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SOURCES OF R&D FUNDING IN CANADA AND INDUSTRIAL GROWTH IN CANADA

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An additional report entitled, "Market Structure and the Technological Disadvantage of Canadian Manufacturing Industries" is also included at the back of this report.

SOURCES OF R & D FUNDING AND INDUSTRIAL GROWTH IN CANADA

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Sources of R & D Funding and Industrial Growth

ABSTRACT

The paper considers the growth-promoting impacts of differently sourced R & D expenditure funds across a sample of two-digit Canadian manufacturing industries. An aggregate production function relating nominal output to various inputs, including R & D expenditures, is specified and estimated for the entire sample of industries as well as for subsets of the sample. The regression results provide the basis for the paper's main conclusion that the growth promoting impact of both government and privately financed R & D is lower in the two industries receiving the bulk of federal R & D funds than in other industries.

EXECUTIVE SUMMARY

The purpose of this study is to provide some additional evidence on the relationship between sources of industrial R&D funding and subsequent industrial growth experience. The specific question investigated is whether government financed R&D has the same impact on industrial growth as privately financed R&D.

The growth in the undeflated dollar value of industrial output over time is used as a single measure of the impact of R&D. This rate of growth of nominal output was calculated for fourteen two-digit industrial groups comprising the industries in the sample. These included fabricated metal products, machinery, transportation equipment, electrical products, petroleum, and chemical products.

The measure of industrial research intensity used was the ratio of total intramural R&D expenditures to one hundred dollars of sales in 1961 for all firms reporting R&D payments.

The study provides some evidence that the R&D growth process is, in part, dependent upon the sources of funding for R&D expenditures. Specifically, the growth promoting impact of privately financed R&D expenditures appears weaker for two manufacturing industries (electrical products and transportation equipment) which received the bulk of federal government financing than for the other industries in the sample. The weaker growth promoting impact for privately financed R&D in the electrical products and transportation equipment industries suggests that private and publically funded R&D are complimentary activities. It appears that in choosing policies to stimulate industrial R&D, the government is confronting a tradeoff between the provision of improved "public-type" goods and more rapid industrial growth. The provision of government contracts for research in the public goods area should not be expected to generate growth to the same extent as outright government grants to firms for performance of market oriented R&D or as indirect measures to stimulate increased private R&D funding.

Introduction

The industrial R & D effort in Canada has historically, been low in comparison to efforts in other developed countries. Policy makers concerned with promoting greater efficiency in Canadian manufacturing industries have suggested implementation of policies to increase industrial expenditures on research and development.[1] Several Canadian studies have demonstrated that a significant relationship does exist between industrial research and development intensity and subsequent industrial growth.[2] Thus, if previous production relationships remain reasonably constant, increases in the level of industrial R & D expenditures can be expected to generate signficantly increased efficiency and subsequent industrial growth.

Even if this premise is accepted, however, several important questions should be addressed before major policy programs are implemented. One such question is, should industrial R & D expenditures be increased directly through the provision of government grants to industry for performing specific R & D projects or should the government employ indirect measures to encourage increased private funding of industrial R & D.[3] A related question is what percentage of government grants should

1. A major recommendation of the Senate Special Committee on Science Policy was that industrial R & D expenditures be increased by sixteen percent per annum over the decade. See Report of The Senate Special Committee on Science Policy, (1972, p. 499).

2. See Globerman (1972) and Wilkinson (1968).

3. Examples of "indirect" policies might include such things as tax credits and depreciation allowances for R & D expenditures, policies to encourage merger activity where returns to scale exist in R & D activity, etc.

be tied to projects falling into the area of public goods (e.g. defence), and what percentage should be devoted to research and development into market oriented products and processes? Strictly from the standpoint of promoting industrial growth, the optimal financing arrangement would result in the private rate of return to the various government financed industrial R & D programs equalling the rate of return to privately financed industrial R & D.

There is some evidence from U.S. experience that the rates of return to government financed and privately financed industrial R & D are not equal. Leonard (1971) found that the relationships between federally funded R & D and various measures of industrial growth were stronger when the two industries receiving the greatest amount of government R & D funding, (i.e. aircraft and missiles and electrical products), were deleted from the entire sample of industries. The author postulated two interrelated reasons for the results: 1. the disproportionate concentration of federal R & D funds in two industries results in diminishing returns to R & D expenditures in those industries; 2. firms heavily involved in defence or space research fail to discern the sales possibilities of products developed with federal funds, or lack the know-how to exploit such products commercially. Leonard's conclusion that the rate of return to privately financed R & D exceeds the rate of return to government financed R & D is based on a simple correlation analysis. The possibility exists that this relationship reflects the influence of differences in other industry specific factors not directly included in the model.

The purpose of this study is to provide some additional evidence on the relationship between sources of industrial R & D funding and subsequent industrial growth experience. The specific question to be investigated is whether government financed R & D has the same impact on industrial growth as privately financed R & D. Some evidence bearing on the important question of whether there are increasing returns to industrial R & D expenditures will also be presented.

Empirical Test and Results

In this study, a single measure of the impact of R & D is employed: the growth in the undeflated dollar value of industrial output over time. Some justification for the use of nominal rather than real output growth should therefore be provided.

Research and development expenditures can be viewed as an input in the production function. The output of the R & D activity in any firm is increased knowledge about the production process enabling the firm to produce existing products at lower cost or to produce new or improved products that are superior to existing products. The development of product improvements as well as process innovations conceptually give rise to increases in real income. If a commodity is defined as a composite of different characteristics, the development of new or improved products can be viewed as allowing consumers to maintain given levels of satisfaction, defined in terms of baskets of product "characteristics", with a smaller expenditure of real resources in the production process.[4]

4. A full discussion of how new product introduction can be successfully analyzed within this consumption technology framework is provided in Lancaster (1966).

Surveys of industrial R & D processes have concluded, on the whole, that the major portion of industrial R & D expenditures are devoted to developing new products or to modifying existing products, (i.e. quality improvement). For example, Gustafson (1962) cites results of surveys conducted by McGraw-Hill into objectives of business R & D. One survey found that 48 percent of R & D was devoted to new product development; an additional 41 percent was devoted to improving existing products while only 11 percent was devoted to developing new processes. Mansfield (1968) found in a survey of R & D activities for a sample of chemical and petroleum companies that most firms expected their R & D processes to pay off in 5 years or less. Since it takes considerably longer than this before a radically new process or product even hits the market, the emphasis on short pay-off periods is taken to indicate that most R & D in these firms is geared toward improvements or minor changes in existing products.

Improved product quality should, cet. par., lead to increases in indices of nominal as well as real output. While growth in total sales and nominal output of any one firm introducing product improvements may be constrained by rival firm innovative activities, total industry sales and output should increase through, if nothing else, increased export activity.[5] It is likely, however, that concomitant with increased quality will be higher prices for new commodities, on net balance still giving rise to increased real income. The problem involved in deflating output statistics by conventional price indices is that these indices do not

5. New product introduction as a source of comparative advantage is the basis of the "product-life cycle" hypothesis of trade. For some recent empirical evidence on this hypothesis see Vernon, ed. (1970).

make adjustments for quality improvements. A potential result, therefore, of using real output measures is serious underestimation of growth rates of technologically progressive industries. Of course, an alternative bias might arise in using nominal output growth rates, since changes in factor prices would bring about changes in this index.

If we were concerned with explaining aggregate industrial growth, real output measures would be appropriate since aggregate price indices are likely dominated by factor price changes. However, our concern is with explaining inter-industry differences in output growth rates. For purposes of comparing industries with reasonably similar production functions, biases associated with the failure to properly account for improved product quality may be more severe than the failure to hold factor price movements constant. Since it is not unambiguously clear, for our purposes, which growth index is less biased, some comfort can be drawn from two previously cited studies which have shown that the empirical relationship between research intensity and subsequent industrial growth is relatively insensitive to the growth measure chosen.[6]

The rate of growth of nominal output was calculated for fourteen two-digit industrial groups comprising the sample of industries in the study. (The list of industries is given in table one of the appendix).

A measure of industrial research intensity used was the ratio of total intramural R & D expenditures to one hundred dollars of sales in 1961 for all firms reporting R & D payments in their respective industries. This variable is henceforth R_1. Obviously this measure of research

6. See Leonard (1971) and Globerman (1972).

intensity is a direct measure only of the research intensity of firms which report explicit R & D expenditures in each of the sample industries. Some rationale must be offered for using this variable as a proxy for the R & D intensity of the entire industry.[7] The explanation offered is that many firms which do not report R & D expenditures receive the benefits of R & D expenditures made by other firms in the industry. The benefits can be received in the form of licensing arrangements and patent purchases. In addition, many new products can be imitated by rival firms without infringing on the patent rights of the innovating firm. An unbiased index of technological progressivity should include payments for licenses, expenditures made for imitating rival products, et. al. Unfortunately, such data do not exist on an industry basis. The use of the chosen research intensity measure as an index of industrial research intensity assumes that the ratio of "unreported" R & D expenditures to sales -- for firms not explicitly reporting R & D payments -- equals the ratio of reported R & D expenditures to sales for firms reporting R & D payments. The alternative index, reported R & D expenditures to total industry sales, carries the implicit assumption that there is no intra-industry technological diffusion. This is, I feel, a far more restrictive assumption than that employed in developing the R_1 series.

The R_1 research intensity measure includes industrial R & D financed with federal funds. An alternative research intensity measure derived

7. An alternative measure of research intensity is the ratio of R & D expenditures to sales of all firms in an industry.

was the ratio of non-government funded intramural R & D expenditures to one hundred dollars of sales for all firms reporting R & D expenditures in 1961; (henceforth R_2)[8]. It is readily apparent that the overwhelming proportion of contracted government R & D in 1961 went to two industries: transportation equipment and electrical products.

A preliminary test of the relationship between industry growth and sources of R & D funding was conducted as follows: growth rates of nominal output were lagged behind the R & D expenditure year so that the growth rates of the output series are measured beginning with the third year after the R & D input; (assuming this is the minimal lag between expenditures on R & D and their impact). In keeping with the evidence from the production literature, i.e. a multiplicative relationship between output and inputs, the two measures of research intensity as well as the output growth rate series were converted to natural logs. A simple correlation analysis was performed for the entire sample. Results of the test are given in table two of the appendix. The simple correlation coefficients are all significant at the .05 level for periods 1960-65 through 1960-68.[9] It can be seen that there is virtually no difference in the relationships between the two measures of research intensity and subsequent industrial growth.

8. Values for R_1 and R_2 are given in table one of the appendix. Since attention will be focused on differences in the R_1 and R_2 parameters, (rather than their absolute levels), the choice of the sales deflator becomes of reduced importance.

9. The strikingly low coefficient for the period 1960-64 probably reflects the unrepresentative nature of 1964 as an end-point basing period.

The possibility exists that the observed similarity in the relationships between the two research intensity measures and industrial growth is the result of offsetting influences of other variables correlated with both R & D and growth. To test for this possibility, the following production relationship was estimated separately for each measure of R & D:

$$\ln Y_i = \ln a + b_1 \ln R_i + b_2 \ln L_i + b_3 \ln K_i + \ln e_i$$

where Y_i = the rate of growth of output for the ith industry 1960-68; R_i = research intensity, (both R_1 and R_2), in 1961; L_i = growth rate in an index of total employment, 1961-68; K_i = growth rate in an index of capital stock, 1960-68, and e_i is a random error term.

When two separate equations were estimated for the two measures of research intensity, significant collinearity was found to exist between the research variables and the capital input variable. The production relationships were, consequently, re-estimated deleting the capital variable. In addition, the degree of foreign ownership in the ith industry, (O_i), for 1962 was introduced into the estimating equation. If export restrictions and similar sanctions constrain the growth of foreign subsidiaries, and R & D performance is correlated with foreign ownership, the simple relationships between research intensity and growth could be biased downward.

The results of the estimation for all fourteen industries are given as equations one and two in table three. No significant difference can be found between the research intensity parameters of equations one and two. This result was not unexpected in light of the fact that there is virtually no difference between R_1 and R_2 for twelve of the fourteen sample industries.

In equation three, electrical products and transportation equipment were deleted from the sample. The production relationship, with the R_2 research intensity variable employed, was estimated for the remaining industries. A comparison of the R_2 parameters in equations two and three shows that the proportionate relationship between growth in output and privately financed research per one hundred dollars of sales increases by approximately eleven percentage points when electrical products and transportation equipment are not in the sample. That is, the elasticity of output with respect to changes in privately financed R & D expenditures is approximately eleven percent lower in the electrical products and transportation equipment industries than in other secondary manufacturing industries.

One possible explanation for the above result is that there are diminishing returns to privately financed R & D expenditures in the two deleted industries. Some evidence that this result is not due to diminishing returns is provided in the following test: equation four was estimated for twelve industries, deleting electrical products and chemical products. Chemical products is the second most research intensive industry in the sample by the R_2 intensity measure. If diminishing returns to privately financed research expenditures are significant, one would expect the R_2 parameter to be higher in equation four than in equation three, since chemical products are more research intensive than transportation equipment. In fact, the parameter is lower.

An alternative interpretation of the results is that increasing returns exist to private R & D expenditures. Hence the R_2 parameter is lower when the more research intensive chemical industry is deleted from the sample than when transportation equipment is the deleted industry. A test of this hypothesis is provided in equation five. For this equation, electrical products and machinery are deleted from the sample of industries. Since machinery is less research intensive (by our R_2 measure) than chemical products, the R_2 parameter should be higher in equation five than in equation four to support the increasing returns hypothesis. The parameter is, in fact, lower.

Another check on the consistency of our results was provided by including electrical products and transportation equipment in the sample and deleting two other industries selected at random. Equation six reports results when the food and beverages and fabricated metals industries are deleted from the sample. The estimated value of the R_2 parameter is consistent with preceeding observations that R & D - output elasticity relationships are lower in the electrical products and transportation equipment industries than in other secondary manufacturing industries. While it would be desirable to test this hypothesis in more detail, by deleting other industries and estimating the production relationship, it does not appear that our conclusion is particularly sensitive to alternative choices of sample industries.

Before drawing further conclusions from these results some additional consideration must be given to remaining potential sources of empirical bias. An assumption implicit in cross-section studies of this type is that the functional relationship specified between the dependent and independent variables is similar for the different industries in the sample. The regression results indirectly support this assumption. For one thing, the overall coefficients of determination are relatively high. If important systematic differences in the relationship existed between industries, one would not expect the aggregate function to fit as well as it does. For another, both the coefficients of determination and the significance levels of the parameters remain virtually constant from sample to sample.

Another potential difficulty with the model is that in focusing solely on the supply side, an important demand variable might have been omitted. The inclusion of the demand variable might alter the observed relationship between the dependent variable and R_2 in equations two through five. The inclusion of a demand variable into the model would require a movement towards simultaneous equation rather than single equation estimation techniques. Fortunately, this does not appear necessary. The relatively high R^2 values lend support to the belief that the equations are not seriously underspecified. Furthermore, if a bias does exist due to an underspecified equation, we can form some a priori notion of its direction. A major institutional change affecting demand conditions in

Canadian manufacturing industries during this period was the implementation of the Canada-U.S. Auto Pact and the Defence Production Sharing Arrangement. The Defence Production Sharing Program gave Canadian firms equal opportunity to compete with U.S. firms as prime or subcontractors in U.S. defence business. A prime beneficiary of this arrangement was the aircraft industry which is included in the sample as a part of the transport equipment industry. The autopact provided for the elimination of duties on trade in all automobiles and components (other than replacement parts) between U.S. and Canada. This provided a large boost to Canadian exports of autos and trucks. Thus, the failure to include a demand variable explicitly into the estimating equation is likely to impart an upward bias to the R_2 parameter in equation two.

Summary and Conclusions

The study provides some evidence that the R & D growth process is, in part, dependent upon the sources of funding for R & D expenditures. Specifically, the growth promoting impact of privately financed R & D expenditures appears weaker for the two manufacturing industries receiving the bulk of federal government financing than for the other industries in our sample. Given the similarity in results for equations one and two, it seems reasonable to infer that government funded R & D in these two industries also has a weaker growth promoting impact than do private R & D expenditures in other industries.

The weaker growth promoting impact for the government funded portion of R & D is not startling and is consistent with Leonard's findings for the U.S. The weaker growth promoting impact for privately financed R & D in these two industries is revealing and suggests that private and publically funded research and development are complementary activities in the two industries performing the bulk of government funded R & D. There are several possible explanations for the existence of such complementarity. One possibility is that firms use a substantial portion of their private funds essentially to generate federal research contracts. Another possibility is that private R & D funds are used to adapt the results of government funded R & D to civilian demand patterns.

The empirical tests provide some indirect evidence that it is the nature of the R & D performed in the transportation equipment and electrical products industries, rather than the level of expenditures, which accounts for the weaker R & D growth relationship in these two industries. That is, either the results of government contracted research have limited spinoffs for exploitation in the market place for non-public goods or the "market R & D" oriented industries are better able to commercially exploit technological break throughs than are the "government R & D" oriented industries. In either case, it appears that in choosing policies to stimulate industrial R & D, the government is confronting a tradeoff between the provision of improved "public-type" goods and more rapid industrial growth. The provision of government contracts for research in the public goods area should not be expected to generate growth to the same extent as outright government grants to firms for performance of market oriented R & D or as indirect measures to stimulate increased private R & D funding.[10]

10. Since the overwhelming portion of federal funds for the performance of industrial R & D in 1961 was to support research and development for defence-related projects, the conclusions of the study are specific to this type of public goods research.

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Appendix

Table One

Values of R_1 and R_2 in 1961 for Fourteen Two-Digit Industries

Industry	R_1	R_2
Food and Beverages	.16	.16
Rubber	1.08	1.08
Textiles	1.01	1.01
Wood Products	.07	.07
Furniture	.67	.67
Paper	.45	.44
Primary Metals	.44	.44
Fabricated Metal Products	.69	.65
Machinery	1.10	1.10
Transportation Equipment	1.47	.97
Electrical Products	2.67	1.51
Non-metallic Mineral Products	.75	.75
Petroleum Products	.35	.35
Chemical Products	1.49	1.48

Source: D.B.S. -- Industrial R & D Expenditures in Canada, 1963.

Table Two

R_1 and R_2 research intensity measures for 1961 correlated with the Rate of Growth of Output for Fourteen Industry Groups

Output Growth Rate For Period	R_1 Intensity Measure	R_2 Intensity Measure
1960-64	.0677	.0368
1960-65	.6503	.6706
1960-66	.7618	.7719
1960-67	.5683	.5599
1960-68	.7229	.7131

Table Three

	Intercept	R_{1i}	R_{2i}	L_i	O_i	$\bar{R}^2$	F
Equation 1	.970	.323		.684*	-.333	.768	15.34
(14 Industries)		(1.72)		(3.06)	(-1.39)		
Equation 2	.998		.357**	.701*	-.332	.784	16.76
(14 Industries)			(1.98)	(3.54)	(1.44)		
Equation 3	1.147		.466*	.593*	-.461**	.845	21.01
(12 Industries)			(2.98)	(3.07)	(-2.22)		
Equation 4	1.028		.406**	.744*	-.309	.834	19.47
(12 Industries)			(2.22)	(3.77)	(-1.42)		
Equation 5	1.041		.369**	.834*	-.279	.853	22.25
(12 Industries)			(2.33)	(4.49)	(-1.36)		
Equation 6	.826		.379**	.750*	-.215	.827	18.52
(12 Industries)			(2.14)	(3.80)	(-.913)		

* = indicates significance at .01 level
** = indicates significance at .05 level
$\bar{R}^2$: Adjusted coefficient of determination
A t ratio is shown in parenthesis below each regression coefficient

Data and Sources

1. Private and federally funded R & D intensity measures in 1961: obtained from Industrial Research and Development Expenditures in Canada, Table 12, and Table 13, published by Dominion Bureau of Statistics, 1963. The reporting unit is generally the company.

2. Output - defined as sales in the current period plus (minus) the change in inventory from the preceding period for the various years by industry: obtained from different issues of Taxation Statistics published by the Department of National Revenue.

3. The index of total employment, (L_i), for various years by industry: obtained from different issues of the Canada Year Book, published by the D.B.S.

4. The percent of industry assets owned by foreigners: B.W. Wilkinson, Canada's International Trade: An Analysis of Recent Trends and Patterns, Table 36.

MARKET STRUCTURE AND THE TECHNOLOGICAL DISADVANTAGE OF CANADIAN MANUFACTURING INDUSTRIES

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Market Structure and the Technological Disadvantage of Canadian Manufacturing Industries

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Introduction

A great deal of public interest has been centered on the foreign direct investment process and its effects on Canadian manufacturing industries, (4,5,10). More recently, the relationship between foreign ownership and the rate of technological change in Canada has become an important topic of discussion among both policy-makers and academics, (6,7,8,9).

It is a well documented fact that R&D expenditures in Canada have been relatively low in comparison with other industrialized countries. The Gray Report (5, p.120) cites the following factors as being primarily responsible for Canada's comparatively low level of R&D activity and comparatively poor innovation performance:

1. the relatively small size of Canada's domestic market;
2. the heavy degree of foreign control in Canada's technologically intensive industries, and the related fact that parent firms in these industries normally tend to centralize research efforts at home;
3. the heavy concentration of Canada's research activity outside the business sector.

Apropos the influence of foreign ownership, Safarian, in his study of the performance of foreign owned firms in Canada, described three important characteristics of the Canadian situation: 1. despite access to parental knowledge, foreign subsidiaries do perform substantial R&D in Canada; 2. differences in research performance, when classified by foreign ownership, were not statistically significant, and 3. non-resident owned firms do more R&D in relation to sales than do resident owned firms, but the difference is statistically insignificant, (10, pp.49-50)

Globerman has suggested that if R&D conducted abroad is complementary to domestic R&D, then greater access to foreign technology could serve to increase rather than decrease subsidiary R&D

expenditures,(9,p.59) In his study of 15 manufacturing industries, Globerman found that "in those industries classified as technologically progressive, increased foreign ownership is associated with greater research intensity", (ibid. p.64).

Associated with the argument that foreign ownership contributes to reduced levels of domestic R&D is the notion that subsidiaries import more technology than resident-owned firms. Given easier access to parent firm technology, this is a reasonable presumption, all other things the same. However, in light of the evidence presented by Safarian and Globerman, it is also conceivable that access to parental knowledge may enable subsidiaries in Canada to not only do more R&D than their domestically owned counterparts, but also to surpass them in technological exports. Thus, if foreign owned firms perform more R&D than domestically owned firms, it is also possible that they export more technology than resident owned firms. It is this hypothesis which forms the basis for the present paper.

The Model

In an attempt to test the hypothesis that foreign ownership does not contribute to the deficit in Canada's technological balance of payments (or Canada's technological disadvantage), a regression model was specified and estimated. The dependent variable, Td-A, was defined as: dollar payments made to foreigners for extramural R&D (imports) minus dollar payments from foreigners for intramural R&D (exports), divided by total industry sales. This difference is a crude measure of what we are calling Canada's technological disadvantage. Data were obtained and averaged over a five year period (1965-1969) to avoid biasing associated with a non-representative year. It should be noted that our measure greatly underestimates the conceptually appropriate measure of the balance of technological payments, since it does not include payments made to parent companies in the form of management or consulting fees, royalties, licensing fees, etc. Unfortunately, a break-down of these payments for technical know-how is not available by industry group for the period under study. However, total figures for all manufacturing industries indicate that a comprehensive measure of Canada's technological disadvantage is on the order of three times the value of our measure.[1] The values for this variable and all the independent variables for the 15 sample industries are provided in Appendix 1.

The independent variables include:

1. A foreign ownership variable, F.O. (5), measured as the percentage of industry assets held by foreign corporations at least 50% of which were non-resident owned in 1968;
2. A concentration index, CR(1), measured as the percentage of total factory shipments of the two digit industry arising from component four digit industries in which the top four firms produce 75% or more of total output for the year 1965;
3. An interaction variable, IN, which is the product of F.O and CR. the variable was included to test the joint effect of the first two variables.
4. A measure of government grants, GG(3), as listed under the Industrial R&D Incentives Act, divided by average sales for the industry in 1969;
5. An index of average firm size, AS(2), as measured by average sales divided by the number of establishments for the given industry in 1969;
6. A discrete variable, T1 (9) representing interindustry differences in technological opportunity, as adapted by Globerman.
7. The industry's nominal tariff level in 1969, taken as a proxy variable for the lack of product specialization, NT;
8. A variable, DE, measuring development expenditures as a percentage of total R&D for 1969.

1. The average annual balance of payments deficit when considering patents, licenses, and technological know-how over the period under study was $35.4 million. The variable Td-A was only $10.9 million. Data are from (3), Table 19

The sample of 14 industries listed in Appendix 1 represents 91% of all industrial R&D for 1969, and virtually all of manufacturing sales for the same year. Therefore, the sample may be considered to correspond substantially to the universe of manufacturing firms. The following equation was estimated for the sample using ordinary least squares:

$$Td\text{-}A_i = a + b_1 FO_i + b_2 CR_i + b_3 IN_i + b_4 GG_i + b_5 AS_i + b_6 TI_i + b_7 NT_i + b_8 DE_i + e_i$$

As mentioned above, one would expect a negative relationship between foreign ownership and the dependent variable if access to the parent's technology created a "spinoff" effect and thus spurred net exports. The concentration parameter should be negative if increased market power and profits (resulting from barriers to entry associated with high concentration) encourage technological innovation. However, concentrated industries may be inefficient performers of R&D as a result of a lack of competition and, hence, an absence of incentives to strive for more efficient methods of production. In this case, the concentration parameter would be positive. One would expect government grants to encourage individual firm R&D, and thus reduce or reverse a dependence on foreign technology. However, the relationship between government grants and the dependent variable could be negative if government grants act to reduce more productive private R&D expenditures.

A feature of the R&D process in Canada is the fact that the bulk of R&D is conducted in the largest firms in an industry, (8, p.13) Therefore, one would expect that average firm size would be negatively related to the dependent variable. As a firm grows in size, it would be able to perform more R&D and, hence, reduce its reliance on imported technology. Globerman found that increased technological opportunity resulted in increased research intensity (9, p.[illegible]). Therefore one would expect that the technology opportunities index would also be negatively related to the dependent variable.

The nominal tariff variable, serving as a proxy for product diversity, presumes that as the tariff increases, the degree of product specialization decreases. A less specialized firm is likely to be less efficient in production and marketing functions, and as a result of the tariff, face less competition from foreign firms. One would not expect a relatively inefficient firm, protected from foreign competition to be an effective innovator. Therefore, the nominal tariff variable should be positively related to the dependent variable. Development expenditures accounted for 70% of total industrial R&D expenditures in Canada in 1969. It has been noted that foreign subsidiaries often adapt products and processes developed by the parent to the Canadian environment, thus contributing to the high percentage of development expenditures. One might predict that the more development oriented the industry, the more commercially useful results it would obtain to sell abroad. Thus, the relationship between the percentage of funds spent on development by an industry and the industry's technological disadvantage should be negative.

In the first series of regressions using the variables, it was observed that the concentration variable was negative and statistically insignificant. It was decided to drop this variable and let average firm size act as an indirect measure of concentration, since the two variables are highly correlated. This, in turn, eliminated the need for the interaction variable.

Equation 1 reports the results for the final estimating equation, (a t-statistic is shown in parenthesis below each coefficient.)

1. Td-A = a + 110F.O. + .278GG - .244AS -1458TI +212NT -3801DE
(4.26) (1.41) (-2.71) (-3.15) (2.91) (-1.93)

adjusted R^2 = .735; D.W. = 2.45

Appendix 2 contains the final regression run, correlation coefficient matrix, and table of residuals.

All variables in equation one have parameters which are significant at the .05 level, except government grants, whose coefficient is only significant at the .20 level. The sign of the GG variable indicates that as government grants to an industry increase, so does that industry's dependence on foreign technology. This may mean that government grants for R&D are an ineffective stimulant for indiginous research or that they distract firms from pursuing commercially-oriented R&D activities. A more detailed study is required before a definitive answer can be provided.

All other parameters had the expected signs with the exception of the foreign ownership variable. The F.O. coefficient was positive and statistically significant at the .01 level. This observation supports the contention that foreign ownership leads to support-type laboratories which simply adapt imported parental technology to the Canadian environment.[2] However, this conclusion is somewhat tenuous in the light of the substantial collinearity between the F.O., AS, and TI variables.

Summary and Conclusions

A study of 15 manufacturing industries performing the bulk of industrial R&D in Canada indicates that foreign-owned firms contribute to Canada's technology payments deficit by importing more technology services than they export. Although the Td-A variable is a very conservative estimate of Canada's technological balance of payments deficit, a more comprehensive measure would likely strengthen this conclusion.

Reductions in domestic tariff levels appear to be a significant policy option for stimulating innovative performance in Canadian manufacturing industries. Concomitant increases in average firm size should also contribute to an improved technological performance.

APPENDIX I

INDUSTRIAL GROUP	TA	FO	CR	IN	GG	AS	T1	NT	DE
Food and Beverages	19.70	31.2	16.94	528.5	102.64	1352	0	13.03	.492
Rubber	64.84	93.1	61.67	5741.5	352.18	7890	1	14.54	.542
Textiles	- 28.66	34.9	46.31	1616.2	22.33	3406	0	19.64	.812
Wood Products	1.51	30.7	2.33	71.5	14.64	566	0	4.63	.529
Furniture & Fixtures	130.08	18.9	0	0	0	269	0	17.95	.838
Paper	-106.53	39.4	0	0	291	6776	0	10.65	.439
Primary Metals	1931.4	55.3	85.74	4741.4	655.43	7296	0	6.65	.643
Fabricated Met. Prod.	15.85	46.9	7.11	333.5	871.88	822	1	10.38	.753
Machinery	775.76	71.8	23.98	1721.8	533.75	2883	1	3.71	.843
Transport. Equip.	-464.3	86.6	70.04	6065.5	464.78	8931	1	2.61	.859
Electrical Products	-308.5	64.2	2.84	182.3	1889.5	4340	3	13.73	.777
Non-Metal Min. Prod.	508.41	51.5	36.88	1899.3	122.45	1086	2	10.29	.362
Petroleum	404.87	99.5	98.9	9840.6	480.12	23626	1	6.34	.391
Chemical Products	454.28	81.5	15.46	1260	903.34	2533	2	9.39	.569
Misc. Manuf.	-114.24	53.9	3.41	183.8	814.4.	407	2	14.28	.704

APPENDIX II

NEWREG

MAXIMUM INPUT: 15 VARIABLES AND 50 OBSERVATIONS

DO YOU NEED INSTRUCTIONS (Y OR N) ?N

DO YOU NEED TRANSFORMATIONS (Y OR N) ?N
**REGRESSION NUMBER 1 :DEPENDENT VARIABLE IS 2

	INDEX	MEANS	STANDARD DEVIATIONS
F.O.	3	57.2953	24.793
G.G.	6	894.496	1641.75
A.S.	7	4818.2	5979.79
T.I.	8	.933333	.96115
N.T	9	10.5213	5.09013
DE	10	.6368	.173587
TdA	2	644.91	1713.93

CORRELATION COEFFICIENTS

	3	6	7	8	9	10	2
3	1	9.60861E-02	.66736	.486081	-.436598	-.104447	.413979
6	9.60861E-02	1.	.183187	-2.13357E-02	-.212973	8.97765E-02	.163448
7	.66736	.183187	1	-.025487	-.326363	-.317957	.180119
8	.486081	-2.13358E-02	-.025487	1	-8.88687E-03	3.11771E-02	-.347746
9	-.436598	-.212973	-.326363	-8.88687E-03	1	.132872	.113335
10	-.104447	8.97765E-02	-.317957	3.11771E-02	.132872	1.	-.198726
2	.413979	.163448	.180119	-.347746	.113335	-.198726	1

INDEX	B	STD. ERROR	T-RATIO	
3	-3108.9	1883.07	-1.75751	
3	109.791	25.7459	4.26391	F.D.
6	.276441	.197519	1.42969	G.G.
7	-.243798	.089735	-2.71336	A.S.
8	-1458.89	466.096	-3.15303	T.I.
9	211.985	72.9648	2.9053	NT
10	-3800.51	1969.84	-1.93014	DE

R-SQUARED= .734783 R= .857195

STAND. ERROR OF EST.= 1167.65 I.T.= 8

df	.20	.10
8	1.397	1.860

.05	.02	.01
2.306	2.896	3.355

ACTUAL	PREDICTED	RESIDUAL	
19.7	847.947	-828.247	FOOD + BEV.
6484	4791.18	1692.82	RUBBER
-28.66	916.251	-944.911	TEXTILES
1.51	-957.879	959.389	WOOD
130.1	-539.117	669.217	FURN. + FIXT.
-106.53	175.605	-282.135	PAPER
1931.4	1915.3	16.1011	PRIMARY METALS
15.85	-97.5587	113.429	FABRICATED METAL PROD
775.76	283.783	491.977	MACHINERY
-464.3	125.231	-589.531	TRANS. EQUIP
-308.5	-1071.11	762.611	ELEC. PROD
596.41	148.492	365.918	NONMETALLIC METAL PROD
404.87	529.773	-124.903	PETROLEUM
454.28	2323.49	-1869.21	CHEM. PROD
-144.24	288.26	-432.5	MISC.

DURBIN-WATSON STAT.= 2.4455

*****PROBLEM COMPLETED*****

DONE

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