Approaches to an International Comparison of Canada's R & D Expenditures

Kristian S. Palda Bohumir Pazderka

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The findings of this study are the personal responsibility of the authors and, as such, have not been endorsed by Members of the Economic Council of Canada.

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We, alone, of course, bear responsibility for the interpretation of empirical findings and the opinions expressed in this study.

1 The Interest of International Comparisons of Research Intensity: An Introduction

In the summer of 1978, Canada's Minister of State for Science and Technology announced a number of government proposals addressing innovation (Buchanan, 1978). He also disclosed a national priority – though not specific measures for reaching it – of achieving a ratio of research and development expenditures to gross domestic product (GDP) of 1.5 per cent by the year 1983. This target was reaffirmed again in May 1980 by the re-established Liberal government (Roberts, 1980), and it represents a substantial increase over the actual 1977 expenditure of 0.9 per cent. (The 1977 ratio of 0.9 per cent was a historical low; the highest ratio within the entire period 1963-77 was 1.3 per cent and was achieved in 1967.)

It is fair to say that the announced federal policy of raising substantially the economy-wide research intensity ratio has gained a level of general consensus rare for Canada, and it has thus far remained the only clearly stated objective of a still gestating federal industrial strategy. "It is universally accepted that Canadians have been underinvesting in R & D, particularly in the industrial sector" is a key sentence phrased by the newly installed president of the National Research Council in its special 1980 publication, *The Urgent Investment* (NRC, 1980); it is typical of other pronouncements by federal and provincial officials and of the chorus of media editorializing, such as Barbara Frum's December 1980 *CBC Quarterly Report* (Frum, 1980).

It is therefore likely that even a minimal activation of a federal industrial policy towards technological innovation will, in the near future, comprise tax subsidy and expenditure measures designed to push the gross expenditures on research and development as a share of gross domestic product – GERD/GDP ratio – towards 1.5 per cent. Thus, in the latest development in January 1981, the current Minister of State for Science and Technology committed the government formally to the 1.5 per cent figure, but he moved the date on which the economy would reach it from 1983 to 1985 (Roberts, 1981). (This time, the target was stated as a ratio of GERD to gross national product (GNP) rather than GDP. According to an unofficial explanation from the Ministry of State for Science and Technology (MOSST), this change was made solely to facilitate communications with the general public.) A recent government paper (MOSST, 1981, p. 22) shows that this objective will draw something on the order of $1 billion a year for several years out of the taxpayer's purse, about $40 for every Canadian man, woman, and child yearly. This sum provides the motivation for asking questions such as: What is the policy supposed to accomplish? Why the target for GERD/GDP of 1.5 per cent? How should the expenditures be distributed among sectors and firms? Are there alternative means of achieving the same result?

The chief purpose of this paper is to provide some analysis that would be useful in understanding the issues surrounding the second question. More particularly, the current GERD/GDP ratio of less than 1 per cent is deemed inadequate by comparison with equivalent magnitudes for other industrial countries. We question the validity of statements about "underinvesting in R & D," which are based on simple juxtapositions of such aggregate ratios for any two or more randomly chosen countries. Doubts about such a procedure were raised by MOSST itself in one of its background papers (MOSST, 1978a).

Our main goal is to outline a methodology that incorporates information about the economic characteristics of the countries under comparison, and thus provides a background for selecting a particular level of the GERD/GDP ratio as a policy goal.

The first question must, however, be addressed briefly, since it logically precedes the second one. It can be formulated more operationally as: What evidence is there that higher R & D expenditures lead to better economic performance? In this context, we understand "R & D expenditures" to be equivalent to R & D intensity measures such as the GERD/GDP ratio or to industry R & D outlays as a share of total industry sales. Economic performance on the aggregate level can be measured in terms of the growth in GNP, the growth in total factor productivity, or growth in labour productivity. At the level of an industry or a firm, the return on investment, sales, employment, and foreign sales figures are often used as performance criteria.

While it is generally presumed that technological change leads to economic growth and productivity increases, it is also widely acknowledged that the quantitative impact of such change is difficult to appraise and, furthermore, that technological progress is driven only in part by organized research and development. Estimates in the early pioneering studies of Solow (1957) and Denison (1962), which assign 90 and 40 per cent, respectively, of the increase in per capita output in the United States over a forty- or thirty-year period to technological change, may be excessive. With regard to organized research and development undertaken in all sectors (government, universities, and industry), Griliches (1973) arrives at the tentative estimate that it contributed one-half of one percentage point to GNP growth in the United States during the late 1960s.

Both Griliches (1979) and Mansfield (1972) have explicitly and at length addressed the conceptual, measurement, and statistical inference problems encountered in assessing the contribution of R & D to growth and productivity on both the aggregate and the industrial sector levels. Among the conceptual issues, the most recalcitrant one is the definition and scope of output.

In measuring aggregate output and its growth – a task that has as its ultimate purpose the quantification of changes in economic welfare – it is nearly impossible to capture such consequences of change in technology as a richer choice of products and services or an improved quality of goods. For example, the growth rate would be unchanged whether new drugs were developed or not. Much of government-performed or government-financed research takes place in the defence and health sectors; an improvement in defence efficiency is not reflected in GNP, since government output is valued at cost. Improved health may actually lead to a decline in gross product as the need for health facilities declines. As Griliches (1979) points out, these quality change issues are likely to affect most severely the more R & D intensive sectors.

In trying to quantify the R & D input that enters a performance function, the most pervasive challenge is to devise a proper measure of the cumulated stock of R & D "capital," most of which is composed of technical knowledge. It is the services of this stock that are the relevant input into the production process, not the current accounting expenses. Successful attempts at quantifying research capital stocks – and their depreciation rates – have only lately taken place in the United States (Griliches, 1980). On the Canadian scene, it is possible to argue that the National Science Foundation/Organisation for Economic Co-operation and Development statistical definitions of organized research and development have a tendency to bring about an underestimation of activities oriented towards technological change. Mining and oil exploration outlays, which are quite substantial in this country, do not qualify under R & D definitions. There may be perfectly valid reasons why they should not be included, although a better knowledge of the existing environment clearly leads to higher productivity.

The severity of conceptual and inferential difficulties with regard to the effects of R & D at the economy-wide level can be indicated by the example of Japan and the United Kingdom. The Japanese GERD/GDP ratio has risen over the last fifteen years from about one-third to about two-thirds of the British ratio. Japan's rate of economic growth has easily been triple that of the U.K. over the same period. To what extent is the adoption and diffusion rate of technology, rather than innovation-oriented R & D activity, responsible for growth? The Science Council of Canada (1980, p. 31) is categorical: "The astonishing industrial success of Japan was not founded on R & D." To what degree is the British failure to obtain benefits from research related to its overemphasis on funding the nuclear and aerospace industries? (Freeman, 1979).

Given such problems, most investigators have preferred to concentrate on the establishment of a causal link between research and some measure of performance at the sectoral or enterprise level, and they have often succeeded. To mention but three, the well-known study of the U.S. agricultural sector by Griliches (1964) reveals that research (and extension) activities of agricultural experimental stations were a significant and important source of aggregate output growth. Gruber, Mehta, and Vernon (1967) show that research-intensive U.S. (two-digit) industries accounted for a disproportionately large share of U.S. exports. A study of a group of chemical firms by Minasian (1969) assigns to R & D "capital" the lion's share in raising value added. Since then a host of other studies, mostly in the United States, tend to indicate that R & D has a measurable, positive impact on output and exports. Yet a number of clarifications are still required before full confidence can be placed in these findings.

It is recognized that matching the industry's or the firm's R & D inputs to the corresponding outputs suffers from errors of measurement. Typically, no estimates are available regarding knowledge spillovers from other industries or firms. In Canada, the substantial, foreign-owned sector derives benefits from a large influx of "invisible" R & D know-how, which it receives at no or little cost from headquarters in other countries (MOSST, 1978b).

When statistical studies use as their units of observation individual firms, they often pay insufficient attention to the possibility that a spurious correlation between R & D and sales growth will mask the real underlying relationship, which is between growth and high-quality management, which supports vigorous R & D activity. Clinical studies (de Woot and Heyvaert, 1979) show that a research orientation not backed up by effective marketing and production policies will not, of itself, lead to a satisfactory level of profitability. Rather, a positive causal relationship between R & D and the firm's performance will show up only when research activities are oriented by sound management strategy.

It should also be mentioned that no Canadian econometric studies provide convincing evidence of R & D's contribution to economic performance, with the possible exception of exporting activity (Hanel, 1976). Several articles (see, for instance, Chand, 1978) document the co-existence of research and industrial prosperity, but not a causal flow. Indeed, McFetridge (1977, p. 74) points out that "economists have yet to produce any statistical evidence that the rate of return to industrial R & D in Canada is not zero." One of the reasons, according to a study by Globerman (1972), is the previously mentioned unavailability of statistics on the "invisible research transfers."

It is probably safe to say that growth, sales, exports, and high rates of return are frequently associated with high levels of research expenditures, but that a clear causal flow from research to economic performance is quite difficult to establish. A policy centred on increasing industrial research expenditures may easily achieve just that – a higher input level – without any guarantee that the desired output will be achieved. In the words of the Science Council of Canada (1980, p. 28):

> Policies structured on the assumption that R & D alone creates industrial strength are found to be insufficient. In fact, the reverse is true; industrial strength creates the fertile ground necessary to promote excellence in research and development. For this reason, any policy seeking to increase Canada's capacity to develop technology will have to concentrate on creating a healthy business climate.

Looking at the issue of government intervention through a different prism, we could ask whether an exclusively demand-oriented view of the innovation process does not neglect supply influences upon it. According to one writer (Pavitt, 1979), we are now leaving a world inspired by Keynes, where demand and investment policies predominate, for a world inspired by Schumpeter, where the entrepreneurial search for product innovation leading to new markets will be dominant, as shown in Figure 1-1.

In this new causality structure, a government R & D funding policy of the private sector could possibly contribute to the betterment of economic performance, provided that the entrepreneurial striving for innovation is not thwarted by bureaucratic misallocation in the choice of recipient firms or sectors.

If it is, then, accepted that there is some case for government stimulation of R & D activities, why should the increase in government funding be targeted to a GERD/GDP ratio of 1.5 per cent?

Among the political grounds for the choice of an economy-wide intensity ratio, instead of a specific dollar amount in a given economic sector, there may well be the relative simplicity of the concept, its mobilizing potential, its slogan-like attractiveness – in short, its "let's do as well as others" appeal. It is difficult to find an economic justification, however.

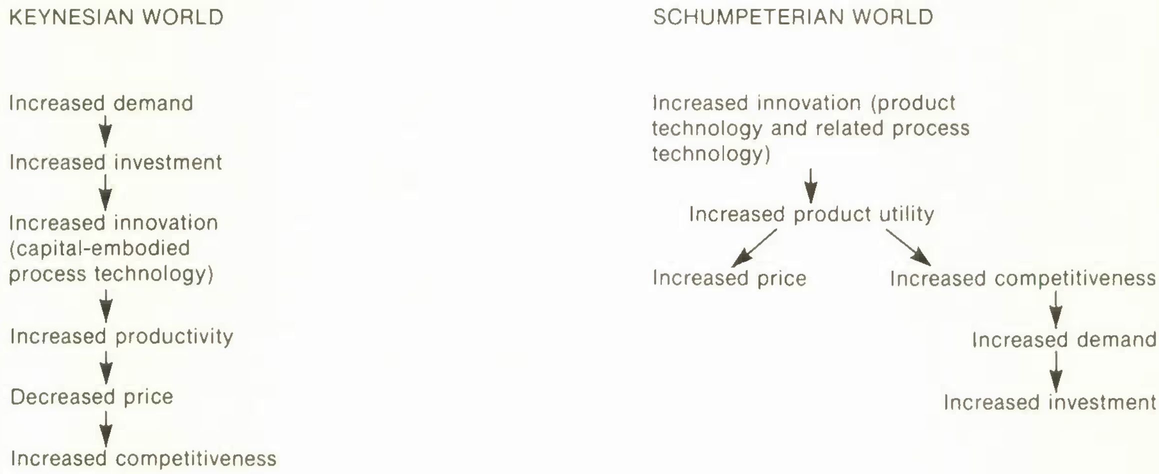
Intercountry comparisons of the GERD/GDP ratio are deficient on grounds of validity and usefulness. Valid comparisons on the aggregate, nation-wide level must take into account basic structural intercountry differences, of which the most prominent is the sectoral composition of GDP: while secondary manufacturing industry, in which the bulk of industrial R & D is performed, accounts for only 20 per cent of Canada's GDP, in West Germany, it generates 40 per cent of GDP. Among other economy-specific factors that may influence overall research intensity, there could be governmental contributions to private sector R & D, the defence burden of the country, the size of the economy, and so on.

Since we have little, if any, theory of R & D expenditure determinants at the macroeconomic level, it would be rash to have confidence in the selection of variables that have to be held constant in order to make acceptable macrointensity comparisons. Given our ignorance at this level of aggregation, the usefulness of GERD/GDP comparisons is in question, as they cannot under the circumstances lead to corrective policy prescriptions.

A clarification (and amplification) of these issues is undertaken in the following two chapters of the

Figure 1-1

Causal Structures of Innovation



SOURCE Pavitt (1979, p. 462).

paper. Chapter 2 is devoted to tabular (and some correlational) comparisons of economy-wide intensity ratios pitted against the variables mentioned above. In Chapter 3, an attempt is made to "build up" economy-wide research outlays from sectoral, less aggregate, research intensity figures calculated by using OECD countries' norms. The question of invisible research transfers is also broached.

The thrust of this paper lies, however, in the later chapters, in which individual manufacturing industries furnish the base for comparison of research intensities. When it comes to individual industries, a certain amount of theoretical and empirical background is available upon which to draw for attempts at comparison. In that context, we may think of industry-specific determinants of R & D spending, whose levels will naturally be different from economy to economy, but whose importance to the industry's R & D will be roughly equal in all countries. Among such industry determinants, we may find technology transfer due to foreign ownership, trade orientation, patent climate, government support for research, past profitability, and so on.

If it were an absolute requirement that comparisons must be made at the GERD/GDP level, then such comparisons, to have any meaning, should be based on a build-up procedure that starts from the level of industries or sectors and relies on an (economic) analysis of R & D spending determinants. The R & D expenditure function would be estimated econometrically for a given industry in a cross-section of "comparable" OECD countries from which one country, such as Canada, would be left out. The estimated parameters would then be used to "forecast" the corresponding R & D intensity ratio for Canada. The basic assumption common to this procedure and to the "direct" comparisons currently practiced is that the chosen OECD countries provide a proper yardstick. The advantages of the econometric procedure are the statistically verified selection of actual R & D determinants, the assessment of their relative influence and, finally, the indication for action they may provide to policy makers.

While several approaches are possible, our initial trial focuses the investigation on a small number of industries, each taken separately. The data base for estimation of the R & D expenditure function consists of a time series for the industry in question in a cross-section of OECD countries. For example, suppose it is desired to calculate the level of R & D spending in the Canadian chemical industry (or pulp and paper industry, or nonferrous metals, or the like), which would correspond to the OECD "norm" during the period 1967-77. (The best available source of data is the *International Survey of Resources Devoted to R&D* published every second year since 1967 by the OECD.) The relevant data for the chemical industry in major OECD countries would then be collected for each of these "international statistical years" and used to estimate the parameters of a function such as:

$$\$\,R\&D_{\text{country } j,\ \text{year } t} = f\text{ (past R\&D success; financial performance; government support; foreign ownership; and so on)}$$

The estimated parameters are applied to calculate the "appropriate" R & D spending in this industry in Canada during the same period of time.

In our study, we apply this methodology to seven industries. Chapters 4 and 5 discuss the employed model of industrial R & D intensity determinants and the data employed in its estimation, while Chapter 6 discusses the statistical results. Chapter 7 presents a summary of our procedure and results, and it speculates on how our findings might be used in policy formulation. These speculations are in the nature of an afterthought; we would like to point out again that the main thrust of the study is in the area of methodological improvements upon making international comparisons of research intensity.

2 Economy-Wide Research Intensity Comparisons

In this chapter, we document with the help of three examples the reservations that can be raised with regard to the validity of using the GERD/GDP ratio in the setting of targets or in international comparisons. The exercise is illustrative and suggestive rather than exhaustive, since there is no theory of R & D outlay determinants on the national level to provide guidance in the selection of those variables that should figure in comparison attempts.

Lest we be accused of knocking down a straw man, we first offer the following quote from the January 1981 ministerial speech solemnly affirming the goals of the government's innovative policy (Roberts, 1981):

> But a country can be scientifically and technologically overdependent. Canada is in that position. We spend less than 1% of our GNP on research and development. Gross Expenditures on Research and Development (GERD) in the natural sciences and engineering is widely used by most countries as an indicator for their R & D expenditures. Most industrialized countries spend at least 1.5% and several 2%.

The most obvious reason for differences in research intensity between apparently comparable economies is clearly sectoral structure, such as the division between manufacturing and other parts of the economy. Structural differences can be expected to play such an important role in this context that a separate chapter (Chapter 3) is given over to that topic. Here the analysis is confined to what we hypothesize are three important differentiating factors: sheer domestic market size, defence responsibilities, and governmental funding of R & D. We look at a group of 13 to 15 industrialized OECD countries, choosing the years 1971 and 1977 (the latest available, with Austria and the U.K. missing) for cross-sectional comparison.

Tables 2-1 and 2-2 list some 13 or 14 OECD countries in order of increasing size of their economies in 1971 and 1977, respectively; the second column of each table shows the corresponding GERD/GDP ratios. Despite some obvious anomalies, as in Canada, where invisible R & D is imported, or in The Netherlands where Phillips exports invisible R & D, the impression is of a positive relationship between market size and intensity, more clearly so in 1971 than in 1977. Spearman's rank correlation coefficients confirm this at the 1 per cent confidence level in the earlier year and at the 10 per cent level in 1977. By that year, of course, Denmark is in the Common Market, and other Common Market countries are more firmly integrated into that larger economy.

Table 2-1

Comparison of Market Size and Research Intensity, Selected OECD Countries, 1971[1]

Country	GNP	GERD/GDP Ratio	GERD/GDP Rank
	(U.S. $ million)	(Per cent)	
Finland	16,663	0.79	13
Norway	17,662	0.90	11
Austria	24,178	0.48	14
Denmark	24,656	0.82	12
Belgium	41,006	1.25	8
Sweden	47,132	1.49	7
Netherlands	54,377	2.08	2
Italy	105,527	0.91	10
Canada	109,912	1.24	9
United Kingdom	146,162	1.90	4
France	204,890	1.83	5
Germany	285,632	2.06	3
Japan	310,043	1.66	6
United States	1,067,714	2.58	1
	$r_S = 0.80$		

1 In this and the following tables, Australia is not included in 1971, and Austria and the United Kingdom are not included in 1977.

SOURCE In this and the following tables, GNP and defence figures come from U.S. Arms Control and Disarmament Agency (1979), and research related figures from OECD, *International Statistical Years.*

A study of eleven countries by the OECD (1978) establishes that the three industries with the highest research intensity are aircraft, electronics (with or without computers), and drugs. The first two of these typically receive heavy research funding out of defence budgets; in certain countries, governments perform a substantial amount of defence-oriented

Table 2-2

Comparison of Market Size and Research Intensity, Selected OECD Countries, 1977

Country	GNP	GERD/GDP Ratio	GERD/GDP Rank
	(U.S. $ million)	(Per cent)	
Finland	29,028	1.0	10
Norway	33,825	1.405	7
Denmark	40,099	0.957	11
Belgium	71,922	1.401	8
Sweden	76,092	1.90	4
Netherlands	96,788	1.97	3
Australia	104,990	0.888	12
Italy	182,927	0.886	13
Canada	206,250	1.1	9
France	376,899	1.77	5
Germany	483,844	2.0	2
Japan	620,032	1.7	6
United States	1,874,402	2.39	1
	$r_S = 0.46$		

SOURCE Same as for Table 2-1.

research. In pursuit of this information, Tables 2-3 and 2-4 match the selected OECD countries by defence and research intensities in 1971 and 1977, respectively. A positive relationship between the two is established at the 1 per cent confidence level in 1977 and at the 10 per cent level in 1971. When free-riding Japan is dropped from the 1971 leagues, the rank correlation coefficient's significance leaps to 1 per cent, suggesting that defence commitment plays a role in research intensity, other things being equal.

Table 2-3

Comparison of Defence and Research Intensity, Selected OECD Countries, 1971

Country	Defence/GNP Ratio	GERD/GDP Ratio	GERD/GDP Rank
	(Per cent)		
Japan	0.9	1.66	6
Austria	1.0	0.48	14
Finland	1.4	0.79	13
Canada	2.0	1.24	9
Belgium	2.1	1.25	8
Denmark	2.4	0.82	12
Italy	2.6	0.91	10
France	3.2	1.83	5
Norway	3.3	0.90	11
Germany	3.4	2.06	3
Sweden	3.4	1.49	7
Netherlands	3.5	2.08	2
United Kingdom	4.5	1.90	4
United States	7.5	2.58	1
		$r_S = 0.43$	
	without Japan	$r_S = 0.86$	

SOURCE Same as for Table 2-1.

Table 2-4

Comparison of Defence and Research Intensity, Selected OECD Countries, 1977

Country	Defence/GNP Ratio	GERD/GDP Ratio	GERD/GDP Rank
	(Per cent)		
Japan	0.9	1.7	6
Finland	1.5	1.0	10
Canada	1.8	1.1	9
Denmark	2.3	0.957	11
Italy	2.6	0.886	13
Australia	2.9	0.888	12
Belgium	3.1	1.401	8
Norway	3.1	1.405	7
France	3.2	1.77	5
Germany	3.4	2.0	3
Sweden	3.4	1.90	4
Netherlands	3.6	1.97	2
United States	5.9	2.39	1
	$r_S = 0.74$		

SOURCE Same as for Table 2-1.

Since the days of the Lamontagne senate committee report in 1972, it is customary, in Canada, to deplore the relatively high proportion of total funding of R & D activity that is borne by the government (MOSST, 1978a). This, it is implied, shows that the private sector is not doing its share. "Yet compared to other governments, the Canadian government does not finance a large share of the R & D *in manufacturing*" (emphasis added; MOSST, 1981 p. 16). These two views are contradictory, and they reflect uncertainty about how much the public sector might stimulate R & D activities in the private sector.

There is but one Canadian econometric study available on the question of the stimulative powers of incentive grants to R & D (Howe and McFetridge, 1976). Coming from a sample of 81 Canadian firms in the chemical, electrical, and machinery industries, the evidence is mixed; in only one of the three industries did recipients of R & D subsidies increase their own R & D expenditures. In any case, the findings can only be suggestive, for they are based on microeconomic data.

The data in Tables 2-5 and 2-6 show a slight association (at the 10 per cent level) between overall research intensity and the proportion of GERD financed by nonbusiness (mostly government) funds in 1971, and none in 1977. This nondirectional result accords well with our lack of knowledge in this area.

Table 2-5

Comparison of the Nonbusiness Share of Gross Expenditures on Research and Development with Overall Research Intensity, Selected OECD Countries, 1971

	Nonbusiness Expenditure on R&D/GERD	GERD/GDP	
Country	Ratio	Ratio	Rank
	(Per cent)		
Japan	27	1.66	6
Italy	43	0.91	10
Finland	43	0.79	13
Austria	43	0.48	14
Sweden	44	1.49	7
Netherlands	45	2.08	2
Germany	45	2.06	3
Belgium	50	1.25	8
Denmark	53	0.82	12
United Kingdom	57	1.90	4
Norway	59	0.90	11
United States	60	2.58	1
France	64	1.83	5
Canada	71	1.24	9
	$r_S = 0.44$		

SOURCE Same as for Table 2-1.

Table 2-6

Comparison of the Nonbusiness Share of Gross Expenditures on Research and Development with Overall Research Intensity, Selected OECD Countries, 1977

	Nonbusiness Expenditure on R&D/GERD	GERD/GDP	
Country	Ratio	Ratio	Rank
	(Per cent)		
Belgium	32	1.401	8
Sweden	40	1.9	4
Japan	42	1.7	6
Germany	47	2.0	2
Netherlands	48	1.97	3
Finland	49	1.0	10
Italy	53	0.886	13
Denmark	55	0.957	11
United States	56	2.39	1
France	59	1.77	5
Norway	64	1.405	7
Canada	69	1.1	9
Australia	76	0.888	12
	$r_S = 0.28$		

SOURCE Same as for Table 2-1.

In summary, it is reasonable to assert that comparisons based on a single criterion are as fraught with danger in the economics of innovation as in the economics of anything else. When the crudest of correlation measures reveals a strong association between the GERD/GDP ratio and defence and economy-size variables, it is time to think of an appropriate multivariate (and, possibly, multi-equation) framework of analysis for research intensity macrocomparisons.

3 Sector-Based Research Intensity Comparisons and Invisible R&D

The importance of being earnest about structural differences when comparing economy-wide research intensities appears clearly from the reading of Table 3-1, as prepared by MOSST (1978b, p. 10). Total R & D outlays in the business sector of the economy as a share of GDP come to 0.40 per cent in Canada, or less than one-third of the 1.28 per cent ratio in West Germany. When, however, the relative sectoral importance of manufacturing is taken into account – for most of R & D is performed in that sector – Canada's R & D spending as a proportion of the GDP of manufacturing industries is 2.0 per cent, or almost two-thirds of Germany's 3.19 per cent.

It has been evident for some time that there are "natural" clusters of R & D intensities located in certain sectors or industry groupings (OECD, 1978). The most obvious reason for this clustering is undoubtedly the technological opportunity available to a sector or to an industry. International comparisons of research intensity can therefore be made somewhat more realistic if they are based on data that are less aggregated and that come closer to the clustering tendencies. Here we look at the major economic sectors only.

While several methods of comparison are possible, we choose one in which two elements are stressed: an OECD-wide norm and a build-up procedure. Unlike the approach in Table 3-1, in which comparisons take place in the last column between the Canadian ratio and that of the other countries, we employ "as if" forecasts of Canadian research expenditures calculated sector by sector, and we add them up to make a forecast for the whole of the Canadian economy. The reference point is the proportion of GDP of a given sector in the selected OECD countries, with Canada excepted. The forecast formula is derived by simple substitution from the identity:

$$\$\,R\&D_{Sector,\ CAN} = \frac{\$\,R\&D_{Sector,\ CAN}}{\$\,GDP_{Sector,\ CAN}} \times \frac{\$\,GDP_{Sector,\ CAN}}{\$\,GDP_{Total,\ CAN}} \times GDP_{Total,\ CAN}$$

Table 3-1

Comparison of Industrial R&D Expenditures as a Proportion of Gross Domestic Product, Selected OECD Countries, 1973

Country	Total R&D performed by the business enterprise sector	R&D expenditures as a share of total GDP	Ratio of manufacturing industries' GDP to total GDP	R&D spending as a proportion of manufacturing industries' GDP
	(U.S. $ million)		(Per cent)	
Canada	487	0.40	20	2.00
Australia	361	0.48	21	2.29
Denmark	123	0.47	26	1.81
Finland	87	0.51	27	1.89
Norway	82	0.43	22	1.95
Sweden	551	1.15	27	4.26
France	2,586	1.09	35	3.14
Germany	4,400	1.28	40	3.19
Japan	4,757	1.20	38	3.16
United Kingdom	2,063	1.26	27	4.66
United States	20,921	1.61	25	6.45

SOURCE MOSST (1978b).

To calculate the R & D intensity for Canada that would correspond to the average OECD sectoral composition of GDP, the middle term on the right-hand side is replaced as follows:

$$\text{Forecast } \$\, R\&D_{Sector,\ CAN} = \frac{\$\, R\&D_{Sector,\ CAN}}{\$\, GDP_{Sector,\ CAN}} \times \frac{\$\, GDP_{Sector,\ OECD}}{\$\, GDP_{Total,\ OECD}} \times GDP_{Total,\ CAN}$$

Table 3-2 sets out the results.

Table 3-2

Forecast and Actual R&D Expenditures by Sector, Canada, 1971, 1973, and 1975

	1971		1973		1975	
Sector	Fore-cast	Actual	Fore-cast	Actual	Fore-cast	Actual
	(Millions of Canadian dollars)					
Agriculture	. .	. .	110.5	103.3	124.7	125.5
Mining	8.2	18.3	8.6	25.7	19.1	41.2
Manufacturing	501.6	354.7	579.6	410.7	785.3	571.4
Tertiary	57.6	62.8	45.0	48.9	74.6	79.7
Total	567.4	435.8	743.7	588.6	1,003.7	820.8

SOURCE "Actual" R&D Expenditures taken from OECD, International Statistical Years. "Forecast" R&D Expenditures calculated with the help of formula given in text.

Before pursuing the implications of Table 3-2, we should say, as we did at the outset of Chapter 2, that our exercise is illustrative and suggestive rather than exhaustive. A more elaborate analysis would, for example, examine the dynamic role that foreign ownership may play in influencing research intensity within each sector. It would, of necessity, require access to rather detailed sectoral information on both output and research spending by type of ownership. The direction of causality between R & D intensity and ownership is the subject of intense discussion. At the level of the firm, the theory pertaining thereto is reviewed in Chapter 4 in the section on foreign ownership.

On the strength of these comparisons, it can be stated that Canada's "underperformance" against the OECD is less severe than what the oft-quoted GERD/GDP ratio or the dismal showing displayed in the third column of Table 3-1 would indicate. The ratio of "actual" to "forecast" total R & D expenditures shown in Table 3-2 is, for instance, 79.1 per cent in 1973. Without taking account of the sectoral composition of GDP, one could compare the 1.02 per cent of Canada's GDP spent on research in that year with the OECD average (based on the countries listed in Table 2-1 with Canada excluded) of 1.55 per cent in that year and arrive at a ratio of 65 per cent only. Canada's below-average performance can clearly be traced back to the reported R & D outlays of the manufacturing sector. Yet, in the words of a recent MOSST research paper (1978b, p. 1):

> Canada's domestically conducted R & D does not begin to approximate its total source of new technology, inasmuch as, being largely foreign-owned, Canadian industry has ready access to R & D imported from foreign parent companies. Significantly, much of this imported R & D enters the country without being financially recorded...

According to MOSST estimates, "invisible" R & D imports in 1975 in the manufacturing sector amounted to over $500 million. This estimate represents more than double the gap between the 1975 "actual" and "forecast" figures for the Canadian economy as a whole. If "access to" rather than "performance of" innovation-oriented activities were the decisive policy question, Canada's ranking in the international league would be near the top. And not only Canada's. As Williams (1973, p. 9) notes:

> Australia, like Canada, has a lower overall R & D percentage than other countries with similar income per head. The explanation is not only industrial structure and low percentage expenditure on defence and space. Both have a large foreign ownership of their science-based industries and therefore lean on the industrial R & D of parent firms. For Australia, I calculated that this "vicarious" R & D practically bridged the gap between actual Australian R & D in industry and what it would be if it matched the British R & D role (with Australian weights).

4 A Model of Industrial R&D Intensity Determinants

The regression approach to the international comparison of R & D intensities in a sample of industries inevitably entails a study of the determinants of R & D effort at the level of firms and industries. As a part of the regression analysis, we test hypotheses relating R & D intensity to several factors suggested by economic theory, and we compare our findings with the published literature. Our regression equation is formulated on the basis of a set of causal relationships developed in the literature together with the frequently contradictory empirical evidence on each. The main purpose of the formulation and estimation of such regression models in this study, of course, is the development of a tool suitable for calculating ("forecasting") the appropriate level of R & D intensity for Canada in a sample of selected industries. This task is performed in Chapter 5.

The rest of this chapter is organized as follows. We first make a few observations about our particular approach to the formulation of the R & D intensity function, emphasizing the differences from previously published studies. Then, we review the literature on the determinants of R & D expenditures, including a sampling of the results of a number of empirical studies. We take pains here to illustrate the extreme sensitivity of the theoretical predictions to the assumptions that are incorporated in models of firm or industry behaviour, and we note that many of the corresponding empirical findings are contradictory. Finally, we provide a selective catalogue of some general problems in measurement of the relevant theoretical concepts. A detailed discussion of the variables included in our own regressions and of our data sources and their shortcomings is incorporated in the following chapter.

Formulation of the R&D Function

The majority of published empirical studies investigating determinants of R & D expenditures apply information drawn from a multi-industry universe (whether they deal with firm or industry data). As a consequence, they have to cope with the problem of controlling for interindustry variations in such important determinants of R & D intensity as technological opportunities, interindustry differences in the cost of producing knowledge, relative involvement in various scientific disciplines, the proportion of output accounted for by industrial versus consumer goods (or durables versus nondurables), and so on.

Both the conceptualization and measurement of these factors pose formidable challenges. In regression analysis, these factors are typically handled by dummy variables or, in a more sophisticated manner, by application of factor analysis (Shrieves, 1978). Our data base consists of information on each of several industries in a cross-section of countries. It therefore enables us to avoid the heterogeneity problems while, at the same time, it allows us to measure the effects of a number of variables common to all firms within an industry and country, but varying between countries.

R & D intensity is determined by both demand and supply factors. Most of the variables traditionally considered in published empirical research on the subject can be labelled "supply variables," since they measure the factors affecting the private cost-benefit analysis, and thus they are incentives to undertake R & D. These factors include cash flow, market conditions, and the institutional framework, including patent protection, taxation, and other government measures affecting R & D funding, foreign ownership, and so on. Among the "demand variables" sometimes analysed in this context are the importance of government contracts (especially in defence and aerospace industries), expected market size, and characteristics of the purchasing industries.

The Determinants of R&D Intensity

This section can be roughly divided into two parts. First, we discuss – individually and in some detail – eight determinants of R & D intensity that we consider to be both important and operational (that is, measurable, with known sources of information). Second, we briefly comment on a number of other factors discussed in the literature, regardless of the feasibility of actually considering them in our regression analysis.

Industrial Concentration

The theoretical analysis of the relationship between the degree of competition and the intensity of inventive and innovative activity dates back to Schumpeter (1950). For purposes of empirical analysis, the Schumpeterian hypothesis has been formulated in two different ways.

The first method assesses the relationship between the size of firms and the intensity of their research effort. The underlying notion here is the "public good" characteristic of knowledge generated by research, which requires that the firm's operations reach a size sufficient to make the private benefits of research larger than the costs. This aspect is discussed in greater detail below.

The second method examines the relationship between the degree of market power prevailing in an industry and the level of the industry's innovative activity. The link connecting the degree of competition with intensity of innovative effort in an industry is the ease and speed with which the results of a firm's research activity can be imitated by competitors. In a perfectly competitive industry with free entry and immediate imitation, the costs of a firm's R & D cannot be passed onto the consumers by way of an increased price; hence, the innovator cannot recover his investment. In oligopolistic industries with entry barriers, a product innovation that shifts the demand curve to the right or a process innovation that shifts the cost curve downward may provide sufficient incentive for innovation by an individual oligopolist.

If imitation is costly, the inventor can capture the benefits of his innovation. For the case of process innovation, Arrow (1962) argues in a classic article that incentives for innovation under these conditions is stronger in competitive markets than under monopoly, since the monopolist views his preinvention profits as a part of the opportunity cost of innovation.

Demsetz (1969) shows that a monopolist has an incentive to spend a larger absolute amount on innovation when account is taken of the "normally restrictive" level of output under monopoly. Shrieves (1978, p. 332) asserts that the ratio of R & D spending to sales (that is, the "relative incentive") remains higher under competition, even when the adjustment suggested by Demsetz is made. Dasgupta and Stiglitz (1980) point out that Arrow's contention appears to be based on a single firm in isolation, and that it disregards the effects of interfirm rivalry on total industry R & D spending.

Empirical testing of this version of the Schumpeterian hypothesis revolves around the investigation of the relationship between innovative activity and market structure, as measured by industrial concentration. The relevant empirical studies have been recently reviewed in extensive analytical surveys by Kamien and Schwartz (1975) and by Scherer (1980, Chapter 15). The bewildering variety of their findings includes the following observations. Inventive output is not systematically related to variations in market power (Scherer, 1965). The relationship is complex, since market power (as measured by industrial concentration) tends to coincide with the availability of technological opportunities in the respective industries (Scherer, 1967). Concentration influences research spending jointly (interactively) with product differentiation (Comanor, 1967). Concentration significantly raises R & D intensity in industries producing material inputs and consumer goods, has a weak influence in industries producing nonspecialized producer goods, and has a marginally significant negative influence in industries producing specialized durable equipement (Shrieves, 1978). And the regression coefficient of the concentration variable is significantly negative for "technology-rich" Canadian industries, and is not significant elsewhere (Globerman, 1973).

A fundamental theoretical challenge to the methodology of existing econometric research was recently published by Dasgupta and Stiglitz (1980). Their point of departure is the argument that, except in the short run, both market structure and inventive activity are endogenous, since both depend on such factors as research technology, demand conditions, financial market conditions, and the legal and institutional structure, including patent rights. The degree of industrial concentration, therefore, should neither be treated as given, nor as causally related to innovative activity.

Both the above authors and Loury (1979) observe that much of the published literature on this subject represents a partial equilibrium analysis of the behaviour of individual firms under various degrees of industrial concentration. In markets characterized by rivalry, however, each firm's R & D effort also depends on the anticipated response by competitors. In addition, the behaviour of the aggregate R & D spending by all firms in the industry cannot be simply inferred from the behaviour of a "typical" firm indicated by microeconomic models. While such models may indicate that rivalry reduces the R & D effort by each firm, the number of firms engaging in R & D may increase, and so may the total amount of the industry's R & D spending. However, R & D rivalry produces some winners and losers, some changes in the distribution of market shares, and thus it also effects changes in the industrial concentration.

Nevertheless, even when market structure is treated as endogenous, the theoretical models developed by Dasgupta and Stiglitz predict that, in a cross-section of industries with low concentration, both the total R & D effort and the effort by a typical firm are positively correlated with variations in concentration. They also suggest that industry-wide R & D expenditures in competitive markets may exceed the socially optimal levels, even though the cost reduction may be less than socially optimal. Similarly, firms in competitive markets may be engaging in overly risky projects and perform research at excessive speed (in an attempt to gain a cost advantage over rivals).

Several other theoretical models and considerable empirical evidence suggest that the relationship between R & D activity and industrial concentration may be nonlinear. Others have argued that the concentration ratio is not an adequate measure of the degree of competition or indeed an appropriate characteristic of market structure. The expected sign of the coefficient of this variable in the R & D function is thus highly uncertain and is likely to differ from industry to industry.

Market Size

The crucial importance of "expected market size" is emphasized by Griliches and Schmookler (1963) and by Schmookler (1966). They argue that the cost of reproducing knowledge is much lower than the cost of generating it, and thus each firm's private return from R & D depends upon the number of times knowledge is reproduced (number of units of output produced).

More precisely, the overall size of the market determines the total volume of monetary benefits generated by the production of knowledge. The private benefits depend, in addition, on the extent of quasi-rents or temporary monopolies, which determine the producers' ability to appropriate the benefits from the knowledge that they have developed (Pakes and Shankerman, 1980, pp. 9-10). Models developed by Dasgupta and Stiglitz (1980) also predict that both the optimal R & D expenditures and R & D expenditures per firm increase with the size of the market. Increased costs of R & D in their model lead to a decrease in R & D expenditures, if demand is elastic, and to an increase, if demand is inelastic.

While "expected market size" in this sense is clearly related to the size distribution of firms in an industry, it is conceptually different from industrial concentration as a determinant of R & D intensity. The latter measure characterizes not only the division of the market, but also, according to the mainstream industrial organization literature, it reflects the intensity of competition in an industry. This, in turn, is related to industry profitability and riskiness of its cash flow, both of which feature prominently in the Schumpeterian theory of innovation. Finally, the size of the market may be endogenous to the product innovation itself.

These considerations suggest that the size of the market variable may not be relevant in an analysis of the determinants of R & D activity at the level of an industry. In other words, the simple fact that a particular industry in a particular country has available to it a larger market than the same industry in another country does not say much about private incentives to engage in R & D, unless the size distribution of firms is incorporated as well. A separate major problem is the definition of the relevant market in the presence of international trade flows.

An analysis performed by Howe and McFetridge (1976) with firm-level data concludes that firm size is largely irrelevant as a determinant of R & D spending in the Canadian machinery industry and among foreign-owned firms in the chemical industry. The study finds, however, that it is related in nonlinear fashion in the electrical industry and among Canadian-owned firms in the chemical industry.

Profitability

The objective of R & D is to raise future profits. The precise nature of this relationship is a part of the larger issue regarding the contribution of R & D to economic growth and productivity, and its full elaboration is beyond the scope of this study. The other relationship between R & D and profits is expressed in the Schumpeterian hypothesis, which maintains that the existence of higher profits and lower business risks associated with monopoly power is a prerequisite for R & D activity.

One of the most elaborate empirical analyses of the complex relationship between R & D profits published to date is that of Branch (1974). He observes that R & D competes for funds with other types of expenditures, many of which are unavoidable (production, capital investment, and taxes). Since R & D investment is riskier than most of the other uses of funds, Branch argues that it is unlikely to be financed by borrowing or by issuing new equity; it depends on profits as a source of funds.

However, in industries characterized by slow technical change, low profitability, and cyclical fluctuations in demand, the relationship may well be perverse. In periods of high demand (and high profits), managers may prefer to invest in fixed capital rather than to finance R & D activity with long and uncertain payoffs. Also, scientists and engineers may be shifted to production tasks. Finally, R & D may be used to stimulate demand in periods of low profits.

Applying a distributed lag analysis to data for a sample of 111 largest manufacturing firms in seven U.S. industries during the period 1950-65, Branch tests both hypotheses on the relation between R & D and profit. The proposition that R & D activity increases both profits and growth is uniformly supported for all seven industries. However, profitability is found to be a statistically significant determinant of R & D effort only in four industries (electrical equipment, paper, mechanical equipment, and petroleum). Its coefficient is not statistically significant in chemicals (with a negative sign), drugs, and nonferrous metals.

Branch suggests that the lack of significance of the profitability variable reflects the contradictory pressures on managerial decisions: high profits lead both to a greater availability of funds for R & D and to an increased demand on these funds for non-R & D uses. This problem is illustrated in an earlier finding (Brown, 1957) of the U.S. machine tool industry, in which managers are found to increase R & D during slumps in order to stimulate demand.

Sherman (1974) hypothesizes that firms may spend higher-than-normal profits on R & D or advertising (both of which are expensed) in order to reduce current reported profits for tax purposes while enhancing future profits. In a recent paper, Nadiri (1979) argues that in a cyclical upswing, firms increase R & D expenditures and reduce or postpone them during recessions. Regression analysis based on a sample of eleven U.S. industries during the period 1958-75 identifies a positive, statistically significant influence of the degree of capacity utilization on the stock of R & D, consistent with this hypothesis.

At a macro level, an examination (Pavitt, 1980, p. 62) of these relationships, by means of a simple cross-tabulation of selected OECD member countries according to the levels and trends of their aggregate R & D intensity and aggregate profitability, proves to be inconclusive. At the time of the study, only Japan had both high and rising R & D expenditures and a high and rising profitability. Meanwhile, the case of the U.K. gives support to the view that low and declining profitability may depress R & D. But, in Canada, R & D was low and falling while profitability was high and rising. For Sweden, the situation was exactly the opposite, with low and falling profits and high and rising R & D.

The statement that the level of research effort by a firm is determined by the expected net income generated by the R & D investment indicates the nature of the conceptual difficulty inherent in incorporating conventional measures of profitability in the R & D function. A more refined analysis (for example, Pakes and Shankerman, 1980) reveals that interfirm differences in expected net income are due to variations in the cost of research inputs, in the productivity of research resources, and in the ability to derive monetary benefits from a given amount of produced knowledge. The conventional measures of profitability, however, reflect (perhaps predominantly so) many other factors completely unrelated to research activity.

Nadiri (1979, p. 13) concludes that "empirical evidence for the proposition that either liquidity or profitability is conducive to innovative effort is weak." Howe and McFetridge (1976) find a positive, statistically significant relationship between R & D spending and depreciation charges only in one of the three industries that they analysed. The coefficient of the after-tax profit variable was positive and significant only for Canadian-owned firms in two of these industries, but not for the foreign-owned firms. In our model of R & D determinants, we accordingly expect that the estimated coefficient of this variable is occasionally not statistically significant and that its sign conceivably varies from industry to industry.

Taxation

The tax burden affects corporate cash flows and, in turn, the amount of resources available for R & D activity. As shown above, the empirical evidence on the influence of cash flow on R & D effort is inconclusive. But, as Nadiri (1979, p. 13) notes, "where evidence of a positive relationship exists, cash flow variables seem to have their strongest effect on R & D during growth periods." Lowering corporate income taxes or increasing depreciation allowances would, therefore, increase the firm's R & D effort.

On the other hand, Sherman (1974) argues that, during cyclical upswings, firms apply a part of their higher-than-average profits to raising their R & D spending to above-average levels in order to reduce current reported profits for tax purposes. Following this reasoning, one would expect a positive relationship between the tax rate and R & D spending (the higher the tax rate, the greater the incentive to write off R & D expenses).

In a multiple regression context, the appropriateness of considering a measure of the tax burden thus seems to depend on whether profit is treated primarily as a component of cash flow, which is essential for R & D financing. If so, the tax rate should be included as a separate variable only if the profit variable included in the same regression is "before-tax" profit, but not otherwise. A test of the hypothesis that R & D is used as a "tax shelter" seems to permit inclusion of the tax rate together with either definition of the profit variable. We include the taxation variable in our model; the balance of the published empirical evidence suggests to us that the sign of its coefficient should be negative.

Investment Climate

This variable serves two main functions illustrated by the theoretical discussion of the determinants of R & D intensity considered above. First, it is intimately connected with the firm's expectations of the future growth of the market, and thus it could be said to act as a proxy for the variable "expected size of the market." Second, investments in "traditional inputs" interact with investments in research resources and influence their productivity. For example, a highly capital-intensive firm would not introduce an innovation that would make much of its existing capital stock obsolete. Nadiri (1979, pp. 15-16) reports the results of an empirical study that supports the hypothesis that R & D decisions are not independent of other input decisions by the firm.

To the extent that past growth of investments is a proxy for expected future growth, a regression variable such as "gross fixed capital formation" is a part of the "demand inducement" mechanism of R & D intensity. Contrary to Schmookler's (1966) theoretical argument, Pakes and Shankerman (1980) do not find it important in explaining intraindustry variations in R & D intensity. However, in previous work by Pakes (1978), it was found to be influential in the interindustry distribution of research activity. Given the nature of our model and our proxy for investment climate, we hypothesize a positive relationship between this variable and research intensity.

Foreign Ownership

The interest in the relationship between foreign ownership and R & D arises from the concern that foreign ownership decreases the amount of research effort in the host country and increases its reliance on foreign technology. Related issues are whether the foreign parent companies provide their overseas affiliates with access to all of their latest technology, at what cost, and with what restrictions. Furthermore, it is relevant to know whether technology imported independently from nonaffiliated firms abroad requires more or less adaptation (modification) to the domestic market needs than technology imported through the intracorporate network.

There are perfectly valid reasons why subsidiaries may be expected to do less research than parent companies. These include existence of economies of scale in research, desired proximity to "centres of learning" and to large markets that may be in the headquarters country, and other factors. The classic Canadian study by Safarian (1966) does indeed establish that Canadian subsidiaries do less research than the parent companies.

On the more meaningful and policy-relevant question whether foreign subsidiaries operating in Canada do more or less research than their Canadian-owned counterparts, the evidence has been mixed. Safarian finds no evidence that foreign-owned firms do less research than comparable Canadian-owned firms. On the other hand, a recent questionnaire-based study of 283 major innovations in five Canadian industries (De Melto, McMullen, and Wills, 1980) concludes that foreign-controlled firms of all sizes had lower R & D-to-sales ratios than their Canadian-owned counterparts.

The reason is access to technology developed by parents and other affiliates, that is, reliance on importation rather than duplication of research effort in Canada; some 70 per cent of technology imports by foreign-controlled firms are on an intracorporate basis. Or, in the terminology used by Bones (1979), while foreign subsidiaries are probably more technology-intensive than their Canadian-owned counterparts, they are less research-intensive because of their access to the know-how developed by parents and affiliates. Given the fact that the foreign technology so acquired may be "free" or "low-cost" to the Canadian economy, it is meaningful to ask why this state of affairs should be a cause for concern. The answer clearly depends on the weight that one attaches to the external effects of R & D, the degree of "sophistication" of the employment mix in Canada, the independence of foreign sources of technology, and so on.

Globerman (1973), in a regression analysis working with a perilously small sample of Canadian industries, finds a positive, statistically significant relationship between foreign ownership and research intensity in "technology rich" industries. Elsewhere, the regression coefficient on the foreign ownership variable is found to be negative, but not statistically significant.

A positive relationship is also tentatively suggested by the first results of Porter's analysis (quoted in Wonnacott and Wonnacott, 1980, pp. 10-12), but this is reversed in a more complete specification of the regression relationship. This takes account of a possible reverse causal influence discussed in detail by Caves (1971) and noted again by Bones (1979) and others; foreign control is widespread in research-intensive industries, not because foreign-controlled firms do more research, but because foreign investment tends to be attracted to industries where R & D intensity is high. This propensity derives from the fact that some unique assets – such as a patented invention or a differentiated product – can be transferred to other national markets at little or no cost. Licensing of foreign producers or similar arrangements are frequently not feasible, because this transfer cannot be made independently of managerial talent, or because uncertainty about the value of this knowledge in foreign market makes impossible a market-type arrangement (Caves, 1971, pp. 6-7).

In order to account for this influence, Porter includes in his analysis the R & D intensities in the U.S. as one of the variables explaining the research spending in equivalent Canadian industries. The results of this analysis shows strong support for the hypothesis that foreign ownership reduces R & D intensity in Canada. The same type of variable is applied in a much simpler model by Lithwick (1969) who concludes that foreign ownership increases R & D. McFetridge (1977) finds a positive effect of foreign ownership on R & D in the Canadian machinery industry, but a stronger negative effect in chemicals and electrical equipment.

It should be noted that all the above contradictory results pertain to industry analysis. On the other hand, recent Canadian analyses dealing with firm data indicate that Canadian-owned firms of all sizes are more research-intensive than their foreign-owned counterparts.

Casson (1979, p. 11) concludes, after a quick analysis of the industry patterns of foreign investments by selected major countries, that the relationship between technological intensity of industries and degree of foreign ownership is by no means uniform across countries. While foreign direct investment by U.S. firms tends to be concentrated in high-technology industries, U.K. manufacturing investment abroad typically represents backward integration by firms engaged in consumer product industries. And, as pointed out by many authors in many different contexts, much of foreign direct investment by Canadians is in banking, finance, and similar lines of activity.

In our opinion the theoretical complexity of the relationship between foreign ownership and research activity does not make it possible to make an unambiguous prediction as to the sign of the estimated coefficient of this variable in our model of R & D determinants.

Government Participation

The government role in influencing the R & D intensity of the private business sector takes two different forms. Their relative importance, presumably, varies from industry to industry as well as across countries and also over time.

First, governments in their role as purchasers may initiate new R & D or increase the scope of existing R & D efforts by the business sector. This government activity on the demand side is likely to increase R & D intensity in the business sector for two related reasons: it positively affects the risk-return calculus for R & D ventures, and it may enable firms to reach the minimum (threshold) size of their R & D operations.

Second, governments directly engage in R & D, they contribute to the financing of research conducted by the private nonprofit sector (such as universities), and they contribute to the financing of R & D performed by the business sector. The latter contribution takes the form of direct research grants or various tax concessions directly related to R & D. In addition, of course, the "economic climate" created by the whole range of government policies, including the overall tax burden and its composition, inevitably has an effect on the business sector's R & D activity.

The supply-side government participation can be divided for analytical and empirical purposes into two different categories. Government policies directly and explicitly related to R & D are discussed in this section, while the "economic climate" effect of government actions is incorporated in the "taxation" and "investment climate" variables discussed above.

On *a priori* grounds, it is reasonable to assume that a more favourable tax treatment of R & D expenditures will increase the total volume of business sector R & D effort. It is much less certain whether direct government grants in support of business R & D will have the same effect; the firms may simply substitute government grants for private funds originally intended for the same purpose. Howe and McFetridge (1976) investigate this issue with a sample of 81 Canadian firms in the electrical, chemical, and machinery industries during the period 1967-71. The Canadian-owned electrical firms are found to have increased the volume of own funds invested in R & D by more than the amount of the grant, while the foreign-owned firms raised their own R & D investment by less than the amount of the grant. In the other two industries, the hypothesis that receiving a grant does not change the total R & D expenditures of a firm cannot be rejected. In no case, however, are these grants deemed to be simply replacing (substituting for) own funds.

Shrieves (1978), using data from a sample of 411 U.S. firms in 1965, finds an inverse relationship between R & D intensity and the percentage of R & D financed by government. (His multiple regression coefficient on this variable is negative and statistically significant at the 0.05 level.) Nadiri's (1979) analysis of a sample of 11 U.S. industries during the period 1958-75 shows a positive, statistically significant effect of the growth of the publicly financed stock of R & D on the private stock of R & D in total manufacturing and in durable goods industries. However, the effect is found to be negative and statistically significant in nondurables.

Our government participation variable reflects the proportion of total R & D spending in a given industry and country that is financed from government sources. Based on our understanding of the decision-making process within firms and on published results of previous studies, we cannot confidently predict either the direction or significance of this variable's effect.

Past R&D Success

Conventional wisdom holds that, in R & D, past success breeds current success; firms that have been successful in such investment in the past will invest more in the future (Grabowski, 1968). The most relevant measure of the success of (past) R & D activity is the profitability of the firm or industry. However, it also reflects a myriad of factors other than R & D performance, apart from being a component of the cash flow, and is thus tied to the R & D effort in an entirely different causal relationship, that is, as a source of financing.

Testing of the "success breeds success" hypothesis therefore requires that a different variable be developed, devoid of the above problem. Suitable empirical proxies include the level of the firm's or industry's patenting activity, number of major new innovations, balance of royalty payments, licensing activity, trade balance, and so on.

All of these measures are not equally suitable for all industries. The recorded patenting activity depends on the propensity to patent, which is known to vary from industry to industry. The simple counts of "major new innovations" raise major issues of interindustry comparability. And reported royalty payments and licensing activities are affected by the prevailing levels of foreign ownership, government regulations, and the particular accounting arrangements between parent companies and subsidiaries.

Measures of past R & D performance based on the industry exports, imports, and their relationship to the size of domestic market are comparable between industries, and are devoid of most of the above problems. They do, however, have another weakness; in industries based on natural resources, they reflect, at least in part, the country's endowment in such factors of production, not merely the past innovative performance of the industry in question.

Our preference for the use of trade balance variables as determinants of research intensity is based on the reasonable assumption of a time lag between research and commercialization. Current trade figures are the outcome of past research and development, and they cannot be influenced by current laboratory activity. A further supporting argument in favour of a causal relationship running from measures of trade balance to research activity (although with a somewhat less clear lag pattern) is advanced by Caves, Porter, and Spence (1980, p. 173). They observe that, whenever a country's firms compete in international markets, it may not be feasible for them to obtain innovations from parent companies or from licensees because of time delays and competitive considerations. A country's industry may thus be expected to spend more on its own R & D as its exposure to international markets increases.

Other Determinants

Effects of Government Regulations – Two types of government regulatory interferences are likely to have an effect on the extent of business sector innovative activity. The first type is the introduction or tightening of the safety standards for new products in industries subject to the market mechanism. The second type is seen in the decisions of regulatory authorities in industries, such as public utilities, that are subject to rate of return regulation (see Nadiri, 1979, pp. 16-18).

A prime example of the former type of regulation is the pharmaceutical industry, where a number of negative effects on research effort have been attributed to the tightening of requirements for introducing new products following the Kefauver amendments to the U.S. Food and Drug Act in 1962. These effects are revealed in the decline in the number of new chemical entities permitted (Peltzman, 1973); the increased cost per new chemical entity (Bailey, 1972); the faster decline in U.S. research productivity compared with that in the U.K., along with the shift in R & D activities by U.S. firms away from the U.S. (Grabowski, Vernon, and Thomas, 1978); and the decline in the private rate of return to R & D Bailey, 1972; Schwartzman, 1976). The validity of some of these findings has been challenged (for a review, see Hansen, 1977). Moreover, any attempt at quantification of the impact of such regulation faces a number of difficult problems; among them are intercountry differences in the meaning (and the consequent cost of compliance) of the various regulatory requirements, different combinations of regulatory policies in different countries, absence of information on the time lags in administering these policies, and so on. It is probably reasonably safe to assume that, for a given industry, the effect of regulatory interference does not vary markedly among the major industrialized countries.

In regulated industries, the slowdown and distortion in the pattern of technological change in railroads have been documented by Gellman (1971) and by MacAvoy and Sloss (1967). The whole issue of technological change in regulated industries is the subject of substantial literature (see for example, Capron, 1971), but this is largely beyond the scope of this study.

Interindustry Flows of Knowledge – R & D-intensive intermediate goods and capital inputs are very important contributors to productivity in the user industries, even though the user industries do little R & D on their own. Thus Nadiri (1979, p. 5) argues that the measured R & D intensity in industries relying heavily on R & D-intensive inputs is likely to be low. The absence in a regression of a separate variable measuring "R & D intensity of inputs" causes the ordinary least squares estimates of coefficients on other determinants of R & D expenditures to be biased.

The magnitude of this bias depends upon the degree of correlation between R & D intensity of inputs and each of the included explanatory variables. *A priori*, it is difficult to see why R & D intensity of inputs should be correlated with any of the variables discussed above. However, since the importance of this difficult-to-measure variable varies from industry to industry, we expect that its omission would cause the explanatory power of our regression to vary from industry to industry, and so it should be weaker in industries that rely heavily on purchases of technology-intensive inputs.

A conceptually different type of interindustry flow of knowledge arises from the "spillover" of information between "technologically close" industries, as briefly discussed in Chapter 1. Measuring its magnitude and effect on research effort is perhaps an even more vexing problem than measuring the R & D intensity of inputs (Griliches, 1979).

Appropriability of Benefits of Research – Schumpeter (1950) emphasizes the importance of the ability of the firm to appropriate the benefits of research as one of the main influences on its innovative effort. Among the major determinants of this ability are entrepreneurial talent, the industrial market structure, and the general institutional framework, including patent rights.

Market structure has been dealt with above; entrepreneurial talent and much of the "general institutional framework" are not easily quantifiable. Given the degree of international economic integration prevailing during the period covered by our sample data, the degree of patent protection in any given industry can be realistically described as uniform in all sample countries. One exception is the pharmaceutical industry, where intercountry differences exist in the availability of product versus process patents.

Further support for the much less urgent need to consider patent protection explicitly is provided by Mansfield et al. (1977). They show that the differences between the social and private rates of return tend to be greater for important innovations and for those that can be easily imitated. For a given cost of initiating research, it does not make much difference whether the innovation is patented or not.

In a similar vein, Pakes and Shankerman (1980) recognize that it is more advantageous for a firm to appropriate benefits from research if the produced knowledge is incorporated in its own output rather than in the output of other firms. This is so because of the difficulties in establishing the value of information in the market, and because reselling information may undermine the monopoly position of the innovator. To capture these effects, they use as the empirical variable the fraction of the industry's output from which the firm derives royalties. In our regression analysis, this type of influence is proxied by a "trade balance" variable.

International Flows of Invisible R&D – One of the few published quantitative analyses of the "invisible" imports of R & D is one carried out by the Ministry of State for Science and Technology (MOSST, 1978b), which uses Canadian data (see above Chapter 3). This calculation assumes that Canadian subsidiaries should have an R & D intensity that is identical to their parent companies. Accordingly, the annual sales of a sample of Canadian subsidiaries in a cross-section of industries are multiplied by the ratios of R & D to sales as reported by the corresponding parent companies, to arrive at "notional R & D." Invisible R & D imports are then obtained by subtracting from this figure the actual R & D performed or bought in Canada by the subsidiary and the payments for technology or R & D results made by the subsidiary to nonresidents, including its parent company. The results are then extrapolated from the sample to the total universe of firms in the relevant industries.

It appears that no adjustment is made for differences in product mix or degree of diversification between the parent company and the subsidiary. Furthermore, the differences in degree of foreign ownership between subsidiaries are not accounted for. While about one-half of the sample companies are 100 per cent foreign-owned, the share of foreign ownership in some is as low as 15 per cent. Finally, it is not clear whether the ratios of "parent" R & D to sales, as used in the calculations, are based solely on data for the country where the headquarters are located or on global (consolidated) figures, including the Canadian operations. There is also the question of whether subsidiaries can be expected to do as much research as parent companies (see above), and whether one dollar spent on R & D performed by the subsidiary is equivalent (in terms of yield) to one dollar spent on R & D purchased from elsewhere.

Our regressions do not explicitly account for the flows of invisible R & D, but they do incorporate a proxy variable – the degree of foreign ownership. Given the fact that our regression analysis accounts for intercountry variations in other factors as well, this approach may be superior to the direct calculations of the MOSST variety.

Quite clearly, the measured effect of this variable (or, for that matter, any other observable magnitude of this nature) on R & D spending does not differentiate between "benevolent" flows of invisible R & D and a deliberate policy of "starving of subsidiaries" of research activity. In the end, they both amount to the same thing – a reduction in the subsidiaries' own R & D spending.

The Structure of R&D Activities – The decision to develop a new product rather than to improve an existing product or process is influenced by the nature of the product line, riskiness of demand, potential entry, size of the existing R & D effort, and so on. Rasmussen (1973) shows that the more certain the growth of demand for existing products and the greater the profitability of the firm, the less incentive the firm has to engage in new product development. The riskier the demand for existing products, the greater the incentive to develop new products.

On a related issue, Nadiri (1979, p. 11) observes that:

> There is very little empirical evidence on the determinants of different types of R & D expenditures... How one stage of R & D leads to the other and with what time lag also remains largely unresolved.

The analysis of the composition of R & D spending between basic, applied, and developmental research, and of the shifts over time in this composition, is underdeveloped primarily because of lack of adequate statistical data. A recent contribution by Mansfield (1980) shows that the composition of R & D expenditures, as well as their volume, affects the rate of productivity increase. He does not, however, find any systematic relationship between R & D intensity in his sample of 119 U.S. firms and the proportion of their R & D expenditures devoted to basic research between 1967-77 or the proportion devoted to relatively risky or long-term projects, or to projects aimed at entirely new products and processes.

Relative Input Prices – Published empirical and theoretical investigations on the effect of changes in input prices on R & D are extremely scarce. Rasmussen (1973) shows that R & D is sensitive to such price changes, and that R & D effort in the business sector is associated with a capital-saving bias. Nadiri (1979) incorporates the price of R & D inputs into his theoretical model, but is forced to approximate it by the user cost of physical capital.

Diversification – The degree of diversification of a firm or an industry may raise the incentives for R & D effort, since a more diversified firm is more likely to find a profitable internal outlet for its R & D results (see, for example, Howe and McFetridge, 1976, p. 60).

Available Science Base – It is plausible to argue that the intensity of R & D effort by the business sector is influenced by the size and quality of the underlying "scientific base" in the country in which its research facilities are located. The variable measuring "government participation" may to some extent reflect the characteristics of one segment of such a base. In an analysis of the effects of U.S. ownership of Canadian industries on their R & D effort, Lithwick (1969) uses the research intensity of an industry in the U.S. as a measure of the science base available to that industry in Canada. Other possible measures include the total stock of scientists and engineers in the country (in relation to total labour force), or total R & D spending as a percentage of GDP, and so on.

Some Measurement Issues

The measured R & D effort as represented by the reported R & D spending reflects only those organized activities in the sample industries that are formally recognized as "research and development." The reported figures thus do not include either the individual inventor's activities or that part of corporate spending on new products or processes whose development is not a part of the official R & D definition. While intercountry variations along both dimensions undoubtedly exist, we assume below that the efforts of the drafters of the "Frascati Manual" (OECD, 1976) have reduced them to tolerable levels.

The regression analysis discussed below works with the flow concept of R & D (such as annual expenditures), and relates them to the annual volume of sales in the sample industries. Some recent empirical studies work with the concept of the stock of R & D capital, which is theoretically more appropriate. Estimation of its magnitude is a major task and has, to our knowledge, so far been attempted only for the U.S. The stock of basic research capital is obtained by adding up annual constant dollar expenditures, disregarding the actual completion or retirement of individual projects, and neglecting any obsolescence (see, for example, Kendrick, 1976, p. 60). The stock of applied research and development capital is estimated by the perpetual inventory method (see, for example, Nadiri, 1979, pp. 22-23). This amounts to establishing some "bench mark" or "original" amount of research capital stock R_{t-1} (often simply by taking the earliest available observation of real R & D expenditure) and applying the formula

$$R_t = I_t + (1 - d) R_{t-1}$$

where

I_t represents R & D expenditures (flow) in year *t*, and

d is a depreciation rate (often an arbitrary number, since the measurement of depreciation rates for the stock of knowledge is a difficult proposition).

Another recent development is an analysis of the determinants of R & D expenditures on each of the major research inputs. An example of the use of disaggregated data for research resources is an econometric analysis of the determinants of R & D intensity in a sample of 433 large U.S. firms during the period 1957-65 by Pakes and Shankerman (1980). In it, they measure "research labour" and "research capital" separately. Furthermore, they explicitly incorporate in their model both an R & D gestation lag and a rate of obsolescence of product knowledge as determinants of R & D intensity. The obsolescence factor essentially reflects the decline in revenues generated by the innovation over time due to the development of new (competing) technologies and the imitation and spread of the knowledge, which reduces the monopoly power of the innovator.

5 Empirical Measures and Data Sources

This chapter provides the background for an application of regression methodology to the international comparison of R & D intensities in selected manufacturing industries. The results are presented and discussed in the following chapter. As explained in Chapter 1, this approach amounts to calculating what R & D intensity in a particular Canadian industry would correspond to some "OECD norm." We accomplish this by estimating an R & D function for each industry from data for specified major OECD countries other than Canada. The estimated coefficients are taken to represent the "average" relationship between R & D intensity and its determinants. Multiplying the estimated coefficients by the levels of the appropriate explanatory variables reported for Canada then yields an expected or "forecast" R & D intensity in that industry in Canada in a particular year.

Our choice of industries and countries is, of course, guided by their economic importance and a desire to provide some new insights into those segments of the economy where R & D and technical progress are most crucial. However, it is apparent, since the early stages of the project, that the availability and quality of statistical information figure prominently in determining the composition of our final sample.

The following industries comprise our final selection for the regression approach to R & D intensity comparison (each industry being analysed separately and independently of the others):

Industry	International standard industrial classification number	1977 Canadian intramural R&D ($ million)
Paper and products	341	36
Industrial chemicals + Other chemicals	351 + 353	48
Pharmaceutical products	3522	28
Rubber products + Plastic products	355 + 356	7
Nonferrous metals	372	45
Machinery, except electrical	382	63
Electrical machinery	383	178

We gathered data for the following countries: Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Sweden, the United Kingdom, and the United States. In spite of a considerable outlay of time and energy, we succeeded in developing a set of data series on these industries only for a subset of these countries. Consequently, both the number of countries and their composition may differ among the seven industries discussed below. We also attempted to include another industry, "Instruments" ("Professional Goods"), but in the end we had to give it up because of the numerous gaps in the data.

We first give definitions of the empirical equivalents of the variables discussed in detail in Chapter 4. The data itself, our procedures for developing some series not directly available, and our sources of information are presented in the Appendix. We then review some econometric issues that arise in our regression work.

Definitions of Variables Used in Regressions

General Remarks

The primary source of quantitative information on R & D spending and its determinants are the various OECD publications. We examined, in addition, several secondary sources, among them United Nations and European Economic Community statistics, official publications of governments of the sample countries, trade periodicals, and a number of books and journal articles dealing with the sample industries. In the case of one industry (pharmaceuticals), we prepared a questionnaire and distributed it to some fifteen national associations of manufacturers in an attempt to obtain data not available elsewhere.

Our initial sample consisted of fifteen OECD countries considered to be "important" by such yardsticks as the volume of their production, size of their market, volume of exports, and research activity. Unfortunately, gaps in a crucial source of data

(*International Survey of Resources Devoted to R&D*, published every second year by the OECD) required us to eliminate some industries in some countries from consideration. Among the other data constraints, the most important were intercountry differences in industrial classifications and a general lack of internationally comparable data on industrial concentration and the extent of foreign ownership.

Our final sample thus consists of a slightly different number of countries in different industries. The specific list of countries included in each industry sample is given in the titles of the tables of the regression results presented in Chapter 6.

The R & D spending figures upon which this paper is based pertain to research activities performed in the business sector alone, although the government, university, and private nonprofit sectors may complement the business spending in different countries to varying degrees. In the context of this study, these differences cannot be accounted for, since the industry breakdown of R & D spending performed outside the business sector is not available. We do, however, deal with government contribution to financing of research performed within the business sector.

In what follows, we give the definitions of our variables and a brief discussion of the problems encountered in their measurement. A complete set of the data upon which our analysis is based is contained in the Appendix tables. The notes to the tables provide details on data sources and describe the procedure employed in deriving some figures not directly available.

The Dependent Variable (*RESINT*)

To minimize the consequences of intercountry variations in absolute levels of R & D spending for regression analysis, we measure R & D activity by "research intensity." It is defined as the ratio of R & D expenditures by business enterprises in a given country and industry to the volume of production, both measured in national currency.

Our main justification for the use of "R & D intensity ratio" is, of course, its notoriety as the publicly debated policy target. (At the level of industries, the ratio of R & D to the value of production is equivalent to the GERD/GDP ratio at the economy-wide level.)

R&D Expenditures (RDNACU) – The data series that we use is available for more countries than any other, and comprises "intramural expenditures, natural sciences and engineering." From statistics for those countries that also give intramural expenditures in all fields of science, we are able to verify that the share of humanities and social sciences research performed by the sample industries is very small, and so the lack of this data is not a problem. Our source of information is the published results of surveys conducted in each of the six "international statistical years."

The quality (especially the intercountry comparability) of this data is by no means perfect, as is clear from the background methodological document (OECD, 1976) and from the "country notes" accompanying the tables for each statistical year. Nevertheless, it is much superior to analogous figures occasionally reported in trade periodicals and other publications. We have also considered an alternative measure of R & D effort, namely, the number of "qualified scientists and engineers" employed. The OECD figures suffer, however, from such problems as intercountry differences in educational background of this personnel, inconsistent accounting for full-time versus part-time workers, and so on. We have, therefore, not pursued this alternative any further.

Volume of Production (PRODNACU) – The denominator in the dependent variable is the value of production (in millions of national currency) in each country in the appropriate OECD statistical year. These figures are obtained from the United Nations *Industrial Statistics* and the OECD *Chemical Industry*. (A good case could be made for using value added instead of our measure in the denominator. It would, presumably, be more precise, since the R & D figures would not be related to previous inputs. This could make a difference if the extent of vertical integration differs from country to country. The value added data, however, are available for a limited number of our sample countries only.)

The Explanatory Variables

Industry Profitability (PROFITA and PROFITB) – Initially, we envisaged developing a measure of "financial" determinants of research effort, such as the flow of funds. The published National Accounts data from which such figures may be derived do not, however, give a sufficiently detailed industry breakdown, and our search of the literature and, in the case of pharmaceuticals, even a questionnaire survey, proved unsuccessful in filling the data gaps.

Within these informational constraints, we formulate two separate proxies for the financial determinants of business sector's research spending: industry profitability and investment climate. The former is discussed here and the latter in the next subsection.

Our industry profitability variable relies upon data on the performance of U.S.-owned subsidiaries operating in each sample industry and country published by the U.S. Department of Commerce. It is therefore representative of the profitability of the particular industry in the particular country only to the extent that the profit performance of U.S.-owned subsidiaries is highly correlated with the performance of firms under other ownership.

Following the theoretical literature on profitability as a determinant of research spending (see Chapter 4), we alternatively apply two versions of this variable to our regressions. The first (*PROFITA*) describes the level of profitability, and is defined as the ratio of net income to equity. The second (*PROFITB*) describes the trend in profitability, and is calculated as the first difference in *PROFITA*.

Investment Climate (INVCLIMA and INVCLIMB) – This variable reflects in part the financial conditions of each industry in the sample countries and in part the overall state of their economies. Once again, we formulate two empirical versions. The first (*INVCLIMA*) is the rate of growth of the gross fixed capital formation in the given industry and country, obtained from the United Nations *Industrial Statistics*. The second (*INVCLIMB*) is based on the performance of U.S.-owned subsidiaries, and is calculated as the ratio of reinvested earnings to total earnings.

Industrial Concentration (CONCEN) – As shown in Chapter 4, the relationship between industry concentration and intensity of research efforts has been extensively debated in the literature. Similarly, the measurement of concentration itself is a subject of numerous studies, dealing mostly with the comparative advantages and disadvantages of measures such as concentration ratios, Herfindahl index, Linda index (see, for example, Linda, 1976), and the like. For reasons of data availability, we have to settle for the four-firm concentration ratio or its various approximations.

Next to foreign ownership, the lack of reliable data on this variable required the most labour-intensive search, and it is responsible for the deletion of a number of countries and industries from our sample. As is evident from the explanatory notes to the appropriate Appendix tables, not all of our concentration figures are strictly comparable; some are based on value of shipments or value added, some on employment, some are calculated from slightly different industry definitions, and so on.

Time series data on concentration in most sample countries are not available. We are, however, able to report concentration ratios for the period around 1973 for most industries; it is then assumed that these values apply to all of the OECD census years. The assumption of no significant change in concentration over the period covered by our sample is largely confirmed by comparing the 1973 figures with earlier ones, where they exist.

Degree of Foreign Ownership (FOROWN) – The numerical estimates of the level of foreign ownership are derived from various industry, government, and international publications. Depending upon the industry and data source, the degree of foreign ownership is measured by the share of domestic sales or production accounted for by foreign-owned companies, or their share of employment, and so on. (Details are given in the notes to the Appendix tables.) Better measures, such as the share of foreign-owned industry assets, are not available for many of our sample countries. As is the case with concentration ratios, we assume that the levels of foreign ownership observed around 1973 prevail throughout the whole sample period.

Trade Balance (TRADEBALA or TRADEBALB or TRADEBALC) – Two of these variables measure the degree to which a given industry in a particular country is export-oriented: *TRADEBALA* is defined as the ratio of exports minus imports to exports plus imports, and *TRADEBALC* is defined as the ratio of exports minus imports to production minus exports plus imports. The inclusion of these measures among our explanatory variables is motivated by the hypothesis that success in export markets depends, to a large extent, on innovativeness of the exporting industry. In other words, they represent past R & D performance as a determinant of current R & D spending.

The variable *TRADEBALB*, on the other hand, measures the degree to which a given industry in a particular country is exposed to import competition. It is defined as the ratio of imports to the size of the total domestic market, that is, the ratio of imports to production minus exports plus imports. Its expected sign in our regressions is somewhat ambiguous, inasmuch as it can be taken to reflect two entirely different factors. On the one hand, it reflects the past lack of success of a given industry in international competition, and it can thus be interpreted analogously to *TRADEBALA* and *TRADEBALC*. On the other hand, it could be argued that intensive import competition represents a stimulus for greater R & D spending. Thus, the higher *TRADEBALB*, the higher the current R & D spending by the given industry and country.

All three trade balance variables, of course, have to be interpreted cautiously in industries heavily dependent on natural resources. In these cases, they reflect relative abundance of factors of production rather than past performance of the industry as an innovator. The required export and import figures are taken from the OECD international trade statistics, and the production figures are taken from the United Nations *Industrial Statistics*.

Direct Government Financing of Business-Sector R&D Spending (GOVCONT) – Our dependent variable is based on data on intramural expenditures on R & D in natural sciences and engineering performed by the business sector. These expenditures are financed largely by the performing firms, but also, to a varying degree, by other business enterprises, by the private nonprofit sector, by the higher education sector, from foreign sources, and from government contributions. This last source of financing is of particular interest, as explained in Chapter 4.

Our regressions include a measure of the direct government contribution to financing of industrial R & D (to be distinguished from the effect that governments exert in their capacity as purchasers of "high technology" and their macroeconomic functions in monetary and fiscal policies, which may create a certain "innovative climate"). It is calculated as the ratio of the amount of R & D financed from government sources to the total R & D performed by the business sector in the given industry and country. The required information is taken from OECD biennial census tabulations "R & D by sources of funds." The large number of gaps in this particular data series forces us to exclude a number of observations from our regressions and, in the case of some industries, to eliminate *GOVCONT* from consideration.

Tax Climate in the Sample Countries (TAXBURDEN) – The construction of this variable differs in two important respects from those discussed above. First, it is an economy-wide, country-specific measure whose magnitude is taken to be the same for all industries in a given country. Second, like the concentration and foreign ownership variables defined above, it does not vary over time. Data constraints force us to apply a measure of the tax burden prevailing in a particular country at a particular point in time and to assume (somewhat unrealistically) that it remains constant throughout our sample period.

Our data is taken from Bergsten, Horst, and Moran (1978). Our measure of tax burden is defined by income taxes paid by U.S.-owned subsidiaries to governments of the host countries as a percentage of taxable income. The total income tax paid consists of "realized foreign income tax" plus "foreign withholding tax paid." The figures refer to the fiscal year 1968. While no comparable tax rates for more recent time periods are available, Bergsten, Horst, and Moran (1978, p. 190) state that their tax rate calculations are broadly consistent with those found by U.S. Department of Commerce surveys in 1966 and 1970.

As is the case with our measures of profitability and with one version of the investment climate variable, the tax burden data refer exclusively to U.S.-owned subsidiaries, and may not be representative of the tax burden faced by firms under other ownership. We have little information on the extent to which tax policies of the various "host countries" in our sample discriminate against foreign-owned subsidiaries or on the extent to which our tax rates may deviate from the total industry rates. Nevertheless, we believe that our figures – realized tax rates – are preferable to nominal (statutory) tax rates, which neglect the differing scopes for possible tax base manipulation in different countries.

Strength of the Underlying Scientific Base (SCIBASE) – This variable attempts to account for the amount of economy-wide scientific resources upon which all industries in a given country can, in some sense, draw. It is calculated as the ratio of total R & D manpower (in full-time equivalents) in a given country to its total labour force. The definition of R & D manpower here includes scientists and engineers, technicians, and "others" working in research in all sectors of the economy (private business, government, private nonprofit, and higher education sectors). The magnitude of this ratio is, of course, identical for all industries in a given country.

Information on R & D manpower appears in a number of sources, but these figures typically exhibit intercountry differences in qualifications of the R & D personnel included, in accounting for full-time versus part-time engagement in research, whether only natural sciences and engineering, or whether all sciences are included, and so on. We uncovered only two sets of consistent OECD figures comparable across the sample countries: one pertaining to the year 1970 and another pertaining to the year 1977. In our regressions, we assume that the former set pertains to the period 1967-71, and that the latter set pertains to the period 1973-77. (Details on data sources and coverage are in the appropriate Appendix table.)

We should re-emphasize here that our dependent variables measure exclusively "private business sector R & D" – that is, research performed in the business sector alone. Thus, there is no reason to expect that the *SCIBASE* variable is just an alternative measure of the dependent variable. First, the shares of R & D done in the whole economy differ from country to country. Second, omission of this variable from our regression equation would amount to misspecification, since it would disregard the varying extent to which different industries in different countries draw upon the results of R & D done elsewhere in the country.

Strength of Patent Protection (PRODPAT) – For most industries in our sample, the degree of patent protection is uniform in all our sample countries. The one exception is the pharmaceutical industry, where some countries make possible only the patenting of the process, but not of the product, thus leaving wide scope for "inventing around" and consequently weakening the incentive to invest in R & D. In the special case of Italy, during the period coinciding with our data, not even the process was patentable. We represent this difference in degree of patent protection by a dummy variable, which takes on a value of one for those countries where both the product and the process can be patented, and zero otherwise. (We initially included two dummy variables in our regression to distinguish between the two types of patent protection. The process patent dummy, however, was consistently insignificant and was dropped from further analysis. It should perhaps be stressed that we are not comparing the effects of a total absence of patent protection with some degree of it, but rather the effects of two levels of protection, one weaker and one stronger.)

An additional consideration in this context is the existence of provisions for compulsory licensing in the pharmaceutical industry and the extent of their utilization in the sample countries. Unfortunately, insufficient information prevents us from measuring their effect on R & D efforts.

Some Econometric Issues

Pooling of Cross-Sections of Time Series

Our data base for each industry regression consists of observations on each variable for the six OECD "international statistical years" 1967, 1969, 1971, 1973, 1975, and 1977. Apart from the possibility of heteroskedasticity and serial correlation of residuals sometimes present in such data sets (discussed below), there is a question of the temporal stability of the regression coefficients.

In other words, it is possible that the impact of each explanatory variable on R & D intensity changes over the ten-year span of the sample period. Our first attempt at addressing this issue consisted of including intercept time dummy variables. The results (not reported here) are remarkably consistent for all industries. The coefficients of the dummy variables were not statistically significant, and neither the magnitudes nor the statistical significance of the other coefficients changed appreciably as a result of including the dummies, nor did the fit of the equations improve. This evidence rather strongly supports the validity of the hypothesized temporal stability of our regression relationships.

In a similar vein, it can be argued that the influence of a given explanatory variable varies across countries. This possibility could, in principle, be investigated by means of country dummy variables. However, it is a fundamental assumption underlying this particular approach to international comparisons of R & D performance that there exists an "average OECD norm," which can be legitimately applied to establishing the expected R & D performance for Canada. While this assumption may be unrealistic, we believe its application in our methodology represents an advance over the aggregate comparisons criticized in earlier chapters.

Heteroskedasticity

Due to the small number of observations in our sample, we are unable to perform a standard rigorous test for presence of heteroskedasticity. We note, however, that all our variables are in ratio form, thus removing the effect of the vast differences in size of our sample countries. We therefore believe that the efficiency of our regression estimates is not significantly reduced on this account.

Serial Correlation

It must be recalled that we have only six temporal observations on a given country's industry – OECD statistical years 1967, 1969, 1971, 1973, 1975, and 1977. It is quite possible that serial correlation is present across these six data point sets, but no statistical test or even visual inspection of print-out residuals can establish this unambiguously. To calculate a serial correlation coefficient based on five observations and to fit then a regression adjusted for serial correlation seems extremely tenuous. The task was nevertheless attempted for three industries – in one of them the results differed drastically from the unadjusted version. The inconclusive nature of these experiments, coupled with the absence of any information about the precise nature of the serial correlation pattern (if any) leads us to conclude that more violence is likely to be done to the data by the adjustment procedure in this case than by leaving it out. The time-dummy results mentioned previously provide indirect support for this decision.

Direction of Causality

In the case of at least two variables included in our analysis (foreign ownership and profitability), the discussion in Chapter 4 suggests the possibility of a causal relationship running the opposite way than that postulated in our regression. This means that the ordinary least squares estimates of the determinants of R & D intensity in our single-equation model would be biased and inconsistent.

With respect to foreign ownership, as discussed in Chapter 4, the argument is that foreign ownership is high in research-intensive industries, not because foreign-controlled firms do more research, but because foreign investment tends to be attracted to industries where R & D intensity is high. In our opinion, this possibility does not undermine the validity of our single-equation model estimated for a given industry in a cross-section of countries. It should be remembered that our dependent variable is based on current flows of R & D expenditures, while the foreign ownership variable that appears on the right-hand side is a stock measure, reflecting the investment flows over long periods of time in the past. Finally, the proper context of the causality problem raised by Caves (1971) is an inquiry into why the levels of foreign ownership vary from industry to industry. Our regressions deal with a single industry at a time in a cross-section of countries and cannot, therefore, be construed as a test of the Caves hypothesis.

A spot check is, nevertheless, undertaken on this issue by using an instrumental variable construction of the foreign ownership determinant of R & D in two industries with a high degree of foreign penetration in Canada – that is, in pharmaceuticals and electrical machinery. The results, shown in the appropriate tables, do not differ markedly from ordinary least squares regression coefficients.

The causal relationship between the profitability variable and R & D intensity may be a more troublesome problem. While the dominant influence seems to be that past R & D affects current profits, the empirical evidence on managerial decisions in dividing current profits between funding of current R & D and other uses (see Chapter 4) leaves some room for further thought on this matter. Our data cannot do true justice to this matter, for what is needed to clarify them are firm-specific, yearly observations.

6 Regression Estimates of the R&D Function for Selected Industries

In formulating our regression equations, we have followed the practice common in the empirically oriented industrial organization literature and recognize that the estimation of any reasonably realistic structural model requires data well beyond those that are typically available. The next best strategy then is to establish which causal influences on industrial R & D spending are found to be theoretically and empirically important in the literature on the subject (see Chapter 4), to identify appropriate measurable proxies, and to formulate a regression equation on that basis.

For each industry, two sets of regressions are run: without Canada and with Canada included in the sample. The former set serves to "forecast" Canada's R & D intensity on the assumption that Canada's performance should conform to the OECD norm. The latter set of regressions can provide a basis for analysing the relative importance of the various determinants of R & D intensity suggested by theory; it can also yield some evidence about the direction of the difference in the influence of a determinant on the Canadian scene. For each of the "without Canada" and "with Canada" industry samples, a linear version and a logarithmic version of a determinants model are estimated and reported as well.

Typically, then, four regression estimates are reported for each industry: *LINEAR* without and with Canada, and *LOGARITHMIC* without and with Canada. The reported equations are the "finalists" that emerged from a larger set of estimates in which several versions of each of the following variables were tried: profitability, investment climate, and past success proxied by different specifications of the trade balance.

Our procedure estimates first the following "complete" equation separately for each of the seven sample industries:

R & D/value of production = *f* (industry profitability; investment climate; concentration; foreign ownership; tax burden; government contribution; scientific base).

The first four variables constitute the core of most models of R & D determinants proposed in the literature. Although the expected direction and exact pattern of their influence on R & D are subject to debate (see Chapter 4), we consider these variables to be of such importance that we retain them in all equations, regardless of the statistical significance of the estimated coefficients. Our decision to include the remaining four variables, on the other hand, is based on less firm theoretical foundations, and we retain them only in those equations where their coefficients are statistically significant. Our results are presented, industry by industry, in the remainder of this chapter.

The Paper Industry

The research outlay figures published by the OECD in their biennial statistical years lump together international standard industrial classifications (ISIC) 341 and 342 – that is, both the paper industry (pulp, processing, and fabrication) and the printing industry. All available information indicates that research expenditures in the printing industry itself are minimal. We assume, therefore, that the research outlays are incurred by the paper industry only, and we utilize exclusively the statistics pertaining to it (such as production, foreign trade, concentration, and so on). In this way, we hope to avoid swamping our model with the redundant and possibly bias-inducing data of the printing sector.

Table 6-1 – as well as the subsequent tables corresponding to the other industries – shows first the linear and then the logarithmic "finalist" regressions. We indicate, in the title the countries included, recalling that there are six observations per country (1967, 1969, 1971, 1973, 1975, and 1977), with the exception of the United Kingdom, whose report to the OECD for 1977 was not yet published as of April 1981.

The equation chosen as performing most satisfactorily is of the logarithmic form. Three variables, however, namely, *PROFITA*, *INVCLIMA*, and *TRADEBALC*, are kept in linear form, since they can take on

Table 6-1

Paper Industry Regressions, Canada, France, Germany, Italy, Japan, Sweden, United Kingdom (not 1977), and United States, OECD International Statistical Years 1967-77

	Linear		Logarithmic	
Variable	Without Canada	With Canada	Without Canada†	With Canada
CONSTANT	.01855**	.02052**	22.2997*	22.3015**
	(3.3)	(3.8)	(4.4)	(4.7)
PROFITA (linear only)	.07269	.00391	2.39971	2.70045**
	(1.5)	(.9)	(1.9)	(2.5)
INVCLIMA (linear only)	.01093	.00075	.38404	.28282
	(0.8)	(.6)	(1.1)	(.9)
CONCEN	-.00006	-.00007*	-.91159**	-.90150**
	-(1.9)	-(2.3)	-(3.3)	-(3.5)
FOROWN	.00008	-.00004	.12851	.15309**
	(1.3)	-(.2)	(1.9)	(2.8)
TAXBURDEN	-.00051**	-.00049**	-7.94434**	-7.93602**
	-(4.7)	-(4.6)	-(6.4)	-(6.8)
TRADEBALC (linear only)	.01437**	.01313**	3.18711**	3.28179**
	(9.1)	(10.5)	(9.7)	(11.9)
SCIBASE	.00088**	.00074**	2.11456**	2.11476**
	(5.6)	(6.2)	(9.3)	(9.9)
$\bar{R}^2$	.76	.78	.85	.82
F	19.2	19.9	26.7	31.7
SEE	.00134	.00134	.33153	.31338
N	41	47	41	47

†Forecasting regression used in Table 6-2.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

negative values. The equation excludes the variable of the government contribution to research performed in the industry. In preceding regression test runs, *GOVCONT* proved to be inconsequential in influencing research intensity. The "without Canada" version serves to forecast Canada's expected research intensity, and undergoes an outlier test.

The profitability variable *PROFITA*, it is recalled, is the income of U.S. subsidiaries abroad divided by the equity of such subsidiaries, and it just misses statistical significance at the two-tail, 5 per cent level. (Incidentally, all significance tests on regression coefficients are undertaken using two tails, with the exception of *SCIBASE*, as the theoretical presumptions about the sign of the influence are not strong enough to warrant a one-tail test.) The investment climate variable *INVCLIMA* is the rate of growth of gross fixed capital formation in a given country, and it is less statistically significant. Both of them, however, have the traditionally expected positive sign.

A strongly significant and negative effect of industrial concentration, *CONCEN*, is in evidence, while the foreign ownership variable *FOROWN* is at the significance edge of showing a positive influence upon research intensity. Both of these results would not be expected on conventional grounds, while the strongly significant and negative impact of the taxation variable, *TAXBURDEN*, conforms to expectation. Similarly, a country's science base, *SCIBASE*, as proxied by the proportion of scientific manpower in the labour force, appears to have a strong positive bearing on research intensity in the paper industry. Finally, the overall regression fit as measured by the R^2 adjusted for degrees of freedom is very satisfactory for a cross-section of time series such as this one.

When the six Canadian observations are included in the logarithmic regression, the preceding results are almost uniformly strengthened, with profitability and foreign ownership reaching significance at the 1 per cent level. At least with regard to foreign ownership, this "enhancing" effect is not in line with the 1975 Canadian statistics, which indicate that foreign subsidiaries do less than their share of research, as measured by their sales, compared with Canadian firms (MOSST, 1979).

Table 6-2 lists the forecasts for this as well as all of the other industries based on the finalist, "forecasting" equations. The point forecasts are given for each of the six years, and a mean forecast is calculated. The forecasts are compared with the actual values, and the 95 per cent confidence intervals around the forecast are also indicated.

Table 6-2

Comparison of Forecast and Actual R&D Intensities in Seven Industries, Canada, OECD International Statistical Years 1967-77

Value	1967	1969	1971	1973	1975	1977	Mean	Forecast as share of actual (Mean)
								(Per cent)
Paper								
Point forecast	.0046	.0057	.0043	.0032	.0037	.0037	.0040	
Actual value	.0077	.0059	.0045	.0035	.0036	.0039	.0046	87
95%	.0003	.0004	.0004	.0002	.0002	.0003	.0003	
interval	.0719	.0881	.0498	.0487	.0454	.0411	.0464	
Chemicals								
Point forecast	.0240	.0195	.0199	.0179	.0195	.0184	.0192	
Actual value	.0174	.0155	.0142	.0130	.0115	.0098	.0133	144
95%	.0029	.0031	.0029	.0033	.0021	.0039	.0033	
interval	.1420	.1240	.1383	.0984	.1810	.0864	.1112	
Pharmaceuticals								
Point forecast	-.01677	-.01045	-.02052	-.02059	-.03477	-.01713	-.02004	
Actual value	.03547	.03765	.03249	.04044	.04396	.03345	.03725	Negative
95%	-.21706	-.22088	-.22046	-.21257	-.26719	-.21173	-.21486	forecast
interval	.18352	.19998	.17942	.17139	.19765	.17747	.17478	
Rubber and plastics								
Point forecast	-.02693	-.02699	-.02705	-.02787	-.02668	-.02602	-.02692	
Actual value	.00403	.00362	.00367	.00287	.00239	.00218	.00313	Negative
95%	-.13481	-.1302	-.13210	-.13500	-.13030	-.12690	-.13130	forecast
interval	.08095	.00362	.00367	.00287	.00239	.00218	.00313	
Nonferrous metals								
Point forecast	.01809	.01596	.01852	.01725	.01789	.01200	.01645	
Actual value	.01129	.00998	.01238	.01118	.01485	.00321	.00951	172
95%	.00033	.00038	.00034	.00405	.00039	.00039	.00039	
interval	.97824	.66831	1.00101	.01118	.01485	.00321	.00951	
Nonelectrical machinery								
Point forecast	.01949	.01995	.01597	.00977	.01055	.01138	.01391	
Actual value	.00633	.00735	.00868	.00928	.01485	.01145	.00928	150
95%	.00001	.00001	.00001	.00001	.00001	.00001	.00001	
interval	57.91637	32.16889	35.80187	17.37444	19.51142	13.06582	23.31274	
Electrical machinery								
Point forecast	.04241	.03923	.04174	.03744	.04105	.04207	.04064	
Actual value	.03410	.03139	.03304	.02987	.02724	.02919	.03072	132
95%	.00771	.00713	.00842	.00617	.00785	.06618	.00777	
interval	.23340	.21589	.20701	.22718	.21459	.26767	.21246	

SOURCE Estimates by authors.

In essence, we take the observed Canadian levels of each of the determinant variables, and multiply them by the magnitudes of the relationship between each determinant and the R & D intensity that prevails in sample countries other than Canada.

In estimating the regression coefficients from a data base consisting of a cross-section of countries, we of course implicitly assume that any given variable "contributes" equally to the R & D intensity in each sample country. The forecasting procedure extends the scope of this assumption to include Canada. This interpretation of the estimated coefficients is strictly true only if all relevant intercountry differentials are accounted for in the regression. However, as discussed before, data availability, conceptual and measurement problems, and other reasons make it impossible to incorporate some of these variables in our regressions. Nevertheless, the relatively high proportion of data variance accounted for by our regressions justifies confidence in the validity and robustness of our procedure.

As can be seen by examining the first two lines, the model rooted in the OECD norm underforecasts slightly Canada's actual R & D intensity in its paper industry. In other words, given the validity of our

R & D determinants model, Canada's pulp and paper industry utilizes a total research input that is relatively as large, if not larger, than that of the advanced industrial nations comprising our sample.

It could, of course, be the case that Canada's paper industry (or the other industries examined) is not a part of the same "universe" or sampling of population as those in the other OECD countries. It is therefore, necessary to test the hypothesis that the observations on the dependent and independent variables for Canada come from the same population or structure as that presumed to have generated the observations for all other countries in the sample.

The appropriate statistic is (Johnston, 1972, p. 154):

$$t = \frac{\hat{Y}_{CAN} - Y_{CAN}}{s\,[1 + c'\,(X'X)^{-1}\,c\,]^{\frac{1}{2}}}$$

where

$\hat{Y}_{CAN}$ = the forecast value of R&D intensity for Canada;

Y_{CAN} = observed actual R&D intensity for Canada;

s = standard error of the regression run on data with Canada excluded;

$(X'X)^{-1}$ = variance-covariance matrix of estimated coefficients in a regression with Canada excluded; and

c = vector of the Canadian magnitudes of independent variables included in the regression.

If the calculated t-value exceeds a pre-selected critical value, here at the 5 per cent, two-tail level for $N-K$ degrees of freedom (where N is the number of observations and K is the number of regression coefficients), the observations for Canada can be presumed to have come from a different structure.

We calculate the t-values based on observations for Canada averaged out over the six census years. The results are summarized in Table 6-3. Clearly, Canada's paper industry is not an outlier on this test, and it belongs to the underlying universe that we postulated.

Table 6-3

Test for Being an Outlier, Seven Industries, Canada, 1967-77

Industry	Actual t-statistic	Critical t-statistic	Is Canada an outlier?
Paper	-.113	2.04	no
Chemicals	.419	2.04	no
Pharmaceuticals	-.579	2.04	no
Rubber and plastics	-.600	2.08	no
Nonferrous metals	.297	2.08	no
Nonelectrical machinery	.111	2.05	no
Electrical machinery	.321	2.04	no

SOURCE Estimates by authors.

The Chemical Industry

In general, only the country-specific variables have a statistically significant impact on research intensity in the chemical industry, as is evident in Table 6-4. However, the industry-specific concentration variable comes alive in the logarithmic version without Canada in the sample, when it and its square value are included (see the last column of the table). It is then seen that the oft-postulated, nonlinear relationship indicates that some concentration does stimulate, but more concentration hinders, research intensity. In the same equation, foreign ownership reaches a positive significance level, but when Canada is included in the sample, both concentration variables and foreign ownership again lapse into insignificance. "*LOG* without Canada" would have been our preferred version for the forecasting and outlier tests, but the very high correlation between *CONCEN* and $CONCEN^2$ ($R^2 = 0.97$) prevents the matrix manipulation necessary to obtain certain ingredients for forecast confidence limits.

Two somewhat interesting aspects of the finalist logarithmic versions ($CONCEN^2$ without Canada) are worth mentioning. The first is that the addition of Canada to the sample makes the positive influence of the tax burden significant (see our discussion of this nonintuitive result in Chapter 4 in the discussion on taxation). Second, it increases, though not to a significant level, the negative value of the foreign ownership coefficient. The latter is in line with 1975 statistics showing that foreign-owned chemical firms operating in Canada spend substantially less on research, in relative terms, than Canadian firms (MOSST, 1979).

Table 6-4

Chemical Industry Regressions, Canada, France, Germany, Italy, Japan, Sweden, United Kingdom (not 1977), and United States, OECD International Statistical Years 1967-77

	Linear		Logarithmic		Logarithmic with *CONCEN*²	
Variable	Without Canada	With Canada	Without Canada†	With Canada	With Canada	Without Canada
CONSTANT	.02314 (.5)	.00945 (.3)	-9.99891 -(1.7)	-15.8111** -(2.8)	-12.2487* -(2.3)	-2.43610 -(.5)
PROFITA (linear only)	.00092 (.1)	.00013 (.1)	-.26429 -(.5)	.04759 (.1)	.19208 (.4)	-.22149 -(.5)
INVCLIMA (linear only)	.00211 (.4)	.00108 (.3)	.13001 (.8)	-.01430 -(.1)	-.08314 -(.6)	.02729 (.2)
CONCEN	-.00033** -(3.7)	-.00032** -(3.9)	-.17271 -(1.3)	-.19657 -(.1)	.01725‡ (1.4)‡	.029421*‡ (2.6)‡
FOROWN	.00008 (.4)	.000004 (.1)	.07084 (.5)	-.14899 -(.2)	-.09813 (1.1)	.24367* (2.0)
TAXBURDEN	-.00039 -(.3)	-.00001 (.0)	1.27904 (.8)	3.10440* (2.1)	1.75237 (1.2)	-1.34048 -(.9)
TRADEBALB	.03227* (2.5)	.03236** (2.9)	.02378 (.3)	.14730* (2.1)	.15459** (2.4)	-.02873 -(.4)
GOVCONT	-.06974 -(1.6)	-.08396** -(2.9)	-.09251** -(3.2)	-.10356** -(3.4)	-.11310** -(3.9)	-.10678** -(4.3)
SCIBASE	.00317** (4.7)	.00301** (5.6)	.67759** (4.4)	.60796** (3.8)	.84129** (4.6)	1.03386** (6.3)
*CONCEN*² (linear only)					-.00024 -(1.9)	-.00036** -(3.3)
$\bar{R}^2$	.68	.77	.69	.77	.79	.78
F	11.5	20.5	12.2	20.3	20.7	16.4
SEE	.000478	.00450	.17044	.18310	.17343	.14503
N	41	47	41	47	47	41

†Forecasting regression used in Table 6-2.
‡Linear only.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

A last result of interest is the negative influence of government financing on research intensity. This potential outcome is also discussed in Chapter 4. The possibility cannot be excluded, however, that most government subsidy is given to an industry in which the least research is being undertaken. We did not have a chance to test this interpretation.

Compared with the paper industry, the regression results in chemicals give a slightly worse fit, possibly due to the fact that chemicals as a group are a less homogeneous industry, and they give a substantial overforecast of research intensity. The outlier test again shows that it seems sound to assume that Canada's chemical industry is drawn from a common universe of OECD countries.

The Pharmaceutical Industry

The research expenditures of this, the only four-digit ISIC industry in our sample are not part of the chemical industry's outlays. Government contributions to business-sector pharmaceutical research are minimal, and are not incorporated into the analysis. Data on the nature of patent protection (is the *PROD*uct *PAT*entable, or merely the production process?), as mentioned previously, have been collected and utilized in the fitting of the function.

The linear function is the one chosen for the forecast. The sample without Canada (see Table 6-5) shows a very significant positive influence of concentration on research intensity as well as a less pronounced effect of patent protection. The crucial impact is that of foreign ownership. This can be seen in the consistent and marked underforecast of Canada's pharmaceutical research intensity, which is mainly due to the very high level of foreign ownership of this industry in Canada (85 per cent of production). Where a comparison is made of the "without Canada" and "with Canada" regressions, it is seen that the negative influence of foreign ownership on research intensity drops off by about 50 per cent. The forecast, however, is obviously based on the "without Canada" data. Clearly, multinationals operating in Canada undertake more research than do those operating in other OECD countries, on average. This may be due to the strength of the university-based pharmacological research establishments in this country; the aggregate variable *SCIBASE* is not able to capture this particular Canadian strength. The outlier test does not indicate that Canada's drug industry stands apart from the OECD universe.

The very strong foreign presence in this industry in Canada suggested this sector for a look at the causality issue raised in Chapter 5: does the presence of foreign subsidiaries have an impact on research intensity in an industry, or does foreign investment flock by preference to research-intensive industries? To examine these possibilities, we employ the instrumental variable technique. The foreign ownership variable is first regressed on most of the exogenous variables available to us, namely, *PROFITA*, *INVCLIMA*, *CONCEN*, *TAXBURDEN*, *TRADEBALA*, *GOVCONT*, and *SCIBASE*, and the estimated values are inserted as *FOROWNHAT* into the original linear equation using the "*with* Canada" sample. The only noticeable change that occurs in comparison with the ordinary least squares estimates is the strengthening and improved significance of the negative relationship between the intensity and degree of foreign ownership. The tentative interpretation of this result – subject to doubts raised in the discussion on causality in Chapter 5 – is that there appears to be no two-way causal relationship between the decision to locate in Canada and the high-technology nature of the industry. Moreover, it appears that foreign subsidiaries tend to undertake somewhat less research in host countries than do domestic firms, perhaps because a significant amount of such research is taking place at multinational headquarters.

Table 6-5

Pharmaceutical Industry Regressions, Canada, Belgium, France, Italy, Japan, Sweden, United Kingdom (not 1977), and United States, OECD International Statistical Years 1967-77

	Linear		Logarithmic		Instrumental linear
Variable	Without Canada†	With Canada	Without Canada	With Canada	With Canada
CONSTANT	.02703	.03460	-3.02320*	-.281328**	.047561
	(1.1)	(1.4)	-(2.6)	-(2.9)	(1.7)
PROFITA (linear only)	-.01989	-.05468	-1.16013	-1.34200	-.07631
	-(.3)	-(.7)	-(.8)	-(1.0)	-(1.0)
INVCLIMA (linear only)	-.02844	-.02047	-.29903	-.18704	-.01669
	-(1.5)	-(1.1)	-(.8)	-(.6)	-(.9)
CONCEN	.00293**	.00259**	.41876	.33726	.00239
	(9.9)	(8.8)	(1.5)	(1.5)	(7.3)
FOROWN	-.00065**	-.00029	-.25055**	-.24871**	-.00058**
	-(3.3)	-(1.8)	-(3.0)	-(3.2)	-(2.7)
PRODPAT	.02436*	.00522	.51365*	.46969**	.01330
	(2.4)	(.6)	(2.7)	(3.0)	(1.3)
$\bar{R}^2$	.77	.73	.37	.47	. .
F	27.2	25.69	5.7	9.1	. .
SEE	.02613	.02754	.51449	9.50231	.02868
N	41	47	41	47	47

†Forecasting regression used in Table 6-2.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

The Rubber and Plastics Industry

Consisting of two ISIC classifications, 351 and 353, this aggregate of two somewhat disparate three-digit industries makes data documentation rather difficult in several instances. Nevertheless, the results are tolerable (see Table 6-6), and the "with Canada" linear regression shows coefficients that are reduced in significance and magnitude. The regression consistently and strongly underforecasts actual intensity; this is likely due, as in the case of the pharmaceutical industry, to the high degree (72 per cent of production) of foreign ownership of this industry in Canada. The outlier test does not indicate that the Canadian industry is not part of the OECD universe.

Nonferrous Metals

Here, the quality of our data, as well as the regression results, are the weakest among all the industries analysed. The industry, for instance, cannot be "reconstructed" for France, and foreign ownership figures for Belgium are drawn from a source that lumps together all 37 and 38 ISIC classifications. As can be seen in Table 6-7, the only significant (positive) coefficient is that of *FOROWN*, and it declines – as well as going from the 99 to the 95 per cent significance level – when Canada is included in the logarithmic equation. This, again, is in line with the MOSST (1979) listing of 1975 Canadian research figures, which shows a higher intensity in domestically owned firms. The fitted model overforecasts substantially. The Canadian nonferrous industry is not an outlier.

Nonelectrical Machinery

In contrast to nonferrous metals, this industry's data provide the best fit to the research intensity determinants model (see Table 6-8), with the logarithmic, Canada excluded, version reaching an R^2 of 0.97. Some of this credit must go, undoubtedly, to the generally prevalent collinearity patterns in this industry (as well as in some others), where some simple correlation coefficients reach about 0.6. The only somewhat surprising element in these orthodox-looking results is the negative and strongly significant coefficient of government support. The forecasts, as

Table 6-6

Rubber and Plastics Industry Regressions, Canada, France (not 1967), Germany (not 1971), Italy (not 1967,1969), Japan (not 1969, 1975), Sweden (not 1967, 1969), United Kingdom (not 1975, 1977), and United States (not 1975, 1977), OECD International Statistical Years 1967-77

	Linear		Logarithmic	
Variable	Without Canada†	With Canada	Without Canada	With Canada
CONSTANT	-.05446**	-.03157*	-24.1325**	-22.2783**
	-(3.8)	-(2.3)	-(4.3)	-(4.1)
PROFITA (linear only)	-.00379**	-.01261	-.73884	-1.31149
	-(0.3)	-(.9)	-(.6)	-(1.1)
INVCLIMA (linear only)	.00005	-.00046	-.07238	-.07630
	(0.0)	-(.3)	-(.5)	-(.6)
CONCEN	.00043*	.00004	2.89301*	1.34940**
	(2.0)	(.2)	(2.7)	(3.1)
FOROWN	-.00048**	-.00018**	-.63231**	-.43192**
	-(4.5)	-(3.4)	-(4.5)	-(5.9)
TAXBURDEN	.00111**	.00104*	2.29475	3.59938*
	(2.9)	(2.7)	(1.3)	(2.3)
TRADEBALC (linear only)	.02745*	.00336	3.17305*	1.45736**
	(2.5)	(.6)	(2.6)	(2.9)
GOVCONT	-.04889	.00770	-.11414*	-.05353
	-(1.8)	(.4)	-(2.0)	-(1.2)
SCIBASE	.00062	-.00039	.49152	-.07852
	(1.2)	-(.9)	(1.1)	-(.3)
$\bar{R}^2$	.52	.44	.51	.64
F	4.9	4.4	4.8	8.9
SEE	.00344	.00372	.35557	.34558
N	30	36	30	36

†Forecasting regression used in Table 6-2.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

Table 6-7

Nonferrous Metals Industry Regressions, Canada, Belgium (not 1969, 1975, 1977), Germany, Italy (not 1967), Japan, United Kingdom (not 1977), and United States, OECD International Statistical Years 1967-77

	Linear		Logarithmic	
Variable	Without Canada	With Canada	Without Canada†	With Canada
CONSTANT	.00873**	.01227**	-5.9679**	-4.7520**
	(3.5)	(5.0)	-(5.1)	-(5.2)
PROFITA (linear only)	.00900	.00271	.23371	.52973
	(0.3)	(1.0)	(.5)	(1.3)
INVCLIMA (linear only)	-.00093	-.00196	-.11299	-.23869
	-(0.7)	-(1.5)	-(.6)	-(1.2)
CONCEN	-.00011	-.00013*	-.31860	-.48515
	-(1.8)	-(2.1)	-(1.0)	-(1.5)
FOROWN	.00047**	.00032**	.70891**	.49485*
	(3.6)	(3.1)	(3.1)	(2.6)
GOVCONT	-.01797	-.02016*	-.22578*	-2.0595*
	-(1.8)	-(2.0)	-(2.7)	-(2.9)
$\bar{R}^2$	.24	.32	.26	.32
F	2.9*	4.4**	3.1*	4.4**
SEE	.00226	.00250	.34581	.36303
N	31	37	31	37

†Forecasting regression used in Table 6-2.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

Table 6-8

Nonelectrical Machinery Industry Regressions, Canada, Germany, Italy, Japan, Sweden, United Kingdom (not 1977), and United States, OECD International Statistical Years 1967-77

	Linear		Logarithmic	
Variable	Without Canada	With Canada	Without Canada†	With Canada
CONSTANT	22.1976	15.75320	-5.62081	02.67627
	(1.7)	(1.4)	-(.4)	-(.2)
PROFITA (linear only)	-.64459	-.52911	-.93702	-.42005
	-(.1)	-(.1)	-(.6)	-(.3)
INVCLIMA (linear only)	-.17192	.28669	-.13405	.06264
	-(.1)	(.2)	-(.4)	(.2)
CONCEN	.28917**	.33532**	5.08199**	5.39543**
	4.7	(6.8)	(8.8)	(9.2)
FOROWN	.20937**	.13369**	.91981**	.91624**
	(3.5)	(5.1)	(5.4)	(6.2)
TAXBURDEN	-.85497**	-.70162*	-6.69978	-7.82459
	-(2.8)	-(2.7)	-(1.5)	-(1.7)
TRADEBALA (linear only)	2.08405	7.79943**	.03299	.48348
	(.4)	(3.4)	(.0)	(1.4)
GOVCONT	-6.11595	-7.18564	-.30769**	-.27677*
	-(1.1)	-(1.4)	-(2.9)	-(2.7)
SCIBASE	-.66338	.284657	3.36867**	3.33315**
	(1.9)	(1.3)	(5.5)	(5.9)
$\bar{R}^2$	.78	.78	.97	.96
F	16.4	18.8	144.5	136.1
SEE	1.97823	1.85727	.43019	.45020
N	35	41	35	41

†Forecasting regression used in Table 6-2.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

Table 6-9

Electrical Machinery Industry Regressions, Canada, France, Germany, Italy, Japan, Sweden, United Kingdom (not 1977), and United States, OECD International Statistical Years 1967-77

	Linear		Logarithmic		Instrumental linear
Variable	Without Canada	With Canada	Without Canada†	With Canada	With Canada
CONSTANT	.02700	.02449	-3.74044**	-3.04777**	.02236
	(1.9)	(1.9)	-(7.3)	-(6.8)	(1.7)
PROFITA(linear only)	.03991	.03741	.93492	1.02084	.04141
	(1.1)	(1.1)	(1.3)	(1.5)	(1.2)
INVCLIMA (linear only)	-.00981	-.00894	-.27187	-.27488	-.00859
	-(1.1)	-(1.2)	-(1.6)	-(1.8)	-(1.1)
CONCEN	.00021	.00024*	.42987**	.35722**	.00024*
	(1.6)	(2.2)	(4.3)	(4.1)	(2.2)
FOROWN	-.00040*	-.00031**	-.15299**	-.22321**	-.00021*‡
	-(2.1)	-(4.4)	-(3.0)	-(5.8)	-(2.2)‡
TRADEBALB	.04837*	.04522*	.56917	.08483	.03713
	(2.3)	(2.4)	(1.5)	(1.8)	(1.9)
GOVCONT	.08396**	.08241**	.25363**	.25722**	.08234**
	(6.3)	(6.9)	(6.5)	(7.1)	(6.6)
$\bar{R}^2$	.58	.63	.69	.70	. .
F	10.1	14.0	15.8	19.3	. .
SEE	.01288	.01197	.25130	.240638	.01228
N	41	47	41	47	47

†Forecasting regression used in Table 6-2.
‡*FOROWNHAT*.
*95 per cent significance.
**99 per cent significance.
SOURCE Estimates by authors.

indicated in Table 6-2, are not as felicitous as the regression results, exceeding the actual figures by 50 per cent on the average. The outlier test statistic is not significant.

Electrical Machinery

Reasonably satisfactory results are in evidence in Table 6-9, with an R^2 at 0.7 in both logarithmic "with Canada" and "without Canada" regressions and coefficients remarkably close in magnitude and significance. The negative sign on the foreign ownership coefficient again conforms to the MOSST (1979) figures. The instrumental variable approach, with *FOROWNHAT* derived exactly as in the case of the pharmaceutical industry, is applied to the linear "with Canada" form. It barely changes the results, pushing down the significance level (as far as we can interpret asymptotic statistics in small-sample language) on foreign ownership to 95 per cent and eliminating the significance of the trade balance variable, but nowhere does it reverse the signs. The mean forecast exceeds the mean actual value of research intensity by about 30 per cent, thus being the second-best forecasting result after the pulp and paper industry, which is 23 per cent off. The outlier test is not significant.

A Summary of Regression Results

Since the chief purpose of this paper is to point the way to valid comparisons of industrial research intensity, the natural focus of this brief overview of the regression results is on the norm-yielding group of OECD countries from which "forecasts" of Canadian intensity are made. Table 6-10 presents those "without Canada" regression equations (corresponding to the seven industries selected) that are considered to be the best of each industry's regression set and are used in the forecasting exercise. Since some of them are linear and some of them logarithmic in functional form, only the signs of the coefficients (+ or −) and their significance levels (** for 99 per cent and * for 95 per cent are recorded.

Going down the table variable by variable, it is seen that the constant term is statistically significant four times out of seven. Of the fourteen coefficients attached to the profit and investment climate variables, only one has statistical significance. No pattern of positive or negative signs prevails as between the two variables, though in three industries (paper, pharmaceuticals, and nonelectrical machinery) *PROFITA* and *INVCLIMA* have the same signs.

In our discussion in Chapters 4 and 5 on the hypothesized relationships between research inten-

Table 6-10

Comparison of Signs of Coefficients (+, -) and their Statistical Significance (*,), Forecasting Regressions for Seven Industries, Selected OECD Countries, OECD International Statistical Selected Years 1967-77**

Variable	Paper (log)	Chemicals (log)	Pharma-ceuticals (linear)	Rubber and plastics (linear)	Nonferrous metals (log)	Nonelectrical machinery (log)	Electrical machinery (log)
CONSTANT	+**	-	+	-**	-**	-	-**
PROFITA (linear only)	+	-	-	-**	+	-	+
INVCLIMA (linear only)	+	+	-	+	-	-	-
CONCEN	-**	-	+**	+*	-	+**	+**
FOROWN	+	+	-**	-**	+**	+**	-**
TAXBURDEN	-**	+	+*	+**	. .	-	
			(*PRODPAT*)				
TRADEBAL	+**	+		+*		+	+
	(*C* linear)	(*B*)		(*C* linear)		(*A* linear)	(*B* linear)
GOVCONT		-**		-	-*	-**	+**
SCIBASE	+**	+**		+		+**	
$\bar{R}^2$	.76	.69	.77	.52	.26	.97	.69
N	41	41	41	30	31	41	41

*95 per cent significance.
**99 per cent significance.
SOURCE Tables 6-1, 6-3, 6-4, 6-5, 6-6, 6-7, 6-8, and 6-9.

sity and profitability, we point out that no clear-cut reasons exist for expecting an unambiguously positive or negative coefficient on either variable. The only common thread linking the two, which could have been tested in principle, is the investment view of R & D outlays; on this perspective, R & D expenditures compete with plant and marketing investments for the disposition of profit (or, better, of cash flow). When profit is cyclically raised, pressures on capacity lead to investment in plant at the cost of research; when general fixed investment is on the rise (*INVCLIMA* increases), this signals, once again, a pressure for increased manufacturing capacity. How can this interpretation be tested? By using dummy variables that proxy either cyclical peaks or troughs. Unfortunately, it is not obvious that an industry in all of our sample countries is on the same cyclical pattern, and imposing individually time-tailored dummies may diminish both credibility and degrees of freedom.

Four positive, statistically significant coefficients (in pharmaceuticals, in rubber and plastics, and in electrical and nonelectrical machinery) of the concentration variable and one negative, significant coefficient (in paper) reflect faithfully the variety of empirical results obtained with this variable in other studies. A nonlinear relationship, as indicated earlier, tests out well in one of the regressions for the chemical industry. No dominant pattern of signs is evident with regard to the foreign ownership variable either, though five out of seven coefficients – the same number as for concentration – are significant.

In the four instances in which the tax burden variable is included in the final forecasting regressions, one out of two negative and one out of two positive signs are backed up by significance, throwing further doubt upon the reliability of investment-related variables in predicting research intensity. *TRADEBALC* is one of our two (the other being the *A* version) trade balance variables, which may be able to stand in for past success in research endeavours. Only in two industries is the coefficient on any version of *TRADEBAL* positive and significant but, of these two industries, paper has a resource-based advantage, and so the interpretation of "past research success" cannot be upheld.

Of the five coefficients of the government subsidy variables, four are negative, and three are significantly so. A curious result, hinting perhaps, as already indicated, at unwelcome simultaneity. The unresolvable question is how to instrumentalize this variable. The four *SCIBASE* coefficients, as expected, are all positive, and three are significant.

The adjusted coefficients of multiple determination are all, with the exception of non ferrous metals, satisfactory, while forecast performance ranges from excellent (in paper and in electrical machinery) to dismal (in rubber and plastics). Finally, the discrepancy between the excellence of fit – as indicated by high R^2's – and the nonsignificance of so many coefficients may be due, in part, to the collinearities encountered between the right-hand variables.

All in all, when the disparate sources of the data and their varying reliability is considered and the modest size of the samples is taken into account, the empirical results obtained appear to vindicate our approach to the selection of "intensity targets."

7 Concluding Remarks

The point of departure for our study was the desire to document the inadequacy of the economy-wide research intensity ratio as a policy target. We found the GERD/GNP ratio of 1.5 per cent, which has surfaced as the only specific goal of the emerging federal industrial policy in Canada, too aggregate in character and therefore unsuitable for international comparisons. Much of our first chapter covers various reasons for avoiding the simplistic use of this measure, while the second and third chapters adduce supporting statistical evidence.

Accepting the need for international comparisons of Canada's economic activities, including industrial research and development, we examine an alternative approach of comparing research intensity on an intraindustry, intercountry basis. We propose that industrial research intensity, as a manifestation of economic choices and decisions, can be modelled econometrically. The parameters of this model should be based, for a given industry, on a sample of advanced industrial countries with which Canada is routinely compared. We present the theoretical background for our model of research intensity determinants in Chapter 4. We think that the comparison of R & D intensities calculated (or "forecast") on the basis of this model with actual Canadian intensities can provide a legitimate judgment on whether Canada's research input performance is below or above the OECD norm. The numerical outcomes are laid out and discussed in Chapter 6.

It is our conclusion that the research intensity model is sound enough, and that the data assembled to estimate it are sufficiently reliable, to yield international comparisons superior to those yielded by the existing macroeconomic ratios. On the whole, the model in its various guises performs reasonably well as judged by standard statistical criteria, and some of the "forecasts" look acceptable. "Reasonably well" is an appropriate expression when it is recalled that a small sample of cross-section, time-series data of sometimes dubious reliability or homogeneity is used in the study. Similarly, the existing industrial organization theory, while offering a plethora of hypotheses, is not definite enough for us to be able to expect firmly any (with one exception) positive or negative direction in statistical relationships.

While the overriding goal of this study is to propose and test a viable method for research intensity comparisons, a by-product of it is the testing of models of research intensity determinants. We are not fully satisfied with our results on this score, because the sheer difficulty of obtaining data prevented us – given our time and resource constraints – from paying more individual attention to each industry. We are convinced, nevertheless, that the validity of research determinant models has been demonstrated sufficiently here and elsewhere to warrant their greater use in both positive and normative applications.

For those who believe that an economy-wide research intensity target should be set, our study outlines a plausible methodology for doing so. The means to complete an industry-by-industry or sector-by-sector build-up are available more readily to government departments possessing adequate support staff and access to international data banks and computing facilities.

A Diversion on Policy Orientation

Our jumping off point for this exercise is the public policy debate – a many-tongued soliloquy in favour of more government intervention is perhaps a better word for it – which takes for granted the premise that Canada's research intensity is too low, and which concentrates on the means to remedy the alleged shortfall. We are, however, reluctant to proffer policy recommendations based on our analysis, being content to document the absurdity of using economy-wide research intensity ratios in their present form and to indicate more valid ways of international comparison. In this general pattern, we also conform to the "ground rules" accepted by the Ministry of State for Science and Technology of using as the proper comparison criterion some OECD intensity norm, rather than an economically optimal intensity ratio, if such can indeed be arrived at.

Our reluctance to tread upon the policy prescription ground is primarily based on our disbelief in research and development spending as the proper instrument for stimulating innovation and so growth by firm and industry. (Most of industrial R & D is of an applied and development nature; our argument is not addressed to the financing of basic research that often has public good or externality characteristics.) R & D is, of course, a necessary but not by any means a sufficient factor in bringing forth innovation. It is likely that those policies that enhance innovation also, ineluctably, raise the level of research expenditures.

Endeavours to stimulate innovation by direct subsidy or tax concession (pump-priming) to a firm's industrial research activity need not necessarily be successful. Stimulating R & D in the firm without the assurance that the organization has competent management to translate technical into commercial success often turns out to be a futile exercise (de Woot and Heyvaert, 1979). The size of the public budget allocated to such endeavours and its specific distribution to individual firms and sectors is subject to "nonmarket failure"; there are no mechanisms, within the government, for reconciling calculations by bureaucratic decision makers of their private and organizational costs and benefits with total costs and benefits (Wolf, 1979). We can expect, with regard to the total budget, tendencies afoot that will maximize the income and perquisites of the members of the disbursing agency (Niskanen, 1967). With respect to the budget's allocation, we can expect the emergence of a constituency group that may co-opt the agency into its mandate (Stigler, 1971). The implication of all of this is that the final emphasis may well be on objectives, such as employment of scientific personnel, that are not necessarily related to innovation.

In our analysis, the variable *GOVCONT* is the one that comes nearest to measuring the direct pump-priming intervention in industrial R & D. Most of the other variables employed as determinants of research intensity may well be conceived of as influencing the general climate for innovation that, in turn, affects the propensity to engage in research. When such an innovation-oriented (rather than R & D-oriented) perspective is adopted, it appears more reasonable to advance certain policy reflections that are grounded in the work undertaken here. From here on, then, our reasoning is based on the premise that, with the exception of *GOVCONT*, all the determinants employed in our analysis are equally likely to affect the rate of innovation and of research expenditures – which are innovation's concomitants.

On a more fundamental level, the question can be raised as to whether a "socially optimal" degree of research intensity can be determined for each of Canada's individual industries (and so, by aggregation, for the whole economy), regardless of what goes on in comparable countries. Following the general line of reasoning proposed by Breton (1974), it can be hypothesized that there indeed is an "optimal" level of R & D intensity, designated as RD^*, in a given industrial sector, such as "high-technology" (*HT*) manufacturing. That level, presumably, is different from the actual level:

$$RD^*_{HT} \neq RD_{HT}$$

The difference between the actual and optimal levels may be due to several factors, the most prominently cited among them being externalities. The other classes of distortionary factors mentioned by Breton are monopoly elements in the market, uninsurable risks, and past government policies. It may be argued, for instance, that a high-technology sector employs a particularly large number of qualified scientists and engineers, that their presence bestows great advantages on the rest of the economy, and that those benefits are not captured by the revenues accruing to the factors of production in the high-technology sector. Provided that the net external benefits arising out of the R & D intensity in this sector exceed the net external benefits from R & D intensity in other industries, a sufficient condition for public intervention is established:

$$(B_{RD_{HT}} - C_{RD_{HT}}) - (B_{RD_i} - C_{RD_i}) > 0$$

where *B* and *C* refer to external benefits and costs and the subscript *i* to non-high-technology sectors. The intervention should then be pursued until the marginal benefits from reducing the gap are equal to the marginal costs of public intervention and private adjustment – that is to say, until a socially optimal gap is reached.

The operational question cannot be ducked: How do we measure the difference that may now exist between optimal and actual levels of R & D intensity? Two ways of doing so are conceivable. The first one would rely on a social policy maker to state what is an industrial sector's optimal R & D intensity, *R&D**. The difference then is determined by matching the actual with the optimal intensity. This appears to be the approach taken on the economy-wide level by MOSST. The second approach would rely on uncovering evidence of market failure in a given industry. The extent of the failure measured by a proportion of R & D intensity, when added to the actual level of R & D intensity, would then define the optimal level. One recent publication (Britton and Gilmour, 1978), for instance, may be interpreted as an exercise in delineating market failure in Canadian manufacturing.

We wish to emphasize that our data and our approach do not allow us to estimate what an optimal R & D intensity in a manufacturing sector in Canada should be, since we have no means of judging the extent of market failure, if any. All we can do is to take as a normative criterion an OECD-related level and then, as will be seen subsequently, to stretch it as far as it will go for policy purposes.

The basic policy issue is, of course, the feasibility of raising the level of innovational activity and, *mutatis mutandis*, of R & D intensity by governmental action. The fundamental proposition that emerges from our statistical analysis is that the economic influences upon research (and innovation) are multiple and complex, and that there is no single "pinpoint" governmental instrument that will do exclusively. If the "social planners" consider a higher R & D intensity in individual industries a priority, it is clear that their approach to this goal will require co-ordinated policies regarding industrial concentration, foreign ownership, general taxation, patent legislation, and so on. While the need for co-ordination of policies in several areas has been noted, particularly by the Science Council of Canada, a Canadian multivariate statistical documentation such as ours is not available at the industrial sector level.

The first immediate implication of the need for policy co-ordination is the explicit recognition of choices or trade-offs to be made; is, for instance, the aggregate (producer and consumer) surplus going to be larger with higher concentration and more innovation, but less competition, in the pharmaceutical industry? We have no means of finding answers, but we can furnish some information that should facilitate an understanding of policy trade-offs. When the emphasis shifts from intercountry comparison to Canadian policy orientation, the version of the model of research intensity determination with Canada included should be considered again. For convenience, the detailed estimates presented in Tables 6-1 to 6-9 of the "with Canada" regressions are summarized in Table 7-1, along the lines of Table 6-10. When the latter two tables are compared, it is readily apparent that some of the coefficient signs change with Canada added to the sample (seven out of forty-seven), and that statistical significance sometimes emerges (five times) and sometimes vanishes (five times as well).

Within Table 7-1, perhaps the most arresting results from a policy perspective are the sometimes positive and sometimes negative signs on the coefficients of concentration, foreign ownership and, to some extent, tax burden. One interpretation of this

Table 7-1

Comparison of Signs of Coefficients (+, -) and their Statistical Significance (*,), for Forecasting Regressions Estimated with Canada Included, Seven Industries, Selected OECD Countries, OECD International Statistical Selected Years 1967-77**

Variable	Paper (log)	Chemicals (log)	Pharmaceuticals (linear)	Rubber and plastics (linear)	Nonferrous metals (log)	Nonelectrical machinery (log)	Electrical machinery (log)
CONSTANT	+*	-**	+	-*	-**	-	-**
PROFITA (linear only)	+**	+	-		+	-	+
INVCLIMA (linear only)	+	-	-	-	-	+	-
CONCEN	-**	-	+**	+	-	+**	+**
FOROWN	+**	-	-	-**	+*	+**	-**
TAXBURDEN	-**	+*	+	+*		-	
			(*PRODPAT*)				
TRADEBAL	+**	+*		+		+	+
	(*C* linear)	(*B*)				(*A* linear)	(*B*)
GOVCONT		-**		+	-*	-*	+**
SCIBASE	+**	+**		-		+**	
$\bar{R}^2$	.82	.77	.73	.44	.32	.96	.70
N	47	47	47	36	37	41	47

*95 per cent significance.
**99 per cent significance.
SOURCE Tables 6-1, 6-3, 6-4, 6-5, 6-6, 6-7, 6-8, and 6-9.

pattern could assign the blame to weak theory, inadequate specification, and poor data. Another interpretation might take the results as valid, reflect on the varying levels of concentration and foreign control in each of the industries, and also reflect on the need for individually tailored intervention approaches to each industry.

To get any further along the policy path, however, the forecasting exercise undertaken in Chapter 6 should be reconsidered. The starting thought is that the Canadian values of the variables used to make the prediction of research intensity for Canada are perhaps "too low." Several of these variables are policy dependent, and their possibly insufficient levels, as employed in our forecast, might yield too small a value for what Canada's innovation – and so R & D level – "ought to be." Once the word "ought" is uttered, a prescriptive path is cleared to the question: Which variables are logical candidates for policies enhancing innovative activity? The following analysis is proposed.

The categorization of the determinants of R & D spending can be addressed in a different way, perhaps more in line with the methodological orientation of this paper. One can argue that the R & D-oriented policies of the various countries may have distorted (positively or negatively, that is, may have increased or lowered) the levels of private R & D spending and thus made a "pure" comparison of the private industry's research spending across countries impossible. To make it "policy neutral," one has to calculate a forecast based exclusively on some subset of "uninfluenceable" or "nonmanipulable" variables. This forecast must then be compared with the "total" forecast to establish what percentage of the total R & D forecast for Canada in a particular industry is accounted for by nonmanipulable factors and is therefore beyond the reach of interventionist policies.

A first look at the determinant variables listed in Table 7-1 makes us realize that all of them with one exception are susceptible to government influence. The investment climate, which we proxy as the rate of growth of gross fixed capital formation, can be changed by a host of policies. Concentration responds to anti-combines legislation and enforcement, while foreign ownership responds to fallouts from the Foreign Investment Review Act or the National Energy Program, the tax burden depends on yearly budgets, the trade balance reflects the tariff stance and central bank policy, and the scientific base varies with the government's science policy. The possible exception is profitability, since one of its factors, corporate taxation, is specified separately.

In one sense, we reach here a *reductio ad absurdum*; should we desire to stimulate innovation (and R & D), a number of important federal policies must be modified, regardless of the many other effects that they may have. But can the federal government really afford to pressure the governor of the Bank of Canada to play for a dollar devaluation on the chance that this will enhance industry's foreign trade balance and thus ultimately industry's innovativeness? This is the familiar dilemma facing an economic interventionist.

In a different sense, we note that, since some policies obviously may have to be excluded from consideration as innovation stimulants, we need some scheme by which to make such exclusion plausible. In theory, this is simple: exclude those policies/variables whose impact upon innovation is small and whose opportunity cost of modification is high.

This exclusion principle is too demanding of our data bank, and so we use a second exclusion principle whose merits can be argued endlessly. We make a distinction along an admittedly arbitrary line of division between variables – and thus policies – that may or may not be considered for amendment as part of an innovation-augmenting strategy.

Investment climate and foreign ownership most likely are dependent on too large a host of policy instruments to be susceptible to pinpoint action; the proportion of foreign-controlled firms in certain industries (such as paper) is shifting rapidly because of market forces. Trade balance, if looked upon as going beyond "past R & D success," is strongly influenced, as already pointed out, by exchange rates and by such other factors as labour productivity, and so it cannot be considered as an appropriate policy-related variable.

What remains in the realm of the "manipulable" is concentration, or rather, merger policies, which, incidentally, could be made more hostile or more friendly (although it is hard to visualize an "improvement" upon the present ineffectiveness of the Canadian merger legislation), depending upon the industry in question. Expansion of the science base also appears to be susceptible to the action of a federal science policy. In the case of the pharmaceutical industry, one can argue that a trade-off is open between a policy aimed at low consumer prices and a high patent protection level, but we cannot substantiate this opinion on the basis of our regression results.

While we do not believe, as explained above, that government contributions to R & D are necessarily innovation-enhancing, we should include *GOVCONT* among the "manipulables," if only because, in the four instances where coefficients are statistically significant, government grants actually tend to lower R & D intensity in three, thereby offering scope for a reduction in subsidies.

To sum up, the determinant variables of our research intensity model have been categorized into two groups. In one group, some factors, though susceptible to government influence, cannot be considered as policy targets, because the opportunity cost of the multiple policy instruments that would have to be brought to bear is too high. These are, in our case, *PROFITA*, *INVCLIMA*, *FOROWN*, *TAXBURDEN*, and *TRADEBAL*. Those factors that are susceptible to relatively "low-cost" policy impact are *CONCEN*, *SCIBASE*, and, in the case of pharmaceuticals, *PRODPAT*.

In Table 7-2, we predict what Canada's R & D intensity would be if the "incorrigible" differences in economic structure between Canada and the other OECD countries were treated separately from the variables subject to policy manipulation. ("Incorrigible" in this context means exogenous with respect to research policies, or "nonmanipulable" by policies designed to promote R & D.) We calculate first the "policy-neutral" forecast (line 3 of each industry block in Table 7-2), and then its share of the total forecast (line 4).

Table 7-2

Comparison of Forecast and Actual R&D Intensities in Seven Industries, Canada, OECD International Statistical Years 1967-77

Industry	1967	1969	1971	1973	1975	1977
			(Per cent)			
Paper						
1 Actual value	.77	.59	.45	.35	.36	.39
2 Total forecast	.46	.57	.43	.32	.37	.40
3 Policy-neutral forecast	.28	.34	.26	.24	.23	.27
4 (3) as % of (2)	61	60	60	75	62	73
Chemicals						
1 Actual value	1.74	1.55	1.42	1.30	1.15	.98
2 Total forecast	2.40	1.95	1.99	1.79	1.95	1.84
3 Policy-neutral forecast	.89	.87	.91	.88	.96	.89
4 (3) as % of (2)	37	45	46	49	49	48
Pharmaceuticals						
1 Actual value	3.55	3.76	3.25	4.04	4.40	3.34
2 Total forecast	-1.68	-1.04	-2.05	-2.06	-3.48	-1.71
3 Policy-neutral forecast	-5.79	-5.16	-6.17	-6.18	-7.59	-5.83
4 (3) as % of (2)	345	494	301	300	218	340
Rubber and plastics						
1 Actual value	.40	.36	.37	.29	.24	.22
2 Total forecast	-2.69	-2.70	-2.70	-2.79	-2.67	-2.60
3 Policy-neutral forecast	-4.20	-4.28	-4.31	-4.31	-4.58	-3.31
4 (3) as % of (2)	156	158	159	155	172	127
Nonferrous metals						
1 Actual value	1.13	1.00	1.24	1.12	1.48	.32
2 Total forecast	1.81	1.60	1.85	1.72	1.79	1.20
3 Policy-neutral forecast	3.08	3.04	3.12	3.24	3.18	2.92
4 (3) as % of (2)	170	190	168	188	178	243
Nonelectrical machinery						
1 Actual value	.63	.73	.87	.93	1.48	1.14
2 Total forecast	1.95	1.99	1.60	.98	1.05	1.14
3 Policy-neutral forecast	0.00	0.00	0.00	0.00	0.00	0.00
4 (3) as % of (2)	. .	. .	. .	. .	. .	. .
Electrical machinery						
1 Actual value	3.41	3.14	3.30	2.99	2.72	2.92
2 Total forecast	4.24	3.92	4.17	3.74	4.10	4.21
3 Policy-neutral forecast	.42	.38	.45	.45	.49	.53
4 (3) as % of (2)	9.9	9.7	10.8	9.5	11.9	12.6

SOURCE Actual value and total forecast taken from Table 6-2; policy-neutral forecast calculated with the help of formula given in text.

The "policy-neutral" forecast is that part of Canada's R & D intensity corresponding to the OECD norm, which is determined by factors beyond the reach of practical research policy measures. It is based on the following equation:

$$\text{Forecast } N_{CAN} = \hat{\beta}_1 CONST + \hat{\beta}_2 PROFITA_{CAN} + \hat{\beta}_3 INVCLIMA_{CAN} + \hat{\beta}_4 FOROWN_{CAN} + \hat{\beta}_5 TAXBURDEN_{CAN} + \hat{\beta}_6 TRADEBAL_{CAN}$$

Here, the $\hat{\beta}$ values are the estimates of regression coefficients reported in Tables 6-1 to 6-9, and they are multiplied by the actual Canadian levels of the relevant variables for the appropriate industry and year in question.

Past research policy actions in Canada have influenced the magnitudes of the remaining variables. The "policy-influenced" forecast is then:

$$\text{Forecast } P_{CAN} = \hat{\gamma}_1 CONCEN_{CAN} + \hat{\gamma}_2 GOVCONT_{CAN} + \hat{\gamma}_3 SCIBASE_{CAN} + \hat{\gamma}_4 PRODPAT_{CAN}$$

Again, the $\hat{\gamma}$ values are the estimated regression coefficients reported in Tables 6-1 to 6-9, and they are multiplied by the actual Canadian levels of the relevant variables for the appropriate industry and year in question.

The total forecast therefore is:

$$\text{Forecast } T_{CAN} = \text{Forecast } N_{CAN} + \text{Forecast } P_{CAN} = \hat{\beta}x + \hat{\gamma}z$$

where

$\hat{\beta}$ is the vector of coefficients of policy-neutral variables;
$\hat{\gamma}$ is the vector of coefficients of policy-influenced variables;
X is the set of Canadian values of policy-neutral variables; and
Z is the set of Canadian values of policy-influenced variables.

Our policy-neutral forecasts, when calculated as a percentage of the total forecast (line 4 in Table 7-2), are as low as 9.5 per cent and as high as 494 per cent, depending upon the industry and year. For convenience, this information is summarized in Table 7-3, where our sample industries are cross-classified according to the relationship between the actual and the forecast total R & D intensity.

Table 7-3

Classification of Seven Industries According to Forecast R&D Intensities, Canada, OECD International Statistical Years 1967-77

	Actual < Forecast	Actual > Forecast
$\frac{\text{Neutral forecast}}{\text{Total forecast}} < 50\%$	A Chemicals Electrical machinery Nonelectrical machinery	
$50\% < \frac{\text{Neutral forecast}}{\text{Total forecast}} < 100\%$		C Paper
$\frac{\text{Neutral forecast}}{\text{Total forecast}} > 100\%$	B Nonferrous metals	D Pharmaceuticals Rubber and plastics

SOURCE Same as for Table 7-2.

In the three industries in slot A, namely, chemicals, electrical machinery, and nonelectrical machinery, the Canadian R & D intensity falls short of the OECD-based "norm." Under the MOSST approach, these industries may be considered as candidates for policy attention. The next consideration is to ascertain the possible scope for intervention. Our breakdown of the total forecast into policy-neutral and policy-influenced components is of assistance here.

As shown in the rows of Table 7-3, we categorize our sample industries into three groups according to the value of the ratio of the policy-neutral component to the total forecast over the entire sample period. If small, say, less than 50 per cent, the ratio may be interpreted as indicating that the levels of Canadian policy variables in *Z* are low enough to give more serious attention to remedial action.

In the electrical machinery industry, for example, this ratio is about 11 per cent. Any discussion of the scope and directions of potential Canadian policy actions should, in our opinion, start with a variable-by-variable evaluation of the components of *Z*. For example, taking the coefficient of *GOVCONT* for this industry, we note its positive sign and statistical significance. Our data show that government funds account for 14 per cent of the total Canadian R & D spending in this industry in 1977. This can be contrasted with the OECD figure averaged over the seven sample countries and the whole sample period, which exceeds 20 per cent. In this particular instance, then, one may think that raising the level of government contributions may result in higher R & D intensity in this industry. The OECD average contribution levels may provide a reference point as to the extent of such intervention.

We hasten to add that no single, mechanically applicable policy rule exists, nor can one be realistically expected to be developed. For example, in the nonelectrical machinery industry, the effect of *GOVCONT* on R & D intensity is exactly the reverse; our finding that this variable may have a different direction of influence on R & D in different industries is consistent with a number of other studies that are reviewed in the discussion on government participation in Chapter 4. Finally, in other industries (and for other variables), the estimated coefficients are not always statistically significant and cannot therefore be taken as policy guides.

There is yet another category of variables in which the estimated coefficients are statistically significant and in which the signs correspond to *a priori* expectations, although policy actions guided exclusively by R & D intensity considerations may not be feasible. The *CONCEN* variable provides an example. Our results show that, for some industries at least, increased industrial concentration raises the levels of R & D intensity. However, looking, for instance, at electrical machinery, one cannot fail to notice that concentration in this industry in Canada is already high (close to 60 per cent over the sample period), compared with the OECD average (around 50 per cent over the same period). It therefore seems that policy action is constrained by "natural limits" arising from other considerations (competition policy and so on).

As for the industries listed in the third column of Table 7-3, we do not comment on policy scope or directions, since the actual R & D intensity exceeds the OECD norm.

In closing, we should state what we consider to be the main practical implications of our study. First, we believe that we show conclusively that an aggregate, economy-wide target of research intensity as set by MOSST is neither valid nor useful. If one were to insist on having a target, then it would have to be built up industry by industry, possibly using the method that we propose. Next, we show that research intensity exhibits responses to economic stimuli that differ considerably from industry to industry. Thus, in some industries, foreign ownership and concentration are related positively to research intensity, in some negatively, and in others there is no relationship. Third, our exercise shows that, when a rigorous comparison is made between a Canadian industry's R & D intensity and the OECD-based norm, some important Canadian industries are doing "better than expected." Fourth, we also suggest that, in industries where Canadian performance falls short of the OECD norm, the scope for intervention differs from industry to industry.

Given the industry-by-industry diversity of our findings, we suggest a two-step procedure to the insistent industrial policy interventionist:

- Extend our "determinants-of-R & D intensity model" to all Canadian industries in which there is interest, and derive OECD-based "forecasts" for these sectors. But use them only for planning tentative indicators.

- Concentrate on those Canadian industries in which a "shortfall" is detected. Then use detailed Canadian data to estimate a viable R & D determinants model for each industry in the manner shown by Howe and McFetridge (1976). This model should be able to appraise much more accurately than an OECD-wide model how a specific Canadian industry's research intensity responds to both structural and policy variables. It could become an operational tool in determining the magnitude and detail of policy action.

Appendix: Data Used in Regression Analysis

In this Appendix, we provide precise definitions of the variables employed in our regression analysis, and we identify the sources of our information. The numerical data themselves (with a few exceptions) are not a part of the Appendix, since their sources are reasonably accessible. We make an exception with respect to information that has to be gathered from a large number of diverse multilingual sources (such as data on foreign ownership and industrial concentration), and list not only the definitions and sources, but also the data themselves.

The complete tabulation of our regression data is available from the authors on request.

Variable *RDNACU*

Definition – Total intramural expenditure on R & D in the business enterprise sector, natural sciences, and engineering, in national currency.

Source – OECD. Directorate for Science, Technology and Industry. *International Survey of the Resources Devoted to R&D*; Volume 1: Business Enterprise Sector (for the International Statistical Years 1967, 1969, 1971, 1973 and 1975); Country Reports and Preliminary International Tables (for the International Statistical Year 1977). Paris: various years.

Variable *PRODNACU*

Definition – Gross output at factor values or in producer values. For Belgium, the reported value added figures were converted into estimated gross-output figures, using an average ratio between gross output and value added for the particular industry in other OECD countries.

Source – United Nations. Statistical Office. *Yearbook of Industrial Statistics, Vol. I: General Industrial Statistics* (formerly *The Growth of World Industry*). New York: annual.

OECD. *The Chemical Industry*. Paris: annual. (Converted from U.S. dollars into national currency using exchange rate series "rf" or "trade conversion factor" or "spot rate at end of period" taken from International Monetary Fund. *International Financial Statistics*. Washington, D.C.: annual).

Variables *EXPORTUS* and *IMPORTUS*

Definition – Values in U.S. dollars; exports are f.o.b., imports are c.i.f. The following standard industrial trade classifications (SITC) are used to represent our sample industries:

Industry	SITC
Paper and products	64
Industrial chemicals – Other chemicals	5
Pharmaceutical products	541
Rubber products – Plastic products	581 + 62 + 266
Nonferrous metals	68
Nonelectrical machinery	71
Electrical machinery	72

The SITC category 71 includes 711.3 (Steam engines) and 711.4 (Aircraft) which are classified in the production statistics with Transportation Equipment, but could not be excluded here for lack of detailed data.

Source – OECD. *Statistics of Foreign Trade, Series B, Trade by Commodities: Country Summaries*. Paris: annual.

OECD. *The Chemical Industry*. Paris: annual

OECD. *Impact of Multinational Enterprises on National Scientific and Technical Capacities*. Paris: December 1977, p. 37.

United Nations. *Yearbook of International Trade Statistics*. New York: annual.

Variable *PROFITA*, *PROFITB*, and *INVCLIMB*

Definition – *PROFITA* is the ratio of "net income after taxes" or "adjusted earnings" to "shareholders equity" or "net investment position" reported by U.S.-owned subsidiaries in the various countries.

PROFITB is the rate of growth of *PROFITA*.

INVCLIMB is the ratio of "reinvested earnings" or "net income retained" to "adjusted earnings" or "income after taxes" reported by U.S.-owned subsidiaries in the various countries. For the U.S., these ratios are based on consolidated global operations of U.S. industries, which include the income and equity of U.S. companies abroad.

The industry breakdown in the relevant sources of statistical data is, unfortunately, not detailed enough to match the industrial classifications applicable to the other variables. The regression analysis, therefore, employs data from the "closest" industries as follows. Data reported for U.S.-owned subsidiaries operating in "Chemical Products" were used for three of our industries: "Chemicals," "Pharmaceuticals," and "Rubber and Plastics." Data reported for U.S.-owned subsidiaries operating in "Primary and Fabricated Metals" was utilized for our "Nonferrous Metals Industry." Data reported for "Machinery" was used both for our "Machinery, Electrical" and "Machinery, Other than Electrical" industries. Figures reported for U.S.-owned subsidiaries in "Other Manufacturing" were employed in our "Pulp and Paper" industry regressions.

Source – U.S. Department of Commerce. Bureau of Economic Analysis. *Selected Data on U.S. Direct Investment Abroad, 1966-76*. Washington, D.C.: G.P.O., 1977 (for countries other than the U.S.).

Kozlow, R.; Rutter, J.; and Walker, P. "U.S. Direct Investment Abroad in 1977." *Survey of Current Business* 58:16-38 (data for 1977, countries other than the U.S.).

U.S. Federal Trade Commission. *Quarterly Financial Report for Manufacturing, Mining and Trade Corporations*. Washington, D.C.: F.T.C., various issues (data for the U.S.).

Variable *INVCLIMA*

Definition – Rate of growth of "gross fixed capital formation." The chemical industry data were used also for pharmaceuticals.

Source – United Nations. Statistical Office. *Yearbook of Industrial Statistics: Vol. I, General Industrial Statistics* (formerly *The Growth of World Industry*). New York: annual.

OECD. *The Chemical Industry*. Paris: annual.

Variable *CONCEN*

Definition – The ratios are shown in Tables A-1 to A-7. All concentration ratios are 4-firm by sales,

Table A-1

Variable *CONCEN* in the Paper Industry, Selected OECD Countries, Selected Years 1963-74

	1963	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Belgium	58.5 E[9]	. .	. .	. .	58.9[10]	56.5[10]	. .	58.5[10]	. .	55.3[10]	63.4*[10]
Canada	. .	36.9[1]	. .	. .	35.9[2]	. .	36.2[2]	. .	34.5[2]	. .	34.0*[2], 34.4[3]
France	26.0 E[4]	. .	. .	. .	. .	33.2[5]	. .	. .	. .	. .	32.7*[5]
Germany	30.7[6]	32.2[6]	. .	36.5[6]	. .	40.4[6]	. .	. .	40.0[7]	. .	40.0*[7]
Italy	24.3[6]	24.6[6]	. .	22.8[6]	. .	23.2[6]	. .	. .	. .	. .	27.4*[5]
Japan	. .	. .	39.2[1]	. .	. .	. .	. .	. .	. .	. .	43.8*[1]
Sweden	. .	42.0 VA*[1]	. .	. .	. .	. .	. .	. .	. .	. .	. .
United Kingdom	35.0 E[4]	. .	. .	. .	50.6[8]	50.6[8]	49.7[8]	. .	49.0[8]	. .	49.0*[5]
United States	. .	. .	24.0[1]	. .	. .	. .	26.0[1]	. .	24.0*[1]	. .	. .

1 Canada. Royal Commission on Corporate Concentration. 1977. *Concentration Levels and Trends in the Canadian Economy, 1965-1973: A Technical Report*. Study 31. Ottawa: Supply and Services Canada.
2 Statistics Canada. 1974. *Industrial Organization and Concentration in Manufacturing, Mining and Logging Industries*. Statistics Canada, cat. no. 31-402 (pulp and paper only).
3 Statistics Canada. 1977. *Corporations and Labour Unions Returns Act, Part I: Corporations*. Statistics Canada, cat. no. 61.210.
4 George, K. D. and Ward, T. S. 1973. *The Structure of Industry in the EEC*. Cambridge: University Press, p. 46 (NICE classification 271 only).
5 European Economic Community. 1979. *Eighth Report on Competition Policy*. Brussels: p. 196.
6 European Economic Community. 1974. *Tableaux de concentration: fabrication du papier*. IV-45/1974 (NICE 271 only).
7 European Economic Community. 1975. *Fifth Report on Competition Policy*. Brussels.
8 European Economic Community. 1975. *A Study of the Evolution of Concentration in the U.K. Paper Industry*. IV-80/1975 (NICE 271 only).
9 Phlips, Louis. 1971. *Effects of Industrial Concentration*. Amsterdam: North Holland, Appendix Tables A4 and A5 (NICE 271 only).
10 European Economic Community. 1977. *Étude de l'évolution de la concentration dans le secteur de la pâte, du papier, et du carton en Belgique*. Brussels: Appendix Tables.
SOURCE Value chosen for final regression.

unless otherwise indicated, where C3 = 3-firm, C5 = 5-firm, C6 = 6-firm or less, and where E = employment and VA = value added. Examples: Chemicals, Belgium, 49.0 E is a four-firm concentration ratio of 49 per cent based on employment in that industry; Chemicals, U.K., 75.4 C5 is a five-firm sales-based concentration ratio. The superscript beside each figure indicates the work from which the data were obtained, as listed in the source notes below each table. An asterisk signifies values chosen for final regressions.

Table A-2

Variable *CONCEN* in the Chemical Industry, Selected OECD Countries, Selected Years 1963-75

	1963	1966	1968	1970	1972	1974	1975
Belgium	49.0 E*[1]	..	..	..	..	..	..
Canada	..	..	..	50.2*[4]	48.3 VA[4]	46.4 VA[3]	25.9[2]
France	24.0 E[5]	..	..	..	29.0*[10]	..	..
Germany	30.0[5]	..	..	27.2 C3*[6]	..	..	..
Italy	35.0*[5]	..	..	..	..	..	..
Japan	..	..	..	27.7 C6*[8]	..	..	..
Sweden	..	53.0*[9]	..	..	..	..	..
United Kingdom	75.4 C5[5]	..	78.9 C5*[5]	..	..	..	..
United States	..	..	..	42.0*[5]	..	..	..

1 Phlips, Louis, 1971. *Effects of Industrial Concentration.* Amsterdam: North Holland.
2 Statistics Canada. 1976 and 1977. *Corporations and Labour Unions Returns Act, Part I: Corporations.* Statistics Canada, no. 61-210.
3 Statistics Canada. 1974. *Industrial Organization and Concentration in Manufacturing, Mining and Logging Industries.* Statistics Canada, cat. no. 31-402, Table B.
4 Ibid., Table 2. (weighted averages).
5 Jacquemin, A. P. and Jong, H. W. 1976. *Markets, Corporate Behaviour and The State.* The Hague: Nijhoff, p. 137 (for France, Germany, and Italy), p. 129 (for U.K.), and p. 346 (for U.S.).
6 Neumann, M.; Bobel, I.; and Haid, A. 1979. "Profitability, Risk and Market Structure in West German Industries." *Journal of Industrial Economics* 27:227-42.
7 Baum, C. 1978. "Systematische Fehler. . ." *Jahrbücher für Nationalökonomie* 193:30-53.
8 Imai, K. 1978. "Japan's Industrial Organization." *Japanese Economic Studies* 6:3-67.
9 Muller, J. and Hochreiter, R. 1977. *Stand der Konzentrazion in Deutschland.* Göttingen: Schwartz, p. 76.
10 OECD 1978. *Multinational Enterprise: Penetration of Multinational Enterprises and Industrial Concentration. DSTI/INDI/78-1 (2nd revision). Paris:* Table 12 (base chemicals only).
SOURCE Value chosen for final regression.

Table A-3

Variable *CONCEN* in the Pharmaceutical Industry, Selected OECD Countries, Selected Years 1965-74

	1965	1969	1970	1973	1974
Belgium	..	42.8[1]	..	41.9*[1]	..
Canada	21.2[5]	..	14.0*[6]	..	..
Denmark	..	..	..	68.0	..
France	..	..	..	20.0*[2]	..
Italy	..	32.3*[4]	..	..	..
Japan	..	23.6 C3[7]	..	..	22.3*[8]
Sweden	..	..	..	68.1*[9]	..
United Kingdom	..	29.5[3]	..	28.8*[3]	..
United States	..	26.1[10]	..	27.8*[10]	..

1 Studia. 1975. *Étude sur l'évolution de la concentration dans l'industrie pharmaceutique en Belgique.* Brussels: EEC.
2 Blunden, K. 1975. *Étude sur l'évolution de la concentration dans l'industrie pharmaceutique en France.* Brussels: EEC.
3 Heath, J. B. et al. 1975. *A Study of the Evolution of Concentration in the Pharmaceutical Industry for the United Kingdom.* Brussels: EEC.
4 Ator. 1973. *Tableaux de concentration, Pharmaceutique, Italie.* Brussels: EEC.
5 Canada. Department of Consumer and Corporate Affairs. 1971. "Concentration in the Manufacturing Industries of Canada." Consumer and Corporate Affairs, Ottawa (figure is for total manufacturers of Pharmaceuticals and Medicines).
6 OECD. 1977. *Impact of Multinational Enterprises on National Scientific and Technical Capacities: Pharmaceutical Industry.* Paris: December.
7 Nakao, T. 1979. "Profit Rates and Market Shares of Leading Industrial Firms in Japan." *Journal of Industrial Economics* 27: 371-83.
8 OECD. 1977. *Impact of Multinational... Pharmaceutical Industry.* Paris: p. 67 (sales of four largest firms, divided by "production plus imports less exports").
9 Ibid., p. 66 (share of production of four largest firms represents 68.1 per cent of total value of "production plus imports less exports").
10 Grabowski, H. G. and Vernon, J. M. 1976. "Structural Effects. . . Ethical Drug Industry." In *Essays on Industrial Organization in Honor of Joe S. Bain,* edited by R. T. Masson and P. D. Qualls, pp. 181-205. Boston: Ballinger.
SOURCE Value chosen for final regression.

Variable *FOROWN*

Definition – Foreign ownership (or penetration) is in most instances defined in the basic OECD source document as "more than 50 per cent direct foreign investment." Thus, for example, "Paper, Canada, 49.5 S means that 49.5 per cent of the sales of the industry are accounted for by subsidiaries held more than 50 per cent from abroad.

Variable *TAXBURDEN*

Definition – Income taxes paid by U.S.-owned subsidiaries operating abroad to governments of the "host" countries. Consists of "realized foreign income tax" plus "foreign withholding tax paid." Reported taxes per $100 of taxable income in 1968.

Table A-4

Variable *CONCEN* in the Rubber and Plastics Industry, Selected OECD Countries, Selected Years 1963-74

	1963	1966	1967	1970	1972	1974
Belgium	38.0 E[*1]	..	..	..	..	..
Canada	..	..	..	..	40.3 VA[*2]	34.1 VA[2]
France	46.0 E[*3]	..	..	..	..	..
Germany	32.0 E[3]	..	34.5 C3[4]	33.9 C3[*4]	..	..
Italy	48.0 E[*3]	..	..	..	..	..
Japan	..	..	..	31.1[*5]	..	..
Sweden	..	53.0[*7]	..	..	..	..
United Kingdom	35.0 E[*3]	..	..	..	..	..
United States	..	..	..	32.0[*6]	..	..

1 Phlips, Louis. 1971. *Effects of Industrial Concentration.* Amsterdam: North Holland.
2 Statistics Canada. 1974. *Industrial Organization and Concentration in Manufacturing, Mining and Logging Industries.* Statistics Canada, cat. no. 31-402.
3 George, K. D. and Ward, T. S. 1973. *The Structure of Industry in the EEC.* Cambridge: University Press (plastics not included for U.K.).
4 Muller, J. and Hochreiter, R. 1977. *Stand der Konzentrazion in Deutschland.* Göttingen: Schwartz.
5 Imai, K. 1978. "Japan's Industrial Organization." *Japanese Economic Studies* 6: 3-67.
6 Jacquemin, A. P. and Jong, H. W. 1976. *Markets, Corporate Behaviour and the State.* The Hague: Nijhoff, p. 346.
7 Muller, J. and Hochreiter, R. 1977. *Stand der Konzentrazion in Deutschland.* Göttingen: Schwartz (no concentration ratio for rubber and plastics industry available for Sweden; chemicals ratio for Sweden taken as proxy).
SOURCE Value chosen for final regression.

Table A-5

Variable *CONCEN* in the Nonferrous Metals Industry, Selected OECD Countries, Selected Years 1963-74

	1963	1965	1967	1968	1970	1972	1974
Belgium	48.0 E[*1]	..	..	..	..	..	..
Canada	..	..	..	80.3[2]	..	77.8[2]	76.3[*2]
France	65.2[4]	..	..	..	..	..	42.1[*3]
Germany	..	30.2 C3[5]	32.1 C3[5]	..	31.5 C3[5]	..	29.7 C3[*6]
Italy	29.0 E[*1]	..	..	..	..	..	..
Japan	..	..	..	..	21.3 C6[*7]	..	..
Sweden	..	..	41.6[*8]	..	..	..	..
United Kingdom	..	..	41.6[*8]	..	..	..	..
United States	..	..	..	..	..	44.7[*9]	..

1 Phlips, Louis. 1971. *Effects of Industrial Concentration.* Amsterdam: North Holland.
2 Statistics Canada. 1974. *Industrial Organization and Concentration in Manufacturing, Mining and Logging Industries.* Statistics Canada, cat. no. 31-402.
3 OECD. 1978. *Multinational Enterprise: Penetration of Multinational Enterprises and Industrial Concentration.* DSTI/INDI/78-1 (2nd revision). Paris.
4 Morvan, Yves. 1972. *La concentration de l'industrie en France.* Paris: Colin, p. 162.
5 Muller, J. and Hochreiter, R. 1977. *Stand der Konzentrazion in Deutschland.* Göttingen: Schwartz.
6 Baum, C. 1978. "Systematische *Fehler. . .*" *Jahrbücher für Nationalökonomie* 193: 30-53.
7 Imai, K. 1978. "Japan's Industrial Organization." *Japanese Economic Studies* 6: 3-67 (C6 or less).
8 No data available; assigned sample average value.
9 Shepherd, W. G. 1975. *The Measurement of Market Power.* New York: Columbia University Press (only primary metals ratio available).
SOURCE Value chosen for final regression.

Variable *SCIBASE*

Definition – Total R & D manpower employed in all sectors of the economy in full-time equivalents as a percentage of total labour force in the reporting country.

Variable *GOVCONT*

Definition – Ratio of the amount of business-sector R & D financed from government sources to the total amount of R & D performed by the business sector and financed from all sources (own funds, other enterprises, from abroad, from private nonprofit organizations, or from governments).

Source – OECD. Directorate for Science, Technology and Industry. *International Survey of*

Table A-6

Variable *CONCEN* in the Nonelectrical Machinery Industry, Selected OECD Countries, Selected Years 1963-75

	1963	1965	1967	1968	1970	1972	1974	1975
Belgium	41.0 E*[1]	. .	. .	. .	. .	. .	. .	. .
Canada	. .	. .	. .	. .	. .	28.5 VA[2]	. .	27.6*[3]
France	26.0 E*[4]	. .	. .	. .	. .	. .	. .	. .
Germany	24.0 E*[4]	9.6 C3[10]	11.9 C3[10]	. .	8.3 C3[10]	. .	9.7 C3[11]	. .
Italy	28.0 E*[4]	. .	. .	. .	. .	. .	. .	. .
Japan	. .	. .	. .	. .	24.1 C6*[5]	. .	. .	. .
Sweden	35.0 C8 VA*[6]	. .	. .	. .	. .	. .	. .	. .
United Kingdom	49.7 C5[7]	. .	. .	53.9 C5*[7]	. .	. .	. .	. .
United States	. .	. .	. .	. .	35.0[9]	37.6*[8]	. .	. .

1 Phlips, Louis. 1971. *Effects of Industrial Concentration*. Amsterdam: North Holland.
2 Statistics Canada. 1974. *Industrial Organization and Concentration in Manufacturing, Mining and Logging Industries*. Statistics Canada, cat. no. 31-402.
3 Statistics Canada. 1977. *Corporations and Labour Unions Returns Act, Part I: Corporations*. Statistics Canada, cat. no. 61-210.
4 Jacquemin, A. P. and Jong, H. W. 1976. *Markets, Corporate Behaviour and the State*. The Hague: Nijhoff, p. 137 (for France, Germany, and Italy), p. 129 (for U.K.), and p. 346 (for U.S.).
5 Imai, K. 1978. "Japan's Industrial Organization." *Japanese Economic Studies* 6: 3-67.
6 Norgren, M. and Norgren, C. 1971. *Industrial Sweden*. Stockholm: Swedish Institute.
7 Shepherd, W. G. 1975. *The Measurement of Market Power*. New York: Columbia University Press, p. 202.
8 Muller, J. and Hochreiter, R. 1977. *Stand der Konzentrazion in Deutschland*. Göttingen: Schwartz, p. 76.
9 Baum, C. 1978. "Systematische Fehler. . ." *Jahrbücher für Nationalökonomie* 193: 30-53.
SOURCE Value chosen for final regression.

Table A-7

Variable *CONCEN* in the Electrical Machinery Industry, Selected OECD Countries, Selected Years 1963-74

	1963	1965	1966	1968	1970	1972	1974
Belgium	81.0 E*[1]	. .	. .	. .	. .	. .	. .
Canada	. .	. .	. .	. .	. .	58.1 VA[11]	58.9 VA*[11]
France	44.0 E*[2]	. .	. .	. .	. .	. .	27.0[3]
Germany	39.0*[2]	34.6 C3[8]	. .	. .	39.0 C3[8]	. .	30.8 C3[7]
Italy	18.0*[2]	. .	. .	. .	. .	. .	. .
Japan	. .	. .	. .	. .	45.3 C6*[4]	. .	. .
Sweden	. .	. .	69.0*[5]	. .	. .	. .	. .
United Kingdom	66.4 C5[6]	. .	. .	75.9 C5*[6]	. .	. .	. .
United States	. .	. .	. .	. .	48.0[9]	43.0*[10]	. .

1 Phlips, Louis. 1971. *Effects of Industrial Concentration*. Amsterdam: North Holland.
2 Jacquemin, A. P. and Jong, H. W. 1976. *Markets, Corporate Behaviour and the State*. The Hague: Nijhoff, p. 137 (for France, Germany, and Italy), p. 129 (for U.K.), and p. 346 (for U.S.).
3 OECD. 1978. *Multinational Enterprise: Penetration of Multinational Enterprises and Industrial Concentration*. DSTI/INDI/78-1 (2nd revision). Paris.
4 Imai, K. 1978. Japan's Industrial Organization." *Japanese Economic Studies* 6: 3-67 (C6 or less).
5 Muller, J. and Hochreiter, R. 1977, *Stand der Konzentrazion in Deutschland*. Göttingen: Schwartz, p. 76.
6 Baum, C. 1978. "Systematische Fehler. . ." *Jahrbücher für Nationalökonomie* 193: 30-53.
7 Shepherd, W. G. 1975. *The Measurement of Market Power*. New York: Columbia University Press, p. 202.
8 Statistics Canada. 1974. *Industrial Organization and Concentration in Manufacturing, Mining and Logging Industries*. Statistics Canada, cat. no. 31-402.
SOURCE Value chosen for final regression.

Table A-8

Foreign Ownership as a Share of Capital Stock (C), Employment (E), Output (O), Sales (S), or Value Added (VA), Selected OECD Countries, Selected Years 1967-77

	Paper		Chemicals		Pharma-ceuticals		Rubber and plastics		Nonferrous metals		Nonelectrical machinery		Electrical machinery	
	Year	Vari-able	Year	Vari-able	Year	Vari-able	Year	Vari-able	Year	Vari-able	Year	Vari-able	Year	Vari-able
Belgium	1968	8.4 E	1968	45.3 E	1972	76.0 S	1968	45.3 E	1968	20.1 E[1]	1968	20.1 E[1]	1968	20.1 E[1]
Canada	1972	49.5 S	1972	81.8 S	1973	84.7 S	1972	72.2 S	1973	36.1 O	1972	71.0 S	1972	87.1 VA
Denmark	. .	. .	. .	. .	1973	1.0 S	. .	. .	. .	. .	. .	. .	. .	. .
France	1974	14.5 S	1973	35.4 S	1973	37.8 S	1973	28.5 S	1974	16.4 S[2]	1973	20.5 S	1973	37.5 S
Germany	1972	1.0 S[3]	1970	35.8 C	. .	. .	1972	43.5 O	1970	9.8 C	1972	25.3 O[2]	1970	18.0 S
Italy	1973	18.9 O	1973	23.1 C	1973	44.5 S	1973	23.1 C	1973	8.6 C[5]	1973	24.8 C	1973	23.9[6]
Japan	1975	1.0 O	1974	5.3 S	1973	23.4 S	1974	24.1 S	1974	5.0 S	1974	5.4 S	1974	3.6 S
Sweden	1973	4.3 O	1975	25.2 S	1973	1.0 S[7]	1975	25.2 O[4]	1973	9.8 O	1973	5.7 O[8]	1973	5.7 O[8]
United Kingdom	1973	4.7 O	1965	10.1 C	1973	63.7 S	1971	27.2 VA	1965	6.4 C	1973	8.3 S	1965	16.0 C
United States	1974	2.4 S[9]	1974	9.1 C[9]	1973	16.0 S	1974	2.2 S[9]	1974	10.2 S[9]	1974	2.2 S[9]	1974	3.1 S[9]

1 Only one ratio in common is available for nonferrous metals, nonelectrical machinery, and electrical machinery (ISIC 37 and 38).
2 Twenty per cent or more direct foreign investment qualifies as "foreign-penetrated."
3 0.8 rounded to 1 per cent of firms are 20 per cent or more foreign-owned.
4 No figure is available, so the ratio in the chemical industry is used as a proxy.
5 The industry is designated simply as "metallurgy."
6 Sample average.
7 The reported percentages (rounded) of the market supplied by indigenous producers and by imports add up to 100, but OECD (1977, p. 71) describes the percentage of the domestic market supplied by foreign subsidiaries as "very low."
8 One ratio for ISIC 38 covers both nonelectrical and electrical machinery (ISIC 382 and 383).
9 Figures are based on OECD (1978), which shows dollars sales of foreign subsidiaries, divided by total sales of the industry, derived from various U.S. censuses of manufactures.

SOURCE With the exception of the pharmaceutical industry and unless otherwise indicated in notes, foreign ownership ratios were taken from OECD. 1978. *Multinational Enterprise: Penetration of Multinational Enterprises and Industrial Concentration*. DSTI/INDI/76-5 up to 78-1 (2nd. revision). Scale A. Paris: October 16. This series is available only on request.

Pharmaceutical data from OECD. 1977. *Impact of Multinational Enterprises on National Scientific and Technical Capacities: Pharmaceutical Industry*. Paris: December. Figure for Belgium estimated from European Economic Community, 1975. *Étude sur l'évolution de la concentration dans l'industrie pharmaceutique en Belgique*. Brussels: November, pp. 37-39, 55 and identification of pharmaceutical enterprises under foreign control on pp. 59-77.

Resources Devoted to R&D. Volume 1: Business Enterprise Sector (for the International Statistical years 1967, 1969, 1971, 1973 and 1975); Country Reports and Preliminary International Tables (for the International Statistical Year 1977). Paris: various years (Tabulation "R & D by Sources of Funds").

Table A-9

Effective Tax Rates (Variable *TAXBURDEN*), Selected OECD Countries, 1968

Country	Rate
Belgium	37.7
Canada	46.2
Denmark	35.0
Finland	. .
France	49.8
Germany	49.1
Italy	43.3
Japan	43.4
Sweden	45.3
United Kingdom	43.4
United States	48.0

SOURCE Bergsten, Horst, and Moran (1978, Table 6-2, pp. 188-89).

Table A-10

Strength of Scientific Base (Variable *SCIBASE*), Selected OECD Countries, Selected Years 1967-77

	1967-71	1973-77
Belgium	6.0	7.3
Canada	5.8	5.3
Denmark	. .	. .
Finland	. .	. .
France	9.2	9.8
Germany	10.6	12.2
Italy	3.6	4.5
Japan	8.2	10.4
Sweden	7.9	8.7
United Kingdom	12.1	12.1
United States	13.6	11.8

SOURCE OECD. *Patterns of Resources Devoted to Research and Experimental Development in the OECD Area, 1963-1971*. Paris: 1975, Table X, p. 98. (Figures for most countries pertain to the year 1970, but some reported data for 1971 or 1972. In our regressions, these figures were assumed to have prevailed during the International Statistical Years 1967, 1969, and 1971).

OECD. Science and Technology Indicators Unit. *Science Resources/Newsletter No. 5*, Summer 1980, Table 4, pp. 12-13. (Most countries reported data for 1977, some also for 1976 or 1978. In our regressions, these figures were assumed to have prevailed during the International Statistical Years 1973, 1975, and 1977).

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Bibliography

ARROW, K. J. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity*, edited by R. R. Nelson. National Bureau of Economic Research. Princeton: Princeton University Press.

BAILEY, M. 1972. "Research and Development Cost and Returns: The U.S. Pharmaceutical Industry." *Journal of Political Economy* 80:70-85.

BERGSTEN, C. F.; HORST, T.; and MORAN, T. H. 1978. *American Multinationals and American Interests*. Washington, D. C.: The Brookings Institution.

BONES, H. P. 1979. "Are Foreign Subsidiaries More Innovative?" *Canadian Business Review* 6:15-18.

BRANCH, B. 1974. "Research and Development Activity and Profitability: A Distributed Lag Analysis." *Journal of Political Economy* 82:999-1,011.

BRETON, A. 1974. *A Conceptual Basis for an Industrial Strategy*. Economic Council of Canada. Ottawa: Information Canada.

BRITTON, J. W. H. and GILMOUR, J. M. 1978. *The Weakest Link: A Technological Perspective on Canadian Industrial Underdevelopment*. Science Council of Canada, Background Study 43. Ottawa: Supply and Services Canada.

BROWN, W. H. 1957. "Innovation in the Machine Tool Industry." *Quarterly Journal of Economics* 71:406-25.

BUCHANAN, Hon. Judd, Minister of State for Science and Technology. 1978. "Measures to Strengthen and Encourage Research and Development in Canada," Notes for an address to the House of Commons, June 1, 1978, Ottawa.

CAPRON, W. M., ed. 1971. *Technological Change in Regulated Industries*. Washington, D. C.: The Brookings Institution.

CASSON, M. 1979. *Alternatives to the Multinational Enterprises*. New York: Holmes and Meier.

CAVES, R. E. 1971. "International Corporations: The Industrial Economics of Foreign Investment." *Economica* 38:1-27.

———; PORTER, M. E.; and SPENCE, M. 1980. *Competition in the Open Economy: A Model Applied to Canada*. Cambridge, Mass.: Harvard University Press.

CHAND, U. K. Ranga. 1978. "Does R & D Boost Industrial Growth?" *Canadian Business Review* 5:27-31.

COMANOR, W. S. 1967. "Market Structure, Product Differentiation, and Industrial Research." *Quarterly Journal of Economics* 81:639-57.

DASGUPTA, P. and STIGLITZ, J. 1980. "Industrial Structure and the Nature of Innovative Activity." *Economic Journal* 90:266-93.

DE MELTO, D. P.; MCMULLEN, K. E.; and WILLS, R. M. 1980. "Preliminary Report: Innovation and Technological Change in Five Canadian Industries." Economic Council of Canada, Discussion Paper 176, Ottawa.

DEMSETZ, H. 1969. "Information and Efficiency: Another Viewpoint." *Journal of Law and Economics* 12:1-22.

DENISON, E. F. 1962. *The Sources of Economic Growth in the United States*. New York: Committee for Economic Development.

DE WOOT, P. and HEYVAERT, H. 1979. "Management stratégique et performance économique". *Economies et Sociétés*, pp. 509-37.

ELLIOTT, J. W. 1971. "Funds Flow vs. Expectational Theories of Research and Development Expenditures in the Firm." *Southern Economic Journal* 37:409-22.

FREEMAN, C. 1979. "Technical Innovation and British Trade Performance." In *De-industrialization*, edited by Frank Blackaby. London: Heinemann.

FRUM, Barbara. 1980. *CBC Quarterly Report*, December.

GELLMAN, A. 1971. "Surface Freight Transportation." In *Technological Change in Regulated Industries*, edited by W. M. Capron. Washington, D.C.: The Brookings Institution.

GLOBERMAN, S. 1972. "The Empirical Relationship between R & D and Industrial Growth in Canada." *Applied Economics* 4:181-95.

———. 1973. "Market Structure and R & D in Canadian Manufacturing Industries." *Quarterly Review of Economics and Business* 13:59-68.

GRABOWSKI, H. G. 1968. "The Determinants of Industrial Research and Development: A Study of the Chemical, Drug and Petroleum Industries." *Journal of Political Economy* 76:292-306.

———; VERNON, J; and THOMAS, L. 1978. "Estimating the Effects of Regulation on Innovation: An International Comparative Analysis of the Pharmaceutical Industry." *Journal of Law and Economics* 21:133-63.

GRILICHES, Z. 1964. "Research Expenditures, Education, and the Aggregate Agricultural Production Function." *American Economic Review* 54:961-74.

———. 1973. "Research Expenditures and Growth Accounting." In *Science and Technology in Economic Growth*, edited by B. R. Williams. London: Macmillan.

———. 1979. "Issues in Assessing the Contribution of Research and Development to Productivity Growth." *Bell Journal of Economics* 10:92-116.

———. 1980. "Returns to Research and Development Expenditures in the Private Sector." In *New Developments in Productivity Measurement*, edited by J. W. Kendrick and B. Vaccara. National Bureau of Economic Research, Studies in Income and Wealth 44. Chicago: University of Chicago Press.

———, and SCHMOOKLER, J. 1963. "Inventing and Maximizing." *American Economic Review* 53:725-29.

GRUBER, W.; MEHTA, D.; and VERNON, R. 1967. "The R & D Factor in International Trade and International Investment of the United States Industries." *Journal of Political Economy* 75:20-37.

HANEL, P. 1976. "The Relationship between the R & D Activity of Canadian Manufacturing Industries and Their Performance in the International Market." Department of Industry, Trade and Commerce, Technological Innovation Studies Program, Research Report 40, Ottawa.

HANSEN, R. W. 1977. "Regulation and Pharmaceutical Innovation: A Review of the Literature on Monetary Measures of Costs and Benefits." University of Rochester, Graduate School of Management, Discussion Paper GPB 77-9, Rochester.

HOWE, J. D. and MCFETRIDGE, D. G. 1976. "The Determinants of R & D Expenditures." *Canadian Journal of Economics* 9:57-71.

JOHNSTON, J. 1972. *Econometric Methods*. 2nd ed. New York: McGraw-Hill.

KAMIEN, M. I. and SCHWARTZ, N. L. 1975. "Market Structure and Innovation: A Survey." *Journal of Economic Literature* 13:1-37.

KENDRICK, J. W., assisted by LETHEM, Y. and ROWLEY, J. 1976. *The Formation and Stocks of Total Capital*. National Bureau of Economic Research, General Series 100. New York: Columbia University Press.

KENDRICK, J.W., and VACCARA, B. N., eds. 1980. *New Developments in Productivity Measurement and Analysis*. National Bureau of Economic Research, Studies in Income and Wealth 44. Chicago: University of Chicago Press.

LINDA, R. 1976. *Methodology of Concentration Analysis Applied to the Study of Industries and Markets*. Brussels: Commission of the European Communities.

LITHWICK, N. H. 1969. *Canada's Science Policy and the Economy*. London: Methuen.

LOURY, G. C. 1979. "Market Structure and Innovation." *Quarterly Journal of Economics* 93:395-410.

MACAVOY, P. and SLOSS, J. 1967. *Regulation of Transport Innovation: The ICC and Unit Coal Trains to the East Coast*. New York: Random House.

MCFETRIDGE, D. G. 1977. *Government Support of Scientific Research and Development: An Economic Analysis*. Ontario Economic Council, Research Study 8. Toronto: University of Toronto Press.

MANSFIELD, E. 1972. "R & D's Contribution to the Economic Wealth of the Nation." *Research Management* 15:31-46.

———. 1980. "Basic Research and Productivity Increase in Manufacturing." *American Economic Review* 70:863-73.

———; RAPOPORT, J.; ROMEO, A.; WAGNER, S.; and BEARDSLEY, G. 1977. "Social and Private Rates of Returns from Industrial Innovations." *Quarterly Journal of Economics* 91:221-40.

MINASIAN, J. 1969. "Research and Development, Production Functions and Rates of Return." *American Economic Review* 59:80-85.

Ministry of State for Science and Technology. 1978a. "Industrial Research and Development in Canada." MOSST, Background Paper 2, Ottawa.

———. 1978b. "Importation of Invisible Research and Development, 1974-1976." MOSST, Background Paper 3, Ottawa.

———. 1979. "R & D in Canadian and Foreign Subsidiary Manufacturing Firms." MOSST, Background Paper 9, Ottawa.

———. 1981. "R & D Policies, Planning and Programming." MOSST, Background Paper 13, Ottawa.

NADIRI, M. I. 1979. "Contributions and Determinants of Research and Development Expenditures in the U.S. Manufacturing Industries." National Bureau of Economic Research, Working Paper 360, Cambridge, Mass.

National Research Council of Canada. 1980. "The Urgent Investment: A Long Range Plan for the National Research Council of Canada." NRC, Ottawa.

NISKANEN, W. 1967. "The Peculiar Economics of the Bureaucracy." *American Economic Review* 57:293-305.

OECD. *International Statistical Years*. Paris: annual.

———. *International Survey of Resources Devoted to R&D*. Paris: biennial.

———. 1976. *The Measurement of Scientific and Technical Activities ("Frascati Manual")*. Paris.

———. 1978. *Problems of Establishing and Comparing the R&D Intensities of Industries*. DSTI/SPR/78-44. Paris.

PAKES, A. 1978. "Economic Incentives in the Production and Transmission of Knowledge: An Empirical Analysis." Ph.D. dissertation, Harvard University.

———, and SHANKERMAN, M. 1980. "An Exploration into the Determinants of Research Intensity." National Bureau of Economic Research, Working Paper 438, Cambridge, Mass.

PALDA, K. S. and PAZDERKA, B. 1980. "Background to a Target: An International Comparison of the Canadian Pharmaceutical Industry's R & D Intensity." Department of Industry, Trade and Commerce, Technological Innovation Studies Program, Research Report 71, Ottawa.

PARRY, T. G. and WATSON, J. F. 1979. "Technology Flows and Foreign Investment in the Australian Manufacturing Sector." *Australian Economic Papers* 18:103-18.

PAVITT, K. 1979. "Technical Innovation and Industrial Development." *Futures* 11:458-70.

———. ed. 1980. *Technical Innovation and British Economic Performance*. Sussex: Science Policy Research Unit.

PELTZMAN, S. 1973. "An Evaluation of Consumer Protection Legislation: The 1962 Drug Amendments." *Journal of Political Economy* 81:1-27.

RASMUSSEN, J. A. 1973. "Applications of a Model of Endogenous Technical Change to U.S. Industry Data." *Review of Economic Studies* 40:225-38.

ROBERTS, Hon. John, Minister of State for Science and Technology. 1980. "Speech." MOSST, Ottawa, May 5, 1980.

———. 1981. "Speech." MOSST, Ottawa, January 19, 1981.

SAFARIAN, A. E. 1966. *Foreign Ownership of Canadian Industry*. Toronto: McGraw-Hill.

SCHERER, F. M. 1965. "Firm Size, Market Structure, and the Output of Patented Inventions." *American Economic Review* 55:1,097-1,126.

———. 1967. "Market Structure and the Employment of Scientists and Engineers." *American Economic Review* 57:524-30.

———. 1980. *Industrial Market Structure and Economic Performance*. 2nd. ed. Chicago: Rand McNally.

SCHMOOKLER, J. 1966. *Invention and Economic Growth*. Cambridge, Mass.: Harvard University Press.

SCHUMPETER, J. 1950. *Capitalism, Socialism and Democracy*. 2nd ed. London: Allen and Unwin.

SCHWARTZMAN, D. 1976. *Innovation in the Pharmaceutical Industry*. Baltimore: Johns Hopkins University Press.

Science Council of Canada. 1980. "Annual Review 1980." Science Council of Canada, Ottawa.

SHERMAN, R. 1974. *The Economics of Industry*. Boston: Little, Brown.

SHRIEVES, R. E. 1978. "Market Structure and Innovation: A New Perspective." *Journal of Industrial Economics* 26:329-47.

STIGLER, G. 1971. "The Theory of Economic Regulation." *Bell Journal of Economics and Management Science* 2:3-21.

SOLOW, R. 1957. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* 39:312-20.

WILLIAMS, B. R., ed. 1973. *Science and Technology in Economic Growth*. London: Macmillan.

WOLF, C. 1979. "A Theory of Nonmarket Failure: Framework for Implementation Analysis." *Journal of Law and Economics* 22:107-40.

WONNACOTT, P. and WONNACOTT, R. J. 1980. "The Tariff-Foreign Ownership-Technology Nexus: Toward a Less Truncated Theory of Canadian Industrial Truncation." University of Western Ontario, Working Paper 8013, London, Ontario.

United States. Arms Control and Disarmament Agency. 1979. *World Military Expenditures and Arms Transfers, 1968-1977*. Washington, D.C.: G.P.O.

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