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Research Report

BACKGROUND TO A TARGET:
AN INTERNATIONAL COMPARISON OF THE CANADIAN PHARMACEUTICAL INDUSTRY'S R&D INTENSITY

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The views and opinions expressed in this report are those of the authors and are not necessarily endorsed by the Department of Industry, Trade and Commerce.

EXECUTIVE SUMMARY

Decrying, as many other political and technology-oriented spokesmen, the low R&D intensity of the Canadian economy, the Minister of State for Science and Technology proposed in the summer of 1978 a government target: raising the R&D/GDP ratio from below one to 1.5 percent by 1983. This target was reaffirmed again in May 1980. It rests, in part, on the unfavourable comparison of Canada's research intensity to that of other industrialized countries.

While the practice of evaluating national R&D efforts by comparison of R&D outlays as a percentage of GDP is widespread, if suffers from limitations basically grounded in the widely differing structures of the economies compared. This study outlines some of these limitations and points out that aggregate comparisons cannot yield policy prescriptions. It advocates, instead, an industry-by-industry buildup toward aggregate comparison and shows how one Canadian industry's R&D intensity can be matched against that of the industry in other countries.

The report presented here is a study into the determinants of R&D expenditures of the pharmaceutical sector in nine OECD countries, including Canada. The regression model employed uses information yielded by five OECD International Statistical Years on R&D expenditures, and by other sources, to relate R&D intensity to a number of economic variables. It is able to account for about 80 percent of the variation in this industry's research intensity in the countries concerned. While the statistically influential determinants have operational policy interpreta-

tions, the character of most of these variables leaves little scope for intervention.

The model is then re-estimated without Canadian data and a "forecast" made from the eight remaining countries to Canada: the "forecast" shows that the Canadian pharmaceutical industry's actual research intensity is very much higher than would be expected from its economic characteristics.

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INTRODUCTION

The "Measures to Strengthen and Encourage Research and Development in Canada" announced in the summer of 1978 by the Minister of State for Science and Technology formulate, among other things, a new national priority for R&D expenditures to reach a target of 1.5 percent by GDP by 1983. More recently, an even higher target (2.5 percent by 1985) was mentioned by Conservative politicians. The re-established Liberal government has affirmed yet again, in May 1980, its 1.5 percent target stated two years previously. The proposed substantial increase over the 1977 figure of 0.92 percent is rationalized by comparison of this number with similar aggregates for other principal OECD countries.

While the practice of evaluating national R&D efforts by comparison of R&D spending as a percentage of GDP is widespread, it may suffer from potentially serious inadequacies. One of them is that the global share of GDP taken by R&D expenditures does not take into account the different economic characteristics of the countries compared. Another one is that this method of comparison is not useful as a source of policy recommendations if it is not accompanied by a causal analysis of R&D determinants. Surprisingly enough a search of the literature fails to reveal, with two rather modest exceptions, analytical investigations of R&D spending comparisons going beyond the simplest tabular evaluation of statistical aggregates[1].

The approach to the analysis of determinants of R&D spending in an international context proposed here attempts to make some initial steps

towards an elaboration of acceptable comparisons. It is summarized in Section 2 and elaborated with reference to the pharmaceutical industry in Section 3. Subsequent sections present the empirical details and results concerning that industry. The underlying data is presented in appendix tables together with a brief description of information sources.

1. CLEARING THE DECKS

Before the subject of comparative methodology in general and specifically with regard to the pharmaceutical industry is broached, it is appropriate to raise the question why the scientific and political communities in Canada are concerned about the alleged low level of R&D private sector expenditures in this country. Economists typically worry about raising real income per capita and about adequate employment, factors which they consider true yardsticks of economic welfare. They would acknowledge that a higher research intensity is better than a lower one only if it could be demonstrated that more research leads to higher growth and employment rates[2].

The difficulties of establishing a link between R&D outlays, private and/or public, and economic growth are well known and have been summarized elsewhere[3]. On an economy-wide level for instance, Great Britain - a country not known for its fast growth - was among the most R&D-intensive OECD members in the fifties and the sixties while Japan, the economic Wunderkind, was among those least intensive during that period[4]. On the level of the individual firm there is reason to doubt the existence of a direct causal link between R&D outlays and output growth. This is attested to by the persuasive evidence of business administration studies which document the role of overall corporate strategy as the drivig force behind new-product and new-process innovative success[5]. (Of course, both of these reservations with regard to the relevance of R&D intensity can be linked by the reflection that there is no obvious relationship between R&D

inputs and the desired output of market-accepted innovational products and processes. The tacitly assumed almost one-to-one relationship has rarely been tested and the evidence is by no means favourable.)[6]

It is thus important to stress that we in no way subscribe to the facile thesis that the comparison of aggregate R&D intensities between countries or of intensities in an industry over a cross-section of countries should lead to policy recommendations advocating increased R&D spending. Such "pushing on a string" recommendations have been abandoned even by thoughtful high-technology protagonists[7]. What does seem feasible, with many reservations attached, is an attempt to provide plausible comparisons of R&D intensities which are grounded in the recognition that R&D spending, a corollary of industrial prosperity, is affected by a set of factors common to many industrial countries. If such factors can be detected and their influence on R&D outlays assessed and if R&D is deemed of being in need of stimulation, then perhaps policy measures aimed at these factors might be proposed. They need not include direct subsidies or tax expenditures.

2. INTERNATIONAL COMPARISONS OF R&D

The current standard way of comparing GERD (gross expenditure on R&D) to GDP ratios between industrial nations is deficient on grounds of validity and usefulness. A valid comparison on the aggregate, nation-wide economy level must recognize, first of all, basic structural differences among which the most prominent is the sectoral composition of the GDP: secondary manufacturing, where the opportunity for technological change is currently most evident, accounts for about 40 percent of the GDP in West Germany, while it is responsible for only about 20 percent of Canada's output. Among other economy-specific factors one could list the comparative magnitude of the defence effort, the prevailing tax climate, and so on.

It is not quite clear, however, what the incantation "and so on" might encompass. It is not clear because we have little, if any, theory of R&D expenditure determinants (economy-specific adjustment factors) on the macroeconomic level. Given our ignorance of determinants at this level, GERD/GDP comparisons are not very useful because they cannot lead to corrective prescriptions.

When it comes to individual industries some theoretical and empirical background is available upon which to draw for approaches to a comparison attempt. We may then think of industry-specific determinants of R&D spending whose magnitudes will naturally differ between economies, but whose importance to the industry under certain conditions will be roughly equal in all countries. Among these we may find technology transfer due

to foreign ownership, trade orientation, patent climate, direct government support for R&D, etc.

From this it follows that at the present stage of knowledge the most promising way to valid and useful GERD/GDP comparisons is a build-up procedure which starts from the levels of industries or sectors and relies on an (economic) analysis of R&D spending determinants. The R&D expenditure function would be econometrically estimated for a given industry in a cross-section of "comparable" OECD countries from which Canada would be left out. The estimated parameters would then be used to "forecast" the corresponding R&D intensity ratio for Canada. The basic assumption common to this procedure and to the currently practiced "direct" comparisons is that the chosen OECD countries provide a proper yardstick. The advantages of the econometric procedure are the statistically verified selection of actual R&D determinants, the assessment of their relative influence and, finally, the indication for action they may provide to policy makers.

Two ways of doing this are possible:

1. A cross-section of industries (sectors) in a number of countries can be used as data base to forecast the appropriate level of Canadian R&D expenditures for the whole group of these industries (sectors) in the relevant time period. This R&D expenditure function would be estimated <u>separately</u> for each of the OECD International Statistical Years. <u>Example</u>: A sample of, say, 15 industries (sectors) in the 10 major OECD countries may be selected. A typical functional relationship for estimating the impact of several industry and economy-specific

characteristics in each of the selected countries on their R&D spending would be:

$ R&D industry i country j = f (Past R&D success; Financial performance; Foreign ownership; Industrial structure; Patent climate; Trade balance, etc.)

The estimated parameters would then be used on data for an identical group of Canadian industries to calculate what their R&D expenditures should have been in that particular year taking the rest of the OECD as the "norm". Proceeding industry group by industry group and forecast by forecast, an aggregate "expected" GERD figure could then be obtained for the whole economy. This would obviously be a very ambitious undertaking and an initial trial of the methodology with a more modest scope would be the following approach:

2. Focus the investigation on a small number of industries, each taken separately. The data base for estimation of the R&D expenditure function would consist of a time series for the industry in question in a cross-section of OECD countries. Example: Suppose it is desired to calculate the level of R&D spending in the Canadian electronics industry (or drug industry, or non-ferrous metals, etc.) which would correspond to the OECD "norm" during the period 1967-1975. The relevant data for the electronics industry in 10 major OECD countries would then be collected for each of the International Statistical Years and used to estimate the parameters of a function such as:

$ R&D = f (Past R&D success; Financial performance; Government support; Foreign ownership; etc.)
country j
year t

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

In this study, we have chosen the latter methodology and applied it to the pharmaceutical industry. Our reasons for the choice of this industry and the main theoretical issues are discussed in greater detail in the following sections.

3. AN INTERNATIONAL COMPARISON OF R&D INTENSITIES IN THE PHARMACEUTICAL INDUSTRY

The Nature of This Study

This paper is to be viewed as a pilot feasibility study of the second comparison approach outlined in the preceding section. The pharmaceutical industry was chosen as our object of investigation for the following reasons: first, as indicated by the proportion of sales revenues spent on R&D by the drug companies, pharmaceuticals rank among the most research-intensive sectors of the economy. Second, a typical drug company operates and does research in several countries. This offers an opportunity for evaluating the various factors influencing the location of R&D activities by firms and thus the level of R&D expenditures incurred by this industry in various countries. Third, direct government support to research is relatively modest so that the industry's decisions with regard to research are very much private investment decisions. Fourth, a considerable amount of economic analysis has been devoted to this industry and much empirical evidence accumulated. Last, a convenience factor: both investigators have some familiarity with the industry.

As pointed out previously, the essence of our method is to build a model of the determinants of R&D expenditures, fit it to data from a group of economies comparable to that of Canada, and use the estimated parameters to forecast the Canadian industry's R&D intensity. A comparison of this forecast with the actual Canadian intensity and an evaluation of the importance of the various determinants is to lead to policy-oriented conclusions.

The causal relationships we specify and utilize in our comparison, together with the frequently contradictory empirical evidence that attaches to many of them, represent the current state of the art as reflected in the literature on the subject.

At this stage it is advisable to discuss issues connected with the "determinants of R&D" model itself which can be written compactly as:

$$\text{R\&D Intensity}_{i,\,t} = f\,(\text{Vector of Determinants}_{i,\,t})$$

where i = country, t = time period.

Inter-Country Comparability

The simple but basic issue here is the soundness of the assumption that the R&D intensity of Canada's pharmaceuticals can indeed by compared with that of some other countries'. In principle, this can be rephrased into the question "Is the Canadian industry a part of the underlying universe within which the comparison is made?" As will turn out, a fully satisfactory test of this question (the so-called Chow test) cannot be undertaken due to the small number of observations. Nevertheless a less powerful test can be performed. Naturally, such tests are influenced by the choice of the dependent and the determining variables and so by the specification of the model itself -- validity of comparison cannot be divorced from choice of model.

Industry Definition

Common to all industrial organization studies is the problem of sectoral definition. While the major component of the pharmaceutical industry are ethical (prescription) drugs, veterinary preparations and non-prescription drugs as well as some fine chemicals typically contribute some part of the SIC 283 output.

R&D Intensity - The Dependent Variable

As alluded to previously, there is no guarantee that R&D intensity will be in a one-to-one correspondence with innovative output measured in economic terms -- a variable that most everyone would agree should be used in performance comparisons. A twenty-year old tradition holds that the number of patents granted to the firm or to a sector probably comes closest to measuring economic innovational performance[8]. Two factors argue against using patents as our dependent variable: patents in relation to something or other (or Canada's lagging behind in the level of patent activity) are not the issue on which the public debate is taking place; and patent statistics by country of origin are simply not available to us in sufficient quantity and quality - proper accounting would require information on the therapeutical and economic merits of the patented discoveries.

We therefore resort to the use of R&D outlays as percent of the industry's value of production as our dependent variable. (A ratio of "qualified scientists and engineers" to total personnel cannot be calculated for all of our sample countries). Focusing on R&D outlays generated by the pharmaceutical industry itself neglects, however, those contribu-

tions to the industry's innovational effort which originate in other sectors.

The most likely contributor to the pharmaceutical industry's technological progressiveness is the work by universities and government-supported research institutes in health sciences, but not even this broad classification is captured in the OECD International Statistical Years on which we rely for our R&D data. A second-rank contributor are probably the industries which are suppliers to pharmaceuticals[9]. It must be stressed that the issue of "intersectoral knowledge spillover" is absolutely fundamental in measuring an industry's innovational performance (or even in measuring innovation-destined inputs) with any degree of accuracy. Both conceptually and statistically it is only now beginning to be attacked seriously[10].

Finally, in an industry so much characterized by multinational operations, the transfer of research results from headquarters to subsidiary or between subsidiaries - if it were accounted for in economically measurable terms - would undoubtedly modify the R&D intensity ratios as officially recorded[11]. Our limited resources have not allowed us to do so but the task is not totally unmanageable.

R&D Determinants

While the specific determinants chosen for the statistical estimation are described and discussed in detail in the subsequent empirical sections, we present here some broader issues connected with the choice of candidate determining variables of R&D intensity or, in other words, with

the specification of the model.

Full-scale models of the determinants of R&D have a reasonably successful track record in industrial organization literature since Grabowski's pioneering article which appeared in 1968[12]. To our knowledge, they have been mostly applied in the context of inter-firm, intra-industry studies; inter-industry studies, with few exceptions[13], have tested limited hypotheses having to do predominantly with structure (concentration, size). We are not aware of any single-industry, inter-country studies of R&D determinants. This means that the best morsels of the theory of R&D determinants, such as they are, pertain to the individual firm level, with empirical findings scattered all over the place and frequently not very strong. In our one-industry, cross-country investigation we therefore resort to a certain eclecticism and examine a broad spectrum of candidate R&D determinants.

We start with a category of factors derived in straightforward analogy to single-firm focused intra-industry studies. These, for want of a better designation, might be called financial or past-success factors.

Financial - Past Success Determinants

Two views dominate (and commingle in) reflections on what drives research in the individual industrial firm. The first holds that past success breeds current success: firms that have invested in innovational endeavours successfully will commit more funds to them. Past success may be measured by the number of patents obtained by the firm deflated by sales or by the number of qualified scientists and engineers. It may, however,

also be measured, especially in research-dependent firms, by the ultimate consequence of successful research, namely profits.

The second view states that because of the well-known risks and relatively long time horizons associated with R&D, borrowing or the issuance of new equity securities is an unlikely source of funds for the support of R&D projects[14]. Profits, or more generally funds-flow variables, such as cash flow, are therefore a necessary prerequisite for research financing.

While both views are plausible, it is immediately apparent that the task of ascertaining causal direction empirically is quite difficult: patents, profits and cash flows are likely to be correlated among themselves and in a tangle of time relations[15]. This led Kamien and Schwartz to remark that the empirical evidence that either liquidity or profitability are conducive to innovative effort or output appears slim; they would not, however discard the hypothesis that such factors may be of a "threshold" nature, necessary in some degree[16].

Another note of caution with regard to the employment of accounting measures of profit is sounded by a growing number of investigators. They point out that in the research- and selling expense intensive pharmaceutical industry the accounting profit shown under current tax rules overstates by at least one third the true profit due to the non-capitalization of R&D and selling outlay investment[17].

The sophistication of these arguments sounds somewhat hollow in the face of the data available and the task before us. Cash-flow information is non-existent for the majority of our sample countries and "profit-

ability" is generally obtainable only on the more aggregate two digit SIC 28 level of the chemical industry[18].

Some crude measures of innovative performance are at hand, however. We had to do with what we had and tested the following proxies for candidate-status of variables measuring "past success":

1. A country's drug patenting activity abroad;
2. A country's trade balance in pharmaceuticals;
3. The number of major drugs originating in a country.

Financial-type variables tested are:

1. Profitability of a country's chemical industry;
2. Investment climate of a country's chemical industry.

Both of them are stated in terms of U.S. subsidiary operations abroad, with the exception of the U.S. home industry. The second variable is somewhat ambiguous in that it could also be considered to be one of the "environmental" determinants.

These and all the other variables proposed here are more precisely defined in the subsequent empirical sections.

Environmental Determinants

By these we understand the whole set of government policies which may affect the pharmaceutical industry in a given country. Recent writings about the industry suggest that the most important governmental impact may be due to the regulatory mechanism for new drug introduction[19]. The general tenor of the findings here is that due to the increased costliness of regulatory requirements imposed upon new-drug approval in 1962 in the

United States (and shortly thereafter in Canada), the number of new chemical entities (NCE's) launched by drug firms operating on this continent has declined. The evidence is less clear on whether the increased regulatory requirements have adversely affected R&D expenditure in the United States and Canada. There are, however, indications that the locus of drug development and testing (the D of R&D) is shifting from North America to the less restrictive climates of Europe[20].

Multinationally-oriented U.S. drug firms, having an inherent advantage on this count, appear to have introdued new products more frequently in North America than firms based predominantly in home markets; the concentration of innovational output (output here are sales of new products during the first full three years after introduction) in the hands of the largest four firms increased markedly[21]. It is not clear whether this might apply to non-U.S. multinationals.

To translate these background observations into a statistically malleable variable for our purposes is, unfortunately, not possible. Our observations start 5 years after the introduction of the Kefauver-Harris 1962 amendments by which time the new-product regulatory environment has presumably stabilized over our sample countries. Cross-sectionally it is not clear how the inter-country regulatory differences could be modelled in the absence of such information as "average number of years between patent grant and market approval" available for the United States. In this, as in other instances, the contrast between the quantity and quality of available U.S. data and the corresponding paucity of rest-of-OECD information leaves the investigator frustrated.

Reasonably ample qualitative information is obtainable on the existence of governmental incentive programs for research, be they of the direct assistance or of the tax expenditure kind. These programs are typically open to all sectors of industry and do not single out pharmaceuticals[22]. Modelling incentive differences across countries must, however, await monetary estimates which go beyond actual direct grants to tax expenditures taken advantage of by the individual industries.

Patent legislation can be envisaged as another research intensity determinant. Other things equal we would expect stronger patent protection to provide greater stimulus to proprietary research. We make a distinction between "product patents" and "process patents"; authorities agree that fewer countries grant the more strongly proprietary product patents (Canada does not). We model the latter as a zero-one dummy variable. Another feature of patent legislation may be compulsory licensing about which we do not have information with regard to several countries in our sample.

Firm Size and Concentration as Determinants

Grist for the mills of industrial organization economists these are the two potential determinants of research outlays which have undoubtedly received priority attention over the last two decades. The state of the art is masterfully surveyed and summarized in the 1980 edition of Scherer's book[23]. Two quotes are pertinent to our investigation:

> "One conclusion relevant to public policy follows immediately. No single firm size is uniquely conducive to technological progress" (p. 432).

> "The main lesson to be drawn from a review of the qualitative evidence is that no single, one-to-one

> relationship between market structure and technological progressiveness is discernible" (p. 432), yet "It seems clear in any event that market concentration has a favourable impact on technological innovation in certain situations" (p. 437).

The impact of firm size, or more properly in our context, the size distribution of firms, we are unable to test since the only relevant data easily obtainable are American. We had access to four-firm concentration ratios for each of our sample countries and they proved to exert a strong positive influence upon R&D intensity in line, perhaps, with the Grabowski et.al., results cited above as well as with other recent studies of the ethical drug industry[24].

Foreign Ownership

The last potential determinant of R&D outlays that we believe might be discernible in a cross-sectional analysis of countries, and that is data-accessible, is the degree of foreign ownership[25]. Of course, no Canadian economist is allowed to forget this factor[26].

Three cross-currents of influence might be discernible. R&D activity is sometimes said to be, with financial control, the most naturally centralizable activity of the firm with far-flung operations; if true, we could expect it to be located in the "headquarters country"[27]. A different hypothesis, grounded in case research, states that product-oriented research will be located close to the largest single market of the multinational firm[28]. The third one, already alluded to, proposes that pharmaceutical development and testing (by far the most expensive portion of the drug research process) will drift to less regulated countries.

Two additional "locational" influences should be mentioned. The first is the availability, on a full-time or consulting basis, of competent research personnel. Canada, for instance, should prove an attractive proposition on this count. The second has already been discussed in connection with the dependent variable and goes also back to the "headquarters syndrome": the so-called invisible importation of research results into a country's industry is likely to result in the underestimation of that country's research intensity. Once again, only fragments of the required information are available, making it impossible to quantify the effects of these factors.

We now turn to the description of our data, their sources and the variables actually employed in the detail necessary for the understanding of our estimation and prediction results.

4. DATA, SOURCES, VARIABLES

General Remarks

The primary source of quantitative information on R&D spending and its determinants are the various OECD publications. We examined, in addition, several secondary sources, among them U.N. and European Communities statistics, trade periodicals and a number of books and journal articles dealing with the pharmaceutical industry. Finally, we prepared a questionnaire and distributed it to some fifteen national associations of pharmaceutical manufacturers in an attempt to obtain data not available elsewhere. We also held discussions on the subject with experts at the Pharmaceutical Manufacturers Association of Canada and several Canadian research-oriented drug companies.

Our initial sample consisted of 15 OECD countries considered "important" by such yardsticks as the volume of their pharmaceutical production, size of their market, volume of exports and research activity. Unfortunately, gaps in a crucial source of data (International Survey of Resources Devoted to R&D, published every second year by the OECD) eliminated a number of countries from consideration. Among the deletions are Germany and Switzerland, whose pharmaceutical industries rank close to the top by all standards of importance. The former reports its pharmaceutical R&D expenditures together with the rest of the chemical industry and the latter reports them for all manufacturing industries combined (or not at all). The responses to our questionnaire and subsequent private communications suggest that the possibility of obtaining this type of data is

very remote.

Other deletions on similar grounds include Australia and the Netherlands, while a number of other countries had to be excluded because of lack of data on other relevant variables. Our final sample thus consists of nine countries, including Canada. (Some of our Appendix tables incorporate a tenth country, Finland. However, the data gaps for this country proved to be unmanageable and it could not become a part of our regression data base.)

The R&D spending figures upon which this paper is based pertain to the business sector alone, although research activities in the government, university and private non-profit sector may complement the business spending in different countries to varying degrees. In the context of this study, these differences cannot be accounted for since the industry breakdown of R&D spending performed outside the business sector is not available. Furthermore, our forecasting model employs some variables which are relevant exclusively to business research intensity, and have no bearing on spending in the other sectors.

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

The Dependent Variable (RESINT)

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

R&D Expenditures

We used that data series which is available for more countries than any other, namely "intramural expenditures, natural sciences and engineering" (figures for ten OECD countries, incl. Finland whose information coverage finally proved incomplete, are reported in Appendix Table 1). From statistics for those countries which also give intramural expenditures on all fields of science, we were able to verify that the share of humanities and social sciences research performed by the pharmaceutical industry is minuscule and so lack of this data is not a problem. Our main source of information were the published results of surveys[29] conducted by the OECD in each of the five "International Statistics Years"; in one instance (Denmark) missing information was supplied from responses to our questionnaire survey.

The quality (especially the inter-country comparability) of this data is by no means perfect as is clear from the background methodological documents[30] and from the "Country notes" accompanying the tables for each statistical year. Nevertheless, it is much superior to analogous figures

occasionally reported in trade periodicals and other publications. We have also considered an alternative measure of R&D effort, namely the number of "qualified scientists and engineers" employed. The OECD figures (reported in Appendix Table 2) suffer, however, from such problems as inter-country differences in educational background of this personnel, inconsistent accounting for full-time vs. part-time workers, etc. We have, therefore, not pursued this alternative any further.

Production of Pharmaceuticals

The denominator in the dependent variable is the value of pharmaceutical production (in millions of national currency) in each country in the OECD Statistical Year. These figures, as annually published by the OECD publication The Chemical Industry in U.S. dollars, are reported in Appendix Table 11 for our sample countries: their equivalents in national currencies are in Appendix Table 5.

Industry Profitability (PROFIT)

Initially, we envisaged developing a set of "financial" determinants of research effort, including the flow of funds. The published national accounting data from which such figures may be derived do not, however, give sufficiently detailed industry breakdown and our search of the literature and questionnaire survey proved unsuccessful in filling in the data gaps.

The closest we could come was a "twice removed" proxy for profitability of the industry in our sample countries, reported in Appendix

Table 9. Its first shortcoming is that it measures profitability in the chemical, rather than the pharmaceutical industry (the latter is a subset of the former). Since this data was available for both industries in the U.S.A., we included both for comparative purposes in Appendix Table 9. It is evident that profitability of pharmaceuticals is considerably higher than that of the rest of chemical industry. The validity of our proxy thus hinges upon the assumption that this differential is identical for all sample countries. The second weakness is probably more serious: our proxy reflects exclusively the performance of U.S.- owned subsidiaries operating in the various countries which may or may not be typical of firms under other ownership.

To moderate the influence of transitory factors, accounting adjustments etc., we calculated profitability cumulatively, so that each figure in Appendix Table 9 represents the ratio of profits to the net investment position since 1966 (the first year for which data is available) up to and including the year in question.

Investment Climate (INVCLIM1)

This variable reflects in part the financial conditions of the pharmaceutical industry in the sample countries and in part the overall state of their economies. Lack of detailed published information forced us, once again, to resort to a proxy based on the performance of U.S.-owned subsidiaries of chemical companies. The figures (reported in Appendix Table 10) represent the ratio of reinvested earnings to total earnings, are calculated cumulatively and suffer from the same shortcomings as the in-

dustry profitability data discussed above. On a priori grounds it is plausible to expect that current R&D spending is influenced by past investment decisions. We have therefore introduced this variable into our regression with a one-period lag. While our data base did not permit us to explore alternative lag patterns the cumulative nature of both the INVCLIM and PROFIT observations yields a time-smoothed effect, reflecting the developments from 1966 on.

Industrial Concentration (CONCEN)

As already mentioned above, the relationship between industry concentration and intensity of research efforts has been extensively debated in the literature. Similarly, the measurement of concentration itself is a subject of numerous studies, dealing mostly with the comparative advantages and disadvantages of measures such as concentration ratios, Herfindahl index, Linda index[31], etc. For reasons of data availability, we had to settle for the four-firm concentration ratio (Appendix Table 4).

The market for pharmaceuticals in any given country consists of a set of submarkets, each of which contains products designed for the same therapy. Strictly speaking, measurement of concentration should, therefore, proceed from individual therapeutical submarkets and the results should then be aggregated to arrive at an overall industry figure. Unfortunately, sufficiently detailed data is available only for a handful of countries, some of which were analyzed in a series of concentration studies published by the Commission of the European Communities (see footnotes to Appendix Table 4). For the other countries, our concentration ratios are

derived from aggregate market figures.

Time series data on concentration in most sample countries are not available. We were, however, able to obtain concentration ratios for the period around 1973; it was then assumed that these values apply to all of the census years. The assumption of no significant change in concentration over the period covered by our sample is confirmed by comparison of the 1973 and 1969 figures, where available (Appendix Table 4).

Degree of Foreign Ownership (FOROWN)

The numerical estimates of the level of foreign ownership in the pharmaceutical industry reported in various industry, government and international sources rely on two main measures: share of domestic sales supplied by foreign-owned companies and share of domestic production accounted for by foreign-owned companies (reported, respectively, in Appendix Tables 3 and 3A). On theoretical grounds, we preferred the latter measure since it seems to be connected much more closely with the corporate decisions on location of R&D activities. Better measures, such as share of foreign-owned industry assets, were not available for many of our sample countries. As was the case with concentration ratios, we assumed that the levels of foreign ownership observed around 1973 prevailed throughout the whole sample period.

Strength of Patent Protection (PRODPAT)

A unique feature of patent protection in the pharmaceutical industry in some countries is the impossibility of patenting the product itself. Only the process enjoys patent protection, leaving thus wide scope for "inventing around" and the consequent weakening of the incentive to invest in R&D. In the special case of Italy, during the period which coincides with our data, not even the process was patentable (Appendix Table 6). We initially included two dummy variables in our regression to distinguish between the two types of patent protection; the process patent dummy, however, was consistently insignificant and we thus dropped it from further analysis. It should perhaps be stressed that we are not comparing the effects of a total absence of patent protection with some degree of it, but rather the effects of two levels of protection, one weaker and one stronger.

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

Past Innovative Performance (INNOV)

We developed and experimented with three different types of proxies for this variable. First, measures based on each country's share of new pharmaceutical products introduced by all OECD countries during a specified period of time (Appendix Table 14). Second, each country's share of pharmaceutical patents granted to foreign companies in the most lucrative

market, i.e., the U.S.A. (Appendix Tables 7 and 8). Third, several measures of "trade balance" were developed by combining, in three alternative ways, the information from Appendix Tables 11, 12 and 13: (a) Ratio: (Exports-Imports)/Imports; (b) ratio: (Exports-Imports)/(Exports+Imports); (c) ratio: (Exports-Imports)/(Production-Exports+Imports)).

None of the three types of measures of trade balance performed satisfactorily - the estimated coefficients were typically not significant. In the text, we report results based on the first and second type of variable only, since these are the influences occasionally explored in economic empirical work dealing either with the pharmaceutical industry or with questions of economic performance (see e.g., Freeman, supra note 4).

Patent Balance (PATBAL)

This is another proxy for past innovative performance and was used in the regression analysis interchangeably with INNOV. It was constructed from data on pharmaceutical patents granted in the U.S. (the largest and most lucrative pharmaceutical market in the world) to residents of each of the sample countries (Appendix Table 7). The shares of each country are calculated in Appendix Table 8, cumulatively from the year 1963 (the first year for which data was available) up to and including the year in question.

With respect to the share of the U.S., it would be clearly inappropriate to count U.S. patents granted to U.S. companies as equivalent to U.S. patents granted to foreign residents. It is plausible to assume that foreign residents are more selective in applying for U.S. patents than

U.S. residents. We have therefore developed an "equivalent" number of U.S. patents by reference to the U.S. share of all new chemical entities introduced in the past in the world markets (Appendix Table 14). The U.S. introduced 48.1 percent and all other countries 51.9 percent of all new chemical entities. An "equivalent" number of U.S. patents taken out in the U.S. can thus be calculated by multiplying the figures in bottom line of Appendix Table 7 by the ratio (48.1/51.9). The resulting numbers are then added to the figures in bottom line of Appendix Table 7 to yield a base for calculating the "equivalent" share of U.S. patents taken out in the U.S. (bottom line in Appendix Table 8).

5. RESULTS OF ESTIMATION OF THE "R&D FUNCTION"

Introduction

Several functional relationships between research intensity and its determinants were specified and estimated once in a linear and once in a logarithmic functional form. Each regression was run first on a full sample of countries, including Canada and then rerun on a reduced sample, excluding Canada. The former set of regressions provide the basis for analysing the relative importance of the various determinants of R&D expenditures suggested by theory. The latter are used to forecast Canada's R&D intensity in the pharmaceutical industry which would correspond to the actual Canadian levels of the determining variables and the "average" relationship (as measured by the appropriate regression coefficient) between R&D intensity and each determinant prevailing in the rest of the sample countries.

The estimated coefficients for all of these regressions are reported in Tables A, B, C and D below. Since the data base is a cross-section of time series (nine countries with five data points for each, corresponding to the OECD International Statistical Years), ordinary least squares regression results may be affected both by heteroskedasticity and serial correlation. We have therefore applied a version of the generalized least squares procedure[32] to improve the efficiency of our estimates. For reasons of insufficient number of observations, we were only able to perform the adjustment for serial correlation; the results of our "best" regression equations are reported in Table E together with the

original (unadjusted) results. The failure to adjust for heteroskedasticity would not seem to be a major problem in this case, since all our continuous variables are in ratio form and the impact of the differences in size of countries in our sample is thus largely neutralized.

In the remainder of this section, we discuss the estimated coefficients in Tables A - E and comment on a number of experiments with regressions including variables other than those contained in the tables. A "forecast" of R&D intensity for the Canadian pharmaceutical industry is developed and discussed in the subsequent section.

Regression Analysis

Both our analysis of the determinants of R&D intensify and our forecasting procedure are based upon the regression results adjusted for serial correlation as reported in Table E. The particular choice of equations presented in Table E was the result of an evaluation of a series of regression analyses summarized in Tables A - D. Each of the latter tables reports the estimates of the coefficients of three pairs of regressions. Within each pair, one equation contains INNOV and one PATBAL as our alternative proxies for the same variable. The first pair of regressions contains the full number of explanatory variables. The second pair does not contain the PROFIT variable whose systematically negative and sometimes statistically significant coefficient initially appeared counterintuitive. As can be seen from the regression statistics and from the t-values of the estimated coefficients, elimination of the PROFIT variable reduces the goodness of fit. On the other hand, elimination of a further

variable, that measuring the investment climate (INVCLIM1) in the third pair of regressions, does not have an appreciable effect either on the goodness of fit or on the magnitudes of estimated coefficients.

Our "complete" regressions (equations 1 and 2) account for at least 72 percent of the variation in the dependent variable; the linear functional form explains slightly more than the logarithmic one (all R^2 are adjusted for degrees of freedom). The somewhat surprising phenomenon of an increase in R^2 in the linear regressions when Canada is eliminated from the sample and the number of observations thus drops from 45 to 40 may reflect the fact that the pharmaceutical industry in Canada is somehow "different" from its counterpart in the other countries. The value of the F-ratio also slightly improves when Canada is dropped. However, in the logarithmic regressions the R^2 remains approximately unchanged and the value of the F-ratio drops when Canada is excluded from the sample.

We now briefly discuss the statistical performance of each variable as a determinant of R&D intensity.

Industry Profitability (PROFIT)

The shortcomings of the figures used as a proxy for profitability in our regressions have been already pointed out. In all of our regressions, the coefficient of this variable has a negative sign which is statistically significant in the linear, but not the logarithmic functional form. The negative sign can be rationalized when it is remembered that the profitability figure is based on net profits, after R&D expenditures. In other words, R&D expenditures and current net profits "compete" for company funds

in any given year. A more sophisticated analysis of the relationship between profitability and R&D intensity would have to examine the possible lagged relationships as well as to include considerations of the tax structure, etc. Our brief exploration in this direction was unsuccessful since the data limitations restricted us to a one-period PROFIT lag. The estimated coefficient (results not reported here) was positive, but not statistically significant.

Investment Climate (INVCLIM1)

This variable is proxied by figures similar in nature to those used to measure profitability and suffers from similar inadequacies. The inclusion of a measure of past investment behaviour (ratio of retained to total earnings, lagged one period) as an exaplanatory variable in an R&D function is based on two different arguments. As explained in Section 3, this variable can be viewed both as an environmental and as a financial (past success) determinant. Viewed as an environmental determinant, it reflects the hypothesis that R&D spending is investment and responds roughly to the same environmental conditions as any other type of investment. Viewed as a past success (financial) determinant, it measures the relationship between the industry's expanding (contracting) posture and its R&D investment. It was introduced in our regressions with a lag in order to accomodate this second interpretation.

The statistical performance of this variable in regressions unadjusted for serial correlation is somewhat disappointing - while its coefficients in all linear and some logarithmic regressions have the

expected positive sign, they are not statistically significant. Its negative coefficients in some logarithmic regressions are not significantly different from zero and elimination of this variable from regressions 5 and 6 somewhat improved the goodness of fit. The coefficient in the regression applied to data on all nine sample countries is, however, positive and statistically significant when the data is adjusted for serial correlation.

Industrial Concentration (CONCEN)

Our regressions indicate a strong net positive correlation between industry concentration and R&D intensity. The statistical significance of this determinant of R&D effort is the highest of all our variables. This is so systematically in all functional forms and specifications of our regressions. Furthermore, the magnitude of the estimated coefficients remains remarkably stable from equation to equation. While the economic meaning of the positive correlation between industry concentration and research intensity is subject to the debate alluded to in Section 3 above, it is not inconsistent with the available information on the high absolute cost of a typical R&D project in this industry and its riskiness. A further analysis would require data on the size distribution of firms from which one could make inferences on the minimum threshold size of research establishment and on the correlation of research intensity with firm size.

Foreign Ownership (FOROWN)

In all functional forms and specifications of our regressions, (with one single exception) the degree of foreign ownership is negatively related to R&D intensity. All of the estimated negative coefficients are statistically significant at the 0.05 level in a one-tail test and half of them are significant at the 0.01 level. While the coefficient of this variable becomes positive when data is adjusted for serial correlations it is not statistically significant. The "invisible" transfer of technology to foreign subsidiaries thus seems to depress the intensity of R&D effort in the host countries - a result consistent with much of the literature on foreign ownership.

Patent Protection (PRODPAT)

As expected, there is a positive relationship between the existence of legal provisions for patenting a pharmaceutical product (rather than merely the process or no patent protection at all) and R&D spending in the sample countries. All except five of the estimated coefficients on this dummy variable in our regressions are statistically significant at the 0.05 level in a one-tail test and fourteen of them are significant at the 0.01 level. In our preliminary regressions (results not reported here), we also tried to make a distinction between the absence of product patent protection alone and absence of both product and process patent protection. The latter situation prevailed only in one country in our sample (Italy); it is perhaps for this reason (insufficient variation in the data) that the process patent dummy was not statistically significant and was dropped from

further analysis.

Past Innovative Performance (INNOV) or (PATBAL)

Contrary to prior expectations, none of our several proxies for past innovative success proved to be a statistically significant determinant of R&D intensity. In Tables A - D, we report the estimated coefficients of two such alternative measures; apart from them, we experimented with three different constructs for the sample countries' balance of trade in pharmaceuticals (results not reported here). None of the estimated coefficients was statistically significant at the 0.05 level. Conventional wisdom holds that, in R&D, success breeds success; our results appear to be inconsistent with this hypothesis. It is, of course, well to remember that the dependent variable in our regressions is a measure of research input, rather than output ("success"). Nevertheless, one would expect that the propensity to spend on R&D would be positively correlated with the results of such spending in the same country in the past.

A Comment on Missing Variables

The brief review of theoretical and empirical writings on the determinants of R&D activity in Section 3 and our discussion of the data used in regression analysis make clear the conflict between the number and content of the determinants desired from the point of view of ideal model building and the constraints of data availability. The following three variables are among those which appear highly relevant on theoretical

grounds, but which could not be considered due to lack of information. (There are undoubtedly numerous other variables one could discuss in a similar manner. However, our purpose here is to make a rough judgement about the presence of serious estimation biases in our results, not to provide an exhaustive discussion of all possible R&D determinants).

Regulatory Climate

This is a shorthand expression describing three broad types of regulatory activities which may have considerable effect on the intensity of R&D efforts in a given country: premarketing screening, post-marketing surveillance and control of business practices. In the case of pharmaceutical research, a considerable body of opinion holds that the tightening of regulatory standards related to approval of new drugs in the U.S.A. after 1962 led to a decline in that country's position as a leader in pharmaceutical innovation[33].

The measurement of this determinant of R&D efforts in a cross-section of countries poses a number of problems. They include intercountry differences in the meaning (and the consequent cost of compliance) of the various regulatory requirements, different combinations of regulatory policies in different countries, absence of information on the time lags in administering these policies, etc. Our efforts in obtaining at least a minimum acceptable set of the relevant information proved unsuccessful[34].

If the findings of Peltzman and others are correct (and they have not gone unchallenged), the omission of regulatory climate as an explanatory variable may impart a considerable bias to estimates of R&D

functions. However, both conventional wisdom and such information as may be gained from the available fragments of data suggest that most OECD countries (except the U.S.A. and Canada) have reasonably uniform regulatory environment. This would significantly reduce the size of any estimation bias, since only one of our sample countries used in the forecast is affected.

Tax Climate

While it is plausible to argue that tax level and structure have an effect on industrial R&D, it is not clear whether the overall tax rate or the tax concessions given to R&D are relevant. More importantly, it seems that effective, rather than the nominal, tax rates should be considered. This type of data is typically available only at the level of all industries in a given country; for some countries, we could not even obtain this aggregate information. We were therefore forced to drop this variable from regression analysis. It can, of course, be argued that a good measure of the after-tax profitability of the industry should reflect (ex post) the tax climate and therefore the resulting estimation bias from omitting the tax climate variable is small.

Government Support of R&D

Broadly speaking, this determinant includes not only direct government grants to the private business firms conducting R&D, but also the benefits firms may derive from results of research conducted either directly by government or by government-funded institutions, such as the

universities. The industry breakdown of these benefits is impossible to calculate - even the OECD Census gives the appropriate R&D expenditures only by groups of science fields, not by industry. An inventory of direct government grants and other incentives for R&D has been recently compiled by the OECD[35]. However, very little information is available as to the extent to which each of these instruments is actually being used. In other words, we were unable to construct a quantitative index of dollar equivalents for direct government support of R&D in each of the sample countries.

The extent of the estimation bias resulting from the omission of this variable is uncertain: Howe and McFetridge[36] found that government incentive grants in Canada were a statistically significant determinant of private R&D expenditures only in the electrical industry, but not in the chemical and machinery industries. They stressed that the effect of each determinant of R&D varies not only from industry to industry, but also as between foreign-owned and domestically owned firms.

TABLE A: LINEAR REGRESSION ANALYSIS OF THE DETERMINANTS OF R&D INTENSITY:
ALL SAMPLE COUNTRIES
(t-values in parentheses)

Regression / Variable	1	2	3	4	5	6
CONST	.03999 (1.9)	.03740 (1.8)	.00665 (0.3)	.00517 (0.2)	.01265 (0.8)	.01133 (0.7)
PROFIT	-.00290** - (3.8)	-.00292** - (3.8)				
INVCLIM 1	.03820* (1.7)	.03813* (1.7)	.00999 (0.4)	.00993 (0.4)		
CONCEN	.00191** (8.0)	.00194** (8.6)	.00194** (7.0)	.00196** (7.5)	.00194** (7.1)	.00195** (7.5)
FOROWN	-.00045** - (2.5)	-.00041** - (2.3)	-.00020 - (1.0)	-.00018 - (0.9)	-.00021 - (1.1)	-.00019 - (1.0)
PRODPAT	.01229 (1.4)	.00970 (1.0)	.01600* (1.6)	.01452 (1.4)	.01472* (1.6)	.01334 (1.3)
INNOV		.00015 (0,5)		.00010 (0.3)		.00010 (0.3)
PATBAL	-.00061 - (0.02)		.00135 (0.04)		.00238 (0.07)	
$\bar{R}^2$	0.77	0.77	0.68	0.69	0.69	0.69
F	25.02	25.20	20.17	20.22	25.71	25.77
SEE	.02202	.02196	.02554	.02552	.02528	.02525

** denotes statistical significance at the 0.01 level or better.

* denotes statistical significance at the 0.05 level or better.

The coefficients on CONST and PROFIT are subjected to a two-tail test, since no strong directional hypotheses are extant.

TABLE B: LINEAR REGRESSION ANALYSIS OF THE DETERMINANTS OF R&D INTENSITY:
ALL SAMPLE COUNTRIES EXCEPT CANADA
(t values in parentheses)

Regression / Variable	1	2	3	4	5	6
CONST	.04304* (2.3)	.03899* (2.1)	.01145 (0.6)	.00929 (0.4)	.01326 (0.9)	.01002 (0.7)
PROFIT	-.00276** - (4.0)	-.00271** - (3.8)				
INVCLIM 1	.03011 (1.5)	.02802 (1.4)	.00301 (0.1)	.00119 (0.05)		
CONCEN	.00199** (9.1)	.00206** (9.7)	.00203** (7.8)	.00209** (8.3)	.00203** (7.9)	.00209** (8.4)
FOROWN	-.00107** - (4.5)	-.00101** - (4.1)	-.00088** - (3.1)	-.00087** - (3.0)	-.00088** - (3.2)	-.00087** - (3.1)
PRODPAT	.04286** (3.6)	.04194** (3.2)	.04849** (3.5)	.04989** (3.3)	.04823** (3.5)	.04982** (3.3)
INNOV		-.00040 - (1.2)		-.00051 - (1.3)		-.00051 - (1.3)
PATBAL	-.05114* - (1.6)		-.05273 - (1.4)		-.05262 - (1.4)	
$\bar{R}^2$	0.80	0.80	0.72	0.72	0.73	0.73
F	27.73	26.68	21.02	20.81	27.04	26.78
SEE	.02008	.02040	.02403	.02412	.02369	.02378

** denotes statistical significance at the 0.01 level or better.

* denotes statistical significance at the 0.05 level or better.

(See note below Table A)

TABLE C: LOGARITHMIC REGRESSION ANALYSIS OF THE DETERMINANTS OF R&D INTENSITY:
ALL SAMPLE COUNTRIES
(t-values in parentheses)

Regression / Variable	1	2	3	4	5	6
CONST	-4.23323** - (5.8)	-4.15694** - (6.1)	-4.69637** - (7.1)	-4.71295** - (8.3)	-4.70879** - (7.4)	-4.71617** - (8.8)
PROFIT	- .11688 - (1.4)	- .12218 - (1.4)				
INVCLIM 1	- .02058 - (0.2)	- .01337 - (0.1)	- .01196 (0.1)	- .00255 (0.02)		
CONCEN	.61302** (3.3)	.58670** (4.3)	.63800** (3.4)	.64728** (4.9)	.63855** (3.4)	.64779** (5.1)
FOROWN	-.12713* - (2.1)	-.13027** - (2.5)	-.10454* - (1.8)	-.10591* - (2.1)	-.10465* - (1.8)	-.10594* - (2.2)
PRODPAT	.28767* (2.2)	.26909* (1.7)	.31229** (2.4)	.33476* (2.1)	.31240** (2.5)	.33535* (2.2)
INNOV		.01477 (0.3)		-.01256 - (0.2)		-.01301 - (0.3)
PATBAL	.00901 (0.2)		-.00368 - (0.07)		-.00451 - (0.1)	
$\bar{R}^2$	0.72	0.72	0.72	0.72	0.72	0.72
F	20.17	20.19	23.21	23.25	29.75	29.81
SEE	.26979	.26966	.27320	.27302	.26980	.26959

** denotes statistical significance at the 0.01 level or better.

* denotes statistical significance at the 0.05 level or better.

(See note below Table A)

TABLE D: LOGARITHMIC REGRESSION ANALYSIS OF THE DETERMINANTS OF R&D INTENSITY:
ALL SAMPLE COUNTRIES EXCEPT CANADA
(t-values in parentheses)

Regression / Variable	1	2	3	4	5	6
CONST.	-5.44732** - (6.6)	-4.84260** - (6.7)	-5.84636** - (8.0)	-5.30851** - (9.0)	-5.84140** - (8.3)	-5.30201** - (9.5)
PROFIT	- .08307 - (1.0)	- .09425 - (1.1)				
INVCLIM 1	- .02778 - (0.2)	- .01837 - (0.1)	- .00441 - (0.04)	- .00515 - (0.04)		
CONCEN.	.95965** (4.4)	.73797** (5.0)	.99971** (4.7)	.79396** (5.7)	.99938** (4.7)	.79293** (5.9)
FOROWN	-.11113* - (1.9)	-.14492** - (2.9)	-.09447* - (1.7)	-.12752** - (2.6)	-.09443* - (1.7)	-.12747** - (2.7)
PRODPAT	.38041** (3.0)	.36895** (2.3)	.40365** (3.2)	.42517** (2.8)	.40358** (3.3)	.42398** (2.8)
INNOV		.04399 (0.8)		.02553 (0.5)		.02628 (0.5)
PATBAL	.07150 (1.4)		.06691 (1.3)		.06719 (1.3)	
$\bar{R}^2$	0.72	0.71	0.72	0.71	0.73	0.72
F	17.65	16.83	20.93	19.83	26.94	25.52
SEE	.25764	.26236	.25787	.26316	.25417	.25938

** denotes statistical significance at the 0.01 level or better.

* denotes statistical significance at the 0.05 level or better.

(See note below Table A)

TABLE E: LINEAR REGRESSION ANALYSIS OF THE DETERMINANTS OF R&D INTENSITY: COMPARISON OF RESULTS ADJUSTED AND UNADJUSTED FOR SERIAL CORRELATION

(t-values in parentheses)

Regression / Variable	All sample countries		Sample countries except Canada	
	Unadjusted	Adjusted	Unadjusted	Adjusted
CONST	.03740* (1.8)	.00748* (1.7)	.03899* (2.1)	.01017* (1.9)
PROFIT	-.00292** -(3.8)	-.00566** -(4.1)	-.00271** -(3.8)	-.00095 -(0.9)
INVCLIM 1	.03813* (1.7)	.05505** (3.4)	.02802 (1.4)	.02176 (1.1)
CONCEN	.00194** (8.6)	.00298** (6.4)	.00206* (9.7)	.00184** (4.4)
FOROWN	-.00041** -(2.3)	.00029 (1.0)	-.00101** -(4.1)	-.00122** -(2.6)
PRODPAT	.00970 (1.0)	.01633 (1.4)	.04194** (3.2)	.06944** (3.3)
INNOV	.00015 (0.5)	.00047 (1.5)	-.00040 -(1.2)	-.00055 -(1.2)
$\bar{R}^2$	0.77	0.94	0.80	0.90
F	25.20	85.98	26.68	49.44
SEE	.02196	.01408	.02040	.01642

** denotes statistical significance at the 0.01 level or better.

* denotes statistical significante of the 0.05 level or better.

(See note below Table A)

NOTE: The unadjusted results are those reported in col. 2 of Tables A and B.

TABLE F: LINEAR REGRESSION ANALYSIS OF THE DETERMINANTS OF R&D INTENSITY: SIMPLE CORRELATION COEFFICIENTS

Regressions unadjusted for serial correlation (all sample countries)

	PROFIT	INVCLIM1	CONCERN	FOROWN	PRODPAT	INNOV	RES INT
PROFIT	1						
INVCLIM1	.48	1					
CONCEN	.29	.17	1				
FOROWN	-.55	-.31	-.54	1			
PRODPAT	-.35	-.37	-.30	-.28	1		
INNOV	.03	-.09	-.19	-.21	.52	1	
RESINT	.05	.15	.83	-.53	.11	-.02	1

Regressions adjusted for serial correlation (all sample countries)

	PROFIT	INVCLIM1	CONCEN	FOROWN	PRODPAT	INNOV	RES INT
PROFIT	1						
INVCLIM1	.85	1					
CONCEN	.98	.83	1				
FOROWN	.07	.19	-.05	1			
PRODPAT	-.08	.03	-.14	.67	1		
INNOV	.05	.11	.01	.15	.59	1	
RESINT	.88	.86	.92	.06	.09	.18	1

6. "FORECAST" OF R&D INTENSITY OF THE CANADIAN PHARMACEUTICAL INDUSTRY

Introduction

In the previous section, we discussed in detail the results of our regression analysis of the determinants of R&D intensity in the sample countries. On the basis of standard statistical criteria, the linear functional form of the regression equation which includes all seven explanatory variables was identified as giving the best fit. On purely statistical grounds, there is little difference between the two versions of this regression (equations 1 and 2). For purposes of forecasting, we have chosen equation 2 over equation 1 since the variable INNOV it contains is slightly easier to interpret than the variable PATBAL. The selected equation was adjusted to remove the effects of serial correlation of residuals (neither a test of nor an adjustment for heteroskedasticity was possible due to insufficient number of observations).

Here we develop a forecast of R&D intensity for the pharmaceutical industry in Canada. In essence, we take the observed Canadian levels of each of its determinants and multiply them by the magnitudes of the relationship between each determinant and the R&D intensity which prevails in sample countries other than Canada (i.e., the regression coefficients presented in the last column of Table E above).

In estimating the regression coefficients from a data base which consists of a cross-section of countries we of course implicitly assume that any given variable "contributes" equally to the R&D intensity in each sample country. The forecasting procedure extends the scope of this

assumption to include Canada. This interpretation of the estimated coefficients is strictly true only if all relevant inter-country differentials are accounted for in the regression. However, as discussed at length above, data availability, conceptual and measurement problems and other reasons made it impossible to incorporate some of these variables in our regressions. Nevertheless, the relatively high proportion of data variance accounted for by our regressions justifies confidence in the validity and robustness of our procedure.

Forecast Results

The point forecasts together with 95 percent confidence intervals are calculated in Table G separately for each of the OECD Census years. They suggest that, given the actual Canadian levels of the determinants, the pharmaceutical industry in Canada need not have spent anything at all on R&D in any one of these years.

Specifically, the calculations in Table G show the overpowering influence of the foreign ownership variable. Its estimated regression coefficient is negative (-.00122) and the level of foreign ownership in this industry in Canada is very high (almost 85 percent). The negative "contribution" of foreign ownership to R&D intensity (based on the point forecast) is thus equal to minus 10.33 percent of production value which does not have to be spent on R&D if Canada were to follow the degree of dependence on transfer of technology resulting from foreign ownership which is the norm in the other sample countries.

The degree of industry concentration observed in Canada "requires"

the spending of 2.58 percent of production value on R&D. The characteristics of the investment climate over the period in question add the requirement of additional 0.09 to 1.29 percent of production value, depending upon the year. The magnitudes of net profitability in the Canadian industry reduce the R&D spending requirements by anywhere from 0.76 to 0.97 percent of production value. Because of the absence of patent protection on pharmaceutical products, the industry in Canada is "justified" in spending exactly zero on R&D. Finally, adding the contribution of the past innovative performance (with its implausible negative sign) reduces the R&D spending requirements of the Canadian industry by about 0.03 percent of production value. (All figures in this paragraph refer to the point forecast).

Due to the large negative contribution of the foreign ownership variable, the overall R&D intensity forecast for the pharmaceutical industry in Canada is a negative number. The meaning of this result is clear when looked at in conjunction with the actual R&D intensities reported below Table G: Given the observed Canadian magnitudes of the determinants of R&D intensity and the average spending response to each of them in the other industrialized countries (as measured by the estimated regression coefficients), the industry in Canada has been spending more than would correspond to the standard of the rest of the sample OECD countries.

Test of Structural Difference

As already mentioned, the validity of inter-country comparisons of R&D intensity and thus also the validity of a "forecasting" procedure such as ours cannot be taken for granted. It depends on whether or not the Canadian pharmaceutical industry is a part of the same "universe" as the industry in other OECD countries. In other words, it is necessary to test the hypothesis that the observations on the dependent and independent variables for Canada come from the same population or structure as that presumed to have generated the observations for all other countries in the sample.

The appropriate statistic is:[37]

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

where

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

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

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

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

c = vector of magnitudes of independent variables for Canada.

If the calculated t-value exceeds a pre-selected critical value, the

observations for Canada can be presumed to have come from a different structure.

We have calculated the t-values based on observations for Canada averaged out over the five census years, both for regressions adjusted and unadjusted for serial correlations. The t-value calculated from linear regression unadjusted for serial correlation was -3.234, i.e., larger than the critical value of t at 99.5 percent confidence level (which for 30 degrees of freedom is -2.750). However, the t-value calculated from data adjusted for serial correlation - to be preferred on statistical grounds - is only 1.37, i.e., smaller than the critical value at 95 percent confidence level, which is 1.697 (although larger than the critical value at the 90 percent level).

The test results are thus not completely clear-cut, but, on balance, they suggest with some component of ambiguity that Canada's pharmaceutical industry is not different from the rest of the OECD sample countries. It is to be regretted that our sample size did not permit of the more rigorous Chow-test. The t-test we did employ is so labour- and computer-intensive in its construction that we could not apply it within our budget constraint on a country-by-country basis, such as the U.S. vs. the rest, Belgium vs. the rest, etc. For what it is worth we opine that, faced with the same task and data availability, other investigators would find it difficult to suggest a different set of countries for comparison; and the basic policy issue, as we understand it, always focuses on inter-country comparisons.

TABLE G: R&D INTENSITY -- FORECAST FOR CANADA

	Estimated coeff.	1967		1969		1971		1973		1975	
		Level	Forecast	Level	Forecast	Level	Forecast	Level	Forecast	Level	Forecast
CONST	.01017	1.0	.01017	1.0	.01017	1.0	.01017	1.0	.01017	1.0	.01017
PROFIT	-.00095	8.0	-.00760	8.4	-.00798	8.0	-.00760	8.8	-.00836	10.2	-.00969
INVCLIM 1	.02176	.426	.00927	.500	.01088	.514	.01118	.549	.00119	.594	.01292
CONCEN	.00184	14.0	.02576	14.0	.02576	14.0	.02576	14.0	.02576	14.0	.02576
FOROWN	-.00122	84.7	-.10333	84.7	-.10333	84.7	-.10333	84.7	-.10333	84.7	-.10333
PRODPAT	.06944	0	0	0	0	0	0	0	0	0	0
INNOV	-.00055	.5	-.00027	.5	-.00027	.5	-.00027	.5	-.00027	.5	-.00027
POINT FORECAST R&D INTENSITY			-.06600		-.06477		-.06409		-.07484		-.06444
FORECAST INTERVAL (95%)		-.06629	-.06571	-.06506	-.06448	-.06438	-.06380	-.07513	-.07455	-.06473	-.06415
ACTUAL R&D INTENSITY			.0355		.0376		.0325		.0404		.0439

Source: Table E (linear regression adjusted for serial correlation) and Appendix tables 1-14.

7. SUMMARY AND CONCLUSIONS

Drawing upon the theoretical and empirical literature on the determinants of R&D spending, we have identified several groups of variables which appear relevant for an analysis of pharmaceutical research efforts. As explained in a detailed discussion of the problems with measurement and data availability above, our regression analysis of R&D intensity in a cross-section of countries had to rely on a number of proxies and some variables suggested by theory could not be considered.

Our results show that for a sample of nine industrialized countries the concentration of the industry, degree of its foreign ownership and patent protection are statistically the most significant determinants of R&D intensity. The past success of the industry as an innovator does not appear to be an important factor in influencing current R&D spending. Similarly, the variable describing the investment climate in the industry in each sample country proved not important. Finally, R&D spending is negatively related to our measure of net profitability of the industry, possibly because it is competing for the flow of funds in member firms of the industry.

Our best regression equation (adjusted for serial correlation) was applied to the task of calculating ("forecasting") the "expected" R&D intensity for Canada. It was shown that in each of the five sample periods, the actually observed R&D intensity in Canada (ranging from 3.25 to 4.39 percent of production value) is much higher than the calculated "expected" magnitude. This result is qualified by our finding that

Canada's pharmaceutical industry may not actually belong to the same "statistical universe" common to the criterion OECD countries. It would not be prudent to hang one's hat on a solitary statistical test, yet one cannot exclude entirely the subversive thought that in this - and possibly other industries - international comparisons are made too lightly.

The study focused exclusively on pharmaceutical R&D spending in the business sector of the sample countries. It should be recognized, however, that the magnitude and nature of related research performed by government institutions and universities vary from country to country. Such research may - at least indirectly - compensate to varying degrees for the shortfall in business sector's spending in different countries. The required information is, unfortunately, not available in sufficiently detailed breakdown to allow the appropriate econometric corrections.

The overwhelming importance of structural variables such as industry concentration and foreign ownership in our regressions indicates that the scope for "pinpoint" policy-induced changes in R&D intensity is rather limited. In other words, to the extent that the structural factors have to be treated as given, public policy would seem to have little leverage. This is, of course, not so in the case of patent protection, shown in our regressions to be a statistically significant determinant.

The effects of factors such as the regulatory climate, tax incentives, and direct government support for R&D we were not able to assess due to lack of statistical information. While data limitations made it impossible for us to evaluate the quantitative importance of such policy tools, indirect evidence from other sources makes us skeptical as to their

potential. For example, in a 1972 submission to a Committee of the U.S. Congress[38] the Pharmaceutical Manufacturers Association reported on the results of a survey of its member companies regarding the reasons for establishing overseas affiliates. Tariff and trade restrictions (listed by 95 percent of respondents as "important"), legal requirements for local production (85 percent) and "better servicing of existing work" (81 percent) were by far the leading considerations. Policy measures such as "tax benefits including host country incentives" ranked way down the list (33 percent of respondents considered them "important") as did intangibles, such as access to scientific research laboratories (14 percent). It seems logical to assume that the finding of relative weakness of tax and other incentives holds a fortiori for the location of R&D facilities (and thus the level of R&D intensity).

In conclusion, we would like to stress the positive outcomes of our study. We believe that our undertaking has demonstrated that a theory-based, reasonably rigorous approach to the policy-oriented question "Is a Canadian industry spending enough on R&D?" is possible and yields a statistically verifiable answer. We also think that we have given an indication as to what additional variables - which we were not able to construct - would be important to consider, at least in principle, before a necessarily costly policy of R&D stimulation is embarked upon. A further elaboration of the modelling approach used here, and especially the quest for plausible proxy variables which would circumvent data scarcity, calls for additional research to which we, at least, will not remain strangers.

FOOTNOTES

1. The two exceptions are an old caveat by B.R. Williams, Industrial Research and Economic Growth in Australia, Adelaide: The Griffin Press, 1962 and Technology, Investment and Growth, London: Chapman and Hall, 1967 and a recent table (Table 3) in a Ministry of State for Science and Technology background paper No. 3, "Importation of Invisible R&D, 1974/1976", Ottawa, July 1978.

2. A.E. Safarian, "Foreign Ownership and Industrial Behaviour: A Comment on the 'Weakest Link'", Canadian Public Policy, V. 3, Summer 1979, 328.

3. E. Mansfield, "R&D's Contribution to the Economic Wealth of the Nation," Research Management (May, 1972), 31-46.

4. C. Freeman, "Technical Innovation and British Trade Performance," in F. Blackaby (ed.), De-industrialisation, London: Heinemann, 1979.

5. H. Heyvaert and F. Martou, Innovation, Strategie, Politique de Produit, Universite de Louvain, 1972. Success and Failure in Industrial Innovation, Report on Project SAPPHO, Centre for the Study of Industrial Innovation, London, Feb. 1972.

6. I.A. McLean and D.K. Round, "Research and Product Innovation in Australian Manufacturing Industries," Journal of Industrial Economics, (Sept. 1978), 1-11.

7. J.N.H. Britton and J.M. Gilmour, The Weakest Link, Ottawa: The Science Council of Canada, October 1978.

8. F.M. Scherer, Industrial Market Structure and Economic Performance, Second Edition, Chicago: Rand McNally, 1980, Ch. 15.

9. For a brief and illuminating description of the innovational maze behind modern drugs consult W.W. Wardell, "The History of Drug Discovery, Development and Regulation," in R.I. Chien (ed.), Issues in Pharmaceutical Economies, Lexington, MA: Lexington Books, 1979.

10. Z. Griliches, "Issues in Assessing the Contribution of Research and Development to Productivity Growth," Bell Journal of Economics, (Spring 1979), 92-116.

11. See the above mentioned MOSST (June 1978) paper.

12. H.G. Grabowski, "The Determinants of Industrial Research and Development: A Study of the Chemical, Drug and Petroleum Industries," Journal of Political Economy (1968), 292-306. For a Canadian investigation see J.D. Howe and D.G. McFetridge, "The Determinants of R&D Expenditures", Canadian Journal of Economics (1976), 57-71.

13. K. Schott, "The Relations Between Industrial Research and Development and Factor Demands," Economic Journal (March 1978), 85-106.

14. B.S. Branch, "Research and Development Activity and Profitability: A Distributed Lag Analysis," Journal of Political Economy 82 (Sept./Oct. 1976), 999-1011.

15. These difficulties are well illustrated by Branch, op.cit., and J.W. Elliott, "Funds Flows vs. Expectational Theories of R&D Expenditures in the Firm," Southern Economic Journal (April 1971), 409-422.

16. M.I. Kamien and N.L. Schwartz, "Market Structure and Innovation: A Survey," Journal of Economic Literature 13 (March 1975), 1-37.

17. K. Clarkson, Intangible Capital and Rates of Return (Washington, D.C.: American Enterprise Institute, 1977).

18. Profitability for the pharmaceutical industry in a number of countries is occasionally reported in trade periodicals and similar publications. However, the figures are usually not comparable across countries: some relate profits to equity, some to assets and some to sales. In addition, human pharmaceuticals are sometimes separated from the rest of the industry operations and sometimes profitability is reported only for the aggregate.

19. S. Peltzman, Regulation of Pharmaceutical Innovation (Washington, D.C.: American Enterprise Institute, 1975).

20. H.A. Clymer, "The Economic and Regulatory Climate: U.S. and Overseas Trends," in R.B. Helms (ed.), Drug Development and Marketing (Washington, D.C.: American Enterprise Institute, 1975).

21. H.G. Grabowski, J.M. Vernon, L.G. Lacy, "Estimating the Effects of Regulation on Innovation: An International Comparative Analysis of the Pharmaceutical Industry," Journal of Law and Economics, (April 1978), 133-163.

22. OECD, Policy for the Stimulation of Industrial Innovation, Annalytical Report, Paris 1978.

23. Scherer, op.cit.

24. H.G. Grabowski and J.M. Vernon, "New Studies on Market Definition, Concentration, Theory of Supply, Entry and Promotion," in R.I. Chien (ed.), Issues in Pharmaceutical Economics, op.cit.

25. The degree of a country's health-sciences socialization was beyond our means to quantify. While some sketchy information is available, quantitative analysis of the influence of this factor on research outlays has appeared. (Consult R.I. Chien, "The Effect of National Health Insurance on the Economics of the Drug Industry," in Chien (ed.), op.cit., and A. Blomquist, The Health Care Business: International Evidence on Private versus Public Health Care Systems (Vancouver: The Fraser Institute, 1979).

26. See the V.3 (Summer 1979) issue of Canadian Public Policy.

27. P. Bourgault, Innovation and the Structure of Canadian Industry, Special Study No. 23 (Ottawa: Science Council of Canada, October 1972).

28. A.J. Cordell, The Multinational Firm, Foreign Direct Inverstment, and Canadian Science Policy, Special Study No. 22 (Ottawa: The Science Council of Canada, Dec. 1971).

29. OECD, Directorate for Scientific Affairs, International Survey of the Resources Devoted to R&D by OECD Member Countries, various years.

30. OECD, The Measurement of Scientific and Technical Activities. Proposed Standard Practice for Surveys of Research and Experimental Development ("Frascati Manual"), Paris 1976.

31. R. Linda, Methodology of Concentration Analysis Applied to the Study of Industries and Markets, Commission of the European Communities, September 1976.

32. See e.g., J. Kmenta, Elements of Econometrics, New York: Macmillan 1971, pp. 508-517.

33. A rigorous analysis of the costs and benefits of this regulatory change is in S. Peltzman, "An Evaluation of Consumer Protection Legislation: The 1962 Drug Amendments," Journal of Political Economy, Vol. 81, No. 5, Sept./Oct. 1973. For a summary of the debate surrounding this issue see R.W. Hansen, "Regulation and Pharmaceutical Innovation: A Review of the Literature on Monetary Measures of Costs and Benefits", Discussion Paper GPB 77-9, Graduate School of Management, University of Rochester, June 1977.

34. For a list of some 25 such regulatory policies and an indication of their presence/absence in a small sample of industrialized countries see U.N. Commission on Transnational Corporation, Transnational Corporations and the Pharmaceutical Industry. Report by the Secretariat, March 8, 1979, p. 187.

35. OECD, Selected Industrial Policy Instruments. Objective and Scope, Paris 1978 and OECD, Policies for the Stimulation of Industrial Innovation, Paris 1978.

36. J.D. Howe and D.G. McFetridge, op.cit.

37. See e.g. J. Johnston, Econometric Methods, Second Edition (New York: McGraw-Hill, 1972), pp. 152-155.

38. Pharmaceutical Manufacturers Association, Survey of Potential Effects on U.S. Pharmaceutical Industry of Burke-Hartke Bill S. 2592, 92nd Congress, Washington, D.C., August 1972.

TABLE 1: R&D EXPENDITURES IN THE DRUG INDUSTRY, SELECTED COUNTRIES AND SELECTED YEARS
(BUSINESS ENTERPRISE SECTOR, INTRAMURAL EXPENDITURES, NATURAL SCIENCES AND ENGINEERING)

Country \ Year	1967	1969	1971	1973	1975
Canada (mill $)	10.5	12.5	14.2	20.1	28.0
Belgium (mill BFr)	339.3	442.9	743.4	787.5	1,312.4
Denmark (mill DKr)	42.2[2]	55.5[2]	65.5[2]	114.4[1]	118.4[1]
Finland (mill M)	N.A.	7.1	11.8	16.4	26.6
France (mill Fr)	210.6	329.3	476.1	590.1	808.0
Italy (mill Lire)	16,270.0	21,788.0	39,251.0	48,320.0	73,958.0
Japan (mill Yen)	18,068.0	29,656.0	55,740.0	64,406.0	95,191.0
Sweden (mill SKr)	69.2	92.2	120.4	154.4	195.1
U.K. (mill £)	29.6[3]	18.9[4]	24.2	41.9[5]	78.7
U.S.A. (mill $)	304.0	437.0	512.0	618.0	981.0

Source: OECD, Directorate for Scientific Affairs, International Survey of the Resources Devoted to R&D by OECD Member Countries, Various years

Notes:

1) Includes all or some R&D in the Social Sciences and Humanities.

2) Source: Questionnaire completed by Foreningen af Danske Medicinfabrikker, The figures reported in the questionnaire (38 mill, 50 mill, and 59 mill for 1967, 1969 and 1971, respectively) represent 90% of national pharmaceutical research expenditures incurred in domestic operations. The questionnaire data was therefore adjusted upward to account for 100% of R&D expenditures.

3) Funds received from abroad and from government sources include extramural expenditures.

4) Funds received from abroad include current expenditure and depreciation. This figure is also reported as "R&D expenditures" in Scrip, May 1, 1976, p. 4.

5) Reporting period is 1972.

TABLE 2: MANPOWER WORKING ON R&D IN THE DRUG INDUSTRY (FULL-TIME EQUIVALENTS)

Country \ Year	1967	1969	1971	1973	1975
Canada	683	626	750	841	972
Belgium	670[1]	774	1,125	918	1,023
Denmark	N.A.	N.A.	422[2]	911	814[3]
Finland	N.A.	197	231	285	381
France	3,935	4,844	5,461	5,716	6,162
Italy	2,802	3,337[4]	5,041[4]	5,034[5]	5,123
Japan	8,932[5,6]	10,137[5]	15,455[5,6]	14,925[5]	14,970
Sweden	877	1,163	1,291	1,275	1,273
U.K.	N.A.	N.A.	N.A.	8,579[5]	10,100[5]
U.S.A.[7]	8,800[8]	11,000	11,600	11,200	15,500

Source: OECD, Directorate for Scientific Affairs, International Survey of Resources Devoted to R&D by OECD Member Countries, Various Years

Notes:

1) Excluding clerical staff.
2) Reporting period 1970.
3) Includes all or some R&D in Social Sciences, and Humanities.
4) Categories "workers" and "others" include only persons working full time.
5) Not in full-time equivalent.
6) Working mainly on R&D.
7) Research scientists and engineers only.
8) Reporting period 1966.

TABLE 3: FOREIGN OWNERSHIP OF PHARMACEUTICAL INDUSTRY IN 1973
(PERCENTAGE OF TOTAL MARKET BY VALUE SUPPLIED BY FOREIGN-OWNED COMPANIES)

Canada	84.7
Belgium[1]	76.0
Denmark[2]	1.0
Finland	N.A.
France[3]	37.8
Italy	44.5
Japan	23.4
Sweden[2]	1.0
U.K.	63.7
U.S.A.	16.0

Sources: B.G. James, The Future of the Multinational Pharmaceutical Industry to 1990, Associated Business Programmes Ltd., London 1977, p. 35 and p. 45.

OECD, Impact of Multinational Enterprises on National Scientific and Technical Capacities. Pharmaceutical Industry, Paris: December 1977.

FOOTNOTES TO TABLE 3

1) Figure for 1972. Estimated from EEC, Etude sur l'évolution de la concentration dans l'industrie pharmaceutique en Belgique, November 1975, pp. 37-39, 55 and identification of pharmaceutical enterprises under foreign control on pp. 59-77.

2) OECD, op.cit., p. 71 describes the percentage of domestic market supplied by foreign subsidiaries as "very low" - the reported percentages of the market (rounded) supplied by indigenous producers and by imports add up to 100.

3) After the acquisition of Roussel by Hoechst, this figure rises sharply to 60 percent. Source: James, op.cit., p. 45.

TABLE 3A: FOREIGN OWNERSHIP OF PHARMACEUTICAL INDUSTRY

(PRODUCTION BY FOREIGN-OWNED COMPANIES[1] AS PERCENTAGE OF TOTAL NATIONAL PRODUCTION)

	1970	1972	1973	1975
Canada		84.7		
Belgium			76.0	
Denmark[3]			0.8	
Finland			N.A.	
France			48.3	
Italy			34.1	
Japan[2]	8.7	6.3		10.3
Sweden[3]			1.6	
U.K.	29.6			
U.S.A.			15.7	

Source: OECD, Impact of Multinational Enterprises on National Scientific and Technical Capacities. Pharmaceutical Industry, Paris· December 1977.

Notes:

1) Based on OECD, op.cit., p. 71. The figure for "per cent supplied by foreign subsidiaries" was recalculated using "Production plus Exports minus Imports" as the base.

2) Data for 1970 and 1975 taken from OECD, op.cit., p. 205.

3) The share of the market supplied by foreign subsidiaries is indicated as "very low" (OECD, op.cit., p. 71). When figures from Table 3 are recalculated using "Production plus Exports minus Imports" as a base, the shares of foreign ownership for Denmark and Sweden are, respectively, 0.8 percent and 1.6 percent.

TABLE 4: FOUR-FIRM CONCENTRATION RATIO, SALES OF PRESCRIPTION DRUGS, 1969 and 1973

	1969	1973
Canada	21.2[1]	14.0[2]
Belgium	42.8	41.9
Denmark	N.A.	68.0
Finland	N.A.	N.A.
France	N.A.	20.0
Italy	32.3	N.A.
Japan	23.6[3]	22.3[4]
Sweden	N.A.	68.1[5]
U.K.	29.5	28.8
U.S.A.	26.1	27.8

Sources:

STUDIA, Etude sur l'évolution de la concentration dans l'industrie pharmaceutique en Belgique, Commission des Communautés Européennes, Novembre 1975

K. Blunden, Etude sur l'évolution de la concentration dans l'industrie pharmaceutique en France, Commission des Communantés Européennes, Novembre 1975

J.B. Heath et al., A Study of the Evolution of Concentration in the Pharmaceutical Industry for the United Kingdom, Commission of the European Communities, October 1975

ATOR, MILAN, Tableaux de Concentration, "Pharmaceutique", Italie, Commission des Communautés, Européennes, 1973

H.G. Grabowski, J.M. Vernon, Structural Effects of Regulation on Innovation in the Ethical Drug Industry, in: R.T. Masson and P.D. Qualls, eds., Essays on Industrial Organization in Honor of Joe S. Bain, Ballinger 1976, pp. 181-205

Sources, Table 4 (cont.)

OECD, Impact of Multinational Enterprises on National Scientific and Technical Capacities. Pharmaceutical Industry, Paris, December 1977, p. 67

Canada, Department of Consumer and Corporate Affairs, Concentration in the Manufacturing Industries in Canada, Ottawa: Information Canada, 1971.

T. Nakao, "Profit Rates and Market Shares of Leading Industrial Firms in Japan", Journal of Industrial Economics, Vol. XXVII, June 1979.

FOOTNOTES TO TABLE 4

1) Figure for "Total Manufacturers of Pharmaceuticals and Medicines" in 1965. Concentration ratio for "Manufacturers of Ethical Drugs" in the same year was 30.8. Source: Department of Consumer and Corporate Affairs, op.cit.,p. 69. The base for this ratio is the value of industry shipments (domestic plus exports).

2) Figure for 1970. Source: OECD, op.cit., p. 67. The base for this ratio is the "Volume of National Sales", i.e., "Production plus Imports minus Exports."

3) Three-firm concentration ratio given in: Japan Fair Trade Commission, Industrial Concentration in Japan 1966-1966. Tokyo: 1969. (Quoted from T. Nakao, op.cit., p. 381).

4) Figure for 1974. Sales of four largest firms taken from OECD, op.cit., p. 182 and divided by "Production plus Imports minus Exports" for that year.

5) OECD, op.cit., p. 66 gives the share of Swedish Production accounted for by four largest firms as 90 percent. This amounts to $168.3 mill in 1973 and represents 68.1% of the total value of "Production + Imports - Exports" in that year.

TABLE 5: PRODUCTION OF PHARMACEUTICALS, SELECTED OECD COUNTRIES
(MILLIONS OF NATIONAL CURRENCY)

Year / Country	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Canada	205	236	263	296	320	332	360	437	459	497	575	637	711
Belgium	3,077	3,475	3,550	3,850	5,800	6,800	8,300	9,188	9,903	11,264	15,038	16,441	16,677
Denmark	485	441	401	388	413	443	450	660	730	792	969	1,080	1,239
Finland	64	77	80	88	109	134	147	167	191	191	238	265	313
France	4,052	5,108	4,769	5,204	5,727	6,379	7,182	8,660	9,271	10,168	11,438	12,962	13,894
Italy	334,893	359,827	400,000	425,000	450,000	470,000	559,375	601,332	669,537	845,350	1,335,148	1,449,980	2,238,028
Japan	421,003	458,704	506,817	562,931	689,040	843,120	1,017,000	1,044,243	1,080,890	1,369,661	1,645,574	1,806,325	N.A.
Sweden	263	300	362	414	445	492	642	609	714	817	1,012	1,179	1,389
U.K.	216	248	218	230	243	276	312	333	367	451	539	674	828
U.S.A.	3,929	4,386	4,826	5,256	5,759	6,335	6,793	7,400	8,071	8,386	9,479	8,059	8,764

Sources: OECD, The Chemical Industry, Various issues (all data in U.S. dollars, as reported in Table 11 below).

IMF, International Financial Statistics, Various issues (exchange rate series "rf" or "trade conversion factor" or "spot rate at end of period").

TABLE 6: PHARMACEUTICAL PATENT LEGISLATION IN SELECTED OECD COUNTRIES, 1973-1976

	Allowable Claims	
	Process patent	Product patent
Canada	Yes	No
Belgium	Yes	Yes
Denmark	Yes	No
Finland	Yes	No
France	Yes	Yes
Italy	NO	No
Japan	Yes	No
Sweden	Yes	No
U.K.	Yes	Yes
U.S.A.	Yes	Yes

Source: J.W. Baxter, World Patent Law and Practice, Matthew Bender, New York, 1968-1979, Appendix 2

TABLE 7: PATENTS FOR "DRUGS AND MEDICINES" TAKEN IN THE U.S. BY SELECTED OECD COUNTRIES[1], 1963-1975 (CUMULATIVE)[2]

Year / Country	1963	1963-1964	1963-1965	1963-1966	1963-1967	1963-1968	1963-1969	1963-1970	1963-1971	1963-1972	1963-1973	1963-1974	1963-1975
Canada	6	18	37	56	69	77	100	124	139	151	166	201	230
Belgium	5	7	11	17	27	32	36	36	41	48	50	59	68
Denmark	3	8	11	16	22	22	27	30	37	45	51	56	63
Finland	0	0	0	0	0	0	0	0	1	1	1	1	2
France	40	93	140	182	239	259	314	353	408	475	541	633	754
Italy	17	45	68	93	112	122	145	163	183	219	236	274	311
Japan	23	58	98	161	215	253	313	366	420	520	599	736	886
Sweden	6	6	13	24	34	40	45	52	67	84	108	126	147
U.K.	29	78	121	169	226	258	310	343	380	448	502	582	691
All foreign countries	318	670	1,064	1,508	1,896	2,117	2,563	2,945	3,314	3,902	4,441	5,161	6,003

Source: U.S. Department of Commerce, Patent and Trademark Office, Patent Activity (1963-1976E) by Date of Patent Grant, SIC 283-DRUGS AND MEDICINES, Special Tabulation

FOOTNOTES TO TABLE 7

1) Country of origin is determined by the residence of the first-named inventor. The figures in this table therefore differ from those given in U.S. Department of Commerce, Patent and Trademark Office, Technology Assessment and Forecast, Eight Report, December 1977, Appendix A, p. 117, where the "country of origin" is the country in which the patent application on the invention was filed.

2) The figures in each column represent the total number of patents granted since 1963 (the earliest year for which data is available) up to and including the year in the column heading.

TABLE 8: PATENT BALANCE[1] FOR "DRUGS AND MEDICINES", SELECTED OECD COUNTRIES VS. THE U.S., 1963-1975 (PERCENTAGES)

Year / Country	1963	1963-1964	1963-1965	1963-1966	1963-1967	1963-1968	1963-1969	1963-1970	1963-1971	1963-1972	1963-1973	1963-1974	1963-1975
Canada	.019	.027	.035	.037	.036	.096	.039	.042	.042	.039	.037	.039	.038
Belgium	.016	.011	.010	.011	.014	.015	.014	.012	.012	.012	.011	.011	.011
Denmark	.009	.012	.010	.011	.012	.010	.011	.010	.011	.016	.012	.011	.011
Finland[2]	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
France	.126	.139	.132	.121	.126	.122	.123	.120	.123	.122	.122	.123	.126
Italy	.054	.067	.064	.062	.060	.058	.057	.055	.055	.056	.053	.053	.052
Japan	.072	.086	.092	.107	.113	.120	.122	.124	.127	.133	.135	.143	.148
Sweden	.019	.009	.012	.016	.018	.019	.018	.018	.020	.022	.024	.024	.025
U.K.	.091	.116	.114	.112	.120	.122	.121	.117	.115	.115	.113	.113	.115
U.S.A.	.481	.446	.481	.481	.481	.481	.481	.481	.481	.481	.481	.481	.481

Source: Table 7

FOOTNOTES TO TABLE 8

1) "Patent balance" is defined as the ratio of the number of drug patents a given country took out in the U.S. to the total number of patents taken out in the U.S. by all foreign countries.

2) No patents taken out until 1970; after that date, the first non-zero number in the ratio appears on the fourth decimal place.

TABLE 9: COMPARISON OF PROFITABILITY[1] IN THE "CHEMICAL PRODUCTS INDUSTRY" IN SELECTED OECD COUNTRIES[2], 1966-1976 (CUMULATIVE)

Year / Country	1966	1966-1967	1966-1968	1966-1969	1966-1970	1966-1971	1966-1972	1966-1973	1966-1974	1966-1975	1966-1976
Canada	8.5	8.0	8.2	8.4	8.0	8.0	8.1	8.8	10.0	10.2	10.3
Belgium[3]	- 2.2	- 3.6	- 0.2	2.5	5.0	6.1	7.8	11.1	14.5	13.0	12.6
Denmark	0.0	25.0[4]	23.1[4]	26.3[4]	23.1[4]	20.6[4]	18.2	19.6	22.4[4]	25.8	30.5[4]
Finland	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
France	8.5	8.2	7.4	9.1	10.0	10.2	11.2	12.5	13.7	13.3	12.1
Italy	10.4	12.4	13.1	14.8	14.7	14.2	16.1	18.0	18.2	17.3	17.2
Japan	13.8	13.6	12.4	14.1	13.6	14.0	13.9	15.5	15.6	15.9	14.0
Sweden	6.7	2.9	3.9	5.6	7.4	8.2	9.3	12.1	19.2	16.8	15.0
U.K.	12.7	11.9	11.7	11.3	11.3	11.3	11.2	11.7	12.1	11.3	10.7[4]
U.S.A.											
a) chemicals and allied products	14.7	13.6	13.4	13.2	12.7	12.5	12.5	12.8	13.5	13.6	
b) drugs	17.9	18.1	18.1	18.0	18.1	17.6	17.8	17.8	18.1	19.6	

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, Selected Data on U.S. Direct Investment Abroad, 1966-76, Washington: U.S.G.P.O., 1977.

U.S. Federal Trade Commission, Quarterly Financial Report for Manufacturing, Mining and Trade Corporations, Various issues.

FOOTNOTES TO TABLE 9

1) "Profitability" is defined here as the ratio of "adjusted earnings" or "income after taxes" to "net investment position" or "shareholders equity". Adjusted earnings are defined as earnings minus foreign withholding tax on dividends plus interest.

2) Data for the U.S. is obtained from U.S. Federal Trade Commission, op.cit. and data for all other countries from U.S. Department of Commerce, op.cit. Profitability in countries other than the U.S. is described here by the ratios of adjusted earnings to net investment position of U.S. foreign subsidiaries operating in those countries.
The figures reported in the U.S. do, however, include income and equity of foreign branches and subsidiaries of U.S. corporations.

3) Includes Luxemburg.

4) Interpolated from adjacent figures.

TABLE 10: COMPARISON OF "INVESTMENT CLIMATE" IN THE "CHEMICAL PRODUCTS INDUSTRY" IN SELECTED OECD COUNTRIES[2], 1966-1976 (CUMULATIVE)

Year / Country	1966	1966-1967	1966-1968	1966-1969	1966-1970	1966-1971	1966-1972	1966-1973	1966-1974	1966-1975	1966-1976
Canada	.489	.426	.465	.500	.487	.514	.515	.549	.601	.594	.580
Belgium[3]	.000[4]	.000[4]	.000[4]	.350	.636	.648	.676	.696	.658	.574	.559
Denmark	.500[5]	.500[5]	.333[5]	.400[5]	.667[5]	.714[5]	.625	.727	.800[5]	.773[5]	.719[5]
Finland	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
France	.429	.226	.156	.317	.436	.451	.479	.497	.577	.578	.543
Italy	.182	.433	.400	.482	.482	.525	.570	.627	.587	.572	.564
Japan	.667	.615	.600	.662	.589	.557	.523	.541	.916	.667	.628
Sweden	.500[5]	.500[5]	.500	.500	.571	.600	.643	.682	.773[5]	.784	.754
U.K.	.320	.315	.337	.339	.400	.429	.448	.484	.523	.519	.317[5]
U.S.A.											
a) chemicals and allied products	.506	.486	.483	.481	.472	.472	.480	.499	.521	.529	N.A.
b) drugs	.459	.473	.481	.488	.498	.505	.515	.526	.523	.520	N.A.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, Selected Data on U.S. Direct Investment Abroad, 1966-76, Washington: U.S.G.P.O., 1977.

U.S. Federal Trade Commission, Quarterly Financial Report for Manufacturing, Mining and Trade Corporations, Various issues.

FOOTNOTES TO TABLE 10

1) "Investment climate" is defined where as the ratio of "reinvested earnings" or "net income retained" to "adjusted earnings" or "income after taxes".

2) Data for the U.S. is obtained from U.S. Federal Trade Commission, op.cit. and data for all other countries from U.S. Department of Commerce, op.cit. Investment climate in countries other than the U.S. is described here by the ratios of reinvested earnings and adjusted earnings of U.S. foreign subsidiaries operating in those countries.

   The figures reported for the U.S. do, however, include net income of foreign branches and subsidiaries.

3) Includes Luxemburg.

4) Both the reported reinvested earnings and adjusted earnings figures are negative.

5) Interpolated from adjacent figures.

TABLE 11: PRODUCTION[1] OF PHARMACEUTICALS, SELECTED OECD COUNTRIES
(MILLIONS OF U.S. DOLLARS)

Year / Country	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Canada	191	220	243	274	296	307	344	433	463	497	588	626	721
Belgium	62	70	71	77	116	136	166	188	225	289	386	447	432
Denmark	70	64[2]	58[2]	52	55[2]	59	60	89	105	131	159	188	205
Finland	20	24	25	26	26	32	35	40	46	50	63	72	81
France	827	1,042	966	1,054	1,160	1,228	1,293	1,563	1,838	2,283	2,378	3,024	2,907
Italy	536	576	640	680	720	752	895	970	1,148	1,450	2,053	2,221	2,689
Japan	1,175	1,271	1,409	1,565	1,914	2,342	2,825	2,985	3,566	5,050	5,645	6,086	N.A.
Sweden	51	58	70	80	86	95	124	119	150	187	228	284	310
U.K.	602	695	611	635	583	662	748	810	917	1,108	1,260	1,498	1,495
U.S.A.	3,929	4,386	4,826	5,256	5,759	6,335	6,793	7,400	8,071	8,386	9,479	8,059	8,764

Sources: OECD, The Chemical Industry, Various issues

OECD, Impact of Multinational Enterprises on National Scientific and Technical Capacities, Paris, December 1977, p. 33

FOOTNOTES TO TABLE 11

1) In different sources, these figures are variously defined as "turnover", or "chiffre d'affaires", etc.

2) Interpolated from adjacent figures.

TABLE 12: EXPORTS OF PHARMACEUTICALS, SELECTED OECD COUNTRIES
(MILLIONS OF U.S. DOLLARS, SITC GROUP 541)

Year / Country	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Canada	11	13	16	18	17	23	25	30	35	48	55	58	58
Belgium[1]	24	30	33	39	46	65	83	105	149	200	282	313	330
Denmark	31	34	33	36[2]	45	50	61	70	78	110	124	141	152
Finland	N.A.	N.A.	1	N.A.	1	2	2	2	3	5	8	11	16
France	104	118	138	161	177	205	230	258	308	436	462	635	628
Italy	52	61	74	78	93	117	154	193	222	262	336	380	416
Japan	27	33	33	37[2]	40	51	66	86	84	100	137	124	145
Sweden	12	15	17	19	23	29	35	42	53	67	86	111	132
U.K.	166	187	205	216	231	282	335	410	452	542	706	826	812
U.S.A.	291	256	269	288	314	363	422	403	480	626	800	866	996

Sources: OECD, The Chemical Industry, Various issues.

OECD, Impact of Multinational Enterprises on National Scientific and Technical Capacities, Paris, December 1977, p. 38.

FOOTNOTES TO TABLE 12

1) Includes Luxemburg.

2) From: U.N., Yearbook of International Trade Statistics, Various issues.

TABLE 13: IMPORTS OF PHARMACEUTICALS, SELECTED OECD COUNTRIES
(MILLIONS OF U.S. DOLLARS, SITC GROUP 541)

Year / Country	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Canada	37	40	44	52	53	69	80	89	95	119	162	180	192
Belgium[1]	52	64	66	79	92	118	138	151	194	249	329	348	379
Denmark	21	25	28	28[1]	32	38	45	51	52	70	93	95	112
Finland	N.A.	N.A.	25	N.A.	26	30	34	41	46	57	69	79	80
France	52	63	76	91	100	129	144	161	194	272	285	342	355
Italy	50	59	73	81	97	116	143	143	177	288	310	340	389
Japan	54	60	79	98[2]	128	158	216	237	261	359	455	440	550
Sweden	30	36	39	46	59	66	72	84	105	127	153	190	196
U.K.	20	31	41	44	47	61	81	92	109	164	216	215	250
U.S.A.	41	58	75	72	76	83	87	119	149	163	214	237	271

Sources: OECD, The Chemical Industry, Various issues

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

FOOTNOTES TO TABLE 13

1) Includes Luxemburg.

2) From: U.N., Yearbook of International Trade Statistics, Various issues.

TABLE 14: INNOVATIVE PERFORMANCE OF SELECTED OECD COUNTRIES

	New chemical entities introduced between 1958 and 1970		Top ranking drugs by prescription since 1950	
	Number	Percentage	Number	Percentage
Canada	N.A.	0.5*	N.A.	0.5*
Belgium	10	2.4	4	2.9
Denmark	9	2.1	3	2.2
France	23	5.4	11	8.0
Italy	17	4.0	1	0.7
Japan	4	0.9	1	0.7
Sweden	7	1.6	N.A.	0.5*
U.K.	51	12.0	10	7.3
U.S.A.	204	48.1	67	48.9
Others	99	23.3	40	29.2
Total	424	100	137	100

*Estimated

Source: OECD, Impact of Multinational Enterprises on National Scientific and Technical Capacities, Pharmaceutical Industry, Paris: December 1977, pp. 47 and 110

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