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A Cross Section Analysis of Research and Development Intensity in Canadian Industries with Particular Reference to Foreign Control

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Analyse et élaboration de la politique économique

A Cross Section Analysis of Research and Development Intensity in Canadian Industries with Particular Reference to Foreign Control

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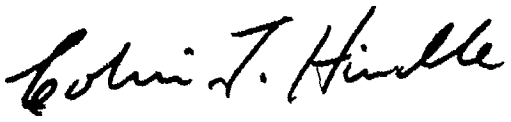

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INTRODUCTION

There has recently been much discussion about the lack of R&D in Canada. It has been asserted that this is due to foreign ownership and that the combination of foreign ownership and low R&D in Canada will make Canada unable to compete effectively in high technology markets which are expected to grow in the future.

In this paper, as in many on this subject, the ratio of R&D expenditures to sales for an industry is defined as the R&D intensity of that industry. The R&D intensity of a U.S. manufacturing industry is assumed to be an approximation to the technological intensity of this industry. This paper tests hypotheses regarding the R&D intensity of Canadian manufacturing industries, 110 industries at the three digit level, and their counterpart industries in the U.S. We then turn to an examination of hypotheses regarding the R&D intensities of the Canadian controlled firms relative to the foreign controlled firms in the same Canadian manufacturing industry. The conclusions of the paper identify the magnitude and the reasons for the gap between the R&D intensities of Canadian and U.S. manufacturing industries, and of Canadian and foreign controlled firms in Canada. The basic data used in this paper is from 1972.

CONCLUSIONS

A. The Canadian Manufacturing Industries Compared to the U.S. Manufacturing Industries

1. The simple unweighted average of Canadian R&D intensities across all sample industries is about equal to the simple unweighted U.S. average U.S. R&D intensities. A comparison of R&D intensities for 50 R&D intensive industries, however, indicates that Canadian R&D intensity averages about 30% lower than U.S. R&D intensity for these R&D intensive industries.

2. R&D intensity levels in Canada were found to be significantly and positively related to the R&D intensity levels of counterpart U.S. industries. This occurred in spite of the option of importing technology through licensing or from parent companies.

3. The degree of foreign control in an industry had a statistically significant negative effect on the R&D intensity of the industry in Canada relative to the R&D intensity of the U.S. industry. This may indicate that foreign controlled firms do not need to undertake as much R&D as Canadian controlled firms because it is easy for them to import technology from their parent firms. While foreign control was a significant variable affecting relative R&D intensities between the two countries, there are likely to be many other factors of significance. One factor examined was relative firm size. It was not a significant determinat in this relationship or in other relationships examined in the study. This could be because firm size effects are captured best by studies carried out at the firm level.

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B. The Canadian Controlled Firms Compared to the Foreign Controlled Firms in the Same Manufacturing Industry

1. R&D intensity levels were generally greater in the Canadian controlled segments of industries than in the foreign controlled segments. The difference between the two intensities were likely to be greater, the greater the R&D intensity of the industry. This is consistent with a hypothesis that there is interaction between two hypothesized phenomena. The first is truncation of the R&D function in foreign controlled firms due to economies of scale in R&D or indivisibilities in R&D. Such R&D generally takes place in the country of the parent firm. The second hypothesized phenomenon is that there are greater barriers to technology flow between independent firms than between affiliates. The difference in R&D intensity levels between the two control segments was not conclusively related to the level of foreign control in the industry.

2. The analysis then focussed on foreign penetration. Foreign penetration of a Canadian market is defined as the fraction of the total market taken up by products that are either exported to Canada by a foreign firm or alternatively produced in Canada by a foreign controlled subsidiary. Thus, from a foreign firm's point of view, exporting to Canada or establishing a subsidiary to produce in Canada are alternative ways which can be used by the foreign firm to exploit its comparative advantage in selling in the Canadian market. Our results indicate that foreign penetration, as well as each of its components, imports by Canada and sales by foreign controlled subsidiaries in Canada, are significantly greater in industries that are R&D intensive. We examined the hypothesis that if the R&D intensity of Canadian controlled firms was high relative to the R&D intensity of the U.S. industry, then the opportunities for penetration by foreign companies would be reduced. There was no strong evidence that relatively strong R&D intensities by Canadian controlled firms reduced foreign penetration.

C. Findings Related to Specific Industries

1. The Aircraft and Parts industry received special attention in the study because of its high technological intensity. Its R&D intensity in Canada was significantly higher than would have been predicted on the basis of the R&D intensity of this industry in the U.S. and the degree of foreign control in the industry. This is a likely outcome of the finding that the group of foreign controlled firms in this industry had a higher R&D intensity than would have been predicted on the basis of the R&D intensity of the industry in the U.S. On the other hand, the R&D intensity of the Canadian controlled firms in the industry was significantly lower than would have been predicted on the basis of the R&D intensity of the industry in the U.S. and the degree of foreign control. The high R&D intensity in the foreign controlled sector may reflect the high degree of world product mandating in the industry, its special ability to benefit from government programs broadening the market for defense products (DPSA) or subsidizing R&D expenditures in defense industries (DIPP) or it may be that foreign ownership was concentrated in the high technology sectors of the industry in 1972-73.

2. The automotive industry forms a large part of Canadian manufacturing. For this reason, it also received particular analysis. The R&D intensity of its foreign controlled sector was significantly lower than would have been predicted on the basis of the R&D intensity of this industry in the U.S. As a result the R&D intensity of the industry as a whole in Canada was significantly lower than would have been predicted on the basis of the degree of foreign control and the R&D intensity of this industry in U.S.

3. Let us shift our attention now from R&D intensities to R&D expenditures, thus taking industry size into account. Total R&D expenditures in Canada would almost double if the foreign controlled segments adopted the R&D intensity of their U.S. counterparts. In particular, increases in the R&D intensity of foreign controlled firms in the Automotive industries to U.S. levels would make a significant impact on the R&D intensity of Canadian manufacturing. This is because these industries account for a large fraction of all manufacturing in Canada and because the R&D intensity of the foreign controlled firms in these industries is extremely low, given the characteristics of the industry. If the foreign controlled segments of the Automotive industry had the same R&D intensity as the U.S. industry, total Canadian R&D expenditures for all manufacturing industries would rise by about 40%. Thus, questions of cost/benefit aside, a major impact on the size of Canada's R&D expenditures could be made by bringing the R&D intensity of the Automotive Industry up to U.S. levels provided that this could be negotiated with the parent companies.

Areas for Further Research

Several hypotheses regarding the determinants of R&D intensities relate to individual firms rather than industries. These hypotheses may be examined in future work as well as the relationship between R&D expenditure and industry or firm performance. Studies such as these are a necessary basis for informed policy decisions regarding the appropriate extent, and form of subsidies for R&D.

AN CROSS SECTION ANALYSIS OF RESEARCH AND DEVELOPMENT INTENSITY IN CANADIAN INDUSTRIES WITH PARTICULAR REFERENCE TO FOREIGN CONTROL

I Introduction

There has recently been a great deal of discussion of the interaction between foreign ownership of industry in Canada, industrial research and development levels in Canada and the ability of Canadian industry to compete internationally.

For example, The Weakest Link, a background study published by the Science Council of Canada, makes a number of assertions about these interactions. It is asserted that foreign controlled firms do an abnormally low amount of R&D[1], that they import an abnormally high proportion of their inputs (thereby inhibiting the development of Canadian suppliers) and that an abnormally high percentage of their production is aimed solely at the Canadian domestic market. Foreign controlled firms are said to have detrimental effects on Canadian controlled firms for two reasons. The influx of too many foreign controlled firms has caused the fragmentation of some industries in Canada. In other industries, foreign oligopolists have weakened Canadian firms. If economies of scale are important in determining R&D, then foreign control, as a cause of small Canadian firm size, could lead to low amounts of R&D in Canadian industry. It is contended that a lack of innovation and exports is due both to the aforementioned problems and the mature industry orientation of most

foreign controlled firms. Concern about some of these issues is also expressed in the MOSST background papers prepared for the Federal/ Provincial conference of July 1978. In addition, the MOSST papers linked R&D to growth in sales, exports, productivity and employment. MOSST also found that the R&D intensity of small companies tends to be greater than that of large companies in R&D intensive industries.

Studies focussed on three sets of issues are necessary to cover the gap between what we now know and what we need to know before making informed policy recommendations. We must first understand the structure of the relationship between R&D expenditures and other aspects of firm and industry structure. An analysis of the implications of these relationships and the impact of R&D expenditures upon firm and industry performance would follow. Only then could those R&D related policies and programs that would contribute most effectively to economic performance be identified.

This paper is intended to contribute to the first part of such a three part series. In particular, it examines some hypotheses concerning the determinants of R&D intensity at the industry level in Canada. It is directed at economists working in the area. A less technical summary will be prepared at a later date.

In this paper we do not attempt to model or statistically explain R&D expenditure decisions. One important constraint is that the data is not sufficiently disaggregated for such a purpose. A full analysis including all the relevant variables would be better accomplished with data at the firm level[2].

Nevertheless, there is an implicit theoretical framework for the paper in which the technological intensity of industries, as represented by their R&D intensity in the U.S.A., is a driving force. Among other factors, it determines foreign control in Canadian industries and the R&D intensities of the group of Canadian controlled and the group of foreign controlled firms in Canada. These latter intensities, weighted by their proportion of sales will by definition determine the R&D intensity of the total industry in Canada.

Rather than develop the above model or framework, this paper attempts to test empirically[3] some specific policy related hypotheses which will be discussed as the paper proceeds within the context of the following questions:

1. What is the relationship between the R&D intensity[4] of manufacturing industries in Canada and that of counterpart industries in the U.S., and what causes variation in that relationship?

2. What is the relationship between the R&D intensity of the Canadian controlled firms and the foreign controlled subsidiaries in the same manufacturing industry in Canada? How does the relationship vary across industries and what causes variation in the relationship?

3. Does the R&D intensity of an industry in Canada relative to the R&D intensity in the U.S. affect the degree of foreign control[5] of and foreign penetration into Canadian markets?

4. What would be the impact upon total expenditures on R&D in the manufacturing sector, if the foreign controlled firms had the same R&D intensity as their Canadian controlled counterparts, or the same as the counterpart U.S. industry? How much of the gap between to R&D intensity of the Canadian manufacturing sector and that of the U.S. manufacturing sector is due to the low level of R&D undertaken by the foreign controlled companies in the Automotive Industries in Canada?

NOTES: SECTION I

1 This and other hypotheses will be expanded upon later in the paper.

2 "The Determinants of R&D Expenditures" by J.D. Howe and D.G. McFetridge, in The Canadian Journal of Economics, February 1976, is a good example of such work, within the Canadian context.

3 The data was gathered by Robert Owen, a graduate student at Princeton University, in the course of preparing the forthcoming paper, "The Role of Marketing in the Concentration and Multinational Control of Canadian Industries" The analysis is cross-sectional, involving observations of 115 industries.

Unfortunately, for Canadian R&D data, there are only 34 different values distributed across the 115 industries. The result of this averaging will be to minimize the variation in R&D data which will generally appear as the dependent variable. This problem can occur at any level of disaggregation and would lead to an understatement of the significance of the explanatory variables but not to a bias in their coefficients. To accommodate the understatement problem, we will accept confidence levels as low as 90%. The alternative approach of compressing the data for independent variables into 34 industries would have involved a loss of information.

4 By R&D intensity we mean the ratio of current R&D expenditures to total sales for the industry or the groups of companies within the industry in 1972.

Because our analysis is interindustry, absolute levels of R&D expenditures could not be used, given that these would be expected to vary with the size of the industry. Deflation by sales is often used to scale down R&D expenditures in the studies. We recognize there are some difficulties with this approach. In particular, if there are economies of scale in R&D, small firms may need to be more R&D intensive than large ones, and new or growing firms will need to be more R&D intensive than established firms. These difficulties in deflation are more apparent at the firm level than at the industry level. Later in the paper an attempt will be made to examine the economies of scale issue.

Another problem with our R&D intensity measure is that sales figures are used in the denominator. Value added figures would have been preferable had they been readily available.

5 Foreign control can be defined in terms of sales of subsidiaries as a proportion of all sales by firms located in Canada plus imports and foreign penetration can be defined in terms of subsidiary sales plus imports all as a proportion of all sales by firms located in Canada plus imports.

II The Relationship Between the R&D Intensity of Manufacturing Industries in Canada and in the U.S.

This section of the paper is an attempt to compare R&D intensities in Canadian industries with those in corresponding industries in the U.S.A. in a systematic way[1]. After the comparison of intensities is accomplished, Section III of the paper will proceed to test hypotheses regarding the factors that are expected to affect the comparison.

A comparison such as the one we are about to undertake is of interest because it is often asserted that Canadian industry is not as R&D intensive as U.S. industry. We wish to determine the characteristics of the industries for which this is true. First, however, we need to refine our sample by testing whether certain industries should be excluded. If so, these industries will be given special consideration in the analysis and conclusions.

Refining the Sample: The Aircraft Industry

1. Without any sample refinement, the relationship betwen Canadian R&D intensity (RDTOT) and U.S. R&D Intensity (RDUSD) defined as current expenditure on R&D divided by sales was found to be the following:

$$RDTOT = .00302 + .53126\ RDUSD \qquad (9.21662)^*$$

$R^2 = .429$
$\bar{R}^2 = .424$
D.F. = 1, 113
F = 84.9461

2. Those industries grouped under Miscellaneous Manufacturing were too diverse to justify the use of the same R&D statistics. The equation without these industries was:

$$NMRDTOT = .00184 + .52611\ NMRDUSD \qquad (1.3332)\ (9.59391)$$

$R^2 = .4648$
$\bar{R}^2 = .4597$
D.F. = 1, 106
F = 92.043

3. The R&D intensity of the Aircraft and Parts industry was examined separately from the rest of the sample for two reasons. The first reason was that, being an industry very much related to defense, there are special markets for this industry (e.g., no tariff on exports to the U.S.A. under the Defense Production Sharing Agreement) and there are special subsidies for R&D (in Canada the Defense Industries Productivity Program). The second reason was statistical, namely that the observation for the Aircraft and Parts

industry was an outlier in terms of the R&D intensity in both countries. This may be a reflection of the structural setting mentioned as the first reason. (Note how the standard deviation for Canadian R&D intensity drops when the Aircraft industry is omitted from the sample. The means of both variables are also lowered).

	Mean of U.S. R&D Intensity	S.D.	Mean of Canadian R&D Intensity	S.D.
Sample with All Industries	.01510	.02032	.01105	.01648
Sample without Miscellaneous Industries	.01466	.02059	.00956	.01589
Sample without Aircraft and Miscellaneous Industries	.01354	.01706	.00821	.00766

For the analysis in question the equation estimated was

$$\text{NMARDTOT} = .00537 + .21043\ \text{NMARDUSD} \qquad (5.43691)$$

$R^2 = .2196$
$\bar{R}^2 = .2122$
D.F. = 1, 105
F = 29.56

where NMA indicates that Miscellaneous and Aircraft industries are omitted from the sample.

A comparison with earlier equations indicates, that, as expected, the inclusion of the Aircraft industry has a profound impact on the coefficients of the equation, increasing the slope and lowering the intercept.

Logically speaking then, for sound a priori reasons, the sample omitting Miscellaneous Manufacturing Industries and the Aircraft Industry is the most representative sample and it shall be the one upon which the remaining analyses of this paper will focus.

At the same time, we do not wish to eliminate this industry from our study altogether. In our sample year, 1972, current Canadian R&D expenditures in the Aircraft industry were $99.315 million. Since this was 13.6% of all the current R&D expenditures that year, this industry merits our special attention. In addition, the test of whether the R&D intensity that actually occurred was higher than would have been predicted, is a rough[2] measure of the effectiveness of the DIPP program in comparison with its U.S. counterpart.

For the Canadian Aircraft industry, our equation would predict an R&D intensity of .033683, much less than the actual figure of .153069. The t statistic for our test[3] is 12.39, indicating that indeed, the R&D intensity in this industry in Canada is significantly higher than would have been predicted from the sample omitting Miscellaneous and Aircraft industries. This confirms our visual impression that the Aircraft industry is an outlying observation.

Expectations for the Relationship between the R&D Intensities of Corresponding Industries in Canada and the U.S.: A Systematic Comparisen

Let us now use our chosen equation to compare Canadian and U.S. R&D intensities in the same industries. The equation presented on page 8 allows us to make predictions about these comparisons. This process is clarified in Diagram I where we have plotted both the equation and a 45° line. Where

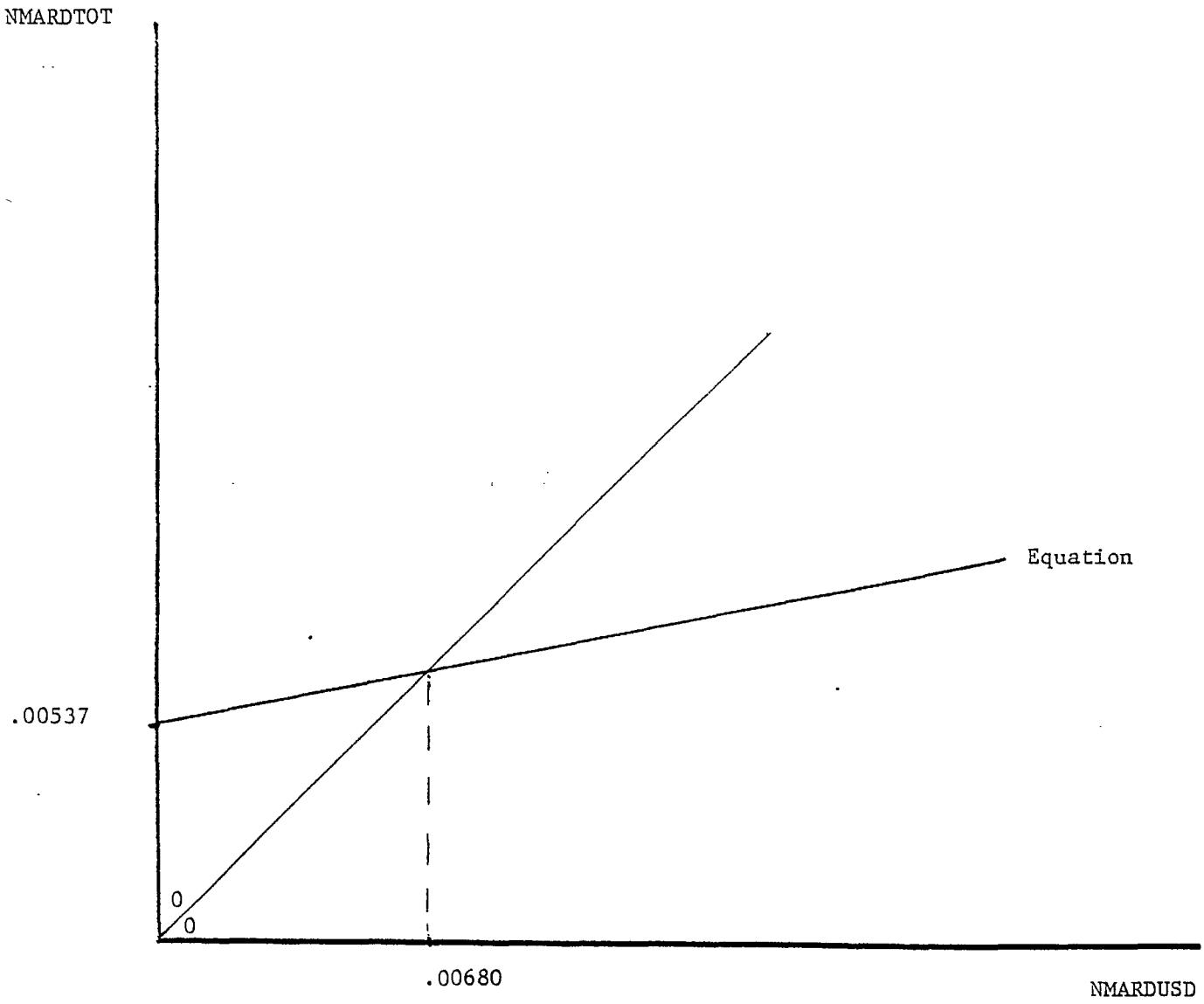

DIAGRAM I

the equation lies above the 45° line, we would predict Canadian R&D intensities to be greater than those in the U.S. Where the equation lies below the 45° line, we would expect U.S. R&D intensities to be greater.

That is, we would predict R&D intensities to be higher in Canada than in the U.S. for industries with U.S. R&D intensities less than .00680, the point at which RDTOT = RDUSD. We would predict the reverse relationship to obtain for values of U.S. R&D intensity greater than .00680. The median value of U.S. R&D intensity is .00637. Thus for 57 observations, more than half the sample, we would predict Canadian R&D intensity to be higher than U.S. R&D intensity. In fact, of these 57 observations on low R&D intensity industries, 32 are consistent with our expectations. The average ratio of RDTOT to RDUSD is 1.453 for these 57 "low" R&D intensity industries. For the 50 high R&D intensive industries, above the "break-even point" of .00680 we would predict the R&D intensity to be higher in the U.S. than in Canada. This prediction proves to be correct in all but 8 cases and the average ratio of RDTOT to RDUSD is .672 for the sample of 50 "high" R&D intensive industries. For the whole sample the average ratio of RDTOT to RDUSD is 1.088.

It was decided to test the possibility that the relationship between R&D intensity in Canadian and U.S. industries differs for high and low technology industries. We used the median value of R&D intensity in the U.S.A. to define our technology groups. Equations were estimated for each of these groups and examined for differences.

One difference was that an equation based on the sample of low technology industries gave a worse fit (R^2 = .0442) than did a similar equation based on the sample of high technology industries (R^2 = .1298). In the low technology industries, Canadian R&D intensities were more likely to be greater than U.S. R&D intensities.

Another way to test the possibility that the relationship between R&D intensity in Canadian and U.S. industries differs for high and low technology industries is to examine the following equation.

$$\begin{aligned} \text{NMARDTOT} = {} & .00300 + .00350\ D + .66887\ \text{NMARDUSD} \\ & (1.08918) \quad (1.01913) \\ & - .48525\ D\ (\ \text{NMARDUSD}) \\ & (-.73744) \end{aligned}$$

$\bar{R}^2$ = .2298
$\bar{R}^2$ = .2074
D.F. = 3, 103
F = 10.24

where D is the dummy variable indicating industries for which RDUSD is greater than the median. A comparison of the R^2 of the equation with dummy variables (.2074) and without dummy variables (.2122-See page 8) indicates that splitting the sample has not improved the goodness of

fit. The t statistics for the dummy variables indicate that there is no significant difference in the relationship for low and high technology industries. Nevertheless splitting the sample has been a useful exercise since it did indicate that RDUSD provides a better explanation of the variance of RDTOT for high technology industries than for low technology industries.

NOTES: SECTION II

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[1] Definitions of R&D from our Canadian source (Statistics Canada 13-203) and U.S. source (National Science Foundation (NSF 75-315) are similar. In addition both surveys include government subsidized R&D and have similar sampling techniques (e.g. 100% sampling of the known large spenders and lesser sampling of the remaining firms). We therefore feel that there is no cause for bias in making our comparisons.

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* Bracketed numbers are t statistics.

$\bar{R}^2$ represents a measure of the goodness of fit of the equation taking into account the number of observations and the number of independent variables. This allows comparisons of goodness of fit to be made between different equations.

D.F. stands for the degrees of freedom in applying an F test. For example, in this equation, there is one degree of freedom in the numerator and one hundred and thirteen degrees of freedom in the denominator of the F statistic.

All of these statistics will be presented for each equation in the paper, even though they may not always be referred to in the analysis.

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[2] A rough measure because

a) Other industries also participated in DIPP.

b) Not all factors affecting R&D decisions are reflected in our equation.

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[3] The test used involves the variance of the residual which can be determined from the formula

$$Sy^2 = Se^2 \left(1 - \frac{1}{n} + \frac{(Xo - \bar{X}^2)}{(Xi - X)^2}\right)$$ (See Johnston 1972, p. 42)

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[4] The median occurs for more than one industry.

III The Determinants of the Relationship

Now that we have compared Canadian and U.S. R&D intensities, we can proceed to examine some factors that could affect these relationships.

It has often been suggested that the degree of foreign control (as indicated by $S = \frac{\text{sales of subsidiaries}}{\text{all sales}}$[1]) would decrease the amount of R&D done in Canada. The hypothesis states that foreign controlled subsidiaries are expected to be truncated in their R&D function, because they depend on their parent companies to carry out this activity. The theory is that there are large economies of scale and indivisibilities in carrying out R&D, so that it is cheaper for additional R&D projects to be carried out in existing facilities rather than to create new ones. Since the existing facilities are for historical reasons usually located at the home office, this leaves the foreign controlled subsidiaries "truncated" in their R&D function (but hopefully receiving the results at marginal cost).

Nevertheless, it is possible to expect S to be positively associated with the R&D intensity of Canadian industries. A common hypothesis is that foreign controlled firms would have an advantage in industries with high technology content because they could benefit

from their parents' technological capacities, i.e., high technological intensity (as measured by RDUSD) could enhance foreign control[2]. Since U.S. and Canadian R&D intensities are positively correlated, this flow of causality could lead to a positive sign on S.

It has often been suggested that observed relationships between foreign control and R&D intensity are not due to foreign control but rather to the fact that foreign controlled firms are generally larger than Canadian controlled firms in the same industry. The relative size of firms in Canada and the U.S.A. (TOTSIZ/ASSAV respectively)* is therefore included in the analysis. Another reason for interest in this variable from a policy point of view is that its coefficient could indicate whether in house R&D is a necessity for survival, assuming there are economies of scale in R&D. A negative cofficient would be expected on the premise of indivisibilities in R&D, if in house R&D is a necessity for survival in the industry. In this case, new firms and small firms would have to undertake a large amount of R&D in relation to their sales in order to survive. Indeed, a study by MOSST has indicated that small firms in R&D intensive industries are more R&D intensitve than large firms. If on the other hand, a firm does not have to undertake its own R&D in order to survive (e.g., licensed technology might be available), smaller firms might opt out of R&D and a positive coefficient would occur in spite

of indivisibilities and economies of scale in R&D**. The results of our econometric testing would be only a rough indication of the validity of the above hypotheses, since hypotheses concerning firm size are best tested at the firm level.

The most direct equation to test the impact of foreign control and firm size on R&D intensity is the following:

$$\begin{aligned} NMARDTOT = .00573 &+ \underset{(5.25303)}{.21703}\ NMARDUSD - \underset{(-.48160)}{.00143}\ NMAS \\ &+ \underset{(.22577)}{.00004}\ NMA\ \frac{(TOTSIZ)^*}{(ASSAV)} \end{aligned}$$

$$R^2 = .2215$$
$$\bar{R}^2 = .1988$$
$$D.F. = 3, 103$$
$$F = 9.7696$$

where NMA means that Miscellaneous and Aircraft industries are excluded. From this equation it would appear that foreign control and relative firm size do not effect Canadian R&D intensity given the inherent technological intensity of the industry as reflected by U.S. R&D intensity. Because of a moderately strong relationship between the independent variables, there is some difficulty in differentiating the impact of one of these variables from the other. One way to lessen the problem is to constrain the coefficient of U.S. R&D intensity to equal one. The resultant equation which follows has the difference between Canadian and U.S. R&D intensities as the dependent variable,

$$NMARDTOT - NMARDUSD = .00147 - .01991\ NMAS \quad . \qquad (3.35479)$$

$$+ .00040\ NMA\ \frac{(TOTSIZ)}{(ASSAV)} \qquad (1.04332)$$

$R^2 = .0982^3$
$\bar{R}^2 = .0808$
D.F. = 2, 104
F = 5.66

The F statistic indicates that the equation is significant as a whole. Because the independent variables are correlated and yet act in opposite directions, the t statistics may overstate their significance as individual variables. An underestimate of significance would be derived for foreign control if it were the only independent variable. The t statistic from such an equation is -3.19, thus indicating that foreign control has a significant negative association with the difference between Canadian and U.S. R&D intensities. The t value for relative firm size does not indicate significance despite its upward bias. We, therefore, have not shown a prevalence of either hypothesis regarding this variable.

The Aircraft Industry

Our first test of the appropriateness of omitting this industry from the sample was done without taking the effect of foreign control into account. When it is taken into account, below, the results remain the same. We find below, that the R&D intensity in the Canadian Aircraft industry is significantly higher than we would have predicted.

The most reliable equation for testing the significance of variables had the difference between R&D intensities as the dependent variable. The most reliable equation, however, for predicting the R&D intensity of Canadian industries would not restrict the coefficient of U.S. R&D intensity, as the equation testing statistical significance did.

Therefore, the equation used as a basis for predicting R&D intensity in the Canadian Aircraft industry is:

$$\underset{\quad}{\text{NMARDTOT}} = .00579 + \underset{(5.28207)}{.21607}\ \text{NMARDUSD} - \underset{(-.44071)}{.00126}\ \text{NMAS}$$

$$\bar{R}^2 = .2211$$
$$\bar{R}^2 = .2062$$
$$\text{D.F.} = 2,\ 104$$
$$F = 14.76$$

The predicted value for RDTOT in the Aircraft industry is .03423 while the actual value is .153069. The t statistic testing the residual is 14.14. Therefore, we can clearly see not only that the R&D intensity of this industry is higher than we would have predicted but also that this industry is such an extreme outlier that our equation results would have been overly affected by its inclusion in the sample. The special environment of this industry (DPSA, DIPP) may have caused it to be an outlier even though the same industry receives special treatment in the U.S.A. Another possibility is the unusually high degree of world production mandating in the foreign controlled firms in this industry.

The Automotive Industry

The Automotive industry has been the subject of frequent examination for two reasons: the automotive trade pact with the U.S. and the size of the industry in comparison to total manufacturing in Canada. For the year of our sample, the automotive industry accounted for 13.96% of manufacturing sales but only 2.35% of current expenditures for in house R&D in the manufacturing industries. The question is whether this low proportionate contribution to R&D is accounted for by the technological intensity of the industry as indicated by R&D intensity in the U.S. and by the degree of foreign control in the industry or whether the industry is atypical even when these factors are taken into account. The equation used to test whether the industry is atypical is:

$$\underset{\text{NMAARDTOT}}{} = \underset{}{.00577} + \underset{(6.02603)}{.24278}\ \underset{\text{NMAARDUSD}}{} - \underset{(-.42848)}{.00120}\ \underset{\text{NMAAS}}{}$$

$$\bar{R}^2 = .2762$$
$$\bar{R}^2 = .2619$$
$$\text{D.F.} = 2, 101$$
$$F = 19.2746$$

where NMAA indicates that Miscellaneous Industries, the Aircraft industry and the Automotive industries are excluded. There are three automotive industries in the sample: Motor vehicles, Truck body and trailer, and Motor vehicle parts and accessories. The Canadian R&D intensity of all three of these industries is defined in this data set to be the same, namely, .000617. Since the Motor Vehicles industry sales is about 77% of the total sales of the group, it is for this particular industry that the test shall be made.

The predicted R&D intensity in the Motor Vehicles industry in Canada would be .01331 and the actual value is .000617. Since the t statistic to test if the residual is significant is -1.8917, we can say with 95% confidence that the R&D level in the Canadian industry is significantly less in the statistical sense than would have been predicted by the relationship derived from the other industries.

Conclusions

The R&D intensity in Canadian industries is significantly positively related to U.S. R&D intensity in corresponding industries. The greater foreign control in an industry, the less is the difference between its R&D intensity in Canada and its R&D intensity in the U.S. Stated differently, given the technological intensity of the industry, foreign control is negatively correlated with the R&D intensity of the

industry in Canada. Relative firm size was not significantly related to the difference between the R&D intensities of Canadian and U.S. industries. The R&D intensity of the Canadian Automobile industry was significantly lower than we would predict on the basis of R&D relationships in other industries taking into account technological intensity and the degree of foreign control. The R&D intensity of the Aircraft industry was significantly higher than we predicted, perhaps reflecting the influence of government support for R&D in the defense industries (DIPP), the access of defense goods to U.S. markets (DPSA) or the high degree of world product mandating in the industry.

NOTES: SECTION III

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1 By all sales we mean both domestic and export sales by all firms located in Canada plus imports to Canada.

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2 See study by English & Owen (amongst others) and Section IV of this paper.

* The TOTSIZ variable is not defined in a consistent manner with the ASSAV variable in that TOTSIZ excludes firms from the sample with assets less than $250,000 whereas ASSAV excludes companies with less than $100,000 in assets. The average of the ratio $\frac{\text{TOTSIZ}}{\text{ASSAV}}$ is 2.74. This would be somewhat surprising unless there were many U.S. companies in the $100,000 - $250,000 asset size range. A test of whether the cut off point makes a large difference in the variation of measured asset size between industries in Canada, is to correlate assets measured with not cut off point against our TOTSIZ measure. Even though the former was defined in terms of total assets and the latter was defined in terms of fixed assets, the correlation was .92. This would indicate that the method of measurement is not likely to seriously effect t statistics.

** One possibility is that the more technology intensive an industry, the more necessary is in house R&D to its survival. An interactive analysis between RDUSD and relative firm size was tried to test this hypothesis, but problems with multicollinearity and the definition of the dependent variable made the results inconclusive.

---

3 The R^2 between independent variables is now only .055.

IV The Relationship Between the R&D Intensity of the Canadian Controlled Firms and the Foreign Controlled Subsidiaries in the Same Manufacturing Industry and the Variation in the Relationship Across Industries

Following the same format as in the previous two sections, we shall now proceed to compare the R&D intensities of the group of Canadian controlled firms and the group of foreign controlled firms within the same industry in Canada. Although we shall use an equation as a tool for making our comparison, we do not mean the equation to imply a causal relationship. The comparison is of interest because of frequent assertions that foreign control of firms leads to low R&D intensities in Canada. A testing of the hypotheses regarding the factors involved in this relationship will be carried out in Section V.

The following equation illustrates the relationship without the miscellaneous manufacturing and aircraft industries[1].

$$\underset{(-1.24330)}{\text{NMARDCAN} = -.00227} + \underset{(11.3484)}{2.23227\ \text{NMARDFOR}}$$

$$\bar{R}^2 = .55085$$
$$\bar{R}^2 = .54657$$
$$\text{D.F.} = 1,\ 105$$
$$F = 128.778$$

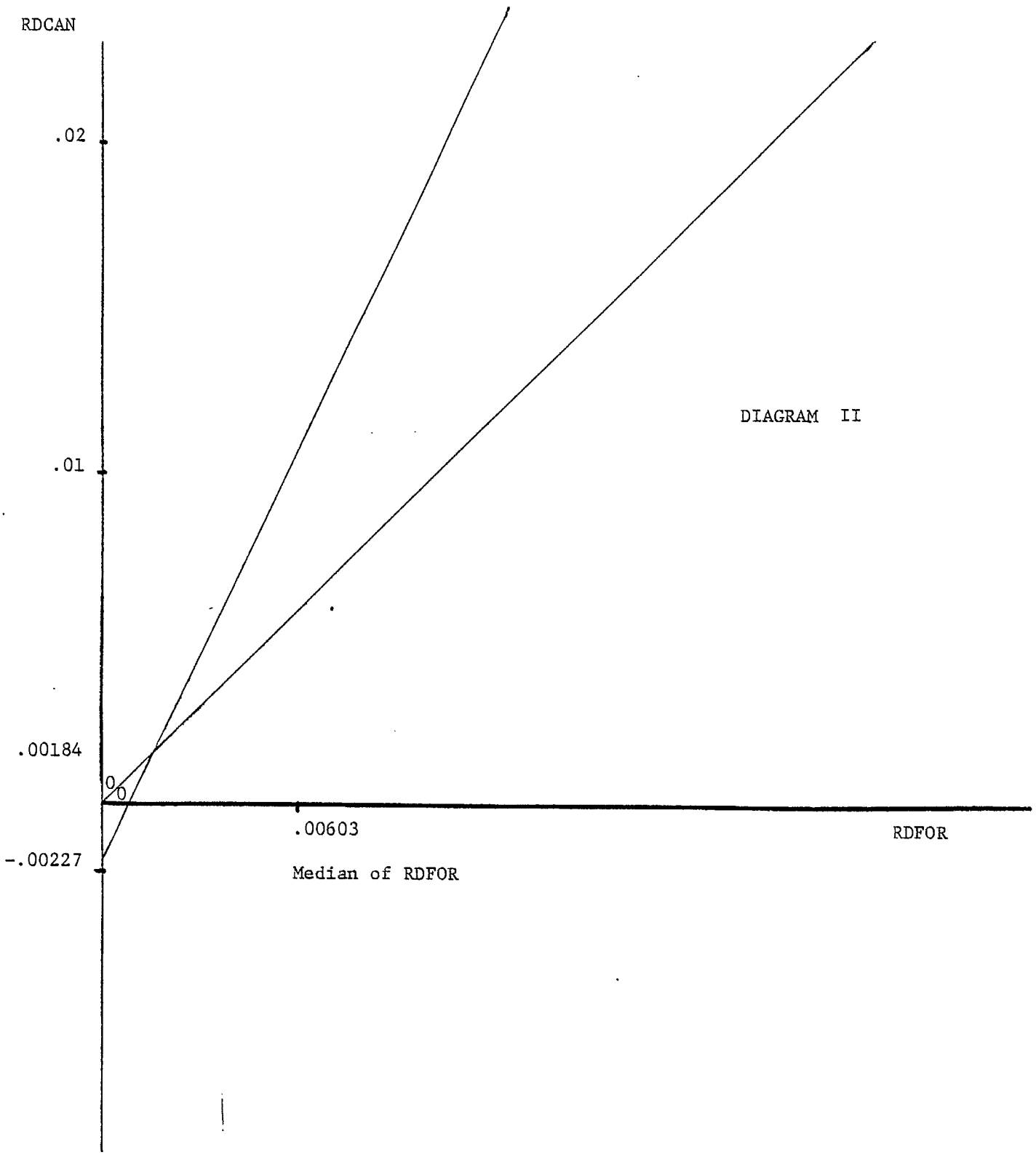

DIAGRAM II

where NMA means that the Miscellaneous and Aircraft industries are excluded, RDCAN means the R&D intensity of the Canadian controlled firms and RDFOR means the R&D intensity of the foreign controlled firms in Canada.

Diagram II clarifies the interpretation of this equation.

On the basis of our equation, we would predict R&D intensities to be higher in the foreign controlled firms than in the Canadian controlled firms for industries in which the R&D intensity of the foreign controlled firms is less than .00184 (the point at which predicted RDCAN = RDFOR, according to the equation). Since this point is well below the median of RDFOR, (.006033), it is not surprising that this prediction would apply for only 26 of the 107 industries in our equation sample. In fact, of these 26 observations, only in four cases was RDFOR greater than RDCAN. The average ratio of RDCAN to RDFOR for those industries below the break even point was 10.06, much higher than we would have predicted. For the 81 industries above the break even point, there were 25 cases in which the R&D intensity of the foreign controlled firms was higher than that of the Canadian controlled firms. The average ratio of RDCAN to RDFOR for these 81 industries was 1.69. For the sample as a whole it was 3.722.

The reason for these anomalies is that the relationship is curvilinear. A regression run for values of RDFOR below or equal to the break even point[2] is

$$\underset{(-\ 7.66720)}{NMARDCAN = .02833 - 19.03269\ NMARDFOR}$$

$$\begin{aligned} R^2 &= .710 \\ \bar{R}^2 &= .698 \\ D.F. &= 1,\ 24 \\ F &= 58.786 \end{aligned}$$

For this portion of the relationship, R&D intensity in the group of Canadian controlled firms falls as the R&D intensity in the group of foreign controlled firms rises . (An area for further research might be to investigate why this occurred.) This explains why our previous expectation that RDCAN would be less than RDFOR for this part of the sample does not hold true.

For values of RDFOR greater than the break even point the equation was

$$\underset{(10.93397)}{NMARDCAN = -.00713 + 2.59289\ NMARDFOR}$$

$$\begin{aligned} R^2 &= .602 \\ \bar{R}^2 &= .597 \\ D.F. &= 1,\ 79 \\ F &= 119.55 \end{aligned}$$

This equation is much more similar to our original equation done over the whole NMA sample.

To compare the equations with and without a split sample, the following equation was run in which DBEBE means the Dummy for values of RDFOR Below or Equal to the Break Even Point.

$$\begin{aligned} \text{NMARDCAN} = &-.00713 + .03545\ \text{DBEBE} + 2.59289\ \text{NMARDFOR} \\ &\quad (4.24660) \qquad (12.26983) \\ &- 21.62557\ \text{DBEBE}\ (\text{NMARDFOR}) \\ &\quad (-3.33322) \end{aligned}$$

$$\begin{aligned} R^2 &= .626 \\ \overline{R}^2 &= .615 \\ \text{D.F.} &= 3, 103 \\ F &= 57.533 \end{aligned}$$

Both the t statistic on the dummy variable and an R^2 comparison lead to the conclusion that making the split in the sample provides a more accurate basis for comparing RDCAN and RDFOR, especially for low values of RDFOR.

Diagram III illustrates all these equations. The steep slopes of these equations lead to predictions of negative (and therefore impossible) values of RDCAN near their intersection at the bottom of an approximate V. An examination of the observations for which these predictions occur (Food processing industries, Pulp and paper mills) indicates that the steepness is due more to observations toward the top of the V than toward its base.

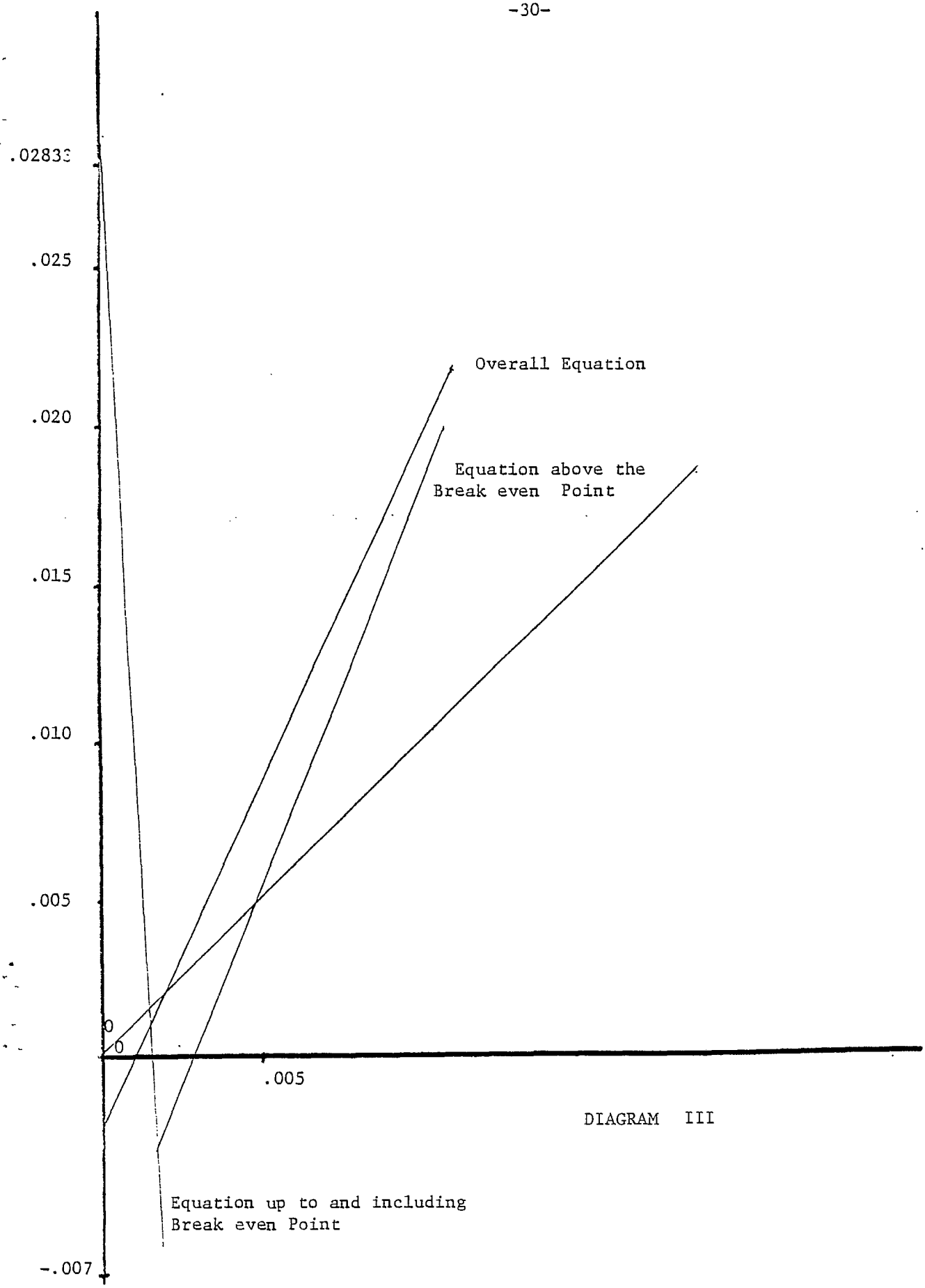
.02833
.025
.020
.015
.010
.005
-.007
0
0
.005
Overall Equation
Equation above the
Break even Point
Equation up to and including
Break even Point

DIAGRAM III

NOTES: SECTION IV

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[1] The ratio of the R&D intensities between the Canadian controlled and the foreign controlled firms in the Aircraft industry is .15, extremely low when compared with the NMA sample ratio of 3.7. A discussion of possible causes for this difference occurs in the section predicting relative R&D intensities for this industry on page 36.

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[2] A split of observations based on the median of RDFOR was tried with less well fitting results.

V Possible Causes of Variation in the Relationship between R&D Intensities in Canadian Controlled and Foreign Controlled Firms

In this section of the paper, we shall examine and test hypotheses about causes of variation in the relationship between RDCAN and RDFOR. Before discussing the hypotheses, let us consider several forms for the dependent variable:

1. RDCAN (with RDFOR as an independent variable)

2. RDCAN/RDFOR

3. RDCAN - RDFOR

The first form was rejected because it is difficult to say that RDFOR affects RDCAN on logical grounds. The second was rejected because ratios are very sensitive to small absolute differences for low values of R&D intensity. This sensitivity is undesirable because low values are particularly subject to errors in measurement and rounding. The third form was accepted.

The Hypotheses

Three variables were expected to affect the relative R&D intensities of Canadian controlled firms and foreign controlled

subsidiaries, as expressed by (RDCAN-RDFOR). The first was the relative size of Canadian controlled firms and foreign controlled firms, CANSIZ/FORSIZ[1]. If there were economies of scale in R&D and small firms required in house R&D for their survival, we would expect small firms to be more R&D intensive than large firms. A negative coefficient on our independent variable would be consistent with a prevalence of the above hypothesis. If there were economies of scale in R&D and small firms could survive by obtaining the results of extra mural R&D, we would expect them to do so, i.e. small firms would be less R&D intensive than large firms. A positive coefficient on our independent variable would be consistent with a prevalence of this hypothesis.

A second variable expected to explain the difference between the R&D intensities of Canadian controlled firms and foreign controlled firms in the same industry would be the technological intensity of the industry as indicated by the U.S. R&D intensity. The more technology intense the industry, the more need for the results of R&D to be used. Our R&D intensity variable measures in house R&D intensity. If the difference between such R&D intensity between Canadian controlled and foreign controlled firms is positive, this may indicate that it is easier for extra mural R&D results to be transferred to foreign controlled firms from their affiliates than it is for Canadian controlled firms to obtain the results of extra mural

R&D. If in addition this positive difference is positively correlated with the technological intensity of the industry, we may infer that the more technology intense the industry, the more need for Canadian controlled firms to increase their R&D intensity. This is consistent with increased barriers to technology transfer as technology intensity increases but this would not be a definite inference.

The third variable considered was S, the ratio of sales of foreign controlled subsidiaries to total market sales. On the one hand, if Canadian controlled firms felt threatened by foreign controlled subsidiaries, they might increase their R&D efforts leading to a positive coefficient for S. On the other hand, there may be a reverse relationship, in that a high relative R&D intensity by foreign controlled firms could increase their share of the market. This would lead to a negative coefficient for S, given that the dependent variable is RDCAN-RDFOR.

Results:

The third form of dependent variable was estimated with observations for Miscellaneous industries and Aircraft industries omitted.

The result was[2]:

$$NMARDCAN - NMARDFOR = .00109 + .37694\ NMARDUSD \quad (4.91328)$$

$$R^2 = .1869$$
$$\bar{R}^2 = .1792$$
$$D.F. = 1, 105$$
$$F = 24.14$$

This indicated that differences between the R&D intensities of Canadian and foreign controlled firms were largest for industries that were highly R&D intensive, i.e., it is likely that it is more difficult or costly for technology transfer to occur between independent firms than between affiliates, and the more technology intensive the industry, the more Canadian controlled firms must use in house R&D to achieve technology competiveness.

Multicollinearity played a major role in our ability to come to conclusions about the significance of our other variables since foreign control is positively correlated with U.S. R&D intensity and negatively correlated with relative firm size[3], the resultant R^2 being .23. Relative firm size was not correlated with U.S. R&D intensity, however, so that the following equation can indicate that relative firm size was not a significant variable[4]:

$$\text{NMARDCAN-NMARDFOR} = .00135 + .37402\ \text{NMARDUSD} - .00043\ \text{NMA}\left(\frac{\text{CANSIZ}}{\text{FORSIZ}}\right)$$
$$(4.81165) \qquad (-.28488)$$

$$\bar{R}^2 = .1875$$
$$\bar{R}^2 = .1719$$
$$\text{D.F.} = 2, 104$$
$$F = 12.005$$

The results of the following equation provide a lower limit for the significance of foreign control, because the independent variables are correlated but only weakly.

$$\text{NMARDCAN} - \text{NMARDFOR} = .00050 + .35580\ \text{NMARDUSD} + .00474\ \text{NMAS}$$
$$(4.39864) \qquad (.83547)$$

$$\bar{R}^2 = .1923$$
$$\bar{R}^2 = .1768$$
$$\text{D.F.} = 2, 104$$
$$F = 12.3844$$

An upper limit for the significance of foreign control is provided when it is the only independent variable:

$$\text{NMARDCAN} - \text{NMARDFOR} = .00123 + .01254\ \text{NMAS}$$
$$(2.14813)$$

$$\bar{R}^2 = .0421$$
$$\bar{R}^2 = .0329$$
$$\text{D.F.} = 1, 105$$
$$F = 4.614$$

Thus, we cannot reject outright the hypothesis that foreign control in an industry induces competitive R&D in the Canadian controlled firms in the industry.

Although the significance of the impact of the foreign control variable is not clear, our most reliable equation for prediction purposes would still include both U.S. R&D intensity and the degree of foreign control as explanatory variables of the differences in R&D intensities between the Canadian controlled firms and the foreign controlled firms in the same industry.

The Aircraft Industry

We have already shown by inspection that the relationship between the R&D intensities of the Canadian controlled and the foreign controlled firms in the Aircraft industry is atypical. We can now test this conclusion statistically taking into account such particular characteristics of the industry as the R&D intensity of its U.S. counterpart and the degree of foreign control in the industry. Our chosen equation taking these factors into account, would predict that for the Aircraft industry RDCAN - RDFOR = .04973. In actual fact, RDCAN - RDFOR = -.139454. The t statistic to test the difference between the actual and the predicted values is -11.3781195. Thus, relative to the Canadian controlled firms in the industry, the foreign controlled firms did have significantly more R&D than we would have predicted. One possible explanation for this is that in 1972 U.S. controlled firms in the defense industries were better able to take advantage of the DPSA and DIPP because of their Washington

connections, better management, etc. These advantages would lead to higher returns to R&D, and therefore to more R&D than would be expected. Another explanation might be that foreign controlled firms produced more technology intensive products than did Canadian controlled firms. Appendix IV finds that the low value of RDCAN-RDFOR is to a large extent due to an unexpectedly high value for RDFOR (possibly because of world product mandating) and to a small extent due to the unexpectedly low value of RDCAN. It is difficult to see how the defense oriented programs could bring about the low value of RDCAN. Therefore, the possibility of the foreign controlled firms specializing in more technology intensive products deserves further investigation.

The Automotive Industries

The foreign controlled firms in the Canadian motor vehicles industry have occasionally been accused of being "poor corporate citizens". One factor contributing to this label is the low amount of R&D that they undertake. Our predictive equation for indirectly testing this hypothesis provides the context of the R&D intensity of the domestically controlled firms (which we expect to be affected by the degree of foreign control in the industry) and the R&D intensity of the industry in the U.S. The test is indirect because it deals with the difference between the R&D intensities according to control rather than the intensity in foreign controlled firms alone. (See Appendix III for a more direct test.)

The predictive equation, when the Automotive industries are omitted from the sample is:

$$\underset{\text{NMAARDCAN - NMAARDFOR}}{} = -.00050 + \underset{(3.95131)}{.32640}\ \underset{\text{NMAARDUSD}}{} + \underset{(.82657)}{.00473}\ \underset{\text{NMAAS}}{}$$

$R^2 = .1667$

$\bar{R}^2 = .1502$

D.F. = 2, 101

F = 10.1055

For the Motor Vehicle industry, the predicted value of RDCAN - RDFOR is .01454 whereas the actual value is .027446, almost twice the difference that we would have predicted.

The t statistic for testing the difference between the predicted and actual values is only .938413. Because this low t statistic occurs in spite of the fact that the actual value of RDCAN-RDFOR is twice that of the predicted value, we conclude that the low t statistic is due to the poor fit of the equation. Appendix III indicates that while RDCAN is only slightly greater than would be predicted, RDFOR is significantly less than would be predicted.

Conclusions

The relationship between RDFOR and RDCAN was estimated to be curvilinear in an approximate V shape. This shape is more a result of the shape of the curve at the top of the two branches of the V than of observations occurring toward its base.

In general, the R&D intensity of the Canadian controlled firms in an industry is greater than that of foreign controlled firms in the same industry. A major and important exception to this rule is the Aircraft industry for which the foreign controlled firms are more R&D intensive than the Canadian controlled firms, each taken as a group. The difference in R&D intensities between the Canadian controlled and the foreign controlled firms is positively related to the degree of technological intensity of the industry in the U.S., i.e., as technological intensity increases, the R&D intensity of Canadian controlled firms increases in relation to that of foreign controlled firms. This is consistent with the hypothesis that as R&D intensity increases, Canadian controlled firms must "try harder" than their foreign controlled competitors, who, perhaps because of economies of scale and indivisibilities, tend to rely on their parent companies to undertake the R&D function. The Canadian firms would apparently "try harder" because there are greater barriers to technology transfer between independent firms than between affiliated firms. It is not clear whether the degree of foreign control in the

industry is significantly related to the differences in R&D intensity, i.e., the statistical significance of the relationship between foreign control of the industry and the differences in R&D intensity between the two groups of firms has depended too much on equation specification to be a reliable test of the hypothesis that Canadian controlled firms make higher R&D efforts in industries with a high degree of foreign control. Relative firm size was not significantly related to the difference in R&D intensities in any of the equations specified. This may indicate that economies of scale in R&D do not exist or even if they do, not all industries require in-house R&D for the survival of independent firms. The observed difference between the R&D intensity of Canadian controlled firms, in the Motor Vehicle industry and that of the foreign controlled firms was almost twice as great as we would have predicted on the basis of the technological intensity of the industry and the degree of foreign control. This discrepancy, however, was not statistically significant. The R&D intensity of the foreign controlled Motor Vehicle manufacturers, however, was significantly lower than would be predicted.

NOTES: SECTION V

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1 A ratio form was accepted here because asset size is a more reliable measure than R&D, the former being more amenable to precise definition.

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2 Because of the interesting results obtained when splitting the sample to compare NMARDCAN and NMARDFOR, an attempt was made to split the sample for this equation. The scatter diagram did not indicate an appropriate value for the split. When the sample was split according to the median value of NMARDUSD, no improvement in fit was obtained.

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3 This is consistent with the Weakest Link hypothesis that foreign control in an industry can cause Canadian controlled firms to be small. It is also consistent with the hypothesis that large Canadian controlled firms are a deterrent to foreign control in an industry.

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4 It could also be argued that since relative firm size is correlated with foreign ownership, that we are really measuring their combined effect. The R^2 for these two variables is .1597.

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5 The size of the t statistic provides support for our decision to omit this industry from the sample.

VI R&D Intensity and Foreign Penetration of Canadian Markets

The determinants of foreign penetration[1] of Canadian markets have been thoroughly investigated by other economists[2]. Among the factors found to be significant in cross section inter industry analysis have been R&D intensity, advertising and sales force intensity, economies of plant size and perhaps the size of Canadian controlled firms.

This section of the paper investigates the possibility that the advantage to foreign and foreign controlled companies would be lessened, the higher the R&D intensity of Canadian controlled firms, RDCAN, as compared with that of foreign and foreign controlled firms as indicated by RDUSD.

The equations testing the effect of relative R&D intensity on foreign penetration (XS) were:

$$XS = .52700 + \underset{(5.23233)}{5.49}\ RDUSD$$

$R^2 = .1950$
$\bar{R}^2 = .1879$
D.F. = 1, 113
F = 27.377

$$XS = .61160 - .0007132 \frac{RDCAN}{RDUSD} \qquad \begin{matrix} R^2 = .00034 \\ \bar{R}^2 = -.0085 \\ D.F. = 1, 113 \\ F = .0393 \end{matrix}$$
$$(-.19819)$$

$$XS = .52424 + 5.523\ RDUSD + .0009908 \frac{RDCAN}{RDUSD} \qquad \begin{matrix} R^2 = .1957 \\ \bar{R}^2 = .1813 \\ D.F. = 2, 112 \\ F = 13,625 \end{matrix}$$
$$(5.21551) \qquad (.30405)$$

RDUSD appears to be the only significant variable in these equations, i.e., the R&D intensity of the industry affects the degree of foreign penetration but the relative R&D intensities between the two countries does not[3]. The failure of the latter variable may reflect the importance of absolute R&D expenditures rather than R&D intensities. Since U.S. firms which undertake to export or have foreign subsidiaries are likely to be much larger than Canadian firms, then absolute level of R&D expenditure could be larger, even with a lower R&D intensity.

Those industries for which foreign penetration is much greater than one would expect from the first equation are Petroleum refineries, Gypsum products and Railway rolling stock. These industries have most of their foreign penetration through subsidiary sales. Those industries for which penetration is lower than would be predicted are Fabricated structural metal, Wooden box, coffin and casket[4] and Household furniture. These industries have low foreign

control as represented by S. Because of the distribution of outliers, we may infer the possibility that RDUSD may be a better predictor of imports than sales by subsidiaries.

The equations to be compared are:

$$*X = .18113 + 2.41331\ RDUSD \quad (3.08761)$$

$R^2 = .0778$
$\bar{R}^2 = .0696$
D.F. = 1, 113
F = 9.53

$$S = .34587 + 3.07718\ RDUSD \quad (2.91931)$$

$R^2 = .0701$
$\bar{R}^2 = .0619$
D.F. = 1, 113
F = 8.52

RDUSD is only a slightly better predictor of X, the import share of the market than S, the foreign controlled share of the market. Interestingly, it is a better predictor of total penetration than of either of its components[5]. This may indicate that the advantages offered by R&D intensity are not very sensitive to the location of production.

NOTES: SECTION VI

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1 By foreign penetration, we mean the sum of imports to an industry market plus sales by foreign controlled subsidiaries all as a proportion of all the sales of firms producing in Canada plus imports. This measure may overstate penetration if foreign controlled companies import final products for resale.

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2 See the forthcoming study by H.E. English and R. Owen, as well as Orr, Hewitt, Horst.

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3 This finding was tested leaving out Miscellaneous Manufacturing industries and it still held. When the relative R&D intensities between Canadian controlled firms and firms in the U.S. was expressed in terms of differences instead of ratios, the relative intensity was signifcant when it was the only independent variable ($t = 2.0$). It was insignificant when RDUSD was included in the equation. The footnoted statement would therefore likely still hold. The finding was also tested using equations with other variables found by English and Owen to be significant in determining foreign penetration. The relative R&D intensity variables remained insignificant.

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* The same additional experiments were done with X as with XS with very similar conclusions. When they were done with S, then (RDCAN-RDUSD) was never significant, even when run alone.

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4 The R&D intensity for this industry is likely overstated because it is in the very heterogeneous Miscellaneous industries group. This is probably why penetration is lower than would be predicted for this industry.

---

5 This merely confirms a finding by Horst.

VII Illustrations of Hypothetical R&D Structures in Canada

It is often suggested that Canada's R&D activity would be increased if:

1. Foreign controlled firms in Canada were as R&D intensive as U.S. firms.

2. Foreign controlled firms were as R&D intensive as Canadian controlled firms.

Some estimates of what would occur if 1. or 2. took place, shown in Table I, have been made based on 1972 R&D intensity figures and 1973 sales. Although these figures would therefore only be approximations of current figures, they still indicate a measure of the magnitude of the differences that would result. The total R&D by foreign controlled companies would amost have tripled if their R&D intensity had been the same as for the same industries in the U.S.A. This would have led to almost a doubling of the total R&D done in Canada. If foreign controlled firms had merely adopted the same R&D intensity as Canadian controlled firms, their own total R&D would have increased by about 130% (from 371.6 to 831.4 million dollars) and total R&D in Canada would have increased by 65% (from 730.1 to 1423.6 million dollars).

For the purposes of this exercise, consider as a goal[1] the case in which the R&D intensity of Canadian controlled firms remains unchanged and that of foreign controlled firms rises to U.S. levels. As indicated in Table I, this goal represents an increase of 693.5 million dollars or 95% above actual levels. If the foreign controlled firms merely adopted the R&D intensity of Canadian controlled firms, 68% of the increase would be made up.

Automotive Industries

Throughout this paper we have given special attention to the Automotive industries. Our econometric work indicates that the foreign controlled firms in these industries have performed an unusually low amount of R&D according to the statistical test in Appendix III. Table II indicates the profound effect that low R&D intensity in the foreign controlled sector of the industry has on the total amount of R&D done in Canada. If foreign controlled firms merely adopted the R&D intensity of the Canadian controlled firms in the sector, their R&D would increase by $275.4 million or 6800%. This increase in itself would provide 39.7% of the gap for all industries to reach the goal of 1423.6 million dollars. If the foreign controlled firms in the Automotive industries adopted U.S. levels of R&D intensity, the R&D done in the sector would increase by $346.0 million over actual levels or 49.9% of the gap! Thus this industry certainly merits special attention in deriving R&D policy.

Table I

	R&D by Canadian Controlled Firms	R&D by Foreign Controlled Firms	Total R&D in Canada
		($000,000)	
When Foreign Controlled Firms Maintain their Measured R&D Intensity	371.6	358.4	730.1
If Foreign Controlled Firms Adopt U.S. R&D Intensity	371.6	1,052.0	1,423.6
If Foreign Controlled Firms Adopt the R&D Intensity of Canadian Controlled Firms	371.6	831.4	1,203.1
If Canadian Controlled Firms Adopt U.S. R&D Intensity	307.7	358.4	666.1

Table II

The Automotive Industries

Based on Measured R&D Intensity	13.136	4.044	17.180
If Foreign Controlled Firms Adopt U.S. R&D Intensity	13.136	350.004	363.140
If Foreign Controlled Firms Adopt the R&D Intensity of Canadian Controlled Firms	13.136	279.452	292.588
If Canadian Controlled Firms Adopt U.S. R&D Intensity	16.452	4.044	20.496
If All Firms Adopt U.S. R&D Intensity	16.452	350.004	366.456

NOTES: SECTION VII

[1] This is a goal in the illustrative sense only. Economies of scale and indivisibilities in R&D might make it uneconomical to transfer parts of the R&D function to Canadian subsidiaries of foreign firms.

VIII Summary of Conclusions

The purpose of the paper has been to test certain hypotheses rather than to model or explain R&D intensity levels.

R&D intensity levels in Canadian industries were found to be positively and significantly related to the technological intensity levels in the U.S. industries as represented by their R&D intensity. While this might appear to be a foregone conclusion, the option of importing technology, for example, through licensing or from parent companies, makes this a relationship worth testing. It has also been found that those industries for which Canadian R&D intensity is greater than U.S. R&D intensity are likely to be the same ones for which U.S. R&D intensity is low. The degree of foreign control as reflected in the percentage of sales by foreign controlled subsidiaries had a statistically significant and negative relationship with the difference between Canadian and U.S. R&D intensities as would be predicted by much of the literature. The relative firm size between the two countries in the same industries was not significantly related to the difference in R&D intensities. Studies of the effect of firm size, however, are best carried out at the firm level.

R&D intensity levels were generally greater in the Canadian controlled segments of industries than in the foreign controlled segments. The difference between the two intensities was likely to be greater, the greater the technological intensity of the industry as represented by its U.S. R&D intensity. This is consistent with a hypothesis that there is interaction between two hypothesized phenomena. The first is truncation of the R&D function in foreign controlled firms due to economies of scale in R&D or indivisibilities in R&D. Such R&D generally takes place in the country of the parent firm. The second hypothesized phenomenon is that there are greater barriers to technology flow between independent firms than between affiliates. Our finding that RDCAN-RDFOR is positively related to RDUSD is consistent with the combination of these two hypotheses. The difference in R&D intensity levels between the two control segments was not conclusively related to the level of foreign control in the industry. No relationship was found between relative R&D intensities and the relative firm sizes in the two segments of each industry.

The relative R&D intensity between the Canadian controlled firms and firms in the U.S.A. did not seem to be a significant factor in determining the degree of foreign penetration into Canadian markets, even though the level of technological intensity of the industry was found to be significant in this study as in others.

The R&D intensity of the Aircraft and Parts industry in Canada was significantly higher than would have been predicted on the basis of the technological intensity of the industry and the degree of foreign control in the industry. To some extent, this is a likely outcome of the finding that the group of foreign controlled firms in this industry had a higher R&D intensity than would have been predicted on the basis of the technological intensity of the industry. On the other hand, the R&D intensity of the Canadian controlled firms in the industry was significantly lower than would have been predicted on the basis of the technological intensity of the industry and the degree of foreign control. The latter finding may result from the structure of the industry in 1972-73. The high R&D intensity in the foreign controlled sector may reflect its special ability to benefit from government programs broadening the market for defense products (DPSA) or subsidizing R&D expenditures in defense industries (DIPP). The high degree of world product mandating in this industry may also be a factor.

With regard to the Automotive industry, the R&D intensity of the foreign controlled sector was significantly lower than would have been predicted on the basis of the technological intensity of the industry. As a result the R&D intensity of the industry as a whole was significantly lower than would have been predicted on the basis of technological intensity and foreign control.

In general, the R&D intensity of Canadian industry is lower than that of the counterpart U.S. industry. Foreign control plays a major role in this outcome. Total R&D expenditures in Canada would almost double if the foreign controlled segments adopted the R&D intensity of their U.S. counterparts. In particular, increases in the R&D intensity of foreign controlled firms in the Automotive industries to U.S. levels would make a significant impact on the R&D intensity of Canadian manufacturing. This is because these industries account for a large fraction of all manufacturing in Canada and because the R&D intensity of the foreign controlled firms in these industries is extremely low. If the foreign controlled segments of the Automotive industry had the same R&D intensity as the U.S. industry, total Canadian R&D expenditures for all manufacturing industries would rise by about 40%.

TABLE OF FINDINGS

STATISTICAL SIGNIFICANCE

Dependent Variables	R&D Intensity in the U.S. Industry	Foreign Control in the Industry	Relative Firm Size	R&D Intensity in the Canadian Controlled Sector Relative to the R&D Intensity in the U.S. Industry
R&D Intensity of the Industry in Canada	Significant and positive			
The Difference Between R&D Intensity in Canada and in the U.S.		Significant and negative.	Not significant	
The Difference in R&D Intensity Between the Group of Canadian Controlled and the Group of Foreign Controlled Firms in Canada	Significant and positive	Findings not clear	Not significant	
Foreign Penetration	Significant and positive			Not significant
Foreign Control	Significant and positive			Not significant
Import Share of the Market	Significant and positive			Not significant

PREDICTIONS REGARDING THE AIRCRAFT AND AUTOMOTIVE INDUSTRIES

Predictions For	Aircraft	Automotive
R&D Intensity of the Industry in Canada	Actual significantly higher than predicted (on basis of RDUSD and also RDUSD and S)	Actual significantly lower than predicted (on the basis of RDUSD and S)
Difference in R&D Intensities Between the Group of Canadian Controlled Firms and the Group of Foreign Controlled Firms	Actual significantly lower than would have been predicted on the basis of RDUSD and S.	Actual higher than would have been predicted on the basis of RDUSD and S, but not significantly higher in the statistical sense.
R&D Intensity in the Group of Foreign Controlled Firms	Actual significantly higher than would have been predicted on the basis of RDUSD	Actual significantly lower than would have been predicted by RDUSD.
R&D Intensity in the Group of Canadian Controlled Firms	Actual significantly lower than would have been predicted on the basis of RDUSD, S.	Actual not significantly different from predicted on the basis of RDUSD, S.

The study has provided the above conclusions regarding the explanation of R&D intensities of Canadian manufacturing industries relative to their U.S. counterpart industries, as well as the explanation of R&D intensities of Canadian controlled firms relative to the foreign controlled firms within the same industry in Canada. Several hypotheses regarding the determinants of R&D intensities relate to individual firms rather than industries. These hypotheses may be examined in future work as well as the relationship between R&D expenditure and industry or firm performance. Studies such as these are a necessary basis for informed policy decisions regarding the appropriate extent, and form of subsidies for R&D.

NOTES: SECTION VIII

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[1] A more complex approach would be to include equations to determine the ratio of SALCAN to (SALCAN + SALFOR).

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APPENDIX I

The industries for which Canadian R & D intensity is greater than U.S. R & D intensity are:

- Stone products, Gypsum products
- Cement manufacturing
- Confectionary manufacturers, Sugar refineries
- Paint and varnish
- Railway rolling stock, Shipbuilding and repair, Boatbuilding and repair, Miscellaneous vehicles
- Electric wire and cable, *Batteries and miscellaneous electrical
- Foundation garments, Men's clothing, Women's clothing, Children's clothing, Other knitting mills, Hosiery mills
- Thread mills, Carpet mat and rug, Miscellaneous textile industries, Wool cloth mills, Textile dyeing and finishing, Wool yarn, Narrow fabric, Cotton yarn and cloth mills
- *Aircraft and parts
- Steel pipe and tube mills, Iron foundaries, Iron and steel mills
- Breweries, Wineries, Distilleries, Soft drink manufacturers
- Shoe factories, Leather tanneries, gloves and luggage
- Publishing only, Printing and publishing, Paperbox and bag.
- Miscellaneous metal fabricating
- Miscellaneous manufacturing industries (in this instance *Broom, brush and mop, Jewellery and silverware, *Sporting goods and toys, *Signs and displays).

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* Indicates values for RDUSD greater than .014

APPENDIX II

In 85 out of the 115 industries examined, the R & D intensity for Canadian controlled firms, RDCAN, is higher than that of foreign controlled subsidiaries, RDFOR. The thirty exceptional industries[1] are:

- Petroleum refineries, *Plastic and synthetic resins, Other petroleum and coal products
- *Abrasives, Cement, Ready mix concrete, Concrete products, *Glass and glass Products, Clay products
- Confectionery, Miscellaneous food, Sugar refineries
- *Boiler and plate works, *Fabricated structural metal
- *Synthetic textile mills, Thread mills, Carpet, mat and rug manufacturers, Miscellaneous textile industries, Wool cloth mills, Textile dyeing and finishing, Wool yarn, Narrow fabric mills, Cotton yarn and cloth mills
- *Explosives and ammunition, *Other chemical industries
- Fish products, Dairy products, Poultry processors
- Slaughtering and meat processing
- *Aircraft and parts

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1 These 30 industries represent 26% of the 115 industries and 26% of the 34 industry groups. This may indicate that we do not unbalance our results too badly by treating the 34 R & D observations as 115.

* indicates values for RDUSD greater than 0.14

APPENDIX III

Automotive Industries

A more direct test of whether the R&D intensity of the foreign controlled firms in this sector is lower than would be expected is to compare their R & D intensity with that which would have been predicted from the behavior of the foreign controlled firms in other industries taking into account the level of R & D intensity of the industry in the U.S. The equation[1] for this test is

$$\text{NMAARDFOR} = .00470 + .18266\ \text{NMAARDUSD} \quad (5.69517)$$

$\bar{R}^2 = .2412$
$\bar{R}^2 = .2338$
D.F. = 1, 102
F = 32.43

where NMAA indicates that Miscellaneous, Aircraft and Automotive industries are omitted from the sample.

The predicted value for RDFOR in the Motor Vehicles industry is .01107 and the actual value is .000403. The t statistic to test the significance of the residual is -1.914393. We can say with 95% confidence that the foreign controlled firms of this industry are performing less R&D than would have been predicted from the behavior of the foreign controlled firms in other industries.

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[1] S is omitted since our hypothesis is that it affects only the Canadian controlled firms.

The fact that the difference in R & D intensities according to control is not greater than we would have predicted could lead one to suspect that the Canadian controlled firms are not as R & D intensive as would be predicted. This does not turn out to be the case as the predicted value (taking RDUSD and S into account) is .0259 and the actual value is .0278.

Therefore, it is safe to say that the discrepancy between the predicted and actual value of RDCAN - RDFOR for the industry is due to the low value of RDFOR.

APPENDIX IV

Aircraft Industries

Our tests within the body of the paper determined that the value of RDCAN - RDFOR for this industry was unusually low. We now examine whether this finding was due to unexpected levels of RDCAN or of RDFOR. The equation for testing RDCAN was

$$\underset{\quad\quad\quad\quad(5.12112)\quad\quad(.82234)}{\text{NMARDCAN} = .00385 + .51175\ \text{NMARDUSD} + .00576\ \text{NMAS}}$$

$\bar{R}^2 = .239$
$\bar{R}^2 = .225$
D.F. = 2, 104
F = 16.37

where NMA indicates that Miscellaneous and Aircraft industries were omitted from the sample.

The predicted value of RDCAN is .07558 and the actual value is .024612, leaving a residual of -.050968. The t statistic testing this error is - 2.4814. Therefore the R & D intensity in the Canadian controlled firms in the industry is significantly less than we would have predicted.

The equation for testing RDFOR was[1]

$$\underset{\quad\quad\quad\quad(4.95017)}{\text{NMARDFOR} = .00470 + .16052\ \text{NMARDUSD}}$$

$\bar{R}^2 = .189$
$\bar{R}^2 = .181$
D.F. = 1, 105
F = 24.5

[1] S is omitted since our hypothesis is that it affects only the Canadian owned firms.

The predicted value of RDFOR for the aircraft industry is .02630 and the actual value is .164066 leaving a residual of .13777. The t statistic to test the residual is 19.9, indicating that RDFOR is much higher than we would have predicted.

Thus both the low value of RDCAN and the high value of RDFOR contribute to the low value of RDCAN - RDFOR for the industry.

APPENDIX V

Areas for Further Research

One area for further research might be to further develop the theoretical framework, part of which was implicit in this paper. The skeleton for such work would be the following set of equations. Part of the research would involve finding more variables for each equation except the last which is an identity[1].

$$S = f_1 \text{ (RDUSD, CANSIZ and other variables)}$$

$$CANSIZ = f_2 \text{ (S, market size, FORSIZ, ASSAV and other variables}$$

$$RDCAN = f_3 \text{ (RDUSD, CANSIZ/ASSAV, S)}$$

$$RDFOR = f_4 \text{ (RDUSD, FORSIZ/ASSAV)}$$

$$RDTOT = RDCAN \left(\frac{SALCAN}{SALCAN + SALFOR}\right) + RDFOR \left(\frac{SALFOR}{SALCAN + SALFOR}\right)$$

where SALCAN is sales by domestically controlled firms and SALFOR is sales by foreign controlled firms.

Firm level data would be a good vehicle for further research into the impact of foreign control since it would allow for the impact of variables best used at the firm level (such as profits) and would permit a more homogeneous selection of products. This sort of data would also be better for examining the economies of scale questions and the effect of foreign control on absolute levels of R&D.

Other suggestions for further work have been to examine our equations for subsets of the data, perhaps defined in terms of technological intesity or in terms of the end use of the product.

In this present study we have tried to be careful not to imply that more R&D in Canada would necessarily be desirable. An area for future research wold be to examine the impact of R&D on the performance of firms and the economy as a whole in the Canadian context. Ideally, this research should examine marginal costs and benefits. Such research would be crucial to policy decisions in the area of R&D.

APPENDIX VI

Variable	Description
AADVAV	U.S.: Ratio of advertising expenditures to total sales, 1965-1971 average.
AM	Prefix indicating that the sample is for industries for which a particular variable value is above the median.
ASSAV	U.S.: Total assets per firm, 1965-1971 average ($'000).
BEM	Prefix indicating that the sample is for industries for which a particular variale value is below or equal to the median.
CANSIZ	Total assets per firm for Canadian controlled CALURA size firms, 1973 ($'000).
D	Dummy for observations for which RDUSD is greater than the median in the NMA sample.
DBEBE	Dummy for observations with values of RDFOR below or equal to the break even point.
FORSIZ	Total assets per firm for foreign controlled CALURA size firms, 1973 ($'000).
NM	Prefix indicating that No Miscellaneous industries are included in the sample.
NMA	No Miscellaneous or Aircraft industries are included in the sample.
NMAA	No Miscellaneous, Aircraft or Automotive industries are included in the sample.
PSIUS	U.S.: Production workers per establishment, 1972.
RDCAN	Ratio of R&D expenditures to sales for Canadian-controlled firms, 1972.
RDFOR	Ratio of R&D expenditures to sales for foreign-controlled firms in Canada, 1972.
RDTOT	Ratio of R&D expenditures to sales for all firms in Canada, 1972.
RDUS	U.S.: R&D expenditures as a % of total net sales, 1973.

RDUSD	RDUS deflated by 100
S	Value of sales for foreign controlled firms divided by the sum of all sales by firms located in Canada plus imports, 1973.
SALCAN	Sales of Canadian controlled firms, 1973 ($'000)
SALFOR	Sales of Foreign controlled firms, 1973 ($'000)
TOTSIZ	Total assets per firm for all CALURA size firms, 1973 ($'000).
X	Value of industry imports, 1973 divided by the sum of all sales by firms located in Canada plus imports.
XS	The sum of X plus S.