qualified organizations.