The Interregional Diffusion of Innovations in Canada

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ECONOMIC COUNCIL OF CANADA

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Preface

In 1974, the Economic Council of Canada began a study of regional disparities. Canada has long been plagued by very large differences between regions in levels of income, rates of unemployment, and rates of population growth, exceeding those found between many European nations. The results were published in 1977 in a report called *Living Together*.[1] One project within the study sought to discover whether any significant part of income disparities could be caused by new technology being adopted later in some regions than in others. This book reports on the results of that project.

The principal researcher on the material presented here, and the principal author, was Professor F. Martin of the University of Montreal. He was exclusively responsible for Chapter 2 (the regional factor in the diffusion of innovations) and for Chapters 4 (steel), 5 (roof trusses), 6 (containerization), and 7 (newsprint). R. Beaudry did the bulk of the research for Chapter 3 (computers), and I. Banks for Chapter 8 (shopping centres), and each wrote a first draft; both left the staff of the Economic Council before completing their work on this project. The necessary additional research and writing for these latter chapters was then most ably undertaken by G. Barker, assisted by F. Martin. G. Barker also did an extensive polishing of the remaining chapters. It was N. Swan who originally suggested the idea of trying to account for part of interregional income differences by technology lags, which are more usually studied in an international context. He was responsible for Chapter 1, where this idea is developed more fully, and for theoretical Appendixes A and B. The concluding chapter was a joint product of N. Swan and F. Martin.

This study would not have been possible without the help and co-operation of numerous people and organizations who supplemented our supply of data with their expert knowledge of the industries we examined.

For our research on the steel industry, among those whose assistance made the study possible, we must mention T.E. Dancy of Sidbec-Dosco; R. Leblanc of Stelco; and Dr. G.E. Wittur of the Ministry of Energy, Mines and Resources.

1 Economic Council of Canada, *Living Together: A Study of Regional Disparities* (Ottawa: Supply and Services Canada, 1977).

The construction industry, from the point of the researcher, is a field where experts are numerous but data scarce. We extend our appreciation to a number of people from several organizations: J.L. Barnes, Primary and Fabricated Metals Section, and P. Martin, Wood Products Unit, of Statistics Canada; G.O. Handegord, Division of Building Research, of the National Research Council of Canada; C. Kemp of the Central Mortgage and Housing Corporation; C.J. Copeland, W.D. Wardle, and J.R. Mihalus, of the Department of Industry, Trade and Commerce; Henry de Puyjalon, W. J. Nevins, and B. Cruikshank, of the Canadian Construction Association; William McCance of the Housing and Urban Development Association of Canada; F.J. Smith of Domtar; A.D. Russel, Department of Civil Engineering, of Concordia University; Evan Fowler and E.N. Aplin, Eastern Forest Products Laboratory, of Environment Canada; A.C. Middleton, President, of the Truss Plate Institute of Canada; and Samuel Charles of the Canadian Mobile Home Association.

On containerization, we received help from M.E. Kieran of Dubois, Ferland, St-Hilaire et Associés; L. Demers of Somer Inc.; and R. Corbett of Transport Canada. We must also express our special thanks to G.B. Bisson of the National Harbours Board, who contributed not only time and knowledge, but also much of the data upon which our study of containerization is based.

On the newsprint industry, several individuals generously contributed their time and knowledge, among them: R.A. Joss, Manager, Technical Section, of the Canadian Pulp and Paper Association; K.M. Thompson, Head, and M.F. Davy, Economic and Planning Section, of the Pulp and Paper Research Institute of Canada; Louis Gagnon, Pulp and Paper Division, of the Department of Industry, Trade and Commerce; and Professor S. Globerman of York University.

For useful comments regarding our examination of shopping centres, we wish to thank C.R. Luft, Assistant to the Vice-President of Operations, of The T. Eaton Co., Ltd.; and G. Snyder, Associate Director, Merchandising and Services Division, of Statistics Canada.

Some other officials from enterprises in the industries, who wish to remain anonymous, also assisted us. It goes without saying that none of those who so ably assisted us are responsible for any of the errors or omissions that remain.

The Interregional Diffusion of Innovations in Canada

1 Introduction

Canada has long had a serious problem of interregional income disparities. In work elsewhere, it has been shown that productivity differences underlying these income differences are only partly explicable by variations in industrial structure and physical and human capital.[1] Once these factors have been allowed for, Ontario has a very substantial productivity lead over the Atlantic provinces, a good lead over the western provinces, and a small lead over Quebec.[2] One example will give a flavour of the order of magnitude of the productivity differences and the difficulty of explaining them. In the 1970-73 period, there was a difference of 27 per cent in output per worker between Ontario and Nova Scotia. Correcting for differences between the two provinces in industrial structure, capital stock, and labour quality reduces this difference, but only to 20 per cent. This unexplained productivity residual is sometimes larger than this, sometimes smaller, but nearly always important.

It is common in the literature to find that intertemporal differences in productivity in a nation can only be partially explained by intertemporal differences in measured factor inputs.[3] A considerable residual is usually left.[4] Denison has studied differences between the United States and Western Europe in productivity levels as well as in growth rates and, once again, a substantial portion is not allocable to differences in measured factor inputs.[5] In explaining this residual, considerable importance has

1 See Economic Council of Canada, *Living Together: A Study of Regional Disparities* (Ottawa: Supply and Services Canada, 1977), especially Chapter 5.

2 See Economic Council, *Living Together*, Table 5-12.

3 See, for example, R. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, vol. 39, no. 2 (1957); and J. Kendrick, Productivity Trends in the United States (Princeton, N.J.: Princeton University Press, 1961) for U.S. material and, for Canadian material, D. Walters, *Canadian Income Levels and Growth: An International Perspective*, Economic Council of Canada Staff Study 23 (Ottawa: Queen's Printer, 1968).

4 Though this has been questioned, see D.W. Jorgensen and Z. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, vol. 34, no. 99 (1967), pp. 249-283.

5 Edward F. Denison, *Why Growth Rates Differ* (Washington, D.C.: Brookings Institution, 1967), Tables 21-28.

been attached in the literature to technical change (in the case of intertemporal comparisons) or to lags in the application of new technology (in the case of international comparisons). Estimates of how much of the residual is due to this factor, as opposed to other phenomena such as scale economies, vary a good deal and are controversial,[6] but it seems that it is at least as important as physical or human capital and is probably more important than both of these combined.

All of this suggests that at least some portion of the substantial Canadian interregional differences in productivity that remain after allowing for physical and human capital and structure may be explicable by lags in the application of new technology in the low-productivity regions. The rate of advance of technology might well be the same but, in the race to adopt new techniques, the technological and productivity levels of some regions would always be behind others if they started from a different technological base. An average lag of five years, for example, in adopting each new method as it emerged could, if productivity resulting from new technology were to advance at 1 per cent a year, give roughly a 5 per cent difference in productivity levels. Referring to Nova Scotia and Ontario, that would be nearly as important as the combined effects of physical and human capital and industrial structure, which amounted to 7 per cent.

To our knowledge, technological lags have not been used before in trying to account for interregional productivity differences. That may be because in only two highly developed capitalist countries, Canada and Italy, are these differences large enough to warrant a major research effort. But the possibility has been hinted at.[7] It seems to us that, in a country with regions as far apart and as different as those in Canada, it is quite reasonable to hypothesize that technological lags may be helpful in explaining productivity differences, and the first purpose of this study is to raise this question for investigation. Before going into detail, it will be useful to canvass briefly four general arguments with which we have often been confronted as to why technological gaps cannot be important between Canadian regions.

The first stems from a common view among industry people in the private sector and government that the level of technology in use does not differ between regions in Canada. While the basis for this view is not clear, it seems to be that national firms would never install nor permit different technology in different places, and that information access within the

6 Some writers are very sceptical and would go for low estimates, like Jorgensen and Griliches, "The Explanation of Productivity Change"; others have assigned as much as 90 per cent to technology, like Solow, "Technical Change."

7 See K. Arrow, "Classificatory Notes on the Production and Transmission of Technological Knowledge," *American Economic Review*, vol. 59, no. 2 (1969), pp. 29-36.

nation is sufficiently good to ensure uniform technology, even in industries where national firms are uncommon or nonexistent.

Second, there is the argument that, though technology may, and perhaps does, differ from firm to firm, there is no systematic tendency for the differences to be related to geography. Technological advance is geographically random. Some firms in Ontario will be ahead of some in the Atlantic region, perhaps even some whole industries, but there will be others in which those in the Atlantic region are ahead. The proportion of firms or industries in each region that are in the van of technical progress will not be significantly different. The reasons for this appear to be the same as in the first case.

Third, there is the "perfect entrepreneurship" hypothesis. Techniques will only be introduced when they are profitable and, if an advanced technique has not been introduced in a region, that is ipso facto proof that it is not worth introducing. This hypothesis is nonrefutable on logical grounds. However, we maintain that regional conditions are not immutable and that information about the current use of technology is consequently useful for regional policy purposes. Finally, it can be maintained that relatively backward technology is to be expected in regions with relatively low wages, so that it is not a cause of low productivity and wages but a consequence of them. Related to this, but conceptually distinct, is the proposition that low wages will lead to a low capital/labour ratio and fewer capital-intensive techniques, which will often appear to be more backward.

This is not the place for a full discussion of the validity of the fourth explanation of technological gaps, but some brief comments may be made. We might comment parenthetically that it would apply, if correct, to all the work that has been done on intertemporal and international comparisons of technology, rather than specifically to interregional comparisons, and would lead to profound pessimism as far as policy for reducing technical gaps or lags is concerned. If there is a flaw in this fourth argument, it lies in a confusion between what is causal for a firm and what is causal for a whole economic system, be it a nation or a region. For some individual firms, specifically the later adopters, high wages will indeed provide the impetus to bring in a new technique but, for firms as a whole, it is the new techniques that will cause the wages to be high. It is a fallacy of composition to suppose that because high wages are often instrumental in bringing about the adoption of new technology at the microeconomic level, they are similarly instrumental at the macroeconomic level.[8]

Returning to the first two views, that technology is geographically either uniform or random, these are testable hypotheses, and the first and major purpose of this study is to examine whether they are valid. We suspect not,

8 A more detailed exposition of this argument is in Appendix D.

for there are several grounds for considering a priori that the timing and speed of adoption of new technology will differ from region to region.

Some theories of technological diffusion,[9] upon which we will draw in our study, imply that the timing and speed of adoption should vary within Canada. The urban hierarchy theory[10] — that innovations first occur in the largest cities and then spread down the urban hierarchy — should ensure that Ontario and Quebec lead the rest of the country, and that the Atlantic region is last. Some researchers have postulated that size of individual firms, or structure of markets, is important,[11] and that there are systematic regional differences in these aspects. Management attitudes are another explanation often offered for the timing of adoption. Evidence on differences in attitudes among initial, early, and later adopters in agriculture[12] lends support to such a hypothesis. There is much folklore, and some evidence, to support the view about differences in management attitudes between regions in Canada,[13] so that regional differences in adoption may exist. On the other hand, the epidemiology theory — that technology spreads outwards from the points where it is first initiated, with distance from these points being the chief determinant of the timing of adoption — would not systematically favour any region, unless the starting points themselves were more likely to be in some regions than in others.

Since distance and culture make the major regions of Canada separate entities in almost the same sense that nations in Europe are separate entities, the empirical evidence from Europe, which demonstrates major differences in the timing and speed of adoption in different countries there,[14] suggests that some of the differences may occur within Canada. So does the evidence of Griliches on the geographical spread of hybrid corn.[15]

9 A complete description of these theories will be given in Chapter 2.

10 B.L. Berry, "Hierarchical Diffusion: The Basis of Developmental Filtering and Spread in a System of Growth Centres," in N. Hansen, ed., *Growth Centres in Regional Economic Development* (New York: Free Press, 1972); and J. Friedmann, "The Spatial Organization of Power in Development of Urban Systems," in J. Friedmann and W. Alonso, *Regional Policy Readings in Theory and Application* (Cambridge, Mass.: MIT Press, 1975).

11 See E. Mansfield, *The Economics of Technological Change* (New York: Norton, 1968); "empirical studies substantiate the hypothesis that large firms are quicker, on the average, than small ones to begin using new techniques" (p. 192).

12 *Ibid.*, p. 127; see also L. Nabseth and G.E. Ray, *The Diffusion of New Industrial Processes: An International Approach* (Cambridge Mass.: University of Cambridge Press, 1974).

13 See R.E. George, *A Leader and a Laggard* (Toronto: University of Toronto Press, 1970); and Economic Council, *Living Together*, Chap. 5.

14 Nabseth and Ray, *The Diffusion of New Industrial Processes.*

15 See Z. Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, vol. 25, no. 4 (1957), pp. 501-523.

A second purpose of this study is to add to the empirical information available in Canada on the process of diffusion of new techniques. We believe that much of the information we provide on technology in individual Canadian industries is new, or at least not easily accessible. Furthermore, the accompanying information on industrial structures and behaviour can be useful from many points of view to Canadian specialists in the economics of industrial organization.

Third, we would like to determine whether there is a positive correlation between regional productivity levels and regional speed in adopting new techniques. This is related to, but not the same as, the first purpose. Conceivably, technological adoption could be consistently faster in some regions, but these regions may not be the most productive ones. The Prairies, for example, may be ahead in adopting certain new technologies and yet be behind in overall income levels for other reasons, such as low prices for their products. Our underlying interest here is in the possibilities for social policy to reduce regional disparities. Of course, even if technological differences were not correlated with income or geography, one could still hope to improve productivity in poor regions by seeking out those particular cases in which they happen to be behind. But, if there was a general tendency to be behind, the scope for policy would be greater. If a correlation existed, one might even hope to quantify its importance (see Appendix E), and determine what portion of regional productivity differences was due to technological gaps.

Fourth, we would like to establish whether, in cases where a region does lag or lead, there exist causes that are themselves characteristic of the region, or that are intimately related to characteristics of the region. This, because we will establish in Chapter 2 that not only do innovations diffuse according to four basic patterns or modes, but also that these modes are differently conditioned by the characteristics of a region. For instance, if an innovation is diffused according to urban size, its speed of diffusion will vary from region to region when the regions differ in their urban hierarchies. On the other hand, if the innovation studied diffuses according to market structure,[16] regional characteristics can largely be ignored. Consequently, the chances of a region being successful in attracting the carrier of an innovation depends upon which mode of diffusion is characteristic of the industry in question and how it relates to the region's characteristics. By extending this analysis to a large sample of representative industries, a general forecast could be made about the future relative position of a region with respect to access to modern technology. There is then the question of whether those regional characteristics can be influenced by direct policy action.

16 See definition on p. 18, Chap. 2.

Our methodological approach has benefited greatly from the pioneering work of Nabseth and Ray. Like them, we found that, while a common theoretical framework is desirable and essential if meaningful generalizations about technology diffusion are to be developed, it is also desirable to be very flexible in allowing for differences between innovations. We have tried to structure the work on each innovation so that, considering all innovations together, we could estimate, however crudely, the average time lags between five major Canadian regions in the adoption of all new technology. The basic idea was that alluded to above — more formally, if we could say that a region was, on average, k years behind another, and if the rate of technical progress in both was the same, at rate g per cent a year, then gk per cent of the productivity difference could be explained by technological lags. Carrying this idea through in full logical and methodological purity would have required us to draw random samples of industries, stratified according to their share of regional value added,[17] and to examine the principal innovations for each one of the industries included in the sample.

But we were not able (for reasons of cost, time, and availability of statistical data) to choose innovations in such a way as to meet the demands of a statistically representative sample. Nevertheless, we took the following precautions. We confined ourselves to innovations in goods and service production. Consumption goods were eliminated because they do not directly influence productivity. We believe that, in an advanced economy, the range of goods consumed is a sign of the degree of development of a region but is nôt itself a source of growth. Moreover, studies of consumption goods diffusion normally conclude that the rhythm of diffusion is above all a function of the level of family income, the very variable we are seeking to explain by (industrial) technology itself. The industries we chose met a number of criteria: if possible, they formed part of the economic base of the region in either the secondary or tertiary sector; they included both those with a small number of large firms and those with a large number of small firms; the available statistical data were, we believe, reliable; they were the subject of similar studies done in other countries; and they were present in all regions or in most of them. In practice, we were not able to rigidly retain all these criteria, but we tried to do so as much as possible.

In retrospect, it seems that, as a result of taking these precautions, we have been able to obtain some useful general insights into the process of the regional diffusion of technology in Canada. Nevertheless, we feel that any future research into this process would now benefit from emphasizing the last criterion rather more than we did. More concretely, greater stress should be laid on those innovations that have occurred in local industries

17 See in Appendix E the reasons for this.

producing nontradables, whether goods or services; examples might include branches of the food industries, metal-working operations, local transportation, wholesale trade, and business services in general.

Finally, we should comment briefly on our sources of data and information. Full details are given in each chapter, but our general procedure consisted first in obtaining a detailed technical grounding in the particular innovation being considered by interviewing knowledgeable people in the industry concerned. Second, our data were mainly obtained from Statistics Canada, sometimes involving special tabulations when desirable and feasible. This information was frequently supplemented by special data furnished by trade or industry associations. Upon completion of our work on a particular innovation, we had it checked for accuracy by having it read by industry and government experts, though we, of course, retain responsibility for any errors that remain.

2 The Regional Factor in the Diffusion of Innovations

Many variables influence the diffusion of innovations in terms of either new products or new production processes. They may include, among others, the proximity of possible adopters, geographical features and obstacles, profitability of the innovation, size of markets, size of firms, size of cities, management attitudes, age of equipment, type of ownership, concentration of the industry, access to information and financial capital (more generally, access to the so-called external economies), cost of labour, international connections, index of technological opportunity, research and development (R&D) activities by firms, and government policy.

The profusion of variables presents a bewildering picture of the diffusion process. This would be less of a problem if it were possible to construct a model that could conceive the diffusion of new technology to be the resultant (vector sum) in a multi-dimensional space where the various influencing factors operate, the impact of these factors on the resulting diffusion being illustrated by the force and direction of the various impulses in this space. However, an attempt to apply this model-like image numerically in a practical context meets virtually insurmountable difficulties.[1]

To begin with, no list can claim to be complete. Consequently, there can be no guarantee that the most important variables necessary for policy purposes are included. Moreover, models involving a large number of variables, besides being costly, sooner or later run into difficulties insofar as the availability of data is concerned. Lack of homogeneity in the variables, in terms of level of abstraction and causal relationships, may render the comparison of results rather difficult and the formulation of policies puzzling. Beyond this, variables are sometimes defined in such a vague way that the studies that use them end up "proving" a tautology. The variable "profitability" has been used in this way; if precautions are not taken, studies can end up "proving" that, if an innovation is profitable, firms will eventually adopt it.

1 L. Nabseth and G.F. Ray, *The Diffusion of New Industrial Processes* (Cambridge, Mass.: Cambridge University Press, 1974), pp. 15, 28, 54. Researchers contributing to this book used no fewer than 40 different variables.

On the other hand, simplicity, unity, and causality can be achieved in the study of diffusion of innovations by relying on a priori models. This approach, which has given rise to much empirical work, also enables us to reintroduce, on the basis of theory, variables rejected for all sorts of reasons by statistical analysis. It differs from factor analysis in the sense that it is not the result of inductive reasoning but of deductive reasoning. But the vast amount of literature dealing with market and urban structures as determinants of initial innovation or the level of R&D efforts is not a substitute for the much smaller body of literature dealing with the diffusion process itself, which we examine here for its regional dimension.

Economists and geographers often examine three main factors: the speed of the spatial diffusion of innovations; the speed of the diffusion of a particular innovation within an industry or among a set of industries; and the motivation for an individual firm to adopt a particular innovation.

Most of the variables that shed light on these factors are associated with four main a priori models of diffusion. They are: the epidemiology diffusion process;[2] the urban hierarchy diffusion process; diffusion according to the economic and institutional environment of firms; and diffusion according to the firms' characteristics.

Each model of diffusion incorporates or is a proxy for a set of many variables explaining the mode of diffusion of a particular innovation. Some, but not all, of the variables may be common to two or more models. What distinguishes them is that each emphasizes a different dominant variable that can be theoretically identified. Epidemiology emphasizes distance; for urban hierarchy, it is size of cities; for diffusion according to the environment, it is either market structure or labour costs; and for diffusion according to the firms' characteristics, it is management attitudes as reflected by the firms' internal structure and behaviour.

Four models are necessary because none of them, alone, seems sufficiently complete to give a satisfactory explanation of the diffusion of different types of new goods or production techniques. Each has been successful in certain categories only.

Epidemiology seems satisfactory in explaining the diffusion of agricultural production techniques and some household goods. For innovations in a few industrial processes like steelmaking, the influence of distance may be either positive, as in the case of electric furnaces, or negative, as for the basic oxygen process (see Chapter 4).

2 Our use of this term is wider than that sometimes used by geographers, like L.A. Brown, *Diffusion Processes and Location: A Conceptual Framework and Bibliography* (Philadelphia: Regional Science Institute, 1968). We incorporate the so-called distance-biased model with the strictly defined emidemiology model under the generic name of epidemiology.

Urban hierarchy can cover much wider geographical areas, the classic example being the diffusion of television stations.[3] Yet, although it seems appropriate, it does not easily explain the diffusion of shopping centres, at least in Canada (see Chapter 8).

On the other hand, there are many cases, especially those involving manufacturing goods, where distance (even in a country like Canada) is not the best explanation of diffusion, nor is the size of cities. For these cases, the environment of the firms has been found to be a good explanation; this has been especially true for coal, steel, railroad, and brewing industries,[4] float glass,[5] computers (see Chapter 3), and twin-wire newsprint machines (see Chapter 7).

Finally, in the study of the diffusion of production processes, such as shuttleless looms and tunnel kilns,[6] and containerization, certain firms' characteristics are found to be important.

The fact that no single one of these models constitutes a general theory of diffusion is not a serious drawback. First, even in the multi-variable approach, across-the-board generalizations have failed. Second, complete explanations are not always necessary. Although not a paragon, take, for example, location theory, which has long wrestled with the problem of determining "the" dominant location factor. Finally, a collection of factors was used, each dominant with respect to a particular industry. The end result is today's custom of labeling industries as market-oriented, transport-oriented, labour-oriented, energy-oriented, resource-oriented, footloose industries, and so forth. A similar approach could be used in the study of the diffusion of innovations through using the predominant mode appropriate for each industry. There would then be epidemiology-oriented innovations, urban-hierarchy-oriented innovations, market-structure-oriented innovations, management-oriented innovations, type-of-ownership-oriented innovations, and so forth.

Some variables are common to several modes of diffusion. Profitability is one. Indeed, it is possible to make profitability[7] the main explanation of diffusion, whatever the actual mode of diffusion. However, this amounts to saying that only profitable innovations will be adopted. That is almost tautological, since it is compatible with all the postulates of the main theories of the firm: profit maximization, profit optimization, or even

3 B.L. Berry, "Hierarchical Diffusion: The Basis of Developmental Filtering and Spread in a System of Growth Centers," *Growth Centers in Regional Economic Development*, ed. N. Hansen (New York: Free Press, 1972), p. 119.

4 See E. Mansfield, *The Economics of Technological Change* (New York: Norton, 1968).

5 See Nabseth and Ray, *The Diffusion of New Industrial Processes.*

6 *Ibid.*

7 Or at least innovations that provide the firms with quantifiable or tangible benefits by saving energy, avoiding labour troubles, or complying with antipollution standards imposed either by law, local social pressure, or "fashion."

"satisficing." But it is not always profitability itself that is interesting, but rather some of its aspects that may explain the speed of adoption and not simply the adoption per se. For instance, when "profitability" is easy to calculate, when the adoption of the innovation does not require large expenditures, or when the equipment to be replaced has a short life, these aspects of profitability are part of a ceteris paribus explanation of the rapid adoption of an innovation.

Conceptually, profitability is nontautological and is therefore an outright determinant in a particular model of diffusion when the hypotheses of pure competition and perfect knowledge are removed. However, in such a case profit expectations are difficult, if not impossible, to measure ex ante.[8] In fact, the ability to recognize and separate cases of profitable innovation from those that are not is the basic explanation of the differences in the performance of entrepreneurs; the successful entrepreneur is precisely the one who sees profitability where others do not, and vice versa. Because most real-life situations are cases of imperfect knowledge and imperfect competition, the analysis of the "causes" of diffusion should then concentrate on the factors that influence the formation of expectations about the profitability of prospective innovations. In other words, diffusion studies should try to go behind the profitability variable.

Size of firms is another ubiquitous variable, especially in the firms' environment and in the characteristics of firms' modes. In this study, size is classified as a component of market structure and thus the environment of firms when it is perceived as resulting from existing technology. Conversely, it is classified as a component of the mode corresponding to firms' characteristics when it is perceived as the result of the manager's motivation. In this latter case, company size is a proxy for many variables internal to the firm. In the adoption of special presses by the newsprint paper industry, for example, it was found that company size had an impact, not because of size as an independent variable, but because the pay-off period and other variables pertaining to company resources appear to be related to size.[9]

The phenomenon of diffusion can be represented by points on an adjustment path.[10] Trend functions are thus the easiest way to represent the phenomenon. Among the many available algebraic forms of such functions, the logistic curve has often been chosen because of its simplicity.

The logistic curve can be seen as a mere description of a diffusion process, or it can also be seen as an embryo of a general theory of diffusion because it makes some vague predictions. Diffusion processes go through

8 *Ibid.*, p. 13; also, Mansfield, *The Economics of Technological Change*, p. 124.

9 *Ibid.*, p. 82.

10 Z. Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, vol. 25, no. 4 (1957), pp. 501-523.

three phases: initial adoption, contagion, and saturation. The schema predicts that the rate of diffusion varies according to the stage. In this aspect, it has an epidemiological flavour. However, the vagueness of its predictions — that is, the lack of statements about the exact slopes of the diffusion curves of different innovations — shows that it needs to be supplemented. When the existence of stages of diffusion has been established in empirical terms for a large number of innovations, the subject of research is not to determine whether or not the diffusion of products or production processes goes through stages, but how this is done. That is, what are the differences in rates of diffusion or slopes of the various logistic curves and the values of their other parameters, and what are the factors accounting for these differences?

Because it is suspected that special characteristics of new products or new production processes lead to different rates of diffusion, there is, then, a relationship of complementarity between the logistic curve and the diffusion modes considered in this study. The models we propose represent the different sets of variables that explain the differences of slopes and other parameters of logistic curves.

Epidemiology Diffusion

This mode emphasizes distance, which can take many forms: physical distance, physical distance corrected by geographical factors such as natural characteristics (mountains, rivers, and so forth), and social and economic distance measured by the probability of concluding social and economic transactions.

The main prediction of the model of diffusion is that innovations are propagated according to an orderly wavelike pattern emanating from a centre and moving towards a periphery. In such a case, the farther an economic agent is from the centre or place of origin of an innovation, the later he is likely to adopt it.

The model applies mainly but not exclusively to innovations whose adoption is automatic except for the information factor, as in the case of small innovations used by small firms.[11] In this mode, an innovation is diffused by contagion, as in an epidemic; it relies on imitation, band-wagon effect, and demonstration effect. Its spreading results primarily from a learning process, hence the importance of information flows and personal contacts.[12] When the physical distance is shorter, the communications

11 In the case of large firms, because there are so few of them, "it is difficult to find definitive evidence that the diffusion of a new technique spreads like an epidemic;" Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 207.

12 Brown, *Diffusion Processes*, p. 40.

system is better, and when the population density is higher, the probability of exposure is greater and, therefore, the probability that an innovation will spread over a large area during a given period of time is greater.

Urban Hierarchy Diffusion

In this approach, the size of cities is the key to predicting and explaining the diffusion of innovations. Geographical or social distance does not intervene explicitly. Innovations are transmitted gradually from large cities to smaller cities. Inside each urban hierarchy, the primary city gets the innovations first and from there they filter down to other levels in the hierarchy. This is logical. Innovations may be risky, or uneconomical below a certain threshold of population, or require special inputs. They will therefore most likely be introduced first in large cities with large markets for outputs and/or low supply costs for special inputs.[13] Only later, if the experiments are successful in the large cities and if the processes involved can be miniaturized without too much loss in efficiency, will they be brought to smaller centres. This is not always the case, however, as some innovations can miniaturize production processes without loss in efficiency, making them suitable for introduction in smaller centres first. In either case, what is peculiar is that proximity does not confer an advantage.

The main analytical tool here is the rank-size distribution of urban populations. This toll of analysis has been found suitable for studying diffusion of TV stations, telephone exchanges,[14] and self-service stores.

The fact that this approach, in its pure form, does not incorporate distance is an important deficiency. Proximity affects most real life situations. This omission has been partly corrected by fusing this model with the epidemiology mode into a variant of the gravity model.[15] Some of the features of the epidemiology model are lost, but it enables the researcher to picture the diffusion of innovations as a simultaneous movement in two dimensions: horizontally, among cities of similar size; and vertically, from large to small cities.

Although geographers, the main proponents of the epidemiology and urban hierarchy modes of diffusion, imply that their approach covers both households and entrepreneurial innovations, the range of empirical cases that they have successfully studied is noticeably poor for manufacturing

13 Cf. T. Hagerstrand, "Aspects of the Special Structure of Social Communication and the Diffusion of Information," A Paper and Proceedings of the Regional Science Association, 1966: "The point of introduction in a new country is its primate city; sometimes some other metropolis" (p. 40). This probably does not include modern marketing techniques such as trial marketing, which is sometimes done simultaneously in all sorts of towns.

14 B.T. Robson, *Urban Growth: An Approach* (London: Methuen, 1973).

15 *Ibid.*, pp. 137-142.

activities.[16] This is especially true in science-based and resource-oriented or monopolistic industries where the facts do not strictly agree with predictions of the geographical models. The inadequacy of the earlier models of diffusion for manufacturing innovations is readily understandable.

It is clear that the location of natural or energy resources introduces some distortion into the usual relationships established by either the distance approach or the urban hierarchy approach. Moreover, competition is far from perfect in the manufacturing sector, whereas the epidemiology approach requires rationality — that is, profit maximization. Once an innovation has been perceived as profitable, adoption is supposed to follow directly from knowing about it.[17] Any delay is attributable to imperfection of knowledge and or uncertainty as to the exact potential of the innovation, imperfection of knowledge being a function of distance. In the case of imperfect competition, one must reckon with the possibility of a modification of profit-maximizing behaviour and the possibility of a variety of modes of behaviour. In such a case, the actual rate of adoption will be different from the rate predicted by geographical models. Finally, other environmental variables, such as government activities and policies or labour market considerations like trade unions' attitudes and labour costs, all interfere with the effects of either distance or urban hierarchy on the diffusion of innovations.

Diffusion According to the Economic and Institutional Environment of Firms

Economists, largely abstracting from epidemiology and urban hierarchy modes, have not infrequently hypothesized that the economic and institutional environment is the predominant factor, especially in the so-called science-based industries. Many years ago, the main prediction regarding the generation and adoption of innovations was not too difficult to identify. It consisted of Schumpeter's contention that monopoly power and large firm size "are prerequisites for economic growth through technical progress."[18] In the words of Galbraith, "most technical innovation comes from the highly organized sector of the modern economy — the sector characterized by the modern large corporation."[19]

16 *Ibid.*, p. 136.

17 Griliches, "Hybrid Corn," p. 522; while studying the diffusion of hybrid corn, he found that "farmers behaved in a fashion consistent with the idea of profit maximization."

18 See M.F. Kamien and N.L. Schwartz, "Market Structure and Innovation: A Survey," *Journal of Economic Literature*, vol. 13, no. 1 (March 1975), p. 15.

19 J.K. Galbraith, "Technology in the Developed Economy," *Science and Technology in Economic Growth*, ed. B.R. Williams (London: Macmillan & Co., 1973), p. 39.

A particular firm operates within two types of economic environment: the market structure of its own industry; and other components of the local economic space (in Perroux's sense). The latter include the local stock of industries, government activity, peculiarities of the local labour market, and natural resources. The market structure consists mainly of some internal characteristics of a particular industry, such as the number of firms, the prevalence of large or small firms, and the degree of differentiation of the product. These characteristics determine the mode of behaviour of firms, whether oligopolistic or polypolistic, and this in turn conditions the phenomenon of leadership, or lack of it, in the adoption of innovations.

It seems natural then to infer that the firm's market structure would explain the rate of diffusion of innovations in the manufacturing sector. This general position has been translated into the more testable proposition that large firms should be early adopters; that monopolistic and oligopolistic firms should be early adopters; and that diffusion should be faster in imperfect markets than in atomistic markets. These propositions have been subject to both theoretical and empirical study but, in each case, attempts to generalize have yielded inconclusive or confusing results. On the one hand, recognition of opportunities may be faster in atomistic industries simply because there are more independent centres of initiative but, on the other hand, it may be faster in monopolistic industries if monopolists alone maintain staffs of researchers to keep track of outside scientific advances.[20]

Moreover, empirically, the interfirm diffusion of technology has been less well documented than the actual generation of new technology.[21] As in the case of generation of technology, the overall judgments are far from clear-cut. After having studied eight manufacturing innovations, Nabseth and Ray came to the conclusion that high concentration, or a monopoly position, may create conditions that can influence innovation or diffusion either way.

The same lack of clear direction of the effect is encountered when the size of firms is investigated as a possible determinant of diffusion. Nabseth and Ray found that "the pilot study provided no definite evidence that large companies have always been in the forefront of technical progress in the sense of being leaders in innovations and the adoption of new techniques."[22]

20 F.M. Scherer, *Industrial Market Structure and Economic Performance* (Chicago: Rand McNally, 1970), p. 375.

21 Recent literature on the subject is found in Nabseth and Ray, *The Diffusion of New Industrial Processes*; J.M. Vernon, *Market Structure and Industrial Performance: A Review of Statistical Findings* (Boston: Allyn & Bacon, 1972); and S. Globerman, *Technological Diffusion in Canadian Manufacturing Industry* (Ottawa: Department of Industry, Trade and Commerce, 1974), p. 4.

22 Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 21.

The only thing that is firmly established is that there is a threshold size that facilitates the diffusion of innovation. It is of no use to try to relate size and diffusion in some kind of monotonic function. "Moreover, this threshold size varies from one aspect of an industry's technology to another, allowing complementarities and interdependencies to exist among large and small firms."[23]

The upshot is that most researchers are convinced that concentration of an industry and the size distribution of firms have an impact on diffusion in many industries. But they are plagued by three problems:[24] they do not know which industries these are; they have been unsuccessful in determining the degree of concentration that is optimal for diffusion; and they have not yet determined the threshold size of the firm for each industry.

There is then a great need for empirical research. In the meantime, any use of this approach has to be "industry-specific."[25]

Diffusion According to Certain Firms' Characteristics

In some cases, researchers have found that distance, size of cities, and even market structure were highly similar but that the diffusion rate varied among countries, regions, or industries. That led them to suspect that some internal characteristics of the firms involved were probably important in explaining rates of diffusion.

This is not to say that external factors consisting of the economic, geographical, and institutional environments of the firms are not strong influences. But the environment does not always completely constrain or predetermine the behaviour of management. What has now been realized is that the same objective environment can lead to different decision-making within firms with respect to the adoption of innovations. This should not be too surprising, as it corresponds to the main contribution of the behavioural theory of firms, rather than to the traditional theory, which ignores the internal structure of the firm.[26]

Researchers have consequently been led to investigate factors internal to the firms that have an influence on the rate of diffusion. These factors have been grouped into a few variables — namely, management attitudes, national and international connections, access to financial capital, and

23 E. Mansfield, "Determinants of the Speed of Application of New Technology," *Science and Technology in Economic Growth*, ed. B.R. Williams (London: Macmillan & Co., 1973), p. 204.

24 *Ibid.*; see also Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 13; and Scherer, *Industrial Market Structure*, p. 376.

25 S. Globerman, "Market Structure and R&D in Canadian Manufacturing Industries," *Quarterly Review: Economics and Business*, vol. 13 (Summer 1973), p. 65.

26 K.J. Cohen and R.M. Cyert, *Theory of the Firm* (Englewood Cliffs, N.J.: Prentice-Hall, 1963), p. 351.

internal conditions of the firms with respect to administrative structure and production equipment. Although not covered specifically in our analysis, this approach incorporates determinants of diffusion of innovations such as age of machines, capacity utilization, the proportion of total costs accounted for by various inputs, information variables, R&D activities, productivity of management, dividend policy, vertical and horizontal integration, and so forth. Obviously, different behaviour is possible only in a nonperfectly competitive situation — that is, a situation where the so-called noneconomic factors (which are nonetheless real) have an influence of their own. But, on the other hand, this seems to be the usual environment of manufacturing firms, especially those of the innovative type.

This approach has been taken as both an extension of and a substitute for the environmental approach. It is an extension when it proceeds by analysing more deeply some of the variables retained by the environment approach to diffusion. For instance, the size of a firm (a factor in the environment approach) is an aggregate concept that covers many internal aspects of the firm, size being the result of the presence or absence of economies of scale, the possibility or impossibility of pooling risks, management productivity, management attitudes, access to capital and know-how, and so forth. This approach, by breaking the aggregate concept of size into its components, makes it possible to reduce the indeterminancy in the analytical results when size is the only variable used in the analysis. When it does only that, it is an extension.

This approach can also be a substitute for the environment-of-the-firm approach when it replaces the aggregate notion of size by its operational components such as management attitudes — that is, aggressive, expansionist, market-share orientation, status quo, senile, or decadent — whether the firm is a multinational or a local firm. These variables are held to be the ones that really matter, and size as such becomes a superfluous variable.

The two approaches are not necessarily mutually exclusive. For example, it is entirely possible that all firms respond eventually in a reasonable fashion to objective economic signals, but the rate of response may differ because of managerial or motivational differences.[27] But because our study focuses on differences in rates of adoption and because rates of adoption are a function of managerial attitudes, the study of a variety of managerial attitudes facing similar objective situations is consequently crucial to us. Furthermore, the variability of management attitudes among firms is crucial to the diffusion of innovations because it makes a difference both to the expected rate of return of a prospective innovation and to the internal rate of return to a particular firm, which

27 J.R. Meyer and G. Herregat, "The Basic Oxygen Steel Process," *The Diffusion of New Industrial Processes*, ed. Nabseth and Ray (Cambridge, Mass.: Cambridge University Press, 1974), p. 192.

serves as a norm for deciding whether to adopt an innovation. It is well-known that expectations vary from firm to firm according to the attidues of management. In other words, the more difficult the computation of the profitability of an innovation, the more important management attitudes become as an explanation of innovation diffusion.

The empirical study of Nabseth and Ray found that management attitude and other company variables were predominant in the diffusion of a few innovations (tunnel kilns, shuttleless looms) and more or less important in a host of others. In the diffusion of the basic oxygen process, for example, Meyer and Herregat attributed some of the differences observed between firms or national industries to such noneconomic factors as differences in management style and motivation.[28] And other researchers such as Layton (who studied different industries) squarely imputed international differences in the generation and diffusion of innovations to differences in management skills.[29]

Similarly, the foreign ownership variable has proven itself as an explanation of rates of diffusion, both theoretically and empirically. Most people would agree that "multinational companies are unquestionably the dominant institutions transferring industrial technologies across national borders."[30] The international version of the product-cycle theory provides another basis for the above contention. In the first phase, a U.S. innovator acquires a quasimonopolistic position within the United States. In the second phase, his competitors imitate it and reduce the extent of his markets. And, in the third phase, the originating firm has to move to some other innovation. Before or during this phase, however, the originating company may invest outside of the United States to take advantage of the factor cost situation in other countries or to preserve an oligopolistic situation.[31]

There are empirical results to support this contention. For instance, Globerman found that, in the case of the Canadian pulp and paper industry, "domestically owned firms were slower adopters than foreign subsidiaries, ceteris paribus."[32] Similarly, Nabseth and Ray noted that "foreign involvement (that is, whether or not a firm has foreign subsidiaries or agreements or other special relationships with foreign companies) appears to be important" in the case of the shuttleless looms innovation.[33]

28 *Ibid.*

29 C. Layton, *Ten Innovations* (New York: Crane, Russak, 1972), p. 11.

30 J.B. Quinn, "Technological Transfer by Multinational Companies," *Harvard Business Review,* vol. 47 (November-December 1969), p. 150.

31 Organisation for Economic Co-operation and Development, *Gaps in Technology* (Paris: OECD, 1970), p. 254.

32 Globerman, *Technological Diffusion*, p. 14.

33 Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 282.

As in the case of environment diffusion, the empirical evidence is small and industry-specific, but the main point is that it exists.

The Regional Factor

The regional factor exists if there is a systematic difference in the diffusion processes among regions. Furthermore, this difference must be attributable to the influence of some of the basic characteristics of the region on one or many of the key explanatory variables proposed by the various models of diffusion. These basic characteristics consist of endowments in natural and human resources, a stock of industries, an urban hierarchy, a social infrastructure, a location (near or far away) in relation to the economic and social centre of the country, a set of government policies, activities, incentives, and regulations, This systematic influence varies with each mode of diffusion. It is theoretically important in the epidemiology and urban hierarchy models. It is much less significant for the modes involving market structures as defined above or management attitudes. For instance, if an innovation originates in an industry where the process of diffusion is governed by the market structure, regional characteristics can largely be ignored. On the other hand, if an innovation is diffused according to the urban hierarchy, the regional factor becomes preponderant.

The links between regional characteristics and the key variables in each of the four models of diffusion can be direct or indirect.

The case of distance is clear. Distances between Canadian regions are enormous by international standards, and this could be an important regional factor. Moreover, other distances involved in the distance model of diffusion can be influenced by the region's own infrastructure and government policies.

In the urban infrastructure model, the degree of urbanization, as well as the distribution of urban centres by size group, varies very substantially indeed among Canadian regions.[34] The Atlantic region in particular is far less urbanized than the rest of the country. Consequently, we might expect urban structure to play the role of a regional factor.

As for the model dealing with the economic and institutional environment of firms, in which market structure is the key variable, the effect of the region's characteristics is much more indirect, if present at all. However, certain cases may be mentioned. For instance, significant depletion of renewable natural resources may have a bearing on firms' decisions concerning the introduction of innovations. In fact, depending upon the nature of the innovation, this phenomenon could either accelerate or stop

34 See Economic Council of Canada, *Living Together: A Study of Regional Disparities* (Ottawa: Supply and Services Canada, 1977), Chap. 6.

its introduction. Local government policies regarding concentration (or deconcentration) and foreign ownership, not to mention fiscal policy, may also have an influence. Similarly, regional peculiarities of trade union attitudes towards labour-saving devices may constitute part of the regional factor that conditions the economic and institutional environment of the firm.

In the final model — diffusion according to firms' characteristics — the regional factor usually plays a marginal role. Yet, the region, through its financial facilities, educational system, and government policies — namely, fiscal policies — may influence the stock, quality, and attitudes of management.[35] Similarly, the region's prospects, social attitudes (including specific local trade union attitudes towards multinational corporations), quality of life, and policies may or may not favour the establishment of national and international firms.

Thus, the regional factor may, in certain cases, play the role of a more fundamental explanation of the varying rates of diffusion of innovations among regions. In the following chapters, we will investigate the diffusion of some innovations and endeavour, in each case, to indicate the relative importance of the regional factor, in an attempt to fill the lack, mentioned by some researchers,[36] of a suitable framework for the analysis of the diffusion of innovations of the manufacturing sector in a regional or interregional context.

35 R.E. George, *A. Leader and a Laggard* (Toronto: University of Toronto Press, 1970), Chap. 10.

36 For example, M.D. Thomas and R.B. Le Heron, "Perspectives on Technological Change and the Process of Diffusion in the Manufacturing Sector," *Economic Geography*, vol. 51, no. 3 (July 1975), p. 243.

3 The Diffusion of Computers

Computers are mainly known for their data processing capabilities. As such, they are rapidly recognized as an indispensable tool for research and management in industry. Besides that, uses have been found for them as production and quality control devices, enhancing their penetration of almost all industries, including agriculture. Furthermore, their enormous capacity to store and retain information has found applications in government departments where large masses of data must be processed. No field of economic activity is completely outside their purview today.

Computer Adoption

The most important aspect in analysing the diffusion of an innovation is the sequence of its adoption in time and space. This can often be represented by a diffusion curve, usually with a logistic function. The curve is composed of a set of ratios involving a numerator (the number of actual adoptions) and a denominator (the number of potential adoptions). In studying computers, we will establish one ratio for each year of the period under study, making the diffusion curve the cumulative distribution of actual users in relation to potential ones. Each diffusion curve (there is one for each region) is the graphic representation of the degree of market penetration of new types of computers in the various regional economies. The construction of the diffusion curve requires one to know the date of the first adoption, the number of subsequent applications (chronological data), and the number of potential users. In a spatial context, as is the case here, the superposition of curves plotted for different regions enables us to determine whether or not regional technological lags exist. However, the study of the diffusion of computers is more complex than that of many other innovations in the various Canadian regions because of the continually changing nature of the product. Even though the computer has been marketed for over a quarter of a century, its adaptation to the

Canadian economy is barely into its first phase.[1] It is not a product whose properties are established once and for all; the capabilities and sophistication of computers have evolved so rapidly that any comparison of one year over another becomes difficult. Indeed, the addition of diversified and complex auxiliary features, the extensive use of telecommunications linkages, and the proliferation of components that are more miniaturized and efficient, all augment computer capacity and increase operating speed in such proportions that it could be argued that the computer is actually a different product from one year to the next. In fact, today's computer is an outcome of several innovations, and a fully comprehensive study of its diffusion would require an examination of each one of them. We believe it is nevertheless useful to study diffusion of "the computer," which we define as "a device capable of accepting, processing and supplying data under the control of an internally stored program which it has the ability to modify."[2]

There are two possible points of view in evaluating the local implications of the locally installed capacity of computers. First, installed capacity in computers can be viewed as an index of the modernism of local methods of production, including both the manufacturing and service sectors. It is true that local capacity in computers is only an approximate index because a local computer can be hooked, through telecommunications facilities, to a much more powerful computer located in another region or even in the United States. In that case, the size of the local computer does not indicate its true ability to contribute to productivity in local manufacturing. It is even possible that the complete absence of computers is not a sure sign of lack of use of modern methods of production related to the use of computers if there exist terminals linked to computers situated outside the region. Both the possibility of interconnection of computers and the use of terminals can thus modify any causal relationship between the local number of computers and the level of local productivity of labour. However, this problem is not serious with our data because the number of interconnected computers was small during the period under study;[3] similarly, it is unlikely that remote terminals play a large role because of the relatively high cost of telecommunications.[4]

1 Despite the fact that approximately 90 per cent of business firms are already using computer products and services. See the results of the survey conducted jointly by the Canadian Chamber of Commerce and the Canadian Computer/Communications Task Force, Study No. 9, *The Use of Electronic Data Processing by Canadian Business* (Ottawa: Information Canada, 1974).

2 Canadian Information Processing Society, *Canadian Computer Census* (Ottawa: CIPS, 1971), p. 9.

3 Compare Table A-6 with Table A-1.

4 On the high costs of conventional transmission circuits, see: *Survey of the Canadian Computer/Communications*, by Task Force Data Communications Survey, vol. 7, no. 16 (Ottawa: Information Canada, 1974). Furthermore, pan-Canadian data transmission networks are recent: Infodat-CN-CP dates from 1972, and Dataroute-Bell from 1973.

Second, installed capacity in computers can also be seen as an index of the regional quality of tertiary activities. By this, we mean the ability of a region to provide jobs (in computer work) requiring high proficiency of the labour force and consequently paying high wages; to provide local markets for businesses that sell computer hardware, software, and maintenance services; and finally to act as a development pole that provides head offices, banking, and similar services for the surrounding regions. These latter functions are particularly computer-intensive.

From the second point of view, the local physical capacity in computers is an important index because, contrary to the approach of the first point of view, a computer terminal does not have as much regional impact as the computer itself.

One way to illustrate the implication of the above distinction is to suppose, for instance, that a system could be designed so that Montreal and Toronto were the country's only data processing centres, with the rest of the country being equipped with data processing equipment consisting only of primary terminals. Barring transmission costs (or these costs being offset by returns to scale of the computers in the two cities), under the first point of view, the concentration of data processing would have no negative impact on the productivity of establishments located in peripheral regions. This is not so under the second point of view; the physical concentration of the computers in central Canada would downgrade the growth pole and other capabilities of the peripheral regions.

The Size of Computers

There are many theoretical ways of measuring the size of computers, but the statistical data on the subject is so lean (or so expensive to acquire and process) that we have only used a few of the possibilities in our analysis. In general, we simply used the numbers of computers without being able, as we did in our study on newsprint in Chapter 7, to combine various sizes of units of measurement of a machine into a unique index of modernity. Had data been available, it might have been preferable to combine together several alternative measures of the size of a computer, including the capacity of the main memory in terms of bits weighted by the speed of operation (or frequency of cycles per time units), the rental cost, the number of employees, and the characteristics of auxiliary servicing equipment.

In order to use memory capacity weighted by frequency, it would be necessary to know the specifications of each type of computer in use in Canada. In this respect, it is necessary to know the frequency of each computer and to ensure the comparability of different measures of the size of the main memory. Depending on the manufacturer and type of the computer, the number of storage cells is defined in terms of bytes, characters, words, or decimal figures; although each of these measures is directly convertible into "bits," the appropriate conversion factors and frequency specifications can only be obtained from the manufacturers. The resources of our study did not permit us to make the numerous contacts necessary — 59 manufacturers (of more than 330 types of computers) were in business in 1973-74.

As for the value of wages and salaries and the number of employees in data processing services, it is impossible to establish a continuous series of data. "The annual census of wages" (also reporting the number of employees) of the Canadian Information Processing Society (CIPS) is the only relevant source of data, but it has not been available for the entire period.

With respect to using the rental cost or purchase cost of installations, we were informed by CIPS than an annual survey of these values for the various regions would again involve resources largely beyond those we had available for this study.

In view of these problems, we used either the total number of computers or the number of computers in three wide size classes defined according to the number of *K* (thousands of bytes, characters, words, or decimal digits) in the main memory.[5] The three classes: small computers having 0*K* to 31*K*; medium, 32*K* to 255*K*; and large, 256*K* and over.[6]

The Distribution of All Types of Computers

In 1956, there were only four computers in use in Canada.[7] However, the number of installations in all regions doubled each year during the first eight years and every three years since. This is shown in Chart 3-1 and Appendix Table A-1.

The regional distribution of the stock of computers has changed little since 1965, except for a certain slowdown in Quebec and a slight improvement in the Atlantic region, British Columbia, and the Prairies (see Table 3-1). This pattern is shown in the annual evolution of the number of computers (see Chart 3-1). It should be noted, however, that the computer did not appear at the same time in all regions and that the belated

5 After R.C. Barquin, in "Computation in Latin America," *Datamation*, March 1974.

6 Note that the procedure of measuring computers simply by their numbers is not unusual. All the studies we have seen involving international comparisons of computer diffusion were done using unweighted numbers of computers. See, for instance, Barquin, "Computation in Latin America", and Scrimgeour, "Computers for Process Control", *Canadian Datasystem*, June 1973.

7 The first use of a digital computer in Canada was in 1948 at the University of Toronto. The first computer commercially sold was installed in 1952, also at the University of Toronto; see CIPS, *Computer Magazine*, July/August 1973, p. 4, and January 1975, p. 8.

installation (relative to Ontario) of the first unit in the Prairies (a five-year lag), in the Atlantic region (a lag of six years for the first unit and eight years for the second), and in British Columbia (a lag of eight years)[8] was followed by a period of catching up, during which there was an increase in the percentage shares of total computers installed in these regions.

Table 3-1

Regional Distribution of Computers, All Types, Canada, by Region, Selected Years, 1965-73

	1965	1967	1969	1971	1973
			(Per cent)		
Atlantic region	3.8	3.4	4.1	5.0	5.6
Quebec	28.7	26.0	23.8	21.6	22.2
Ontario	46.5	50.3	51.3	51.1	49.0
Prairie region	13.7	13.0	13.8	14.1	14.5
British Columbia	7.3	7.3	7.0	8.2	8.7
Canada	100.0	100.0	100.0	100.0	100.0

Source: Calculations based on data from Appendix Table A-1.

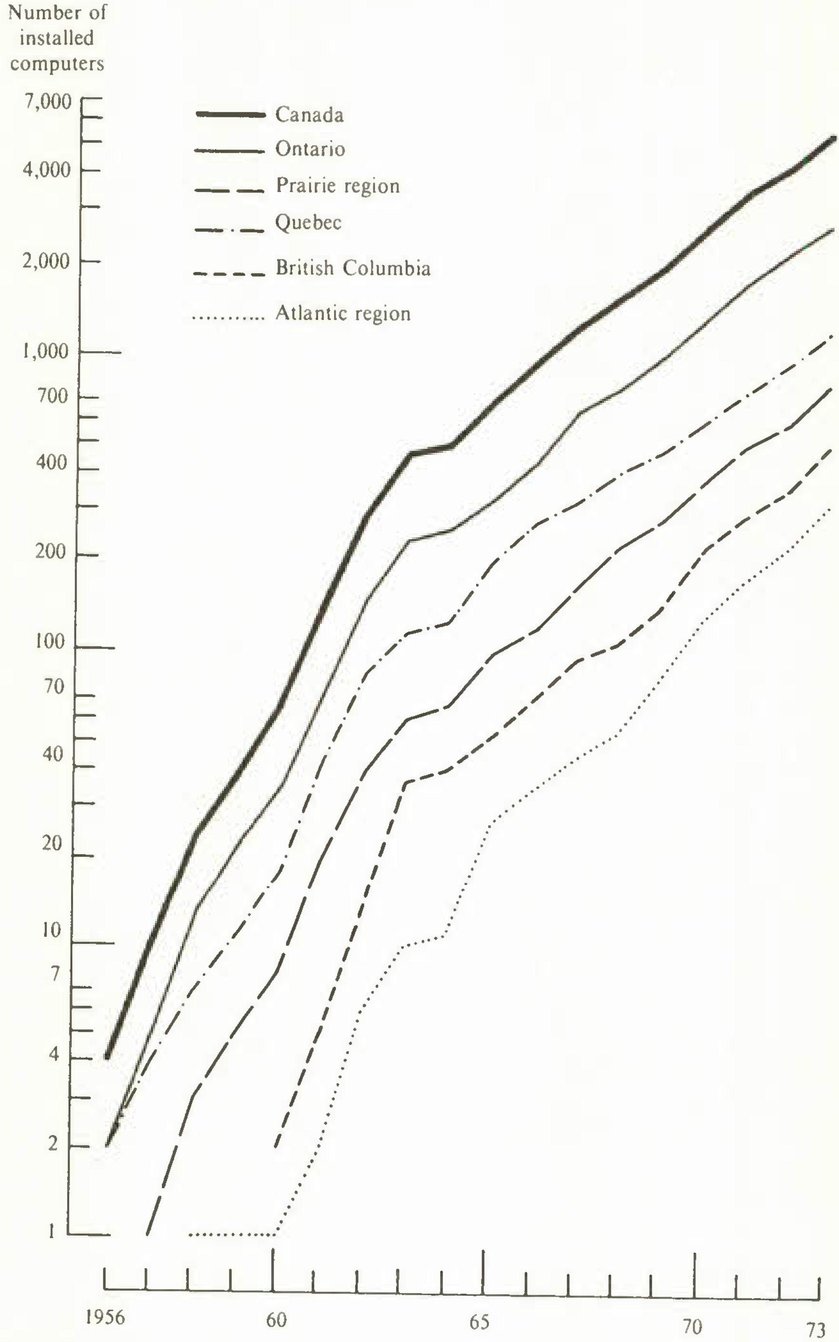
Since size of computers is a factor (albeit a minor one, as we will see later) conditioning the regional diffusion of computers in general, it is useful at this stage to picture both the Canadian and the regional evolution of computers according to their size. This is done in Chart 3-2 and in Appendix Table A-2. Both show that, during the period 1965-73, over three-quarters of all units installed had less than 32*K* and that only approximately 5 per cent could be classified as large computers. These proportions changed, however, from one region to another and from one year to another during that period. Thus, the proportion of small computers decreased until 1969 to the benefit of medium and large sizes but, in 1971-73, there was a reversal of that trend. During the latter period, the trend would probably have continued had there not been the extraordinary proliferation of mini-computers starting in 1970.[9] This is clearly confirmed by an examination of the proportions for Canada as a whole when the latter are eliminated (see Table 3-2). At the regional level, the percentage share of each size of computer has not changed much, but there are significant differences in the level of these shares between regions. In the Atlantic region, the popularity of the small computers is obvious, whereas in Quebec, during the period 1969-73, the proportion of small-sized units was less than the average for all regions, with large- and medium-sized computers better represented.

8 We used 1952 as the base to evaluate these lags, although Chart 3-1 shows figures beginning in 1956 only. Regarding Quebec, we cannot give data, but we assume that no lag existed at that time.

9 According to CIPS, the number of mini-computers installed in Canada from 1970 to 1973 was as follows: 1970, 535; 1971, 1,070; 1972, 1,472; and 1973, 2,448.

Chart 3-1

Evolution of the Stock of Computers, All Types, Canada, by Region, 1956-73



Notes: Data cover:
- January to December from 1956 to 1963;
- January to March for 1964;
- April 1964 to June 1965 for 1965;
- July 1965 to June 1966 for 1966;
- July 1966 to April 1967 for 1967; and
- May of previous year to May of current year for other years.

Data from 1956 to 1964 were compiled from subsequent censuses.

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table 3-2

Distribution of Computers, Canada, by Size, 1965-73

	1965	1967	1969	1971[1]	1973[1]
			(Per cent)		
Small	84.5	79.0	72.5	64.8(75.4)	64.7(79.7)
Medium	15.4	19.5	22.0	28.3(19.8)	28.0(16.1)
Large	.1	1.5	5.5	6.9(4.8)	7.3(4.2)
Total	100.0	100.0	100.0	100.0	100.0

1 Figures in parentheses include mini-computers.

Source: See Appendix Table A-2 and special computations.

Because of variation in computer size, great care must be taken in the interpretation of the trends described in Chart 3-1; for example, the slowdown and the acceleration in the growth rates of the number of computers, as observed in Quebec and the Atlantic region, respectively, cannot be interpreted as a relative decrease or a relative increase in capacity. In the first case, installations were less numerous because of a higher than average capacity; in the second, the capacity per unit installed was less, but the number of installations was higher.

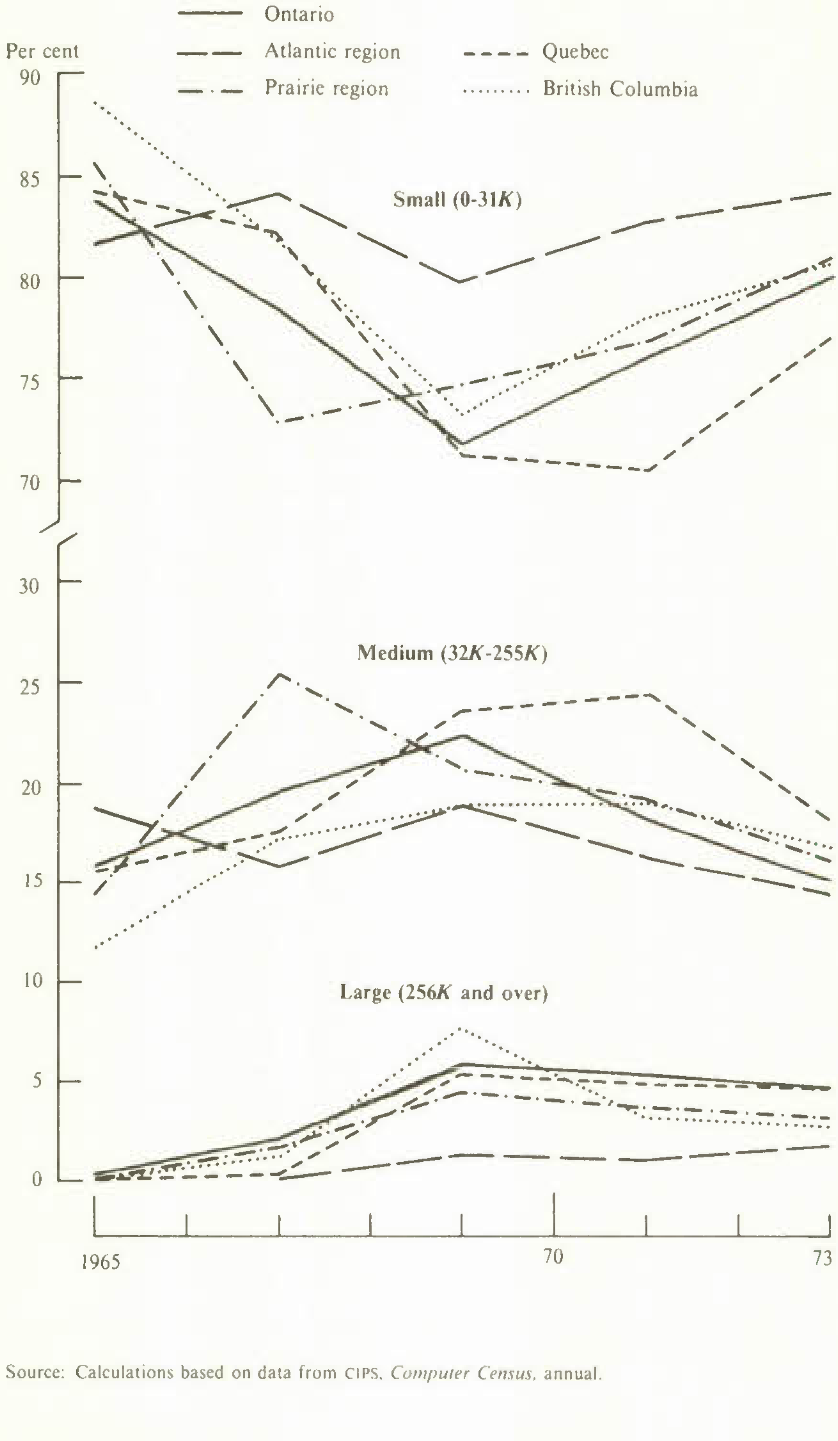
Information on other characteristics could, of course, improve our analysis in this respect. For example, one could consider either the actual applications of the computer or the activity sector in which it is used. Hence, in a region where most of the computer potential is used for tasks such as production control or accounting, installed capacity is not likely to be as great as in another region specializing in financial services, which requires high-capacity installations. However, we were unable to obtain regional statistics on these matters.[10] Similarly, there are sometimes quite pronounced discrepancies between the number of computers in use and the rental value, the latter reflecting much more accurately the level of installed capacity (see Appendix Table A-8).

While Chart 3-1 shows that there has been growth of computer installations in all regions, it also indicates, for some of them, significant lags in initial adoption. Although there is subsequently a near parallelism of the curves throughout the period and only minor changes since 1965 in the percentage shares of total computers installed, this does not necessarily mean no changes in technological lags, as will be seen when more refined diffusion measures are presented below. Such measures require the development of an appropriate norm, such as evaluation of the potential number of computers in each region, to be used as the denominator of a ratio in which the actual number of computers in place will constitute the numerator.

10 The data supplied by the censuses of CIPS can be used as a basis for compiling such statistics, but the exercise would require greater resources than those available to us.

Chart 3-2

Distribution of Computers, Canada, by Size and Region, 1965-73



Source: Calculations based on data from CIPS, *Computer Census*, annual.

After a thorough assessment of the facts, the explanatory factors that might account for regional differences in either the date of initial adoption or the subsequent rates of diffusion will be briefly explored in an attempt to determine whether a regional factor is at the root of these differences. It is to these two tasks that we turn now.

Measurement of Regional Diffusion

Since there exists no annual survey of regional needs for computers, we have had to resort to proxy variables (as is done in most studies) to indicate the size of the potential computer market. Among the likely variables (suggested or derived from similar studies) are the general level of needs represented by the population; the general level of economic activity represented by the gross national product (GNP); and the level of activity of economic sectors that have special needs for computers—such as the goods-producing industries that, among other things, may need special types of computers like production control computers and so forth.[11]

The Case of "Retired" IBM Computers

Besides attacking the problem in a classical manner—that is, finding the proper index of needs for computers (differentiated or not, by type)—we can learn from history. Indeed, because of the incessant innovative activities in the field of computers, a particular model of computer goes through a "life cycle" so that there are some computers whose history is now complete, in that they were introduced to the market place, adopted (presumably by all those who needed them), and either they were retired (replaced by others) or, at least, their production and diffusion progress came to a stop. Theoretically, then, we do not have to establish independently their potential market. All the potential uses were (presumably) exploited, and the whole thing is a matter of history. Records of these life cycles are available for some IBM computers. For illustrative purposes, we present below the cases of nine IBM computers whose history is complete (in Canada as a whole) and, of these nine, six which also have a complete regional history. Furthermore, since IBM technology is preponderant in Canada[12] and also because IBM products have been the only ones simultaneously well represented in all regions, an a posteriori study of

11 For a more complete catalogue of these variables, see Barquin, "Computation in Latin America," pp. 73-74. By using such variables and giving weights to them, this author develops a unique ranking of countries according to what he calls their "computer industry development potential."

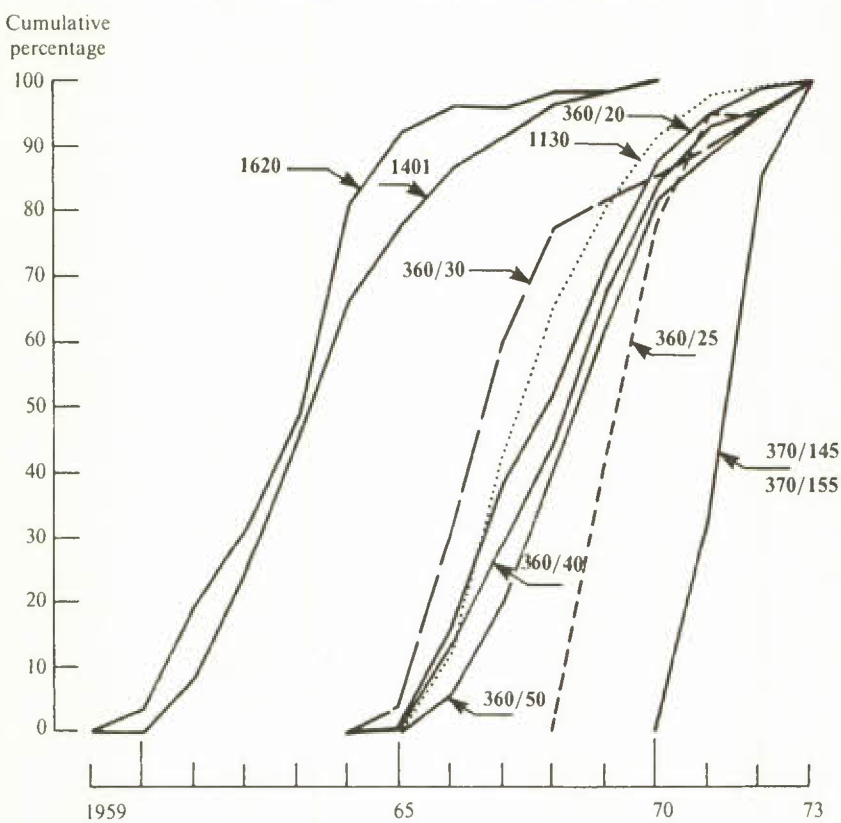
12 More than 75 per cent of the market is controlled by three manufacturers, IBM, Honeywell, and Univac, with only a few best sellers.

the diffusion of these computers is, to some extent, a good primer for understanding the regional diffusion process. Among the IBM computers, we have presented the following series: 1620, 1401, 1130, 360/20, 360/30 and 360/40 as well as some others that have proved important on the IBM market, like 360/25, 360/50, 370/145 and 370/155, but for which the geographical distribution does not permit a regional breakdown.[13]

The analysis is based on life-cycle curves for each of the series. The vertical axis measures the cumulative percentage of sales of a particular computer in each year, with total sales over its whole life being 100 per cent. Chart 3-3 shows the various curves obtained for Canada as a whole.

Chart 3-3

Life Cycle of Selected IBM Series, Canada, 1959-73



Source: Calculations based on data from CIPS, *Computer Census, annual.*

The configuration of the curves leads us to conclude that the average life cycle of a given type of computer ranges from eight to ten years and that the types of computers studied had relatively similar life cycles, except for

13 Appendix Table A-3 shows the distributions as cumulative percentages, as well as the total number of installations.

series 360/25 and 370/145-370/155 whose periods of marketing have been much shorter. The rapidity of diffusion of these latter series might, however, be explained by the fact that they are improved versions of system 360; it is quite possible on the other hand that the market for series 370/145 and 370/155 is not completely exhausted, though the data for 1973 and 1974 suggest that this is likely.

At the regional level, an examination of curves plotted in Chart 3-4 for the selected types of computers leads us to several observations. From the first series of the period (1620 and 1401), we can deduce that there were lags of one to three years in initial diffusion of the computer in the Prairie, British Columbia, and Atlantic regions in comparison with Quebec and Ontario. Not only did the first units of new series generally appear in the Quebec and Ontario markets, but also the rate of diffusion was often fastest there, though catching up is observed in many instances for British Columbia and the Prairies. With only a few exceptions, the Atlantic region ranks last in both early adoption and the speed of later diffusion. In particular, the catching-up phenomenon is observed for series 1620, 1401, 1130, 360/20, and 360/30. The analysis of larger-sized series such as 360/40, 360/50, and 370/145-370/155, available on the market since 1965, still reveals lags for the first installations, especially in the Atlantic region. However, these series never became really popular outside Quebec and Ontario; for example, out of 196, 109, and 111 installations in Canada for the three series, only four, two, and five, respectively, occurred in the Atlantic region.

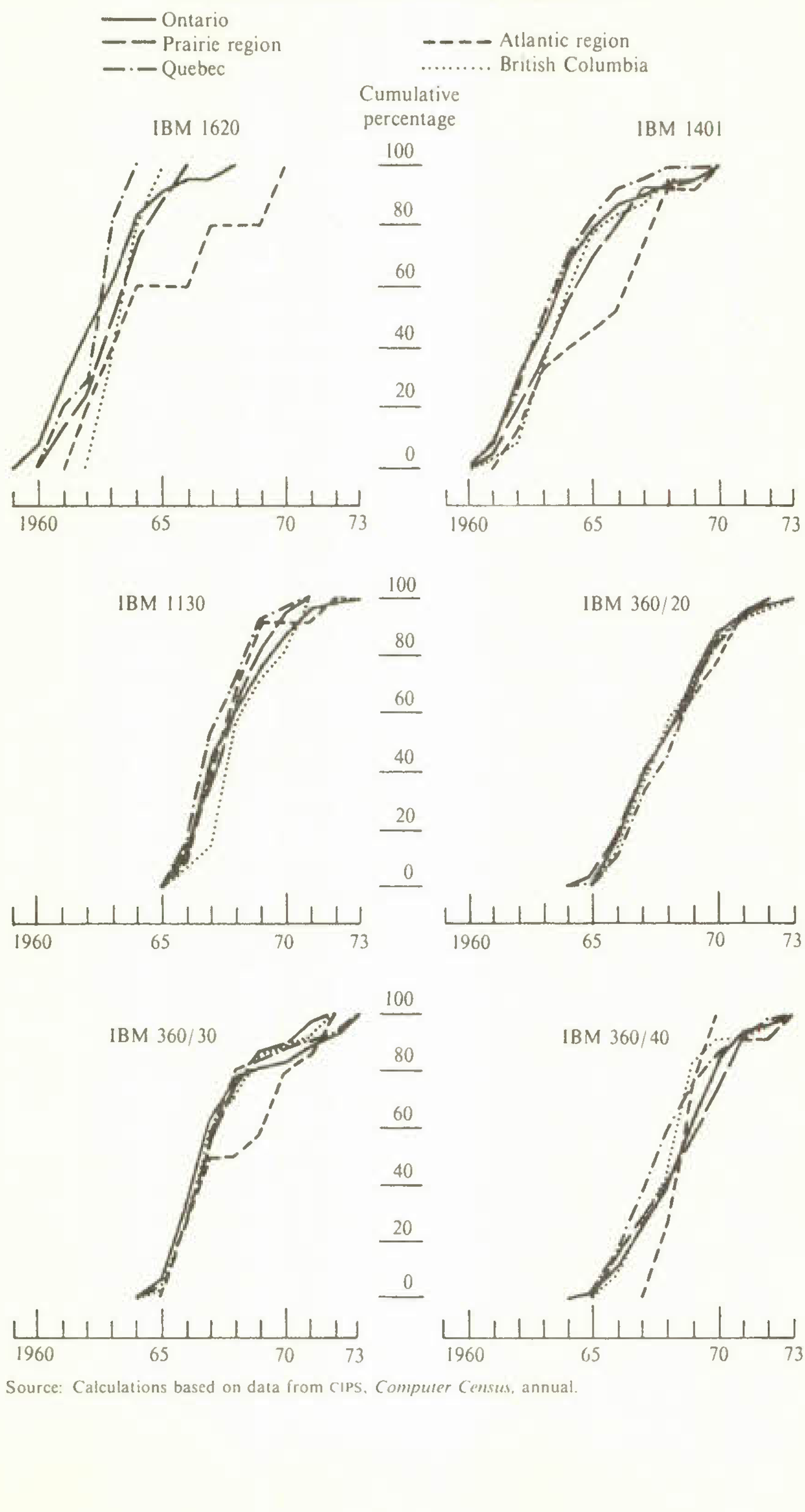
Although IBM technology has always been recognized as leading in the marketing of data processing techniques, the analysis based on IBM data alone cannot be used to do more than suggest plausible generalizations about the evolution of general computer technology in the various Canadian regions. It does indicate that certain lags probably existed at the beginning between Quebec and Ontario, on the one hand, and the remaining regions, on the other. It is also possible that these lags have dwindled, especially in view of the diffusion curves for series 1130, 360/20, and 360/30.

The Case of "Process-Control" Computers

This is a case where, in measuring diffusion, we need to divide the number of computers in use by some variable that can act as a proxy for the size of the potential market. In deciding upon a suitable candidate, we note that process computers are a highly specialized type. Compared with nonprocess computers, "the major difference is that the process computer has additional interface equipment enabling it to obtain its input data directly from sensors measuring process variables such as flow, pressure,

Chart 3-4

Life Cycle of Selected IBM Series, by Region, 1959-70



Source: Calculations based on data from CIPS, *Computer Census*, annual.

temperature, speed, etc. These inputs make the system an on-line system operating therefore in real time on an interrupt basis."[14] This makes them appropriate for use in primary industries and, to some extent, in manufacturing industries and utilities such as nuclear power stations. But we find that they are also used by universities and the government of Canada (Environment Control and Research). However, since process-control computers are mainly used in the production of goods, their penetration into goods-producing industries is what we should measure. An interregional comparison of intensity of use of these computers will then reveal some aspects of the modernism of production techniques in different regions.[15] With these facts in mind, a suitable divisor would be value added in goods-producing industries. We have therefore calculated the ratio of the number of computers used directly or indirectly in goods-producing industries to the value added in these industries.

Chart 3-5 (or Table A-5) shows the results and gives the regional evolution of computers used per billion dollars of value added in goods-producing industries.[16] The curves of Chart 3-5 show that Ontario was the early adopter but that, from 1964 to 1966, the Atlantic region had a small lead. In turn, that leadership was lost to the Prairies from 1968 to 1972. In 1973, the central provinces of Ontario and Quebec were in the lead again, with the Atlantic region last. In sum, for industrial process-control computers, recent trends (1972 and 1973) show a widening of the gap between the Atlantic and the other regions, despite an early but very small lead by the former in the early phases of diffusion.

The Case of Autonomous Computers

In this section, we analyse the regional diffusion of nearly all the stock of computers. For reasons mentioned before, we have eliminated inter-

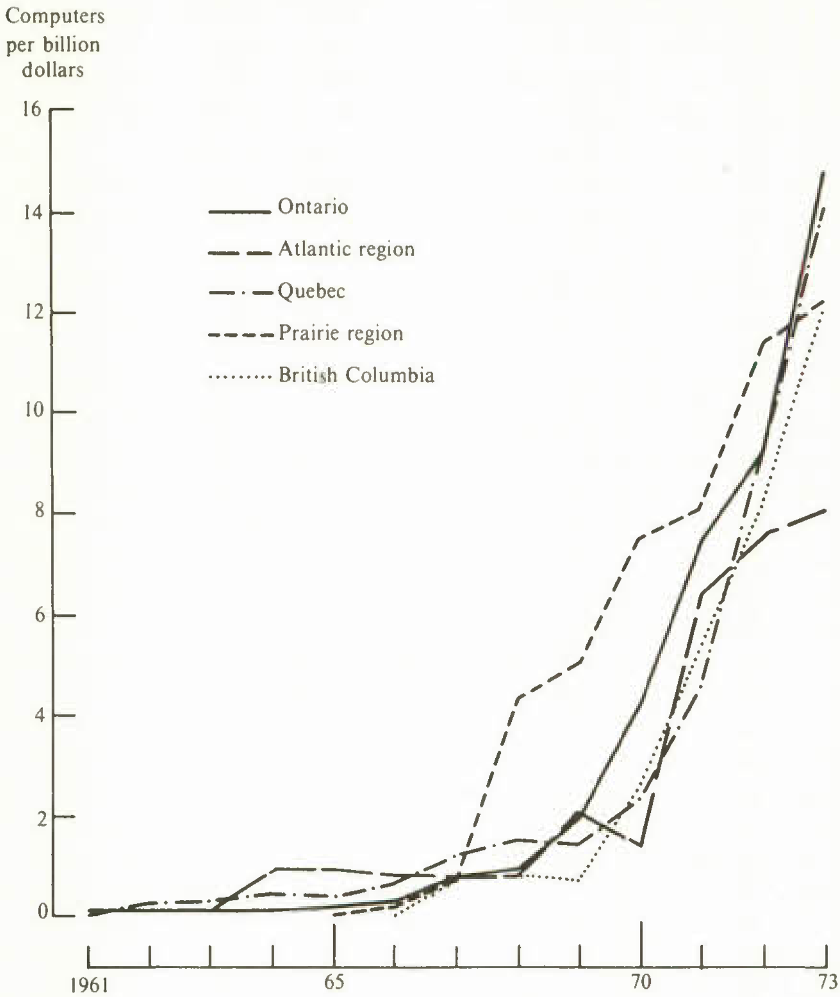
14 Scrimgeour, "Computers for Process Control," pp. 38-39.

15 This is far from being the only possible indicator of the modernism of regional production methods because process computers accounted for only 13 per cent of all computers in use in Canada in 1973. It is an important one, however, because these computers are in a strategic position in the industrial world and thus may have a disproportionate influence on the level of local productivity in comparison with, for example, computers located in universities and used mainly for research and teaching.

16 We have eliminated from the numerator all federal government process-control computers and also local government, college, university, and hospital process-control computers. Although general computers in universities are sometimes used by industry on a time-sharing basis for data processing, it is impractical for industry to use university process-control computers. This is why these computers have been eliminated. We have, however, included the process-control computers of public utilities and transport companies because they contribute directly to the production of goods by industry. We have also included the process-control computers of private equipment companies because they are largely rented to industries that produce goods.

Chart 3-5

Evolution of Computers Used in Production Control per Billion Dollars of Value Added in Goods-Producing Industries, by Region, 1961-73



Source: See Appendix Table A-5.

connected computers from the analysis[17] but included all others — process-control, public, private, and other computers. In the construction of diffusion curves for these computers, we considered two problems: whether to include the federal government computers installed in Ottawa and which

17 Although their inclusion would not materially change the results because the regional proportion of interconnected computers does not vary much: in 1973, this proportion was 13.7 per cent in the Atlantic region; 12.5 per cent in Quebec; 14.1 per cent in Ontario; 13.0 per cent in the Prairies; 14.8 per cent in British Columbia; and 13.5 per cent in Canada. Sources of data for these calculations are Appendix Tables A-1 and A-6.

denominator to use as a proxy for the potential use of computers in general.

It can be maintained that one should eliminate from the Ontario data the computers installed in Ottawa by the federal government because federal government activities in Ottawa are only arguably part of the regional characteristics of Ontario and that including the computers associated with them would widely distort regional comparisons. We have, nevertheless, included them because to exclude them would be to confuse measurement with interpretation. Federal government computers do raise the productivity and income of Ontario workers, just as computers in any other industry would.[18] The data for Ontario, therefore, include a larger than average share of federal computers, and this is an important reason, though not the only one by any means, for the lead in adoption that Ontario is observed to have.

In studying the evolution of the diffusion of computers of all types (except those that are interconnected), we considered two possible denominator variables as proxies for the potential computer market in a region: gross national product and labour force. The case in favour of GNP is that, when one is dealing with all types of computers simultaneously they are likely to permeate all fields of economic activity. Given a certain general level of technology present in a region and a given GNP, it would be interesting to know whether computer technology has kept up with the penetration of other technologies. Local GNP is then a suitable choice as denominator in evaluating diffusion. This approach is compatible with the second point of view mentioned above. A serious problem with it occurs, however, if there is a good correlation between GNP per employee and computers per employee. Interregional differences in our measure of the spread of computer technology will then be biased towards zero, masking somewhat the very kind of effect of technology spread on local productivity that we seek. This argues in favour of employment or the labour force as denominator.[19] In other words, if we wish to know the impact of the diffusion of computers on the general level of productivity in a region (the first point of view described above), then the labour force is the better denominator. Because both denominators have qualities and defects, we will present both measures. Chart 3-6 shows the evolution of the number of computers per billion dollars of GNP, whereas Chart 3-7 presents the evolution of the index using the labour force as denominator.

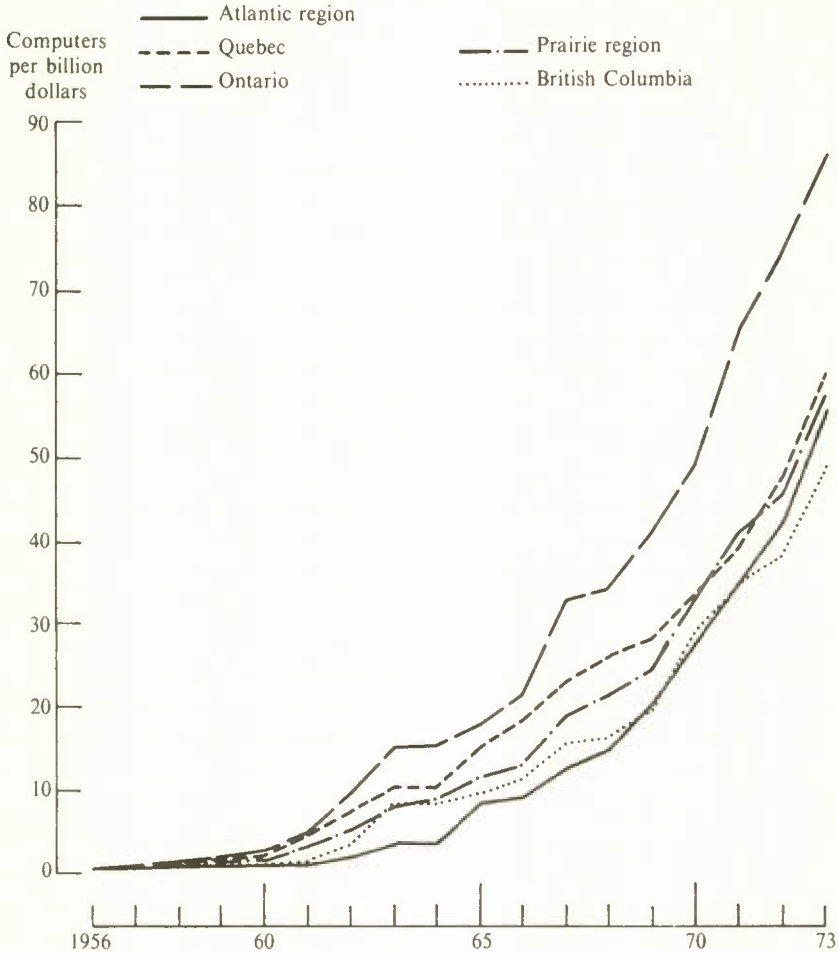
For the initial years, the earlier noted lags remain, but the charts permit a close examination of the evolution of the lags. On either measure, Ontario

18 In the case of interconnection, they would even raise the productivity of government workers in other regions.

19 Employment is logically the best choice, but it introduces the difficult practical problem of correcting for cyclical variations—possibly differently timed among regions. To avoid this problem, it seemed better to use labour force data.

Chart 3-6

Evolution of Autonomous Computers per Billion Dollars of Gross National Product, by Region, 1956-73[1]

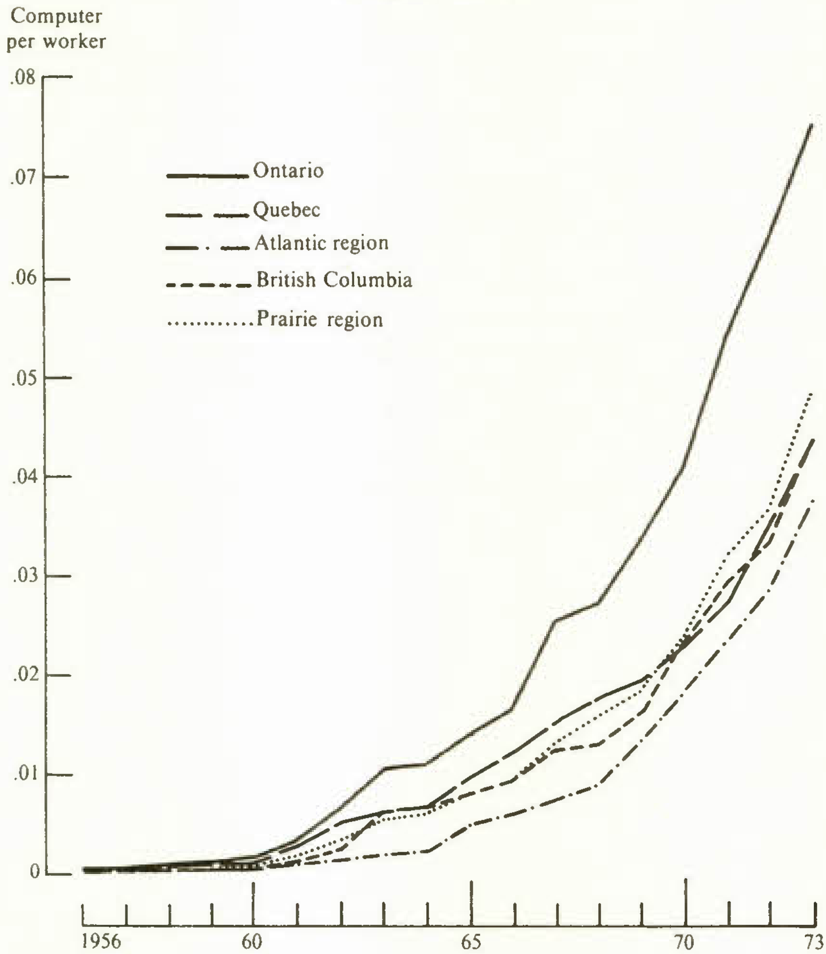


1 The number of autonomous computers is arrived at by taking the difference between the stock of computers as presented in Appendix Table A-1 and those that are connected as shown in Appendix Table A-6. Estimates of provincial GNP are furnished in Appendix Table A-7, as they are not publicly available.

Source: See Appendix Tables A-1, A-6, and A-7.

Chart 3-7

Evolution of Autonomous Computers per Labour Force Member, by Region, 1956-73[1]



1 The number of autonomous computers was again arrived at by taking the difference between the stock of computers presented in Appendix Table A-1 and those that are connected as shown in Appendix Table A-6.

Source: See Appendix Tables A-1 and A-6, and Statistics Canada, *The Labour Force*, Cat. No. 71-001.

leads in initial adoption and over the whole period covered by our data. It gradually outdistances the others. The Atlantic region is last in the beginning, and it stays in last place throughout when the labour force is the denominator; when GNP is the denominator, it becomes second to last from about 1969 onward, when British Columbia is seen to lag farthest behind. In general, though, Quebec, the Prairies, and British Columbia fall in between Ontario and the Atlantic region, and frequently in that order, on either measure.

In Table 3-3, we give approximate estimates of lags in initial adoption and of average lags over the period of our data. For finding the initial adoption lags, we took the initial adoption phase as completed when computers per billion dollars of regional product reached 0.8 computer per billion, and when computers per labour force member reached 0.004. These choices are arbitrary, but not unreasonable. Average lags were calculated by taking a number of additional readings during the period and calculating the average.

Table 3-3

Estimated Lags of Regions Relative to Ontario in the Use of Computers, 1956-73

	Atlantic region	Quebec	Prairie region	British Columbia
		(Number of years)		
Lags in initial adoption				
Chart 3-6	3.5	.25	1	3
Chart 3-7	3.5	.25	1	2.5
Average lags				
Chart 3-6	3.5	1.25	2	3
Chart 3-7	3.75	2.0	2.25	2.5

Based on the data in Table 3-3, Quebec lagged by a quarter of a year in initial adoption, then fell behind somewhat for an average lag of one and a quarter to two years. The Prairies and British Columbia are not close together for the initial lag—one lagging one year and the other two and a half to three years behind Ontario; for average lag, they are much closer. The Atlantic region trails badly, with an initial lag of three and a half years, and an average lag of between three and a half and three and three-quarters years behind Ontario.

Is there evidence that the lags in adoption among regions have decreased over time? Visual inspection of Charts 3-6 and 3-7 shows no overall trend. The comparison of initial and average lags in Table 3-3 shows a slight widening, most of which appears to have occurred fairly early on in the diffusion process. Up to the end of our data period, then, we can surely say that the lags did not decrease.

To sum up, the evidence in all three categories of computers studied in this section (IBM, Process Control, and all types without data transmisssion line) suggests that, in the initial stages of the diffusion of computer services, definite and sometimes important lags and leads existed. The Atlantic region is invariably well behind, and Ontario well ahead.

Have the gaps tended to decrease over the period? This was the case for certain IBM computers, especially recent models. For production control computers, the Atlantic region became the undisputed lagger only at the end of the period. Its position did therefore worsen with time. Let us note that, as a condition to high productivity in manufacturing, production control computers are relatively more important than other computers, so that this poor performance might perhaps be heavily weighted in any overall judgment. When almost all computers are examined, the relative distance between the regions' performances is found to have increased slightly over time, with average lags in terms of years exceeding initial lags. On balance, we conclude that there is no convergence yet between the regions that is detectable in the available data, and there may be some small divergence.

Factors Pertaining to the Diffusion of Computers

The data we have analysed suggest that the diffusion process of computers in Canada is comparable to the propagation of a concentric wave with Toronto-Ottawa-Montreal as the epicentre. Yet, as we will show below, the diffusion lags owe very little to the usual impact of geography on diffusion processes. It is true that we have observed that the first computers appeared in Ontario and Quebec, later in the Prairies, and finally in the Atlantic region and British Columbia, but distance or geography—that is, the cost of overcoming space—has played, in this sense, only a small retardant role;[20] paradoxically, on the other hand, it may have helped diffusion. Distance for computers translates into transmission costs and difficulties in establishing efficient and reliable transmission circuits. Figuratively, it acts as a local protective tariff. Since experts hold that transmission costs were high during the period, distance actually boosted local demands for computers, so that geography does not explain the observed regional lags. Furthermore, distance seems unlikely to have made access to information more difficult.[21]

Three facts support the latter contention. First, important computer services have existed since 1961 in centres as remote as Kitimat and Sept-Îles. Since then, the list has become considerably longer with the addition of towns such as Flin Flon, Yellowknife, Labrador City, and so forth.

20 Hard to quantify with the data we have.

21 In Chapter 4, which studies the diffusion of new technologies in the steel industry, we also found that distance boosted the adoption of a new technology (electric furnaces) and did not impede access to information.

Second, the study of the diffusion process of IBM technology allowed us to establish that, from about 1965, there were no noticeable lags in the adoption of this type of new computer series. Finally, a survey carried out jointly by the Chamber of Commerce of Canada and the Canadian Computer/Communications Task Force in 1971, concluded that no problem exists in that respect.[22]

Certain other observations suggest that it would be difficult to associate this sequential process with an urban hierarchical phenomenon (propagation from large cities towards small ones); in fact, in many cases, computers were put to use in small towns at the same time, if not before they were being utilized in urban centres higher in the hierarchy (for example, Port Alberni and Powell River versus Vancouver). The factor of urban size, frequently suggested as an explanation of lags in the adoption of innovation, seems therefore not significant.

The major portion of gaps between regions with respect to computer services seems to be explained by economic factors rather than geographical ones.[23] Two factors contribute here to the explanation: specific needs for data processing services, principally in mining, manufacturing, and financial services industries; and the size of the enterprises or companies into which data processing services can be introduced. Regional differences in these factors bring about regional differences in the rate of adoption of computers.

Evidence for the importance of the first economic factor is that remote agglomerations and small towns having data processing systems are, in most cases, specialized either in mining or manufacturing activities and that more than 75 per cent of all computers in use in Canada are in the Quebec-Windsor corridor where the country's highest concentration of economic activity is located (80 per cent of manufacturing). With respect to company size, a survey shows that approximately 50 per cent of businesses having 100 employees or less do not use computer services, compared with 13 per cent for those having between 101 and 250 employees, and with only 1 per cent for those having more than 250 employees (see Table 3-4).[24] This means that a very high correlation exists between company size and computer usage. This reason is the converse of another one often given (for the nonadoption of computers) consisting in high costs of data processing services.[25] However, what counts is not the absolute cost but the cost per unit of output. Since computers involve some indivisibilities in terms of their size or restrictions in terms of versatility, only large firms can utilize

22 CCC and CCCTF, *The Use of Electric Data Processing*, pp. 4 and 8, Table 4.

23 *Ibid.*, p. 8, Table 4; 40 per cent of the firms that do not use computers to not do so because they find no application in their enterprises.

24 *Ibid.*, p. 6, Table 2.

25 *Ibid.*, p. 8, Table 4; 60 per cent of industrial and commercial enterprises contacted that "do not use or do not intend to use computer products services" gave this reason.

all their capabilities, so that some computers appear too costly to small firms. Closely related to these factors is the changing size distribution of computers during the period: gradual miniaturization, on the one hand, and the advent of giant computers, on the other. The miniaturization allowed regions such as the Atlantic, whose industrial structure did not favour the massive use of medium-sized computers, to gain access to this technology. This made the evolution of computer use less unfavourable than it would have been if technological progress had simply increased the average size of computers.[26] But the advent of giant computers (which have productivity advantages for large financial institutions) did not favour the Atlantic region, because this region was not well endowed with this type of firm.[27]

Table 3-4

Data Processing Equipment and Services Used, by Size of Business

Number of employees	Used	Not Used	Total
		(Per cent)	
1—50	48	52	100
51—100	50	50	100
101—250	87	13	100
251—500	97	3	100
501—750	100	0	100
750 and over	99	1	100
Total	91	9	100

Source: Canadian Chamber of Commerce and the Canadian Computer/Communications Task Force, *The Use of Electronic Data Processing by Canadian Business*, Study No. 9 (Ottawa: Information Canada, 1974), p. 6, Table 2.

The Regional Factor

Given the facts regarding the diffusion of computers in various regions, the question remains whether or not a regional factor is at work through the various determinants of the diffusion of computers. A regional factor is operative if the basic characteristics of a region introduce regional differences in the determinants of diffusion.

Distance, as we have seen before, was a factor — albeit hard to quantify but, more important, an ambivalent factor — in the regional diffusion of computers; however, on both counts, it is an undeniable regional charac-

26 Note (in Appendix Table A-2) that, from 1967 onward, the Atlantic region is the region with the highest proportion of small computers.

27 This affirmation and many others in this section is based on a general knowledge of the economic structure of the regions. Rigorous verification would require much more work involving correlating the evolution of certain aspects of the regional economic structures, company sizes, types of businesses, and so forth, with the evolution of the regional distribution of different types of computers.

teristic. It has, then, a regional factor aspect. On the other hand, since population concentration and urban hierarchy seem to have had no impact on the types of computers studied, there is no point in searching for a regional factor in these instances.

However, regional economic characteristics, particularly structural differences in terms of industrial and commercial specialization and company size, provide a more fundamental and conclusive explanation for the gaps between regions. The mode of diffusion of computers is consequently roughly equivalent to what we have called, in Chapter 2, diffusion according to the economic and institutional environment of firms.

Indeed, since computer diffusion follows large manufacturing, mining, superior tertiary firms, and federal government activities, regions already well endowed with these activities lead in both initial adoption and later diffusion. This is why Ontario is usually first and the Atlantic usually last.[28] This is also why the Prairies led in production control computers between 1968 and 1970, when there occurred the mass conversion of pipeline flow regulation to electronic controls.

Furthermore, the Canadian regional distribution of computers is, in fact, in better shape than it could have been, given only the local endowments in manufacturing, mining, and large superior tertiary activities, if the size of the computers had not varied. Taking into consideration its endowment in the private industries mentioned above, the Atlantic region should have lagged to a great extent whereas, in fact, it did not. The reasons are, first, the increase in the variety of sizes of computers (something that has nothing to do with the regional factor) and, second, its greater than proportional share of federal government computers. Similarly, Ontario is marginally better than it should be, also because of federal government computers, many of which are located in Ottawa. But Ottawa is in Ontario, and that is a regional characteristic.

28 Note that by leading we mean not only that Ontario has more computers than the Atlantic region, which of course is expected because Ontario is larger than that region. But also, we mean that it has proportionately more computers per member of the labour force.

4 The Steel Industry

Steelmaking is a very important industry in the Canadian economy. With the exception of Prince Edward Island and New Brunswick, it is present in all provinces, and it plays a key role in the economies of Ontario and Nova Scotia.

Technology, energy, natural resources, markets, transport facilities and costs all combine to influence the choice of location of the steel industry at a given time. Initially, coal, coupled with good transportation and the encouragement of civic governments, underlay the emergence of Hamilton and Sydney as the main centres of the Canadian steel industry. Later, technological changes gradually eroded the importance of coking coal as the source of heat for the open-hearth process of making steel from pig iron. The use of other forms of energy such as oil and electricity permitted the installation in other centres of bigger and more efficient furnaces as well as small electric furnaces entailing little loss of efficiency, mainly in Ontario.

Although the concentration of steel production in Ontario might suggest that this is a poor example for the study of regional factors of diffusion, one finds, in fact, that there are few instances in Canadian manufacturing industries where Ontario is not preponderant. Indeed, our purpose here is to show how diffusion of one innovation—in this case, the electric furnace—can in fact contribute to a reduction of this concentration of the steel industry in Ontario, although other innovations do work to reinforce Ontario's paramount position.

At the Canadian level, locational decisions in the primary metal and fabricating metal industries are self-reinforcing because of the importance of agglomeration economies. To a large extent, steel users locate near steel producers, and steel producers (when not tied down to sources of raw materials) try to locate near their markets. This explains why the Quebec region, although it accounts for a bit more than one-quarter of the Canadian economy, has historically accounted for an insignificant portion of Canadian steel production. And because steelmaking was initially located in Ontario, with subsequent comulative effects accruing there, it was impossible, before 1950, to build a viable primary steel industry either in Quebec or, for that matter, in the western provinces. With technological changes after 1950, however, it became more feasible to do so. But, even then, because most of the steel users were already located in Ontario, the reduced dependency on coal and the increased importance of local markets as locational factors did not reduce, but really buttressed, Ontario's importance in the industry. As so, while Ontario's steel production remained almost stable, production in the Atlantic region underwent a relative loss of importance as steel output there fell from 29 per cent of the Canadian total in 1939 to only 6 per cent in 1975.[1] This difference was largely replaced by steel production in Quebec and the western provinces as a result of technological changes.

There were three main streams of technological change that influenced directly the production of steel in Canada and indirectly—but this remains to be demonstrated—its location. These were continuous improvements to the electric furnace; the advent of the basic oxygen process (BOP), which was installed commercially for the first time in Austria in 1953 and in Canada in 1954; and improvements in the operation of open-hearth (OH) furnaces through oxygen-lancing devices. Other major technological changes affecting the production of steel were beneficiation and pelletization of iron ore, direct reduction, continuous casting, and computer controls. These are not examined in our study, however, because data about them are not so readily available as for the three we focus on here.

Electric furnaces use electricity, in place of the coking coal used in the open-hearth method, as the heat source for achieving the very high temperatures needed in steelmaking. And, instead of relying on pig iron as the main ingredient, electric furnaces can use inputs of scrap metal, pellets of metallized iron, or any combination of the two materials. Until 1973, however, there were no direct reduction plants to produce metallized iron in Canada, so electric furnaces were built to use scrap. Moreover, since the process also eliminates the need for blast furnace facilities for the making of pig iron, electric furnaces can operate at a smaller minimum efficient size. Electric furnaces can then potentially be located in any metropolitan area in Canada where scrap iron is available.

Electric furnaces are technically most appropriate for producing special types of steel or small quantities of the type of steel used to make rods and bars. In such cases, they are part of mini-mills since their small size makes them uneconomical for flat-rolled steel products. Similarly, their sources of raw material often prevent them from producing high-quality billets. However, in their own line of products, they have proven competitive even in Ontario, where there is an ample capacity of the larger open-hearth and

1 G.E. Wittur, *Primary Iron and Steel in Canada*, Mineral Information Bulletin MR 92 (Ottawa: Department of Energy, Mines and Resources, 1968), p. 33; also Table 4-2 below.

basic oxygen furnaces.[2] In 1975, they had a capacity of 1.2 million tons a year in electric furnaces, or slightly more than one-quarter of the Canadian capacity from electric furnaces. Since 1973, some electric furnaces in Quebec have been fed with pellets produced by an adjoining direct reduction plant that uses natural gas to transform iron ore into pellets that are sufficiently metallized. In this case, production of primary steel is not tied to local supply of scrap; neither is production limited to billets suitable only for rods and bars of special steels. Sidbec-Dosco Limited, the main Quebec producer, uses electric furnaces and produces almost the whole spectrum of steel products.

For very large quantities of production, electric furnaces (at least those fed only by scrap) are usually considered to be more costly than other processes. The main advantage of electric furnaces is their low capital costs and their ability to attain their economical size at small output. However, when coupled with a direct reduction plant, they can produce all types of steel (including flat-rolled) on a large scale. Actually, they are efficient at almost any scale. In this case, a producer can envisage a fully integrated steel mill that is economically efficient for either small or large markets, something impossible with basic oxygen or open-hearth processes.

The basic oxygen process differs from the old open-hearth process by using pure oxygen, rather than air, directed with a lance to a point above the surface of a mixture of molten pig iron and scrap. The change in technique permits a reduction in the proportion of scrap metal used from 50 per cent to 30 per cent and a reduction in the time necessary for the process from eight or ten hours to forty-five minutes. At the same time, capital costs are reduced by one-half and labour costs by one-third. Finally, BOP requires no fuel whereas OH requires large amounts, usually fuel oil. Thus the process has a cost advantage over any other method, especially for large-scale production, for ordinary steels, and for those using very low-grade ore.[3]

2 Nonetheless, researchers are not in agreement as to whether electric furnaces provide competition to other processes. H.G. Bauman, "The Diffusion of the Basic Oxygen Process in the U.S. and Canadian Steel Industries 1955-69," Queen's University Research Report 7307, Kingston, 1973, p. 13, thinks that they are not in direct competition with BOP or OH. But the U.S. Bureau of Labor Statistics, "Technological Change and Manpower Trends in Five Industries," U.S. Department of Labor Bulletin 1856, Washington, D.C., 1975, p. 23, sees the electric ore furnace (SIC) as a substitute; it predicts that, while it accounts at present for over 15 per cent of the U.S. output of steel, it will account for 25 per cent by 1980. Similarly, R. Meyer and G. Herregat, "The Basic Oxygen Steel Process," *The Diffusion of New Industrial Processes: An International Study*, ed. L. Nabseth and G.F. Ray (Cambridge, Mass.: Cambridge University Press, 1974), p. 184, found that electric processes were sometimes in serious competition with the oxygen process. J.R. Miller, "The Direct Reduction of Iron Ore," *Scientific American*, July 1976, p. 80, predicts that, in the future, the choice among steel production techniques will be between two tandems: direct reduction coupled with electric furnaces, or a conventional combination of blast furnaces and basic oxygen furnaces.

3 See Meyer and Herregat, "The Basic Oxygen Steel Process," pp. 158-162. But, in other cases, this supremacy is not assured; see Miller, "The Direct Reduction of Iron Ore," p. 80.

Meanwhile, the old open-hearth process, despite the competition from substitutes, especially BOP, has far from disappeared. In 1975, more than twenty years after the appearance of its main competitor, it still accounted for 21.9 per cent of Canadian capacity. Part of the explanation is that new technology, in the form of oxygen-lanced devices, has prolonged the economic life of open-hearth furnaces.

At the international level, diffusion of these innovations has been studied extensively, with interesting implications for theoretical developments in the field of technological spread. For instance, the fact that BOP was perfected outside the United States and the fact that U.S. steel mills have been quite slow in adopting it have been perceived as challenges, or at least as elements that challenge, established doctrines of innovation diffusion. Furthermore, the fact that the Canadian industry is even more concentrated than the U.S. steel industry presents an interesting field of application for the theory of the diffusion of innovations under oligopolistic conditions.

The empirical research found in the literature has produced a number of hypotheses concerning diffusion according to the internal characteristics of firms.[4] One is that large plants would favour adoption of the oxygen process, at least after 1962.[5] Another is that if the price of electricity were moderate, plants small, and scrap easily available, then direct reduction (that is, electric furnaces) would be competitive with all other processes. In this study, our goal is to look at these hypotheses and to determine to what extent regional factors influence their diffusion in Canada.

The Pattern of Regional Diffusion

The basic oxygen process and electric furnace process are becoming increasingly important in Canada and, unmistakably, are replacing the open-hearth process (see Table 4-1). Yet, the big thrust in this direction is

4 This oligopoly presently consists of eleven principal firms — that is, firms having an annual production of more than 25,000 tons (our data, however, include many other small primary steel producers). In this oligopoly, leadership is assumed by three big Canadian-owned firms (Stelco, Dofasco, and Algoma, although Algoma was partly foreign-owned until very recently); they control 80 per cent of Canadian capacity. There are two medium-sized firms (Sidbec-Dosco and Sysco), which are government-owned. They are both 1967-68 takeovers of Dosco, which was foreign-owned. The other six firms are much smaller electrical mills largely Canadian-owned. Price leadership is assumed in turn by each one of the Big Three according to the type of products involved. Furthermore, contrary to U.S. practice, conscious parallel pricing and basing point system pricing (an almost universal practice in Canada) are not considered as infringements of the Canadian law.

5 Meyer and Herregat, "The Basic Oxygen Steel Process," pp. 162-163.

Table 4-1

Distribution of Total Steel Capacity, by Process, Canada, 1956-75

	Open-hearth process	Basic oxygen process	Electric furnace
		(Per cent)	
1956	74.78	6.34	18.88
1957	74.30	9.03	16.67
1958	71.95	11.24	16.81
1959	67.99	16.60	15.41
1960	64.61	20.57	14.82
1961	59.74	20.87	19.40
1962	60.38	22.18	17.43
1963	59.16	24.41	16.43
1964	57.66	26.90	15.44
1965	54.83	28.42	16.75
1966	53.67	30.09	16.24
1967	53.11	29.80	17.09
1968	54.06	28.15	17.79
1969	53.15	28.98	17.88
1970	52.63	28.70	18.67
1971	49.49	31.24	19.27
1972	34.80	43.27	21.93
1973	36.50	42.13	21.37
1974	22.50	54.27	23.23
1975	21.90	54.23	23.87

1 Yearly tonnages, by region and process, are available in Appendix Tables B-1 and B-2.

Source: Statistics Canada, *Iron and Steel Mills*, Cat. No. 41-203; and Statistics Canada, *Primary Iron and Steel*, Cat. No. 41-001. Data for 1965-64 are for December 31 of the preceding year; those for 1965-75 are for January 1 of the current year.

rather recent, beginning in 1972.[6] Meanwhile, Canada's capacity increased from 5.5 million tons a year in 1956 to 18.8 million tons a year in 1975.[7] The magnitude of the expansion at the national level thus provided ample opportunity to introduce new production processes.

The regional shares of total capacity have fluctuated to some extent since the advent of BOP (see Table 4-2). Looking at the initial and terminal years of the period, 1956 and 1975, the Atlantic region's share has been reduced by almost half, while the West's share has increased by three-

6 Compared with the United States, Canada was a faster adopter from 1954 to 1962 and a slower adopter during the period 1962-70. By 1970, Canada's BOP share of output was 29 per cent, while the U.S. share was around 48 per cent; Bauman, "The Diffusion of the Basic Oxygen Process." Let us note that capacity expansion in the United States until 1960 was still largely derived from installing oxygen-lancing devices on old open-hearth furnaces; B. Gold, W.S. Peirce, and G. Rosegger, "Diffusion of Major Technological Innovations in U.S. Iron and Steel Manufacturing," *Journal of Industrial Economics*, vol. 18, no. 3 (1970), pp. 218-241.

7 See Appendix Table B-1.

Table 4-2

Shares in Canadian Steel Capacity, by Region, 1956-75[1]

	Atlantic region	Quebec	Ontario	Prairie region and British Columbia
		(Per cent)		
1956	11.83	4.44	79.38	4.35
1957	13.58	4.69	77.45	4.27
1958	14.79	5.40	75.52	4.29
1959	13.95	4.46	77.51	4.08
1960	13.76	3.85	78.01	4.38
1961	12.72	6.49	74.45	6.34
1962	11.93	5.73	76.53	5.81
1963	11.66	5.91	76.08	6.35
1964	10.58	6.16	77.66	5.59
1965	9.38	5.84	79.15	5.63
1966	9.45	5.55	79.76	5.24
1967	9.71	5.16	78.98	6.15
1968	9.17	5.09	79.77	5.97
1969	8.79	4.92	80.43	5.85
1970	8.93	4.98	79.56	6.53
1971	8.40	6.21	78.72	6.67
1972	7.65	9.66	76.44	6.25
1973	8.28	9.44	76.23	6.05
1974	5.90	9.76	77.85	6.48
1975	5.74	9.82	77.19	7.25

1 Yearly tonnages, by region and process, are available in Appendix Tables B-1 and B-2.

Source: See Table 4-1.

quarters, and Quebec's share has more than doubled. Despite these regional shifts, however, Ontario's share remained constant at around 78 per cent of the Canadian capacity, fluctuating between a low of 74 per cent and a high of 80 per cent. Consequently, we can hardly talk about deconcentration of production; we can, however, note that the growth in Ontario's share, which began during the war, was arrested. In 1939, Ontario's share of Canadian steel production was 65 per cent, while the Atlantic region's share was 29 per cent. With the Second World War, there was substantial growth in the Ontario industry, which attained 76 per cent of Canadian production in 1946 and 80 per cent in 1969. At the same time, however, a relative movement of productive capacity from the Atlantic to the western provinces and Quebec seems to have taken place. In 1956, the Atlantic capacity was about one-third higher than that for Quebec, the Prairie provinces, and British Columbia combined. But, by 1975, the total produced in the latter regions was three times the Atlantic capacity.

What has been the role, if any, of technological changes in curtailing Ontario's progression and in the relative flight of capacity from the Atlantic region? To answer this, we examined the interregional diffusion of electric furnaces and the basic oxygen process.

In the past, the main constraint to the diffusion of electric furnaces was the shortage of local scrap. Nowadays, however, Prairie producers can buy a large portion of their supply of scrap from the United States. Sidbec, the major Quebec producer, has instead integrated its electric furnaces with a direct reduction plant to meet its input needs. The use of such alternate sources, plus the fact that they have no minimum efficient size requirements, means that electric furnaces can be diffused all across Canada.

In order to measure the rate of this spread, it is first necessary to establish the maximum potential volume of demand that this innovation can theoretically satisfy—the denominator in our diffusion ratio—in order to construct our diffusion curves. However, the complex geographical association of steel mills with steel users through direct linkages and with manufacturing activities through general agglomeration economies makes it difficult to establish this potential accurately.

If we take the demands of steel users as the only norm for establishing the ceiling of the diffusion curve—our denominator—we run the risk of over- or underestimating the potential. Local users do not always wait until a local supply of steel is established before they begin operations. There are steel users in every region of Canada, but their numbers are not in direct proportion to each region's primary steel production capacity. On the other hand, steel mills do not depend exclusively on local markets to absorb their local primary steel outputs; rather, all regions export steel to all other regions as well as abroad.

Nevertheless, the proportion of local demand for primary steel supplied by electric furnaces can help to establish the ranking among regions in the use of this process in order to determine which region has been the relatively faster adopter of electric furnaces. Two versions of this index are calculated for each region for each year.[8] One relates steel production to purchases by local industries within the steel complex (see Table 4-3). The other relates production with purchases of all local manufacturing industries (see Table 4-4). Plotting the data of these tables is equivalent, in each case, to drawing the diffusion curve for electric furnaces in Canada, as is done in Charts 4-1 and 4-2.

These tables and charts show that all regions (except Ontario and British Columbia) have, over the period, increased their ability to supply local needs, the most spectacular diffusion having occurred in the West, particularly in the Prairies, but closely followed in the recent period 1970-73 by Quebec, where there was an upsurge.

8 See Appendix B for a description of our methodology in constructing this index.

The results of the computations of the index are as follows:

Table 4-3

Index of Ability to Satisfy Apparent Needs of Local Steel Complex through Local Electric Furnaces, by Region, Selected Years

Region \ Year	1957	1961	1965	1967	1970	1973
Atlantic region	.28	.28	.26	.48	.50	.33
Quebec	.19	.30	.36	.30	.30	.70
Ontario	.12	.10	.08	.08	.09	.08
West[1]	.42	.71	.71	.74	.79	.67
Prairie region	.46	.79	1.05	1.09	1.21	1.08
British Columbia	.38	.47	.34	.26	.32	.24

1 West includes Prairie provinces and British Columbia.

Source: Computations based on "Electric Furnace Capacity," Appendix Table A-1, and "Cost of Materials and Supplies Used" from *Manufacturing Industries in Canada*, Statistics Canada, Cat. Nos. 31-203/4/5/6/7.

Table 4-4

Index of Ability to Satisfy Apparent Mutual Needs of All Local Manufacturing Activities and of Steel Producers through Local Electric Furnaces, by Region, Selected Years

Region \ Year	1957	1961	1965	1967	1970	1973
Atlantic region	.17	.12	.12	.24	.21	.14
Quebec	.13	.19	.19	.19	.18	.35
Ontario	.18	.15	.11	.11	.13	.11
West[1]	.20	.33	.31	.32	.35	.34
Prairie region	.24	.43	.46	.51	.54	.48
British Columbia	.16	.19	.15	.12	.14	.10

1 West includes Prairie provinces and British Columbia.

Source: Computations based on "Electric Furnace Capacity," Appendix Table A-1, and "Cost of Materials and Supplies Used" from *Manufacturing Industries in Canada*, Statistics Canada, Cat. Nos. 31-203/4/5/6/7.

Since manufacturing activities are least developed in the Atlantic and Prairie regions, the indexes recorded here may be the result of a small numerator over a proportionately small denominator. Therefore, it may be that the rate of diffusion recorded is unnecessarily high. For the Prairies, this position must be rejected because the leadership remains even when we combine it with British Columbia to form the West region. As for the Atlantic region, the lack of outstanding performance is partly due to the fact that there is local competition by the basic oxygen process. (It is purely for illustrative purposes that we present the Atlantic region and Ontario in this section of our analysis.)

Chart 4-1

Index of Ability to Satisfy Apparent Needs of Local Steel Complex through Local Electric Furnaces, by Region, 1957-73

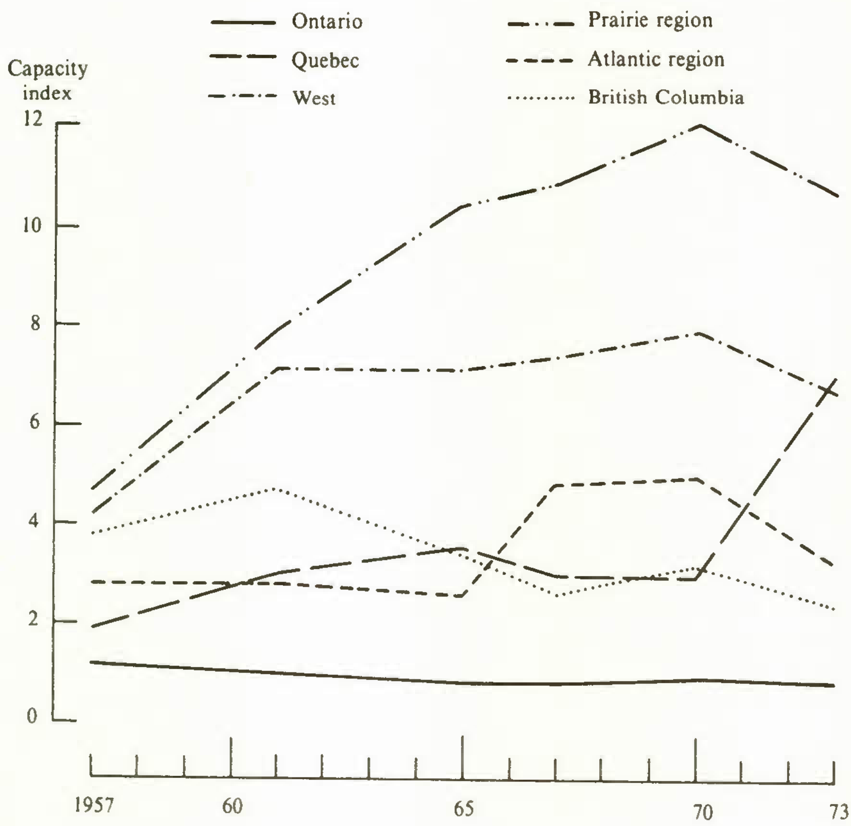
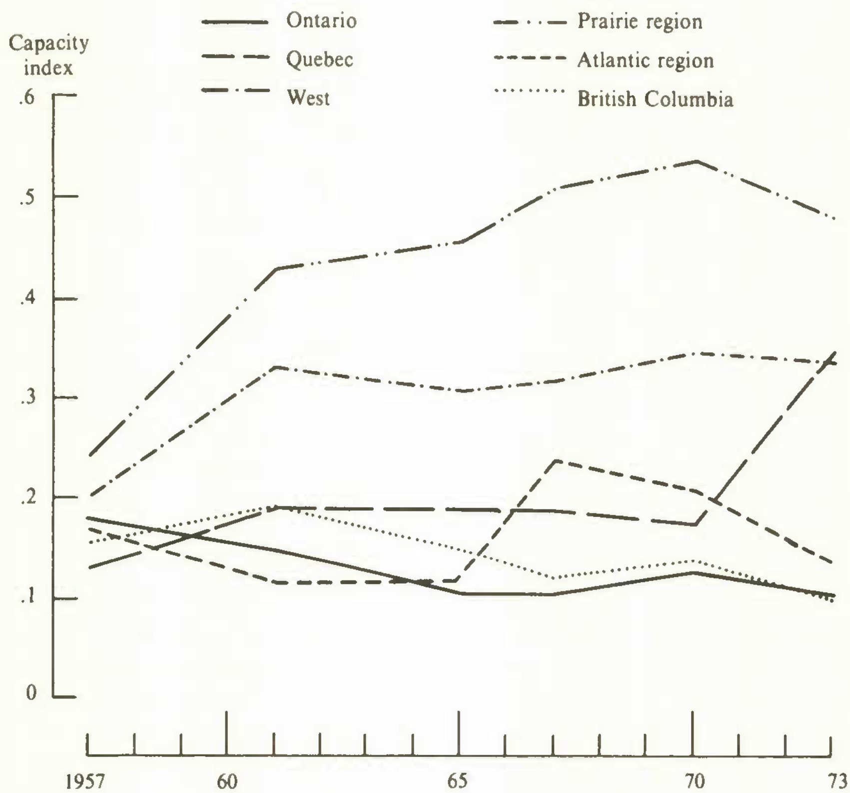


Chart 4-2

Index of Ability to Satisfy Apparent Mutual Needs of All Local Manufacturing Activities through Local Electric Furnaces, by Region, 1957-73



It seems that this innovation has been instrumental in enabling the western region to almost double its share of Canadian total steel capacity from 1957 to 1975. Similarly Quebec, which is in more direct competition with Ontario because of the lesser distance, is progressing slowly, but may do better in the future if it follows the recent trend. The data also show that close proximity to BOP facilities retards the diffusion of electric furnaces. To determine Quebec's technological lag, we measured the distance in years between the diffusion curve for Quebec and the one for the Prairies, as shown in Chart 4-1. For initial adoption, we measured at the level of the origin of the Prairies curve. For average lag during the period, we took two readings at levels .46 and .70 in Chart 4-1 and averaged the results.

In sum, the Prairie region has led Quebec in the adoption of electric furnaces by a margin of about 14 years in initial adoption and about 13.5 years on average over the period.

The constraint to the diffusion of the basic oxygen process, on the other hand, is the fact that it is always used in tandem with blast furnaces. Since only Ontario and the Atlantic region had blast furnace facilities in 1954, it is not surprising that the first experiment with BOP took place in one of these regions — Ontario. Later, the other regions could theoretically have adopted BOP but, over time, the minimum economical size of a BOP furnace increased tremendously, making the local markets of western or Quebec locations too small. For example, some individual BOP furnaces recently installed in Ontario have a capacity of more than a million tons a year and, today, the minimum capacity is 2 million tons.[9] This disqualifies most Canadian locations outside southern Ontario. Therefore, BOP is mainly viewed as a replacement for OH facilities, where quantities produced are large. Until 1966, there existed in Quebec and Manitoba some OH facilities, but their scales apparently were too small to warrant the adjunction of BOP, and so they were phased out.[10]

In summary, the history of BOP in Canada began in Ontario, where it was first adopted in 1954. In 1956, BOP accounted for 8 per cent of its steel capacity; in 1960, it was 26.4 per cent; in 1965 and 1970, it was over 35 per cent; and in 1975, it was 70 per cent. It was then adopted on a small scale of about 80,000 tons a year in British Columbia in 1967, but that project was terminated in 1973. Nova Scotia, the only other location with blast furnace capacity and large-scale production, never adopted BOP. Management chose instead to increase capacity and modernize mills with the oxygen-lanced process applied to old open-hearth furnaces.

Factors Pertaining to the Diffusion of Innovations

In the literature on the diffusion of steel innovations, many factors have been suggested: age of capital, amount of investment, relative factor prices,

9 W.S. Nasralla, "Integrated Steelmaking at Sidbec," Sidbec Marketing Dept., Montreal, 1974, p. 5.

10 See Appendix Tables B-1 and B-2.

internal and external competitive pressures,[11] management attitudes,[12] lack of information, distance from central Canada,[13] and so forth. In the Canadian case, we can immediately rule out any variable related to access to information, in that few industries can match the steel industry in the rapid dissemination of technical knowledge.[14]

First, let us consider factors peculiar to electric furnaces. The conditions of competition are somewhat different in this section of the industry. On one hand, it is more atomistic; on the other, imports compete more directly with special steels. Both these facts are positive factors favouring the adoption of innovations. Furthermore, the diffusion of electric furnaces supports a prediction of Meyer and Herregat, referred to above, concerning the dissemination of electric furnaces; because of the moderate price of electricity in Canada, the availability of scrap in metropolitan areas, and the small minimum efficient size of plants, electric furnaces have proven competitive.

However, it remains to be explained why the West apparently led Quebec during the period under study. The answer seems to lie in the difference in the distance of these two regions from the centre of the industry in Hamilton. Because transportation of steel is relatively costly, distance acts as a protective tariff for the West, at least to a greater degree than for Quebec, so that, even if the electric furnaces are more costly than BOP, a sufficiently large distance makes the electric process preferable. Distance, as an explanation of the diffusion of innovations, is used here in a special sense. The standard geographical model predicts that the farther an agent is from the centre, the later he will adopt the innovation. Here, it operates in the opposite fashion: the farther the agent, the more likely he is to become an adopter.

The distance factor could not have materialized but for one other circumstance: the capability of steel plants using electric furnaces to produce the steel required for pipelines locally. Indeed, the biggest installation in the Prairies is that of Interprovincial Steel and Pipe Corp., Ltd., at Regina. Distance was less influential in British Columbia, not only because the demand for steel there is more difficult to satisfy in terms of types required, but also because foreign producers—the United States and Japan—have greater access to the local market. Combined with a greater degree of industrialization—which means a bigger denominator—this partly explains why the index for British Columbia is so low.

11 Bauman, "The Diffusion of the Basic Oxygen Process," p. 2.

12 Meyer and Herregat, "The Basic Oxygen Steel Process," p. 166.

13 S. Czamanski, *Regional Science Techniques in Practice* (Lexington, Mass.: D.C. Heath, 1972), p. 159.

14 Wittur, *Primary Iron and Steel*, p. 11.

Among the factors peculiar to the basic oxygen process, market structure is an important variable to consider. Because the Canadian steel industry is oligopolistic, it might be expected that the competitive pressure would be strong enough to force members of the industry either to modernize at the same pace or to disappear. In fact, this is not what has happened in Canada. For instance, two of the Big Three producers in Ontario (only the Big Three use either OH or BOP) have still not converted more than 50 per cent of their facilities to BOP, twenty years after their main competitor introduced the innovation. The reason is that production techniques are only one of the many components in the competitive strategy of the firms. For instance, some technological inefficiency can be compensated by organizational efficiency, by differentiation of products, by cross-subsidization among products, and the like. Consequently, the competitive pressure may be unequally transmitted to the production field. This is probably why, in the United States, firms with very different technological productivity still compete. In this respect, the Bureau of Labor Statistics estimates that the ratio in terms of productivity of the most-efficient to least-efficient plant is 2.96.[15]

Moreover, the oligopoly is not subject to the discipline of competition from imports of ordinary steel. Actually, in recent years, it has been the other way around. World prices have been higher than Canadian prices so that Canadian producers could have exported if they had wanted to.[16]

More intriguing is the factor of profitability[17] of the innovations. The fact that OH capacity of the major Ontario producers increased from 3,390,000 to 5,900,000 tons a year, even after the initial adoption of BOP, suggests that, in the Canadian context, the profit advantage of BOP was not so great as to make the existing equipment and processes immediately obsolete. This is not to say that a profit advantage does not exist since, after 1971, OH capacity declined rapidly in Ontario. In the very long run, BOP seems to be a definite replacement for OH.

We must also study the amount of investment undertaken as a factor exerting a positive influence on the diffusion process.[18] Presumably, the more investment during a period, the greater the number of occasions on which to introduce innovations. In the case of Ontario, the large increase in capacity during the period indicates that a sufficient rate of investment was a positive factor in the adoption of BOP. This does not seem to be the case

15 U.S. Bureau of Labor Statistics, "Technological Change," p. 27.

16 M.W.Z. Estey, judge, *Steel Profits Inquiry* (Ottawa: Information Canada, 1975), pp. 27, 37, and 122.

17 As proposed by E. Mansfield, *The Economics of Technological Change* (New York: Norton, 1968), p. 120. Here, we use profitability in the nontautological way of being a factor affecting the speed of adoption, as opposed to the simple fact of eventual adoption. Profitability includes relative factor prices, age of capital, and so forth.

18 See Meyer and Herregat, "The Basic Oxygen Steel Process," p. 184.

in the Atlantic region, where the increase in capacity from 1956 to 1973 was roughly 500,000 tons, which is only half the size of some BOP furnaces installed recently in Ontario. In a way, then, the diffusion of BOP in Canada is in accord with the hypothesis mentioned above, which predicts that BOP adoption will be favoured by large plants.

Furthermore, the lack of investment in the Atlantic region is the consequence of lack of markets due to the great distance of the Atlantic region from central Canada. Distance from central Canada affects the Atlantic industry in two concurring ways. It saddles local primary iron producers with high transportation costs for both outputs and inputs, thus reducing their access to markets in central Canada. And it prevents them from having access to a local market made up of steel utilizers. Transportation costs are even higher on finished products, preventing the flourishing of a complex of steel utilizers. For example, the Sydney centre is confronted with high transportation costs in marketing its output, with high-cost local coal, and with iron ore inputs shipped from Labrador. The Atlantic region has been and still is unable to attract significant steel processing industries.[19]

Finally, we note that we have not assigned a role to management attitudes as an explanatory factor. This factor may have been at work among Ontario producers. However, this is outside our frame of reference since our goal is to explain interregional differences in the rate of adoption of innovations, not intraregional differences. To show that management attitudes should be included in our set of explanations requires demonstrating that differences in efficiency of BOP and electric furnaces over OH could compensate for the various disadvantages of distance and vanishing natural resources in the Atlantic region. This is a possibility, but we do not have the necessary data with which to assess the situation. All we know is that even a government take-over of the steel industry in Cape Breton, N.S., has not, to date, brought about the installation of BOP furnaces, although it has been much discussed.[20]

In conclusion, it would seem that the ability of the competitive process in the Canadian steel oligopoly to tolerate differences in technical efficiency among firms, coupled with the relatively small profit advantage of BOP over OH partly accounts for the long period it takes to adopt BOP.

The Regional Factor

Defined as a systematic influence of the basic characteristics of a region on the diffusion process of innovations, the regional factor may permeate

19 Czamanski, *Regional Science Techniques*, p. 159.

20 V.B. Schneider, "Iron and Steel," *Canadian Primary Iron and Steel Statistics to 1969*, Mineral Information Bulletin MR 113 (Ottawa: Department of Energy, Mines and Resources, 1968), p. 94.

some of the general factors that have been indentified in the previous section.

In the case of electric furnaces, the regional factor, in the form of distance, is an overwhelming explanation of the performance of the Prairie region.

In the case of BOP, three factors are present: the small cost advantage over OH for producing ordinary steel in large quantities; low competitive pressures for adoption; and the distance from central Canada. Furthermore, the minimum size of a BOP furnace keeps increasing. Differences in basic regional characteristics between Ontario and the Atlantic, the only regions involved, have little to do with the first two factors. But they surely make their influence felt in distance expressed either as high transport costs for outputs of primary iron producers or as lack of local steel-using industries — a feature of the regional industrial structure.

5 The Case of Roof Trusses

Roof trusses are one of the rare identifiable and quantifiable major innovations in the construction industry. They are mainly used in residential construction, which accounts for more than 30 per cent of all construction in Canada. The diffusion of roof trusses then presents an interesting case study in which to examine some hypotheses embodied in the theory of diffusion of innovations.

One hypothesis is that rates of diffusion will vary according to market structure. Since the diffusion process of roof trusses involves two different market structures for its two component parts—oligopolistic firms for metal plates and monopolistic competitive firms for wood roof truss fabrication—will there be a difference in the modes of diffusion of each part? Second, some researchers suggest that the construction industry is conservative.[1] Does this mean that the rates of diffusion of roof trusses will be inordinately slow? Third, will the centre of Canada—that is, Ontario—follow the usual pattern of leading peripheral regions such as the Atlantic provinces in the initial adoption of roof trusses? And finally, will the leader in the initial adoption of roof trusses maintain this position throughout the period, or will it become a laggard later on?

As for many innovations, measuring regional differences in the degree of utilization of roof trusses may provide a clue to explaining observed regional differences in productivity. For researchers, this work fills part of the need for studies on the effects of technological change in the construction industry, which have been in short supply.[2] We investigate innovation and productivity in one section only of the construction industry, and so our conclusions may not apply to all innovations in the industry. In addition, we investigate whether the adoption of roof trusses is affected by the construction cycle. For those concerned with increasing

1 A.D. Boyd and A.H. Wilson, "Technology Transfer in Construction," Science Council of Canada, Background Study 32, Ottawa, 1975, p. 21.

2 Economic Council of Canada, *Toward More Stable Growth in Construction* (Ottawa: Information Canada, 1974), p. 34: "Virtually no studies of the effects of technological change in the construction industry could be found."

local productivity in this part of the construction industry, our study includes a list of factors that may hinder diffusion of wood trusses. It is possible that local productivity in this area can be improved simply by removing obstacles to the diffusion of roof trusses. On the other hand, our list may show that, because of the nature of the obstacles, little can be done to improve local productivity in this way.

Because changes in the construction industry are gradual rather than revolutionary,[3] identifying significant innovations can be a problem in itself. Innovations are, however, most likely to occur in the area of prefabricating factory-made building components. Although prefabrication in the past played a minor role in the construction industry, it has today become part of conventional construction technology, and roof trusses occupy a special place in it.[4]

Roof trusses consist of a system of wooden rafters set at specific angles and connected to each other by metal plates. They come in various shapes, the most popular being the "W" shape. They are used mainly in residential housing, but also in commercial, industrial, and farm buildings. They have many advantages. They are usually prefabricated and brought to the construction site; hence they require less on-site labour and speed the job of erecting a building. Because they use less lumber than traditional methods of construction, they reduce the cost of materials. They also provide for more freedom in design.

The Pattern of Regional Diffusion

The diffusion of roof trusses occurs not within one industry but across two—the metal fabricating industry, which provides the metal plates, and that part of the wood industry responsible for wood roof trusses. Truss fabricators, which number around 400, are franchised or licensed and are supplied with plates by nine truss plate manufacturers. For the most part, truss fabricators are sash and door producers, and in a few instances are vertically integrated mobile and factory-built home builders, lumber dealers, or farm building suppliers. However, most truss fabricators specialize in fabricating and supplying roof trusses. The truss plate manufacturers not only manufacture and supply the metal plates but also provide designs and technical advice to fabricators.

3 Boyd and Wilson, "Technology Transfer," p. 93.

4 See E.N. Aplin, "Canadian Roof Trusses," Environment Canada Bulletin LDSE, Ottawa, 1976: "The design of such an apparently simple structure . . . is fairly complex in terms of theory." Indeed, the National Research Council of Canada, the Central Mortgage and Housing Corporation, and the Eastern Product Laboratory as early as 1956 began to take an active part in testing and perfecting roof trusses, including them in the National Building Code, and collecting information about their diffusion. See also A.T. Hansen, "New Nailed 'W' Roof Truss Designs Offer Small Builders Advantages," *Canadian Builder*, August 1963; and R.E. Platts, *Prefabrication in Canadian Housing*, National Research Council of Canada Technical Paper 172 (Ottawa: Queen's Printer, 1964).

The first metal plate factory in Canada was set up in Ontario in 1959 (see Table 5-1). Before this, metal plates were imported from the United States, where they originated. Later, other metal plate plants were established in Canada and they eventually took over most of the market, although imports continued to flow in. Whereas Ontario was the earliest adopter of metal plates, it was followed closely by Quebec and the Prairies. The Atlantic region never did attract production. By 1976, there were nine members of the Truss Plate Institute of Canada, five located in Ontario, two in Quebec, one in the Prairies, and one in British Columbia. According to expert opinions, the two Quebec producers supply only between one-third and one-half of the Quebec market and do not sell to the Atlantic region. This latter region imports all of its needs from Ontario manufacturers.[5] There remains a small amount of U.S. imports not exceeding 5 per cent of Canadian needs.

Table 5-1

Initial Year of Operation of Truss Plate Manufacturers, Canada, by Region, 1959-74

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1			1959		
2				1960-65[2]	
3		1961-62[3]			
4			1962		
5			1967		
6		1968			
7			1969-74[2]		
8			1974		
9					1973

1 This table is only indicative. It is possible that some firms may have existed in the past and do not exist today. However, if they were absorbed by today's producers, this fact was taken into consideration. Single years denote beginning of production by the firm.
2 The first date indicates the beginning of imports into Canada, and the second one indicates the beginning of manufacturing in Canada. In one case, between the two dates, a producer subcontracted the manufacturing of plates to outsiders not specialized in this kind of work.
3 The firm began by importing for a few months before setting up its own production facilities.
Source: Telephone interviews.

Production of wood roof trusses began in Ontario and Quebec. Together they accounted for 91 per cent of shipments in 1963 (see Table 5-2). The Prairies had a negligible share until 1971, as did the Atlantic region until 1972. However, during the 1963-74 period, Ontario and Quebec gradually lost their relative importance, especially after 1971 when the Prairies began to experience a phenomenal growth relative to other regions.

5 Quantitative information about other producers is not available.

Table 5-2

Wood Roof Truss Production (Excluding Laminated) as a Proportion of Total, Canada, by Region, 1963-74

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada
			(Per cent)			
1963	C	52.7[2]	38.3	C	9.1[2]	100
1964	C	66.6[2]	27.6	5.7[2]	C	100
1965	C	62.8[2]	31.6	C	5.6[2]	100
1966	C	49.1[2]	42.1	C	8.8[2]	100
1967	C	48.3[2]	41.9	C	9.8[2]	100
1968	C	48.8[2]	38.6	2.4	10.2	100
1969	C	27.1[2]	42.5	C	30.4[2]	100
1970	0	40.9	39.8	0	19.2	100
1971	0	35.3	38.5	6.5[1]	19.7[1]	100
1972	3.9[1]	23.4[1]	35.9	22.1[1]	14.7[1]	100
1973	5.7[1]	45.9[1]	22.7	16.5	9.2	100
1974	6.8[1]	30.8[1]	23.4	30.6	8.3	100

C Confidential.
1 The shipments figures have been estimated through the number of firms in the regions.
2 Quebec includes Atlantic region, and British Columbia includes Prairie region or Prairie region includes British Columbia. The Atlantic region is reputed to be negligible up to 1972.
Source: Special compilation by Statistics Canada.

One way to measure the progress of roof truss activity nationally is in terms of its monetary value (Table 5-3, first row). Production progressed slowly during the years 1963-70 and then grew spectacularly from 1971 to 1974. Over the whole period, the value of output increased by 26.5 times.

Another way is to measure the changes in its relative importance within the sash and door industry. To the extent that the output of the sash and door industry represents the level of construction industry demand for prefabricated products, it can be used as an index of how modern the techniques of construction are. We have used Statistics Canada data on provincial totals of the sash and door industry to compile our index of diffusion (Table 5-3, second row).[6]

Measurement problems arise, however, because, as the industry grows and changes, so do the data. Components of the industry have grown to the

6 Only those firms whose main output is roof trusses, as described in Statistics Canada industry category SIC 2541, are covered by the data, although the definition of this category has changed over the years. There is therefore a possibility of underestimation of total production of roof trusses to the extent that vertically integrated construction firms also produce wood trusses. It is unlikely, however, that this is serious enough to jeopardize our construction of meaningful regional indexes of the production of roof trusses because most truss fabricators specialize in fabricating and supplying roof trusses. Moreover, Statistics Canada officials are confident that their data represent the majority of important producers. It should also be noted that we have excluded laminated trusses. This is an advantage because laminated trusses rarely use metal plates and/or are used mainly in the construction of large buildings, bridges, and the like. Since we want later to relate the production of roof trusses to residential construction, the inclusion of laminated trusses could pose significant problems.

Table 5-3

Diffusion of Wood Roof Trusses (Excluding Laminated) within the Sash and Door Industry[1] and Relative to Residential Construction, Canada, 1963-74

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
	(Thousands of dollars)											
Value of shipments of wood roof trusses[2]	928	1,517	1,611	3,050	3,914	3,675	3,631	2,881	4,769	9,990	19,107	24,599
Value of shipments of sash and door industry[3] (SIC 2541 current definitions)	164,073	185,461	189,058	233,767	254,524	270,109	330,064	224,343	267,351	290,516	362,482	403,936
	(Per cent)											
Wood roof trusses as a proportion of sash and door industry (SIC 2541 current definitions)	0.57	0.82	0.85	1.30	1.54	1.36	1.10	1.28	1.78	3.44	5.27	6.09
Ratio of value of shipments of roof trusses to value of residential expenditures[4]	0.056	0.076	0.073	0.140	0.165	0.131	0.107	0.092	0.118	0.207	0.320	0.353

1 (SIC 2541 current definitions.)
2 Special compilation by Statistics Canada.
3 Statistics Canada, Cat. No. 35-205.
4 Residential expenditures from Central Mortgage and Housing Corporation, *Canadian Housing Statistics, 1975* (Ottawa: CMHC, 1976), p. 23, Table 27.

point where they become new industries and data about them are collected on a new basis. For example, Statistics Canada compiled information about prefabricated houses and buildings separately from that for the sash and door industry beginning in 1970. Similarly, data on wooden kitchen cabinets were listed under a separate industry category after 1972.

Therefore, strictly speaking, before relating wood roof truss output to sash and door output, we should construct a homogeneous series of data for the sash and door industry that excludes prefabricated homes before 1970 and wooden kitchen cabinets before 1972 in order to avoid understating roof truss penetration in earlier years. In fact, we have not done so because the data required for the task are not available at the regional level. Moreover, in some respects, it is even desirable to include data on prefabricated homes because the same manufacturers sometimes make roof trusses, which would otherwise not be included in our diffusion index. In any event, at the national level at least, the main characteristics of the diffusion curve are much the same whether we use current industry definitions or not. To demonstrate this similarity, we have computed two versions of the ratio of wood roof truss shipments to sash and door shipments: one is based on current definitions and the other excludes output of prefabricated homes and wooden kitchen cabinets by firms classified as sash and door producers for all years under study, including 1973 and 1974. The results are shown in Table 5-4. The two ratios seem to follow the same pattern of change through time, except for the years 1969 and 1970. Therefore, they could be used interchangeably to construct an index, even though this may involve a gradually increasing underestimation of the ratio of wood roof truss shipments to sash and door shipments during the years 1963-69.

Hence we see that the relative value of roof truss shipments relative to sash and door shipments has increased elevenfold from 0.57 per cent in 1963 to 6.09 per cent in 1974 (Table 5-3, third row).

A third way to measure the evolution of the relative importance of roof truss activity is to view it as an input to the residential construction industry (Table 5-3, fourth row). The ratio of the value of roof truss shipments to residential expenditures in Canada has increased 6.3 times from 0.056 per cent in 1963 to 0.353 per cent in 1974, although the increase is not monotonic.[7]

7 To the extent that large economies of scale end effects of the learning process affect costs of production over time, this ratio would underestimate the penetration of roof trusses in the construction industry. However, a superficial check with people in the industry tells us that there are economies of scale that, while important, can be reaped at relatively small outputs, and so the extent of the local markets is not an impediment to the use of optimal plants. Moreover, the learning process over the period did not materially change things since, in real terms, roof trusses cost as much today as they did in 1960. The main reason is that the wood, steel, and machinery components have not varied in importance over time. Finally, even if our above hypotheses are wrong, in order to change our ranking of regions in this matter, one would have to prove that the economies of scale and effects of the learning process were both very different among the regions.

Table 5-4

Ratio of Roof Truss Shipments to Sash and Door Shipments, Two Versions, Canada, 1963-74

	Version 1	Version 2
	Sash and door shipments (current definitions)	Sash and door shipments (excluding prefabricated homes and wooden kitchen cabinets)
	(Per cent)	
1963	0.57	0.71
1964	0.82	1.04
1965	0.85	1.22
1966	1.31	1.89
1967	1.54	2.35
1968	1.36	2.09
1969	1.10	1.85
1970	1.28	1.55
1971	1.78	2.20
1972	3.44	3.51
1973	5.27	5.46
1974	6.09	6.32

Source: Special compilation by Statistics Canada, Cat. No. 35-205.

At the regional level, the main difficulty in measuring the extent of diffusion is how to determine the appropriate basis or norm for judging it. The real problem lies not in selecting the numerator of our diffusion ratio but in choosing a meaningful denominator.[8] The case of wood roof trusses is no different. The obvious suggestion is to relate roof trusses to housing construction because the ultimate demand for roof trusses is, after all, mainly housing. Hence, regional variation in the numbers of houses using this technique would represent differing degrees of acceptance (diffusion) of this innovation. Constructing a corresponding index would ideally require data on the number of housing units actually built with roof trusses and the number of those theoretically suitable for use of this innovation. Unfortunately, no such data exist on a regional basis.

We can, however, construct a meaningful index using data on the total amount of housing expenditures for all purposes within each sector (see Table 5-5). Presumably, the ratio of expenditures on roof trusses to expenditures on housing represents the degree of use of this innovation.

By comparing the regional ratio with the Canadian norm for any given year, such an index can then be used to rank the regions and to show the year-to-year penetration of roof trusses within the construction industry (see Table 5-6). Any ratio below 1 signifies a lower regional acceptance of roof trusses than the Canadian average while a ratio over 1 implies greater acceptance.

8 L. Nabseth and G. F. Ray, *The Diffusion of New Industrial Processes: An International Study* (Cambridge, Mass.: Cambridge University Press, 1974), p. 297.

Table 5-5

Ratio of Roof Truss Shipments to Residential Construction Expenditures, Canada, by Region, 1963-74

	East			West		
	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada
1963	C	.0008482[1]	.0002149	C	.0001767[2]	.0005618
1964	C	.0014823[1]	.0005509	.0001579[1]	C	.0007624
1965	C	.0014169[1]	.0005760	C	.0001713[2]	.0007261
1966	C	.0022499[1]	.0014221	C	.0004392[2]	.0013993
1967	C	.0027413[1]	.0016724	C	.0005416[2]	.0016457
1968	C	.0023278[1]	.0011980	.0001947	.0009394	.0013095
1969	C	.0010898[1]	.0010826	C	.0010262[2]	.0010730
1970	—	.0017387	.0008929	—	.0011677	.0009182
1971	—	.0019572	.0011167	.0004912	.0015944	.0011847
1972	.0011341	.0024114	.0017621	.0029924	.0020014	.0020725
1973	.0022231	.0075042	.0016800	.0037186	.0019682	.0031965
1974	.0029641	.0051489	.0020169	.0070799	.0020203	.0035266

C Confidential.
— Negligible.
1 Quebec includes Atlantic region.
2 British Columbia includes Prairie region, or Prairie region includes British Columbia.
Source: Special compilation by Statistics Canada for roof truss shipments. Residential expenditures are from Central Mortgage and Housing Corporation, *Canadian Housing Statistics, 1975*, p. 23, Table 27.

Table 5-6

Ratio of Roof Truss Shipments to Residential Construction Expenditures Relative to the Canadian Norm, by Region, 1963-74

	East			West	
	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1963	C	1.51[1]	.38	C	.31[2]
1964	C	1.94[1]	.72	C	.21[2]
1965	C	1.95[1]	.79	C	.20[2]
1966	C	1.61[1]	1.02	C	.31[2]
1967	C	1.67[1]	1.02	C	.33[2]
1968	C	1.78[1]	.92	.15	.72
1969	C	1.01[1]	1.01	C	.97[2]
1970	0	1.89	.97	0	1.27
1971	0	1.65	.94	.41	1.35
1972	.55	1.16	.85	1.44	.97
1973	.70	2.35	.53	1.16	.62
1974	.84	1.46	.57	2.01	.57

C Confidential.
1 See Table 5-5.
2 See Table 5-5.
Source: Special compilation by Statistics Canada for roof truss shipments. Residential expenditures are from Central Mortgage and Housing Corporation, *Canadian Housing Statistics, 1975*, p. 23, Table 27.

Thus we see that Ontario was never the leader in the use of roof trusses. In fact, the index of roof truss production for Ontario fell to slightly more than 50 per cent of the Canadian average in 1973 and 1974. On the other hand, the West, more specifically the Prairies (as the British Columbia index showed a decline in the last three years), showed great strength in the second half of the period.[9] The index indicates that the production of roof trusses was negligible, if not nonexistent, before 1972 in the Atlantic provinces.

These results are not the last word on the subject, however. The use of housing expenditures as a denominator yields only a crude measure of diffusion because they are not restricted to only those houses most suitable for using this technique. As in the case of port traffic,[10] where adoption of containerization is best measured in terms of cargo considered suitable to be containerized, the indiscriminate use of total residential expenditures to roof truss value would produce an unduly small ratio. Furthermore, the regional figure for residential expenditures does not account for possibilities of exporting or importing roof trusses.

The index can be refined by substituting the value of the shipments of the sash and door industry for the denominator. Sash and door output is a better indicator of the real potential for the roof truss market because roof truss production is closely allied with it and the dynamism of the industry conditions the prosperity of roof truss activity. Both have the same local markets or similar export markets. Indeed, roof trusses are often produced jointly with sash and door products. The same sales organization may distribute roof trusses in addition to sashes, doors, and other prefabricated products. Hence, the output of the sash and door industry is an indicator of the potential for all prefabricated products in the housing market. If, because of the type of houses built in a region, or for other reasons, the extent of prefabrication is small, then the prospects for roof trusses should accordingly be low. The advantage, then, of using this measure in our diffusion index lies in its better ability to incorporate potentials for roof trusses.

In other ways, however, this approach is less than perfect. It would not accurately reflect the low utilization of roof trusses in regions where use of all prefabricated products is low for reasons other than the unsuitability of the types of houses for them—for example, if the regional industry is slow to adopt new techniques—because the denominator would be correspondingly low. At the same time, it would be unrealistic to expect roof truss products to be more acceptable than other closely related construction innovations, which often go hand in hand. For instance, in an Inuit village,

9 Figures for the Prairies before 1969 are uncertain because of confidentiality. According to informed members of the industry, however, there was a small number of large firms producing roof trusses during this period.

10 See Chapter 6 below.

where manufactured doors and windows are seldom used, one should not expect (or require through a norm) that roofs would be erected with prefabricated roof trusses.

The above discussion points, however, to an important consequence of using the sash and door industry as our denominator. It now means that the diffusion index measures the relative progress of roof truss production among the various products of the sash and door industry, given the regional level of modernity of construction techniques. This is a second-best index compared with an ideal one that would measure independently the general backwardness of a region with respect to prefabrication and its relative backwardness in the use of roof trusses.

This aside, let us now compute an amended diffusion index using sash and door output. Just as the progress of the sash and door industry, as well as the progress of roof trusses within it, are known at the national level (see Table 5-3), so the regional rates of diffusion can be calculated. A region that is relatively more advanced technologically than others will show a higher degree of penetration of roof trusses within the local sash and door industry (see Table 5-7 and Chart 5-1).[11] There are two distinct periods in

Table 5-7

Roof Truss Shipments as a Proportion of Sash and Door Shipments, (SIC 2541 current definitions), Canada, by Region, 1963-74

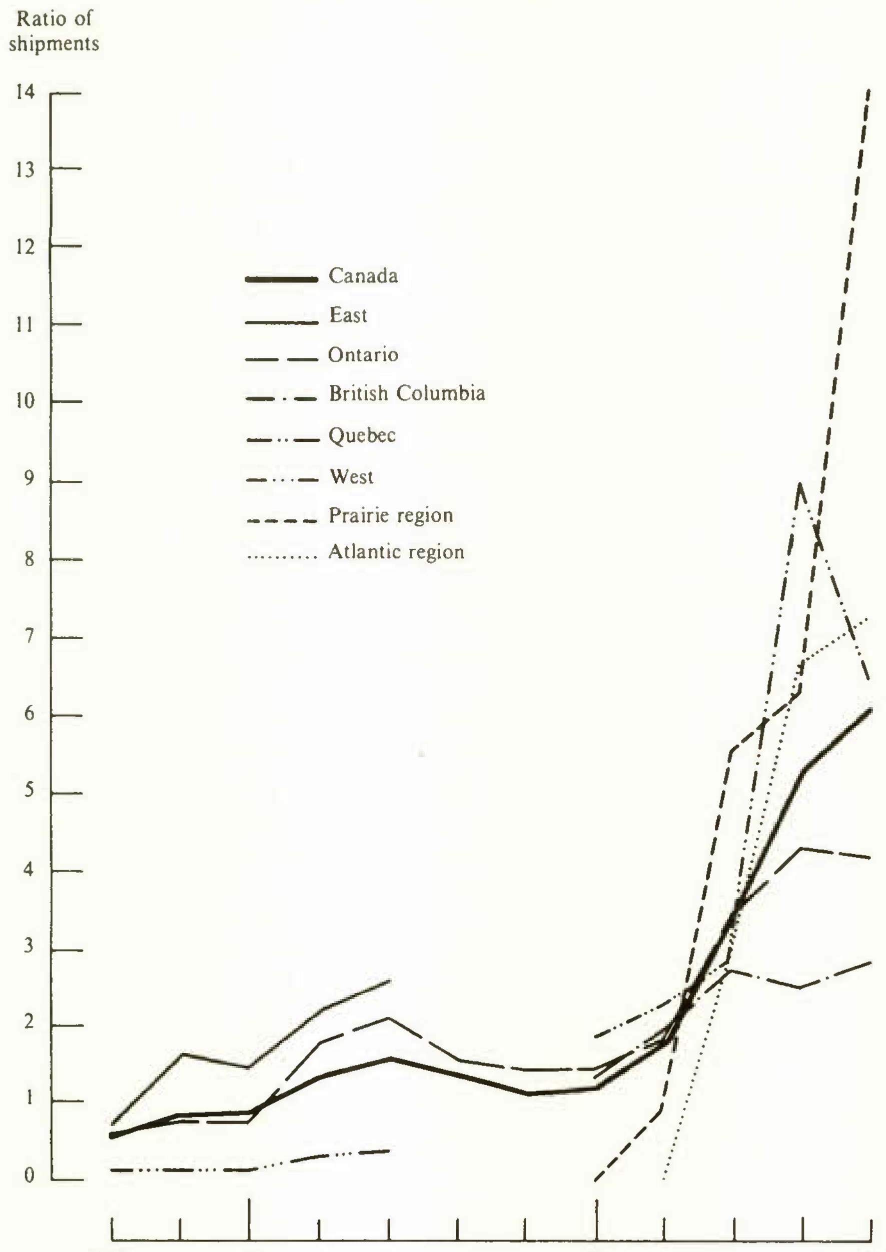
		East		Ontario		West		Canada
				(Per cent)				
1963		.75		.62		.127		.57
1964		1.61		.72		.13		.82
1965		1.43		.73		.13		.85
1966		2.20		1.78		.29		1.30
1967		2.60		2.09		.37		1.54
	Atlantic region		Quebec	Ontario	Prairie region		British Columbia	Canada
1968	—	2.27	—	1.51	.17		.89	1.36
1969	—	1.07	—	1.40	—	.86	—	1.10
1970	0		1.84	1.41	0		1.37	1.2
1971	0		2.26	1.82	.89		1.96	1.8
1972	2.99		2.85	3.50	5.49		2.78	3.44
1973	6.64		9.01	4.27	6.29		2.47	5.27
1974	7.29		6.45	4.17	14.09		2.86	6.09

Source: Special compilation by Statistics Canada for roof truss shipments. For sash and door shipments, see Statistics Canada, Cat. No. 35-205, annual.

11 As explained previously at the Canadian level, the importance of the roof truss industry is a bit understated during the period 1963-69; the same may well be true at the regional level.

Chart 5-1

Ratio of Roof Truss Shipments to Sash and Door Shipments, (SIC 2541 current definitions), Canada, by Region, 1963-74



Source: See Table 5-5.

which this process occurred. The first, prior to 1970, shows the East—this means mainly Quebec, since it is known that production in the Atlantic region in 1970 and 1971 was zero and presumably weak before that—as the leader, followed by Ontario, then the West (the Prairies and British Columbia combined). In the second period, after 1970, activity picked up generally in Canada, to a large degree in Quebec, and even more so in the Prairies.

From this, we can compute the time lags in diffusion among regions by measuring the length of time it takes a particular region to catch up with the leader in the degree of utilization of roof trusses. Using as the norm a share of roof truss shipments of all sash and door shipments of 1.43 per cent, Quebec emerges as the leading region, with the other regions following about two to eight years later (see Table 5-8).

Next, we can calculate the degree of penetration of roof trusses within the sash and door industry, as we did above for all housing expenditures, by relating the regional ratio to the Canadian norm for any given year (see Table 5-9). Ontario's roof truss production up to 1973 (except for the years 1964 and 1965) was generally in line with the requirements of its sash and door industry, although it was never a leader. It fell short in the Atlantic provinces, in the West until 1969, and in British Columbia in all years except 1970 and 1971. On the other hand, the Prairies experienced a marked growth in roof truss production during the 1972-74 period.

Factors Pertaining to the Diffusion of Roof Trusses

One feature of the regional diffusion process of roof trusses is the dichotomy between that for metal plates and the one for wood roof trusses themselves. Whereas metal plates are concentrated in Ontario, production of wood roof trusses is spread across Canada to the extent that production in 1974, in absolute terms, was greater outside Ontario than within.

Table 5-8

Regional Lags by Roof Truss Producers in Attaining 1.43 Per Cent Share of Sash and Door Output, by Region, 1963-74

	Year of attainment	Number of years behind leading region
Quebec (East)	late 1963	0
Ontario	late 1965	2
Prairie region	early 1971	7.25
British Columbia	1970	6
Atlantic region	mid-1971	7.75

Source: See Table 5-7 and Chart 5-1.

Table 5-9

Ratio of Roof Truss Shipments to Sash and Door Shipments, (SIC 2541 current definitions) Relative to the Canadian Norm, by Region, 1963-74

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1963	C	1.316[1]	1.088	C	.223[2]
1964	C	1.963[1]	.878	C	.158[2]
1965	C	1.682[1]	.859	C	.153[2]
1966	C	1.692[1]	1.369	C	.223[2]
1967	C	1.688[1]	1.357	C	.240[2]
1968	C	1.669[1]	1.110	.125	.654
1969	C	0.973	1.273	.782[2]	C
1970	0	1.533	1.175	0	1.142
1971	0	1.256	1.011	.494	1.089
1972	.869	.829	1.017	1.596	.808
1973	1.260	1.710	.810	1.193	.469
1974	1.197	1.059	.685	2.314	.470

C Confidential.
1 Quebec figures include Atlantic region.
2 British Columbia figures include Prairie region or Prairie region includes British Columbia.
Source: See Tables 5-3 and 5-7.

The initial adoption of metal plates is linked to metropolitan areas where mass production of residential housing is more feasible and less risky.[12] Hence, Ontario and Quebec, the regions with the largest urban environments,[13] are the sites of initial location of plate manufacturers. Why Ontario should be favoured over Quebec is more a question of individual entrepreneurial attitudes, in that the firm to initially adopt this innovation has the reputation among experts consulted for our study of being very progressive.[14]

In the period of subsequent diffusion, Ontario continued to be the leader in the production of metal plates, while, at the same time, it gradually lost its relative position in the production of wood roof trusses, for several reasons. First, freight costs in transporting plates is a much less important factor than might be imagined. Transportation is easy because metal plates are not bulky or breakable and their value per unit of weight is higher than

12 These opinions were collected through interviews with people either in the industry or in some way connected with it. We tested either directly or indirectly initial hypotheses furnished by the economic theory and/or by comparisons with other empirical diffusion studies. This was done both through initial conversations with experts and through their criticisms of a first draft of this study.

13 As initial adoption first took place in Ottawa, followed by Montreal, it might be argued that it is a certain minimum city size that is the important factor.

14 For more on management attitudes as a factor of diffusion of innovations, see R. Meyer and G. Herregat, "The Basic Oxygen Steel Process," *The Diffusion of New Industrial Processes: An International Study*, ed. L. Nabseth and G. F. Ray (Cambridge, Mass.: Cambridge University Press, 1974).

for wood roof trusses. Moreover, the product includes not only the metal plate but also the engineering services provided by plate manufacturers. Second, it is more important for metal plate producers to be close to an industrial complex of primary and fabricated metals than to wood roof truss producers, in order to reap certain agglomeration economies. Because metal plate producers are small relative to other steel producers, they generally require more external economies. Third, the oligopolistic structure of the industry and the fierce competition among producers encourage participants to locate near each other in order to keep abreast of each other's market activities.

The initial adoption of wood roof trusses also is linked to the metropolitan environment.[15] Because regional or urban production figures for wood roof trusses during the adoption period 1958-62 are lacking, it is not known for certain which firm was the first to adopt the innovation or where it was located. But the metropolitan environment is where residential houses are most apt to be mass-produced and roof trusses most economical.[16] Hence, the first few to adopt the innovation were all located in metropolitan areas.

The internal structure of the initial adopting firms is another important factor. For example, one of the first adopters was part of a conglomerate oriented towards the construction industry. The fact that it was more or less vertically integrated may have minimized certain of the risks such as those related to the supply of metal plates. Moreover, the interaction within one organization of a section fabricating metal plates, one fabricating roof trusses, and one constructing houses was surely beneficial for the initial adoption of this innovation.

The subsequent diffusion of wood roof trusses in all regions, relative to the sash and door industry, came about in a two-period cycle that corresponds more closely to the cycle of residential construction activity than to any change in data compiled on the sash and door industry as a result of the changes in Statistics Canada industry definition. This is shown by using a constant definition, which also yields a two-period cycle of diffusion, separated by a regression in the years 1969-70. Even in absolute terms, the values of wood roof trusses peak in 1967 and trough in 1970, defining a cycle. Residential expenditures also went through two different periods of expansion: one of slow growth at an average rate of 12.85 per cent a year from 1963 to 1969, and one of fast growth at an average rate of 30.58 per cent a year from 1970 to 1974 (see Chart 5-2).

15 R. E. Platts, "How Will Prefabrication Affect Your House Building Business," *Canadian Builder*, December 1964, p. 13.

16 Platts, *Prefabrication*, p. 23: "Medium and smaller builders—producing say 100 houses a year or fewer—cannot readily. . .set up central prefab shops. Their total volume cannot properly 'feed' their own prefab shops."

Chart 5-2

Residential Construction Expenditures, 1963-74

Source: Central Mortgage and Housing Corporation, *Canadian Housing Statistics, 1975*, p. 23, Table 27.

The correlation between the two phenomena is accentuated when two particular years, 1966 and 1970, are singled out.[17] Residential construction expenditures in those years declined in absolute terms, which is not too far from the peak in 1967 and the trough in 1970 for roof trusses. Two recovery years for residential expenditures are also significant: 1967, which corresponds to a local peak in roof truss output, and 1971, which is a recovery year for both roof trusses and residential construction. These correlations strongly suggest that fluctuations in residential expenditures

17 There was a similar correlation, except for 1974, between roof trusses and housing starts; see Central Mortgage and Housing Corporation, *Canadian Housing Statistics, 1975* (Ottawa: Information Canada, 1975), p. 9, Table 9.

and, more precisely, their annual growth rate were instrumental in either accelerating or reducing the speed of acceptance of an innovation like roof trusses.[18] Hence, it seems that, at the Canadian level, expansion of the use of roof trusses depended upon a very rapid phase of expansion in residential construction expenditures.

Differences in the regional acceptance of roof trusses can be attributed to the characteristics of the product; these are different from those of metal plates as is its pattern of diffusion. Because wood roof trusses are not easily transportable over long distances, proximity to a local market is necessary. Economies of agglomeration are not as important as economies of scale; size and concentration of local markets are also influential factors. Indeed, prefabrication is economical only when large-scale, continuous production is possible. Usually, large metropolitan areas are needed to support such markets, although large foreign or military markets can be good substitutes for them, as in the case, in western Canada, where the RCAF was an important customer of prefabricated homes.[19] The lack of strong market support has hindered diffusion in the more distant parts of Canada, especially the Atlantic provinces during the 1963-70 period. Europe, in contrast, has had more success with prefabrication because of the greater concentration of its population in metropolitan areas.

Sometimes, institutional constraints are mentioned as causes for regional differences in rates of adoption of new construction material and techniques.[20] However, it is unlikely to have been so for roof trusses. There are many reasons for this. In small towns, the absence of adoption of the National Building Code often means more lenient local by-laws. Thus, for wood roof trusses, this difference was not a factor in limiting diffusion in the Atlantic provinces. Furthermore, for certain large cities such as Halifax, the Code was rapidly adopted.[21] Similarly, zoning laws are not usually found to be impediments to diffusion of construction innovations in general, though they may be so indirectly where they influence the type of housing constructed in a region.[22]

18 This statement is weaker than the one in Economic Council, *Toward More Stable Growth,* p. 34, saying that "cyclical instability in the construction industry tends to impede the development and use of new technology." Consequently, we cannot directly fill the gap in studies on the diffusion of technology in the construction industry, which the Economic Council deplored in 1974.

19 Platts, *Prefabrication,* p. 6.

20 See Boyd and Wilson, "Technology Transfer," p. 74; Economic Council, *Toward More Stable Growth,* p. 32; and Platts, *Prefabrication,* p. 10. What we say here should not be construed as a general proposition for all construction innovations.

21 Platts, *Prefabrication,* p. 11: "Roof trusses are prohibited in several areas, or must be uneconomically placed at 16 in. o.c." If this was true at the time Platts wrote, these barriers disappeared rapidly thereafter, according to some experts consulted on the subject.

22 Boyd and Wilson, "Technology Transfer," p. 30.

Single detached houses are likely to use more roof trusses (in value terms relative to the value of other prefabricated components) than apartment buildings or row and semi-detached houses. The difference in relative terms is even greater when one considers that apartments use only one set of trusses for several housing units, even though the degree of prefabrication for all products used in apartments may be somewhat lower, while single detached houses use one set for each housing unit. For this reason, diffusion of wood roof trusses will be faster in regions where the ratio of single detached houses over other types of housing is greater (see Table 5-10).[23]

Table 5-10

Ratio of Single Detached Dwelling Starts to Apartment Building and Row and Semi-Detached Dwelling Starts, by Region, 1963-70 and 1971-74

	East		Ontario		West
1963-70	.70		.65		1.03
	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1971-74	2.17	.95	.60	1.35	1.21

Source: Computations based on data from CMHC, *Canadian Housing Statistics, 1975*, Table 10.

Although Ontario has large concentrations of metropolitan markets, which usually favour prefabrication in general, its dwelling mix favours the type of housing (apartment buildings and the like) least likely to use roof trusses. Moreover, a high percentage of its single detached houses are more likely to be in the high-priced category, where lack of uniformity in design makes use of prefabricated roof trusses unsuitable.[24] Hence, Ontario showed a lack of leadership in both the 1963-70 and 1971-74 periods in use of wood roof trusses. Leadership went instead to the West during the first period and to the Atlantic provinces during the second.

Diffusion in the West requires a more detailed analysis of the data during the two periods. Whereas the housing mix in the West has always favoured

23 The computations are done for all dwelling starts for the whole of the regions (rural and urban areas). The results would have been even more striking if we had restricted the data to dwelling starts in centres of 10,000 population and over, by region.

24 Housing and Urban Development Association of Canada, *Survey of Housebuilders 1974* (Toronto: HUDAC, 1975), pp. 21-23: this survey reports that, curiously, Ontario has the lowest percentage (65 per cent) of builders reporting normal use of trusses in single detached home construction, whereas the Canadian average is 74.9 per cent.

single detached houses, the relative use of roof trusses was under par during the 1963-70 period. The only explanation that can be objectively introduced is that exports of the sash and door industry were relatively greater there than in other regions of Canada.[25] In this case, the denominator serving to establish the index of diffusion of roof trusses in the Prairies is unduly increased. For the 1971-74 period, export data are lacking, which prevents us from pursuing further explanation along these lines.

A complete explanation of the regional diffusion of wood roof trusses would require examining several other factors, including the degree of vertical integration of house builders, their use in mobile home manufacture, and the size of firms making them. Although we have not pursued these matters in detail, industry experts indicate that size of firm is not a determining factor in roof truss diffusion. The industry is not an oligopolistic one, but constitutes many monopolistic competitive groups (in Chamberlain's sense). To investigate the industry structure more fully would require extending the research to include also firms whose specialty is not roof trusses, which goes beyond our purpose here. Rather, our goal is to determine whether, among the plausible explanations, we can detect the presence of a regional factor, and there seems to be one.

The Regional Factor

The regional factor at work in the initial diffusion of metal plates is the size of metropolitan areas. Ontario, with the greatest concentration of metropolitan areas, was in the forefront in the initial adoption phase, followed closely by Quebec. In the phase of further diffusion, the two most important relevant factors were proximity of the firm to a metal fabricating industrial complex and the oligopolistic relationship of firms. In this case, only Ontario had the local stock of industries that could simultaneously satisfy both conditions. For this reason, Ontario continues to dominate this industrial sector.

For the initial adoption of wood roof trusses, the presence of large metropolitan areas was the decisive factor, as for metal plates. Therefore, Ontario and Quebec were in the forefront. For the phase of further diffusion, the two most important factors were the metropolitan areas and the dwelling mix in them. Since the mode of diffusion of wood roof trusses is the urban hierarchy,[26] which is definitely a regional characteristic, the

25 Statistics Canada, Cat. No. 31-504, 1967.

26 We are not completely sure that this mode of diffusion is perfectly adequate to describe the diffusion process because we could not investigate the existence of a filtering-down process along each regional hierarchy.

lack of large metropolitan areas in the Atlantic region explains its lagging position. The dwelling mix explains the predominance of the East, especially Quebec, in the 1963-70 period and of the West in the 1971-74 period.

Is the type of dwelling a regional characteristic? In some cases, yes. In Ontario, for instance, the proliferation of sprawling suburbs based on single-unit dwellings was impeded because of high land costs and high taxes imposed by metropolitan governments required to pay the increased social costs of metropolitan living. Consequently, high-density housing such as apartments became relatively more important there. In Quebec, these factors were less important. And, in the western provinces with the exception of Vancouver, space for urban expansion has been less of a constraint to growth of cities; the shift to high-density housing was less imperative than in Ontario cities, and single-unit housing was therefore more prevalent. Thus, specific regionalized urban development patterns and policies seem to be the fundamental regional factor underlying the regional diffusion of roof trusses across Canada.

6 Containerization of International Ocean Cargo

Containerization[1] is the most significant recent technological development in general cargo transportation, so important, in fact, that it is currently a powerful force acting to concentrate international traffic in a few ports.[2]

The impact of container technology is felt on the efficiency of the whole of maritime transportation. For instance, it has considerably increased the productivity of labour in the ports. Perhaps even more important, however, are the drastic changes it has induced in the economics of shipping, through the building of ships designed especially to carry containers, and improvements in the efficiency of the railways, through unit trains, which have become an integral component of the system. And it has also increased the quality of the transport service. With the diffusion of containerization, overall decision-making has become highly dependent on a partnership involving both private interests and the public sector, especially insofar as port installations are concerned.

The innovation falls into the category of entrepreneurial services innovations.[3] This is a field that has received little attention in the literature, most existing case studies being of entrepreneurial goods

1 Definition of containerization: "container" means an article of transport equipment (a) of a permanent character and accordingly strong enough to be suitable for repeated use; (b) specially designed to facilitate the transportation of goods, by one or more modes of transport, without intermediate reloading; (c) designed to be secured and/or readily handled, having corner fittings for these purposes; or (d) of a size such that the area enclosed by the four outer bottom corners is either: at least 14 square metres (150 square feet); or at least 7 square metres (75 square feet) if it is fitted with top corner fittings. The term "container" includes neither vehicles nor packaging; however, containers when carried on chassis are included. "Corner fittings" mean an arrangement of apertures and faces at the top and/or bottom of a container for the purpose of handling, stacking, and/or securing; see *Manual: Port Statistics*, Section 2, Subsection 2.4, January 1, 1974, p. 4.

2 E. Schenker *et al.*, "The Great Lakes Transportation Systems," University of Wisconsin Sea Grant College Program Technical Report 230, Rockville, Maryland, 1976, p. 32.

3 For a distinction between entrepreneurial innovations and consumer innovations, see J. Friedman, "The Spatial Organization of Power in the Development of Urban Systems," *Regional Policy Readings in Theory and Applications*, ed. J. Friedman and W. Alonso (Cambridge, Mass.: MIT Press, 1975), p. 278.

innovations like the basic oxygen process, consumer goods like television ownership, or consumer services like shopping centres.

Containerization is gradually changing the regional economic impact of ports. On the one hand, by reducing shipping costs and by improving the quality of shipping services, it makes a port's hinterland more accessible and thus more competitive. On the other hand, it has a tendency to reduce the direct regional economic impact of ports. For instance, the local economic impact of break-bulk cargo in the Port of Montreal is estimated at $44.72 a ton, while the economic impact of containerized cargo is $20.96 a ton.[4] When the traffic of general cargo is constant, containerization reduces, among other things, the port labour force necessary for its operation. In terms of economic impact, however, it is superior to bulk cargo, which produces only $5.20 of economic impact a ton for solids and $2.15 a ton for liquids. For example, although containerized cargo in the Port of Montreal accounted for only 7.4 per cent of total traffic in 1974, in the region's economy, it accounted for 17 per cent of the total economic impact of all traffic.

Because containerization is applied almost exclusively to international general cargo, we are interested only in port systems that serve international shippers. The eastern port system comprises Toronto, Montreal, Quebec City, Saint John, and Halifax. The western system has only one Canadian unit—Vancouver—but it is part of a system of competing ports that includes Seattle, Tacoma, Portland, and Oakland. The volume of international general cargo for Vancouver alone is about half as great as that for the whole of the eastern Canadian system.

Before the advent of containerization, the ports of central Canada—Montreal, Toronto, and Quebec—were by far the main ports in the eastern system. The ports of Saint John and Halifax were mainly complementary ports, in that they served, along with some U.S. coastal ports,[5] as winter ports. These ports had and still have local hinterlands of little importance. The main reason for the complementarity between ports was that ocean freight rates in the summer were almost equal among all the ports, except

4 See L. Pedneault, *Highlights on the Economic Impact of the Port of Montreal* (Ottawa: National Harbours Board, 1974), p. 28. The local economic impact consists of the change in the level of local economic activities directly connected with the port, plus the changes in the level of other local economic activities indirectly related to the port activities through income or job multiplier effects.

5 See P.M. Bunting and L.M. O'Connell, *The Containers Study Report 70* (Ottawa: Canadian Transport Commission, 1973), p. 26. An estimated 1.8 per cent of total Canadian general cargo goes through U.S. ports.

Toronto.[6] Since most of the market is in central Canada, weather permitting, shippers and consignees had an incentive to use the ports of central Canada. Using the ports of the Atlantic provinces would have meant paying the same basic ocean rate plus rail transportation from Halifax or Saint John to Montreal. The situation was and is much less complicated in the west. In international traffic, Vancouver competes directly for the Far East freight with the American ports, especially Seattle.[7] Short-run fluctuations in the relative prosperity of all these ports depend upon the state of local labour relations.[8]

But containerization, along with a flurry of other technological changes including supertankers, during the past 15 years has revolutionized maritime transportation.[9] Containerization refers to putting merchandise, which was previously packaged in all sorts of ways (often called break-bulk merchandise or general cargo), into large (usually sturdy) boxes of standardized dimensions.[10] Standardization of boxes enables ships and mechanized equipment to be designed for greater efficiency in loading and unloading operations and in transferring containers to the ultimate consignee of the goods. Their use increases the efficiency of all components of this intermodal system of transport. In part, this is achieved by using more capital-intensive ships and by the more intensive utilization of the ships that standardization permits. For instance, port time on the North Atlantic has been cut from approximately two weeks to two days, while the voyage itself has been cut from about ten days to seven.[11] Standardization also enables use of unit trains and door-to-door services, economizes on

6 Economist Intelligence Unit, *Atlantic Provinces Transportation Study*, vol. 9 (London: Economist Intelligence Unit Limited, 1967), p. 28: "Summer ocean rates generally are the same for Montreal, Quebec, Port Alfred, Three Rivers, Saint John, West Saint John, and Halifax." During the 1960s, it seems that the conferences did not try to differentiate in their rates between Halifax and Montreal because they thought that it was not possible to attract traffic from central Canada to Halifax. They also had little incentive to do so because the daily operating costs of a ship at that time were much smaller than the daily costs of today's container ships, to the extent that the marginal cost of going up the St. Lawrence River was smaller than the cost of using the railways from Halifax.

7 B. Brouillette, *Prospective Change for Handling of Commodities in Canadian Ports*, Transport Canada (Ottawa: Information Canada, 1974), p. 29.

8 Bunting and O'Connell, *Containers Study Report*, p. 26: "In general trade diversion between Canada and the United States serves as a 'safety valve' in cases of regional or national port strikes. . ."

9 H. H. Mayer, "Some Geographic Aspects of Technological Change in Maritime Transportation," *Economic Geography*, vol. 49, no. 2 (1973), pp. 145-155.

10 For a more complete definition, see footnote 1 above.

11 Ian Wallace, "Containerization at Canadian Ports," *Annals of the Association of American Geographers*, vol. 85, no. 3 (1975), p. 434.

labour in ports,[12] and cuts losses from theft, breakage, and spoilage. The drawbacks of this new transport system are the high fixed costs of container ship terminal facilities and containers themselves, plus the desirability, if not the necessity, of return freight, to reduce shipment of empty containers. Overall, this technological change exploits the economies of scale accruing when larger and faster ships are used in conjunction with terminals that are more land- and capital-intensive.

The Pattern of Regional Diffusion

The scale economies involved in containerization eliminate all but the major ports as possible adopters of this innovation. The process of adoption has two dimensions: the date of the first adoption by each port; and the changes, over the years, in the proportion for each port of the containerizable goods that are effectively containerized. Indeed, a port may perform very differently on these two accounts. A port that is an early adopter may later have a lower proportion of its traffic containerized.[13]

Measuring these dimensions raises practical difficulties. First, there is the problem of ascertaining the date of initial adoption. Large boxes of freight have been used for many years without being called containers.

12 M. Brooks *et al.*, *Development of Container Ports in Eastern Canada* (Ottawa: Transport Canada, 1975), p. 20: "For example, at a reasonable efficient break-bulk berth, one man will be employed for every 750 to 1,000 tons of cargo a year at that berth; with containerization, the figure was from 8,000 to 9,000 tons in 1971 and it is expected to rise to 12,000 tons by 1975." On the other hand, labour and wharf charges at various ports do not reflect these changes in productivity so that, in the end, labour costs are probably not decisive in the choice of a port.

Comparison of Port Charges for Longshoremen, Wharves, and Supplements at Three Ports, 1975

Type of cargo \ Port	Montreal	Halifax	New York
		(Dollars per ton)	
Break-bulk	11.20	8.10	13.60
Containers	11.05	8.67	19.51

Source: Confidential.

Since the total transport cost of a container coming from Europe to Toronto on a door-to-door basis is somewhere around $1,200, the above differences in the costs of loading and unloading at ports amount to $33 more per container (14 tons per container) at Montreal compared with Halifax. This is a relatively small difference.

13 This corresponds to the frequently observed phenomenon of "a fairly marked negative relationship between the speed of diffusion and the time lag in introduction: in countries which are pioneers, diffusion tends to be slower;" L. Nabseth and G.F. Ray, *The Diffusion of New Industrial Processes: An International Study* (Cambridge, Mass.: Cambridge University Press, 1974), p. 19.

Furthermore, even when recognized as containers, they circulated in Canadian ports before a regular conference service was established between Canadian ports and overseas ports. Without this regular service, containerization could not flourish and become an important system of transport. Consequently, we will take the initial adoption of containerization to be the year of the establishment of a regular service of ships more or less specialized in containers, accompanied by the installation of more or less specialized port equipment, such as gantry cranes (Table 6-1).

Montreal led all other Canadian ports by roughly two years, followed by Quebec City, Halifax, and Vancouver two years later, Saint John three years later, and finally Toronto five years later.

This does not present a complete picture of the initial adoption process because it does not measure the magnitude or importance of these adoptions. There is difficulty here in choosing the correct measure of the

Table 6-1

Starting Dates of Container Services at Major Ports[1], 1968-75

	Toronto[2]	Montreal	Quebec City	Saint John	Halifax	Vancouver
1968		Manchester				
1970		CAST	C.P. Ships		Dart[3] ACL(1)	Japan 6 Lines
1971				ACT	Columbus	Johnson Line
1972		CARE		Atlantica	Zim ACL(2) Hapag-Lloyd[5] Mitsui OSK[6]	Columbus[4] Pacific Far East Pacific Curo Orient Fesco Scan Star
1973	Black Sea	Saguenay		NYK Orient	Saguenay K. Line[6] Japan Line[6]	
1974				Atlant- trafik	Maritime Coastal	
1975	CARE			Black Sea	Italian Line	

1 The names in the table are those of the ocean carrier establishing a regular service. The numbers in parentheses indicate the number of different services by the same company.
2 Strictly speaking, Toronto should not figure at all because it has no gantry crane; it offers a service only at general cargo terminals equipped with mobile cranes. On the other hand, in 1976, three companies called regularly with cellular ships that offered a complete service for containers. One must also note that, in 1969, Toronto's volume was similar to those of Saint John and Halifax. It was in later years that it almost stopped growing while the others went on.
3 Dart service began in the middle of 1969. However, we count it only in 1970 because gantry cranes were operational only in 1970. Furthermore, the volume of containers moved in 1969 was very low. For the same reason, Saint John, which had the same volume, and Quebec, with a slightly greater volume, were also excluded before 1970.
4 The exact date for this line and the others below is indeterminate between 1971 and 1975.
5 Stopped in 1973; recommenced in 1975.
6 Stopped in 1976.

progress of the diffusion of containerization, which can be expressed either in absolute terms or in terms relative to a ceiling representing the potential quantity of containerizable cargo. Neither is ideal.

Containerization is not completely analogous to the phenomenon of manufacturing firms modernizing their equipment to produce a given output. It is more like competing firms modernizing to produce a new product. In the case of port services, the objective of the competing ports is not only to containerize their own traffic, but also to use containerization to divert traffic usually handled by other ports. The absolute growth of containerization may also have the effect of making the region surrounding the port more accessible and thus more desirable as an industrial location. A cumulative process can thus be triggered whereby a port brings more industrial locations into its region, which, in turn, increases the volume of traffic in the port.[14] For all these reasons, diffusion in absolute terms matters (see Chart 6-1).

In general, container traffic began to boom in earnest only after 1970, although Montreal began a little earlier, in 1969. This confirms our approach in Table 6-1, which considered establishment of regular service as the criterion for initial adoption of containerization. Further, Chart 6-1 indicates that, although Halifax was a very small complementary port before containerization, it overtook Montreal in 1975; in fact, Halifax and Saint John, taken as a unit, overtook Montreal as early as 1972. Containerization is consequently a very potent competitive force.

However, no absolute measure is a complete description of the diffusion of an innovation. Some attempt must be made to relate it to a norm to aid us in making judgments about certain aspects of the performance of the ports. This is done by establishing a ceiling corresponding to the technically containerizable cargo.[15] In turn, technically containerizable cargo is usually defined as cargo that is neither bulk nor pieces of machinery over five tons.[16] In our study, we will use this ceiling but restrict it to

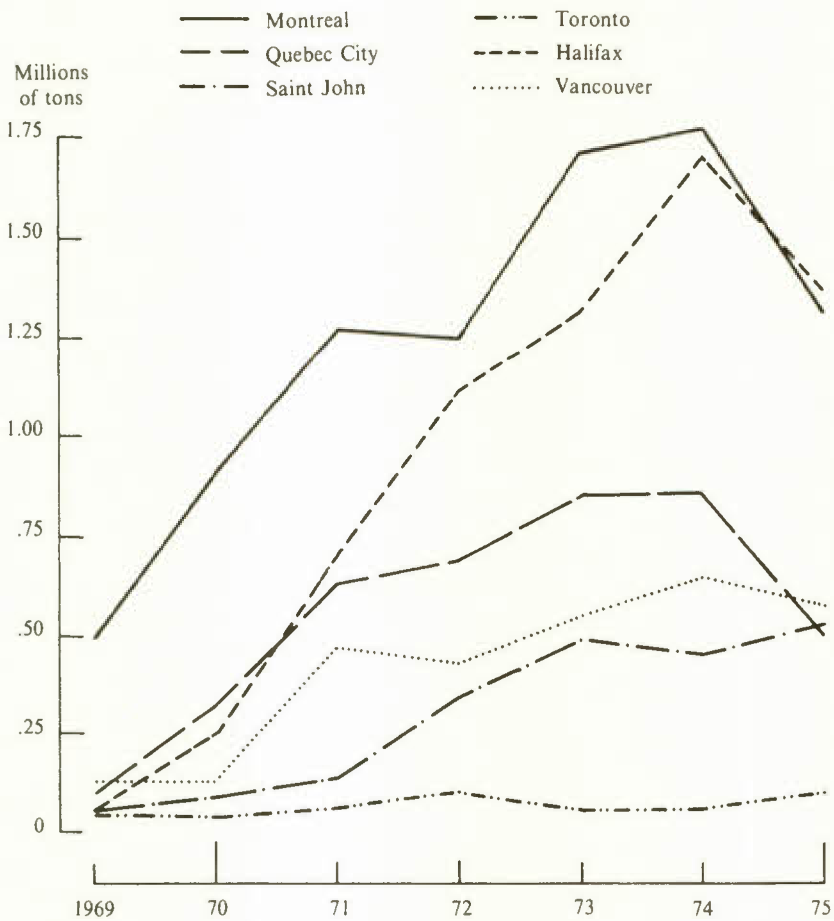
14 In the case of Halifax, this process leads to a dichotomy between the economic region of the port (the geographical area whose industries are directly or indirectly linked to the port) and its hinterland (strictly defined, the geographical area over which the port draws its traffic). The latter now corresponds to the eastern portion of Canada and the United States.

15 Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 242. The technical ceiling is not completely independent of marketing (or profitability) considerations. It simply does not include all marketing (or profitability) aspects. For instance, engineers would not propose chimneys made of gold, but they would say that both brick and aluminum chimneys are technically feasible without choosing between them — that is, without introducing profitability considerations.

16 H.M. Johnson and H.C. Garnett, *The Economics of Containerization* (London: Allen & Unwin, 1971), p. 53. The authors refine the concept by distinguishing another category—moderately containerizable cargo consisting, for example, of pulp and paper and waste paper. One of many hypotheses they envisage includes moderately containerizable cargo so long as it is needed to balance traffic flows.

Chart 6-1

International Containerized Cargo at Major Ports, 1969-75



Source: Based on data from National Harbours Board and Toronto Harbour Commission.

international general cargo because national and transborder cargos have not been in the past, nor are they likely to be within the the next ten years, containerized to any appreciable degree.

The choice of a technical ceiling does not imply that the identification of containerizable cargo is not a highly controversial matter.[17] For instance, in Canada, the various reports on the prospects of containerization differ

17 Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 297.

considerably among themselves.[18] The earlier ones completely missed one commodity, asbestos, which later turned out to be the most important single user of containers in Canadian shipping. Some experts have recently made other suggestions for the standard of comparison, though, in doing so, they have adopted profitability measures rather than just the concept of simple technical feasibility. For instance, by inspecting each type of merchandise transhipped through ports, one report made an evaluation for each port as to the probability of containerization over the next ten years, based on 1971 figures (Table 6-2).[19]

Table 6-2

Distribution of International Cargo at Five Ports, 1971

	Containerized	Containerizable (within the next ten years)	Noncontainerizable
		(Per cent)	
Montreal	32.7	30.8	36.5
Quebec City	35.9	8.2	55.9
Saint John	11.4	15.7	72.9
Halifax	57.7	22.3	20.0
Vancouver	12.4	14.7	72.9

1 Vancouver includes some bulk cargo circulating on a national basis. Quebec includes some national cargo also.

Source: See B. Brouillette, *Prospective Change for Handling Commodities in Canadian Ports*, Transport Canada (Ottawa: Information Canada, 1974).

These results set a different norm per port: 63.5 per cent for Montreal, 44.1 per cent for Quebec City, and so on. This would be a satisfactory approach if it were not for the fact that this norm is static; that is, it depends upon a given set of individual port policies and policies of ship owners. For instance, although the report proposed 44 per cent as a norm for the port of Quebec City, by 1975 that port had effectively attained 78 per cent, largely because one shipping line made it a port of entry.[20] Since, in the long run, port policies and ship owners' policies can change, the static marketing (profitability) approach is an arbitrary criterion from the point of view of

18 See Matson Research Corporation, *A Research Base Development of a National Containerization Policy*, vol. 1, Phase 1 (San Francisco: Matson Res. Corp., 1970); and Brouillette, *Prospective Change for Handling Commodities*, pp. 9-13.

19 Brouillette, *Prospective Change for Handling Commodities*.

20 The high percentage of containerization results from a mathematical phenomenon that occurs for ports that depend upon containerized cargo to increase their traffic. If each increase in traffic is in the form of containerized cargo, both the numerator and the denominator are increased by the same amount, thus gradually increasing the ratio of containerized cargo to total cargo.

each individual port. At the aggregate level of all general international cargo, it has been suggested that, in the case of the Great Lakes area, containerizable cargo could amount to 83 per cent of the total international cargo.[21] Whether this particular percentage is universally applicable or not is not too important for us. Since this percentage applies to all ports, it does not change the ranking of ports in the diffusion diagram whether we use 83 per cent, 100 per cent, or any other percentage, as long as we do not use a percentage below that of the ports with the highest proportion of containerized cargo. What matters is the use of total international cargo as a base reference.[22]

Chart 6-2 relates containerized cargo to total international cargo. The initial adopter did not remain the leader in the field for long. Actually, in the eastern system, it was the late adopters who made the most important use of the innovation. In 1975, containerization represented the mainstay of business in general cargo for Halifax and Quebec; for Montreal, only half of its business. This is perfectly understandable since Montreal's general cargo business, not being the result of any special marketing and institutional promotion, naturally contains a fair proportion of cargo that is not easily containerizable.

Moreover, as international traffic is gradually containerized, ports that are not equipped for containerization, or are not on the routes of the main container services, are bound to lose their share of the traffic.[23] Thus the status of many ports has been drastically changed. For instance, the relationship between the port of Montreal and those of Quebec City, Halifax, and Saint John has changed from one of complementarity (in the winter) to a year-round state of competitiveness.[24] The ports of Toronto and

21 Schenker *et al.*, "Great Lakes Transportation," p. 45.

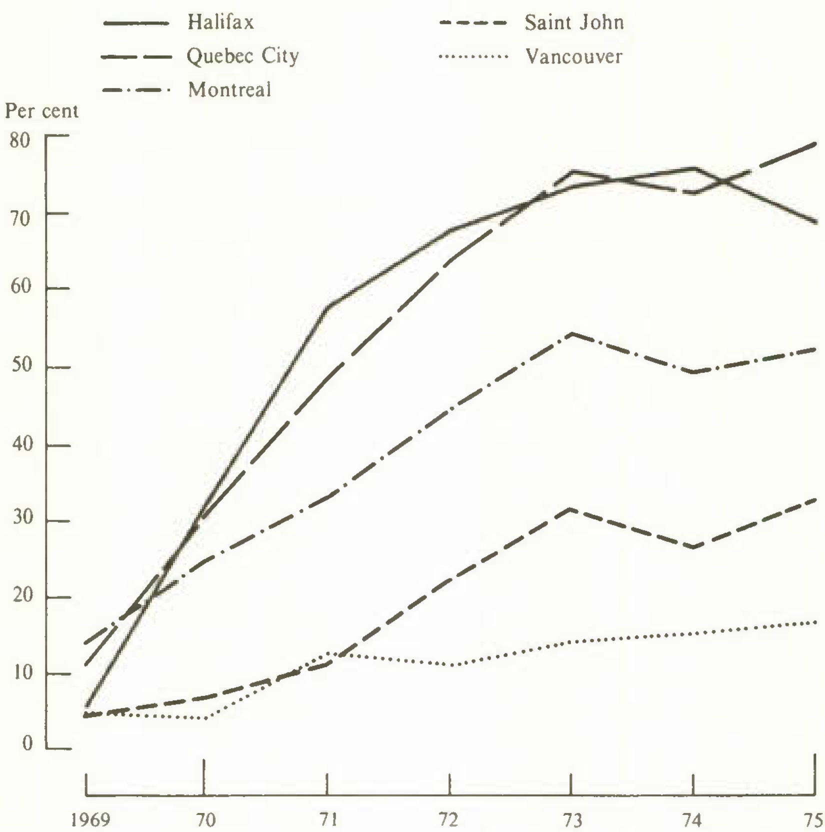
22 *Ibid.*, p. 10. Similarly, Ontario's ports' performances have been largely negative when evaluated by a shift-share analysis. The net relative change for the 1965-74 period for the ports of Ontario has been negative to the tune of 804,820 tons, or 33 per cent of their 1965 traffic. The shift-share analysis (not yet published) involves all ports of central and eastern Canada and covers both national and international cargo. As for the port of Toronto itself, its "container" activities have been very small; see R. Ramlalsingh, *A Study of the Decline of Trade at the Port of Toronto* (Toronto: University of Toronto Press, 1975).

23 The percentage of containerization cannot be used to determine the quality of the performance of the management of ports. For instance, a small new port dealing almost exclusively with containers is not necessarily superior in every respect to an old port, which may have a smaller percentage of its cargo containerized, yet be ten times more important in absolute terms (even in containers) than the small port in question.

24 The competitiveness between Montreal and other Quebec ports and between Saint John and Halifax is depicted by the size and sign of net relative change during the 1965-74 period. Shift-share analysis shows a net change in miscellaneous commodities together with containerized freight of -866,972 tons for Montreal, +479,420 tons for other Quebec ports, -98,712 tons for Saint John, and +1,291,695 tons for Halifax. In 1965, the latter two ports had 14.2 per cent of the general cargo of the whole eastern port system and, in 1974, they had 29 per cent, according to confidential sources.

Chart 6-2

Percentage of General International Cargo in Containers at Five Ports, 1969-75



Source: Based on data from National Harbours Board.

Montreal have shown a relative loss in favour of Quebec City, Halifax, and probably Saint John. However, Saint John seems also to have lost certain traffic to Halifax, although it has gained other (such as that traveling on the southern routes); overall, its relative loss has been small. This is a situation undreamed of even a few years ago.[25] As for Vancouver, for whatever reason, it seems that its containerized traffic has not grown at a rate comparable to that of its competitors. Vancouver's grew from 130,000 tons in 1969 to 577,000 in 1975 while Seattle's, for instance, went

25 Economist Intelligence Unit, *Atlantic Provinces Transportation Study*, p. 44. In 1967, the opinion was that no definite conclusions favouring the Atlantic ports could be reached, but rather that the St. Lawrence ports could easily maintain their competitive position by also adopting container services.

from 241,000 tons in 1969 to 2,560,000 tons in 1974.[26] Containerization can thus be said to have upset the previous competitive equilibrium among ports.

Factors Pertaining to the Diffusion of Containerization

The factors underlying initial adoption and subsequent performance of containerization at Canadian ports differ.

In terms of initial adoption, we have ranked Montreal first, followed by Quebec City, Halifax, and Vancouver in second position, then Saint John, and Toronto last. In the case of Montreal, proximity to a large established port market seems to be the main explanatory factor. This is normal, since an established market minimizes the risks of introducing an innovation. It is for this same reason that Saint John was opened much later in that, besides having practically no hinterland of its own, it was the terminal for much less important ocean routes, such as those from South America and Japan. Vancouver's lateness is usually imputed to a different cause—lack of interest by both private and public entrepreneurship.[27]

However, initial adoption and later utilization of an innovation may be two different stories. We have established that there was a relative shift of container traffic from Ontario and Montreal to Quebec City, Halifax, and Saint John, while Vancouver's performance was far from spectacular. What were the factors that operated in the long run? Briefly, they were the effects of containerization upon the economics of ocean transportation—such that ports that previously had no possibility of competing with Montreal were put on an equal basis as far as total costs of door-to-door transportation were concerned—and commercial connections with concomitant marketing activities. Because the large railway and ocean carrier companies involved have very good research departments, we can rule out lack of information as a reason for the late adoption of containerization.

Proving that the economics of ocean transportation have changed the direction of port traffic is not an easy task. Some theoretical models still show that shipping containers directly to Montreal is the cheapest way to reach Canada's heartland, at least for general merchandise, rather than the more indirect route involving land transportation from Halifax to Montreal.[28] However, these models are probably too simplistic to infer the

26 *Jane's Freight Containers* (London: Jane's Yearbooks, annual).

27 See Wallace, "Containerization at Canadian Ports," p. 44, which puts the blame squarely on the National Harbours Board. On the other hand, the author says that the federal government puts the blame on the lack of interest by conference lines calling at Vancouver.

28 B. Riendeau, *Concurrence et complémentarité des ports du Québec par rapport à d'autres ports au Canada et aux États-Unis* (Québec: Office de Planification et de développement du Québec, 1974), p. 106.

general primacy of Montreal. More complex models that simultaneously take into account the whole of ocean shipping and railway economics, in addition to simply the published rates, might show otherwise. However, the problems involved in building such simulation models lie in the indeterminacy in establishing the pertinent total costs of ocean carriers who provide a package deal on door-to-door delivery. All simulation models require some basic assumptions about costing principles that govern the distribution of joint costs and about the normal target rate of return. Moreover, the results of the simulations depend partly upon the depth of the analysis. Indeterminacy results from the fact that there is a variety of costing approaches and rates of return on invested capital that are all equally legitimate; the choice among them depends upon the organizational structure of the firms, the structure of the market in which they operate, and other aspects of the economic environment of the firms.

The cost of the total package to the ocean carrier thus depends upon a complex set of circumstances. The first component is ocean transport costs, which include the nature of the sea route (which may involve many ports of call),[29] the mixture of general cargo and containers in the same vessel, the kind of operations maintained in the overseas port of origin, the destination of the ocean carriers, and the subsidies received for the construction of the vessels (this can amount to 55 per cent in the United States) and/or on their operation. All this makes identifying long-run marginal costs attributable to a particular traffic (not to mention the target return rate) a somewhat complicated task, where value judgments, especially on costing, intervene to a significant degree.[30] The problem is well illustrated by an ocean carrier sailing from Rotterdam or Antwerp to New York. In this case, the costing of containers destined for Halifax can be done in many ways. The carrier can recognize as costs either the average cost per ton for the whole trip or consider Halifax the frosting on the cake; the voyage to New York being already justified in economic terms, the carrier can count as costs only the marginal costs of a small detour to Halifax (a six-hour delay). Between full costs and the marginal cost of a

29 This may involve many ports of call. For instance, "DART's (a consortium of ship owners) largest American market is in the New York area. A great circle route that includes Halifax and New York is then logical," Matson, *National Containerization Policy*, p. 87. Furthermore, it has been suggested not only that costs change whether we are considering one or many routes, but also that a single route study is incomplete; see E. Bennethan and A. A. Walters, *The Economics of Ocean Freight Rates* (New York: Praeger, 1969), p. 76.

30 "If . . . economies (of scale) . . . existed, no single system figure could be derived," H. L. Purdy, *Transport Competition and Public Policy in Canada* (Vancouver: University of British Columbia Press, 1972), p. 252. Similarly, in the North Atlantic route controversy of the 1960s, it became known that there were many ways to calculate costs and that no agreement could be reached; see Bennethan and Walters, *Ocean Freight Rates*, Chap. 5.

small detour lies a whole range of options open to the decision-maker.[31] In another dimension, there are other costing approaches such as single-ship versus fleet analysis,[32] the network approach, and the like.

The second component of the cost of the total package is railway costs. Here also, there is some indeterminacy in costings.[33] The rates that the railways quote to the ocean carriers depend upon both objective circumstances, like the use of conventional or unit trains, and their current marketing strategy, determined by how badly they want the traffic.

The third component consists of the costs of port installation services. They present some uncertainty in that ocean carriers can either build their own facilities or enter into partnership with governments and railways to build and use terminals.

Therefore, it seems that the theoretical indeterminacy in costing, combined with the empirical fact that containers do actually transit through Halifax in large quantities, enables us to surmise that, from the point of view of some ocean carriers, the economies of scale of larger and faster container ships calling at Halifax, modified by the economic environment described above and which may vary from firm to firm, compensate for the additional cost of a railway trip to the heartland of Canada. This is probably how the coastal ports became, in total cost terms, equivalent to Montreal and Quebec.[34]

Once a rough equality of costs among ports is assured, then other factors become decisive in the choice of a port of entry or exit. The other main factor is commercial connections, including the association of port interests, ocean carriers, and railways, coupled with the marketing forces that follow such a community of interests.[35] For instance, the marketing policies and freight solicitation of a particular railway are no longer neutral

31 Cost perspectives surely differ among carriers. For instance, CAST is charging about $250 to move a container of asphalt roofing shingles to Europe from Canada, while the conference line charges approximately $500; see "New Container Power Launched on the Atlantic," *Canadian Transportation and Distribution Management*, March 1976, p. 25.

32 See B.M. Deakin, *Shipping Conferences: A Study of Their Origins, Development, and Economic Practices* (Cambridge, Mass.: Cambridge University Press, 1973), p. 93.

33 See Purdy, *Transport Competition*.

34 Although, according to the reasoning on the indeterminacy presented above, we will never know whether this equivalence is strict or approximate. In other words, proving that Halifax is a viable port for containers does not amount to proving that Montreal is not also a desirable port for certain types of traffic. Furthermore, as we shall see below, transport companies like C.P. Navigation can make errors in their calculations.

35 See Wallace, "Containerization at Canadian Ports," p. 438. Halterm, the container facilities in Halifax, for example, is owned jointly by Canadian National Railways, Clark Transportation Canada (a company with widespread domestic transport interests and, until 1973, a partner in Dart Container Line), and Halican (which is composed of Nova Scotia provincial and Halifax municipal government interests).

among the ports once the railway has entered into a partnership with a terminal or with an ocean carrier. Similarly, an ocean carrier will not promote all possible ports of entry if he has access to only one of them. And finally, a fully integrated carrier such as Canadian Pacific will naturally favour its own land routes as well as its own port of entry. In fact, according to opinions offered in a case pending in Canadian courts, "a marine-rail agreement . . . could change shipping patterns to and from this nation."[36] This statement is important because it implies that commercial connections can, to some extent, overrule objective cost calculations regarding optimal routing. It also presupposes that shipping agents, ocean carriers, and railways have some control over the routing of traffic. Put another way, the choice of a port is not the result of a simple objective set of cost calculations.

We have to conclude then that the prosperity of Halifax and Saint John is the result, first, of containerization, which roughly equalized the cost advantages of these ports and, second, of their success in establishing organizational structures, such as the terminal company of Halterm and Brunterm, which brought in commercial and marketing preferences for these ports.

In the case of Quebec City, it seems that Canadian Pacific Navigation for a while preferred not to be in direct competition with its competitors. Now they are thinking of going back to Montreal because of the presence of their competitors—CAST, ACL, and Manchester Lines—and in order to get nearer to their Great Lakes and western markets.[37]

Toronto's case is also straightforward; containerization that favours large ships almost eliminates Toronto because of the navigational restrictions of the St. Lawrence Seaway. The cost equality among Canadian eastern ports does not apply to Toronto.

As for Vancouver, the port was apparently unsuccessful in attracting prestigious shipping lines that, through their commercial connections and marketing power, could have counterbalanced the attraction of Seattle. To this, we must add the fact that the incentive to containerize is partly dependent upon the Far East ports with which Vancouver is connected. Apparently, these ports, because of local labour conditions, are less anxious to containerize.

36 See "New Container Power," p. 22. Here we are alluding to the famous proposed agreement between Canadian National and CAST, which was vehemently opposed by such groups as Canadian Pacific, the Seafarers' International Union, Dart Container Line, and Halifax politicians.

37 P. Bennett, "Le départ de CP Navigation de Québec entraînera des pertes de $40 millions," *Le Devoir*, 21 January 1978.

The Regional Factor

The regional factor affected the diffusion of containerization at Canadian ports in two ways. In the first instance, minimization of distance from large markets was the decisive factor for initial adoption. Later, however, the realization that containerization had roughly equalized the costs of door-to-door service regardless of port of entry, the upsurge of Halifax and Saint John must be imputed to management attitudes. Management (both public and private) capitalized on an opportunity provided by the establishment of North Atlantic container services to New York. In addition, they were able to provide ocean carriers with the possibility of sharing a terminal built with public funds.[38] However, these funds and the organizational structure of such an enterprise are peculiar to the region. It is the local management (public and private) that promoted the idea, secured the necessary co-operative agents who would assure a commercial preference to their port, encouraged the railways to set low railway rates (although it appears that the railways have not been completely passive in this respect), and finally got the funds from public bodies.

Meanwhile, in Montreal, there was no countervailing entrepreneurship. We know now that location near the central market was not enough to assure continuous pre-eminence in container traffic.

As for Vancouver, we have already mentioned that it was lack of local public and private entrepreneurship that was one of the causes of the underperformance of the port in containerization.

It seems, then, that, in Canada, for the phase of subsequent diffusion of containerization, the regional factor expressed in the form of local management attitudes (public and private) was an important underlying factor conditioning the extent of diffusion.

38 See Wallace, "Containerization at Canadian Ports," p. 441. In the case of Saint John, more than half of the project was met by the province and a good portion of the rest, by the National Harbours Board.

7 The Newsprint Industry

Because of the oligopolistic structure and strong international competition of the Canadian newsprint industry, we suspected at the outset of this study that, possibly, we would find no regional differences in diffusion of innovations and hence no regional factor of diffusion. Distinguishing among the various modes of diffusion, as discussed in Chapter 2 above, is possible only when market discipline is not so strong that it eliminates all traces of special behaviour on the part of individual firms. We discovered, however, that the introduction and use of technology in this industry has not always been the same in all regions.

Early paper mills were established near urban centres where skilled labour and markets were near distinctly limited raw materials.[1] At the beginning of the twentieth century, with wood pulp as the main ingredient, newsprint paper began to dominate the paper industry. Because wood was available not far from earlier plant locations and because of the reluctance of plant owners to change location, newsprint mills were largely concentrated in central Canada between 1900 and 1940. After the Second World War, regional government policies helped to spread the industry to less industrialized areas of Canada. The uneven pattern of expansion that resulted is seen in the differences in age of machines in the various regions. By 1964, Quebec and Ontario, the pioneers in the industry, tended to have the greatest proportion of old machines. The newest machines were most likely to be found in New Brunswick, followed by Nova Scotia.[2] And so, beginning in 1968, newsprint mills began in earnest to modernize their equipment and to increase production.

Modernization of newsprint mills can be achieved in many ways. In this study, we examine changes made in the wet section of a paper mill, but there are equally good if not better possibilities in such areas as the drying section, the headbox section, the preparation of stock or furnish mix, or the

1 D.M. Ray, R.A. Roberge, and P. Villeneuve, "Invention, Diffusion, and Allometry: A Study of the Growth and Form of the Pulp and Paper Industry in Central Canada," Ministry of State for Urban Affairs Discussion Paper B.73.20, Ottawa, 1973.

2 Of the Atlantic provinces, Newfoundland, having been developed in the newsprint industry much earlier, was the least advanced.

use of computer control. Our choice of innovations is governed by the availability of data and the possibility of comparing our results with similar work by other researchers. Thus, our study does not present an unequivocal measure of the overall degree of modernity of a mill but only of that part affected by the innovations we have selected for examination.

We focus here on four innovations that illustrate technological progress in the newspaper industry. One is to install completely new Fourdrinier machines that differ from old ones in either greater width of rolls or faster production speed of newsprint or both. A second is the substitution of the horizontal wire-screen belt of the Fourdrinier machine, which vibrates and forms the paper sheet from wood pulp stock on it, with two screen belts that sandwich the stock between them. This twin-wire innovation is a major technological change in itself. It helps increase production because it requires fewer delays for periodic replacement of screens than the single-wire mesh of the Fourdrinier machine. Two other innovations are less important. Synthetic fabrics can replace the woven bronze or brass mesh of the Fourdrinier wire in order to obtain maximum wire life as an alternate method to the twin-wire system of reducing machine stoppages for repairs. And special presses, including fabric, shrink-fabric, venta-nip, and high-intensity presses, can be added to Fourdrinier-type and are standard equipment on twin-wire machines; they apply coatings to the paper and so upgrade the quality and value of paper produced.

The Pattern of Regional Diffusion

A pulp and paper mill is usually organized around one or a few large paper machines that occupy the central space in a plant. The machines may differ from each other in age or in process. This is quite different from, say, a textile plant, where a very large number of machines are all alike.

It is often impossible to unequivocally determine the age of a newsprint machine because it is continually being modified and modernized. It is not unusual, in Quebec and Ontario, to see machines originally installed in the early 1900s still in operation, although it would be hard to find significant parts of them that qualify as original, except the frames. Usually when a section of a machine wears out or needs to be replaced for other reasons, management seizes upon the occasion to modernize it. The new pieces of equipment are not always small gadgets. One, for example, installed by the Three-Rivers Pulp and Paper Co. costs $40 million.[3] Hence, it is very difficult to calculate the average age of a machine or to appraise its overall degree of modernity. The Canadian Pulp and Paper Association periodi-

3 "Capital Expenditures Forecast," *Pulp and Paper Magazine of Canada*, July 1974, p. 31.

cally publishes for its members an up-to-date list of all pieces of equipment used by the various mills and their ages, but this list is not available to outside researchers.

Therefore, in studying the time lag in the diffusion of Fourdrinier machines, we relied on an overall index of modernity as determined by its capacity rather than its age. The index of capacity called product is the maximum output in square feet of paper produced each minute that is obtainable if the machine were operated at maximum design specifications.[4] Actual capacity is a lesser amount allowing for down-time for normal maintenance of equipment and is usually expressed in tons of standard-weight paper.

The increase in product capacity of newly installed Fourdrinier machines in Canada has been mainly a function of time (see Table 7-1). But the rate at which the index of product capacity increased varied significantly among regions (see Table 7-2).[5] The Atlantic provinces registered the highest rate of increase, followed by Ontario, Quebec, and then the West.

Product capacity, an aggregate technical indicator of modernity of a machine, is measured in terms of the combined effects of speed and width. Consequently, it may be argued that speed of linear paper production and width of paper rolls, taken individually, are better measures of modernity. Moreover, a lack of perfect correlation with either component of product capacity, taken individually, shows how firms in some regions substitute one component for the other in order to maintain their rank in the capacity index (see Table 7-3).

The time trend of speed of paper machines supports the hypothesis that there is no statistically significant difference among regions with respect to date of installation (see Table 7-4). Rather, the increase in speed of machines is almost exclusively a function of time. Indeed, the independent variables of time and a constant — that is, the hypothetical speed of the machines installed at the beginning of the period — account for 93 per cent of the reasons for differences in speed of new machines installed in Canada

4 The speed and width of a machine combine, through a complex formula, to give the product capacity of the machine.

5 The rate of increase of the product capacity index in the regions were calculated from linear regressions, fitted to the data for each region, of the form:

$$x_i = a_i + b_{it}$$

where

x = the index of capacity of the machines;

i = Atlantic, Quebec, Ontario, or western (Prairies and British Columbia) regions; and

t = time of installation from 1907 = 1.

The coefficient of the time variable was then used to determine the index of product capacity, width, and speed, and its slope was used to indicate the rate of acceptance of Fourdrinier machines in the regions.

Table 7-1

Product Capacity of Fourdrinier-Type Newsprint Machines Installed, Canada, by Region, 1907-71[1]

	Atlantic region	Quebec	Ontario	West
		(Square feet per minute)		
1907		6,333		
1912				7,750
			11,783	
1915			9,875	
1916		8,883		
			8,667	
1917			8,883	
1920			9,500	
1922		13,833		
1923		13,333		
1924		13,650		
		10,933	19,500	
1925		16,400	11,617	
1926		16,000		22,600
		27,000		
1927			28,250	
			24,500	
1928		16,000		
		27,300		
		24,500		
		25,350		
1929		23,400		
	20,717	16,000	27,107	
1930	26,367			26,367
1938		32,750		
1948				37,667
1949	47,333			
1953		17,000		47,333
1957			49,867	54,583
				43,333
1958			76,950	
1959			51,750	
1960				75,396
1963		58,067		54,167
		60,042		
1964		60,042		64,125
1965	81,500	59,000		
	81,598			
1966		58,067		
1967		64,000		
1968				49,583
1969	54,583	85,950		
1971	86,500			
	96,213			

1 This table does not account for all machines of this type installed in Canada, especially for the period before 1940. Nevertheless, it is a good indicator of the state of technology that was embodied in machines in various regions during this period.

Source: Adapted from M. F. Davy and K. M. Thompson, "Newsprint Machines: Historical Trends and Projections for Speed, Width and Production Capacity," *Pulp and Paper Reports*, vol. 3, Pulp and Paper Institute of Canada (Montreal: CPPI, 1974), Appendix 2.

Table 7-2

Time Trend of Product Capacity of Fourdrinier-Type Newsprint Machines Installed, by Region, 1907-71

	Constant	Time period	$\bar{R}^2$	F	Number of observations
Atlantic region					
Coefficient	-10,250.1	1,463.99	.81	30.99	8
S.E.	13,685.8	262.996			
Quebec					
Coefficient	-2,060.29	1,076.63	.85	129.86	24
S.E.	3,448.96	94.476			
Ontario					
Coefficient	-1,076.93	1,183.03	.87	82.41	13
S.E.	3,656.25	130.431			
West					
Coefficient	3,875.50	954.01	.78	35.99	11
S.E.	7,220.18	159.02			

Source: Calculations based on Table 7-1.

between 1907 and 1971. The uniformity of change across regions suggests that all regions had equal access to innovations in the speed of machines.

The time trend of width of paper machines also shows that there are no statistically significant regional differences in installation (see Table 7-5). At the start, machines in the western and Atlantic provinces had a greater average width than those in Ontario and Quebec, but this was not significant on a formal statistical test. Throughout the rest of the period 1907-71, firms in Ontario registered the highest rate of increase, followed by those in the Atlantic provinces, Quebec, and the western provinces, but again this was not statistically significant.

Nevertheless, some comparisons can be made (see Table 7-6). Whereas the West falls into last place in terms of rates of increase in machine speed, width, and product, its constant term is consistently highest. Hence, a picture emerges showing the West at the frontier of technical progress in the earlier years but a follower of other regions by the end of the period. Quebec falls into third place in all rankings except the constant term in the speed equation, where it is second. The reason behind this is Quebec's lag in the adoption of more efficient new machines, except during the early 1920s, when the speed of new machines installed in Quebec was the highest in Canada. The low ranks of constant terms and high ranks of increase in machine speed and product for the Atlantic region show the trend of the industry there in advancing from a relatively backward position during the 1930s and 1940s to a position of industry leader by the mid-1960s. Meanwhile, Ontario's record has varied throughout the period relative to other regions.

Table 7-3

Speed and Width of Fourdrinier-Type Newsprint Machines Installed, by Region, 1907-71

	Atlantic region	Quebec	Ontario	West
1907		500/152		
1912				500/186
			700/202	
1915			750/158	
1916		650/164		
			650/160	
1917			650/164	
1920			750/152	
1922		1,000/166	800/	
1923		1,000/160		
1924		700/234		
		800/164	1,000/234	
1925		1,200/164	850/164	
1926		1,200/160		1,200/226
		1,200/270		1,200/
1927			1,500/226	
			1,200/245	
1928		1,200/160		
		1,400/234		
		1,200/245		
		1,300/234		
1929		1,200/234		
	1,100/226	1,200/160	1,070/304	
1930	1,400/226			1,400/226
1938		1,500/262		
1948				2,000/226
1949	2,000/284			
1953		1,200/170		2,000/284
1957			2,200/272	2,500/262
				2,000/260
1958			2,700/342	
1959			2,250/276	
1960				2,750/329
1963		2,600/268		2,500/260
		2,750/262		
1964		2,750/262		2,850/270
1965	3,000/326	3,000/236		
	2,830/346			
1966		2,600/268		
1967		3,000/262		
1968				2,500/238
1969	2,500/262	2,700/382		
1971	3,000/346			
	3,280/352			

Note: The first number is the speed of the machine in linear feet per minute and the second is the width in inches.
Source: Adapted from Davy and Thompson, "Newsprint Machines," Appendix 2.

Table 7-4

Time Trend of Speed of Fourdrinier-Type Newsprint Machines Installed, by Region, 1907-71

	Constant	Time period	$\bar{R}^2$	F	Number of observations
Atlantic region					
Coefficient	266.411	43.093	.912	73.324	8
S.E.	261.882	5.033			
Quebec					
Coefficient	328.761	40.080	.900	207.294	24
S.E.	101.625	2.784			
Ontario					
Coefficient	321.075	40.240	.923	157.919	14
S.E.	87.444	3.202			
West					
Coefficient	425.686	38.029	.919	126.399	12
S.E.	148.270	3.383			

Source: Calculations based on Table 7-3.

Table 7-5

Time Trend of Width of Paper in Fourdrinier-Type Newsprint Machines Installed, by Region, 1907-71

	Constant	Time period	$\bar{R}^2$	F	Number of observations
Atlantic region					
Coefficient	171.403	2.530	0.671	15.279	8
S.E.	33.680	0.647			
Quebec					
Coefficient	156.798	2.020	0.468	19.331	24
S.E.	16.771	0.459			
Ontario					
Coefficient	155.886	2.933	0.587	18.028	13
S.E.	19.362	0.691			
West					
Coefficient	190.816	1.447	0.437	8.760	11
S.E.	22.206	0.489			

Source: Calculations based on Table 7-3.

Average capacity, expressed in tons of paper a year, also can be used as a proxy to determine modernity of newsprint machines (see Table 7-7). In terms of this measure, Quebec and Ontario firms in 1964 had the least modern machines and New Brunswick firms, followed by those in Nova Scotia, had the most modern ones. This shows that the two Atlantic provinces certainly had access to the most advanced technology. Yet, although firms may have equal access to information about new technology, all sorts of technical, financial, and market constraints peculiar to each firm may prevent them from adopting the latest innovations.

The substitution of twin-wire machines for Fourdrinier machines as a method of reducing down-time began in Quebec in 1968. The last Fourdrinier machine in Canada was installed in 1971 and, after that date, all new installations or modernizations were of the twin-wire type (see Table 7-8). All but one were installed in Quebec, where diffusion of twin-wire machines spread slowly (see Chart 7-1).

Table 7-6

Ranking of Regions by Initial Level (Constant Term) and Rate of Increase in Machine Speed, Width, and Product

	Speed		Width		Product	
	Constant	Rate of increase	Constant	Rate of increase	Constant	Rate of increase
			(1 = highest)			
Atlantic region	4	1	2	2	4	1
Quebec	2	3	3	3	3	3
Ontario	3	2	4	1	2	2
West	1	4	1	4	1	4

Source: Calculations based on Tables 7-2, 7-4, and 7-5.

Table 7-7

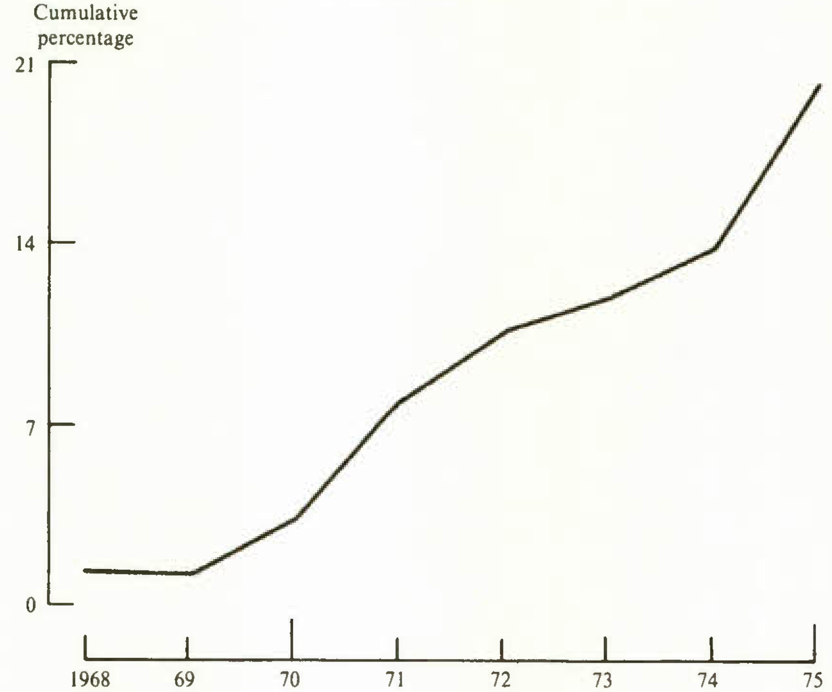
Average Capacity and Width of Fourdrinier-Type Newsprint Machines, Canada, by Region, 1964

	Number of machines	Average width per machine	Average capacity per machine per year	Average capacity per inch of machine width per year
		(Inches)	(Tons)	
Atlantic provinces	20		66,280	
Newfoundland	13	195	47,752	244
Nova Scotia	2	237	91,260	385
New Brunswick	5	250	104,465	417
Quebec	80	190	56,377	295
Ontario	34	218	58,577	269
Prairie region	2	228	73,150	320
British Columbia	18	221	73,275	332
Canada	154	203	60,392	296

Source: Confidential.

Chart 7-1

Total Capacity of Quebec Newsprint Mills Accounted for by Twin-Wire Machines, 1968-75



Source: Canadian Pulp and Paper Association, *Annual Newsprint Supplement* (various issues), and confidential sources.

The use of synthetic fabrics in a Fourdrinier table section is an alternate method of increasing production by reducing stoppages for repairs and so lowering operating costs. Annual savings from total industry fabric conversion could be as high as $100 million.[6] Initial adoption began in Ontario and quickly spread to most paper mills using the old Fourdrinier machines (see Table 7-9). Although data about regional diffusion of this innovation are lacking, they provide another viewpoint from which to appreciate the speed of diffusion of a particular innovation in the newsprint industry. By comparing the diffusion of twin-wire machines (Table 7-8 and Chart 7-1) in Quebec and synthetic fabrics (Table 7-9) in the rest of Canada, it is easy to see the wide discrepancy possible in the pace of diffusion of different innovations. In this case, diffusion of twin-wire machines reached barely 20 per cent of newsprint mills in Quebec in seven years after initial adoption, whereas utilization of synthetic fabrics encompassed more than 86 per cent of newsprint mills in all regions of Canada during the same time period.

6 D.H. Armstrong, "Total Industry Fabric Conversion Could Mean Annual Savings of $100 Million," Canadian Pulp and Paper Industry, June 1974, pp. 50-51.

Table 7-8

Speed and Width of Twin-Wire Machines Installed, Quebec and British Columbia, 1968-75

	Quebec	British Columbia
1968	2,000/170	
1969	2,000/274	2,500/238
1971	3,500/386	
	—/288	
1972	2,500/172	
1973	2,500/240	
1974	3,500/240	
1975	3,000/238	
	3,000/238	

Note: The first number stands for machine speed in linear feet per minute and the second one stands for width in inches.

Source: Adapted from Davy and Thompson, "Newsprint Machines," Appendix 3.

Table 7-9

Utilization of Synthetic Fabrics in the Canadian Newsprint Industry, 1969-75

	Newsprint machines with fabrics	Total newsprint machines in Canada	Proportion of newsprint machines using synthetic fabrics
1969	3	147	.0204
1970	11	147	.0748
1971	38	139	.2734
1972	56	133	.4211
1973	70	137	.5109
1974	106	147	.7211
1975	129[1]	147	.8776

1 Estimate.
Source: Confidential.

Special presses may be added to Fourdrinier machines in order to modernize them; twin-wire machines already come equipped with the features of special presses. Initial adoption of special presses began in Quebec in 1963. The use of any of a variety of special presses on Fourdrinier machines at any given time or of twin-wire machines indicates the degree of modernity of the wet section of paper machines in operation in Canada (see Table 7-10). From this, we can derive the lags of diffusion among regions in attaining a given percentage of their total capacity accounted for by Fourdrinier machines equipped with special presses and/or twin-wire machines (see Chart 7-2). In Quebec, there was a lag of five years after initial introduction of special presses for firms to use them in 33 per cent of total capacity. In Ontario, this level of capacity was reached

Table 7-10

Newsprint Capacity Accounted for by Either Fourdrinier Machines Equipped with Special Presses or by Twin-Wire Machines, by Region, Selected Years, 1964-72

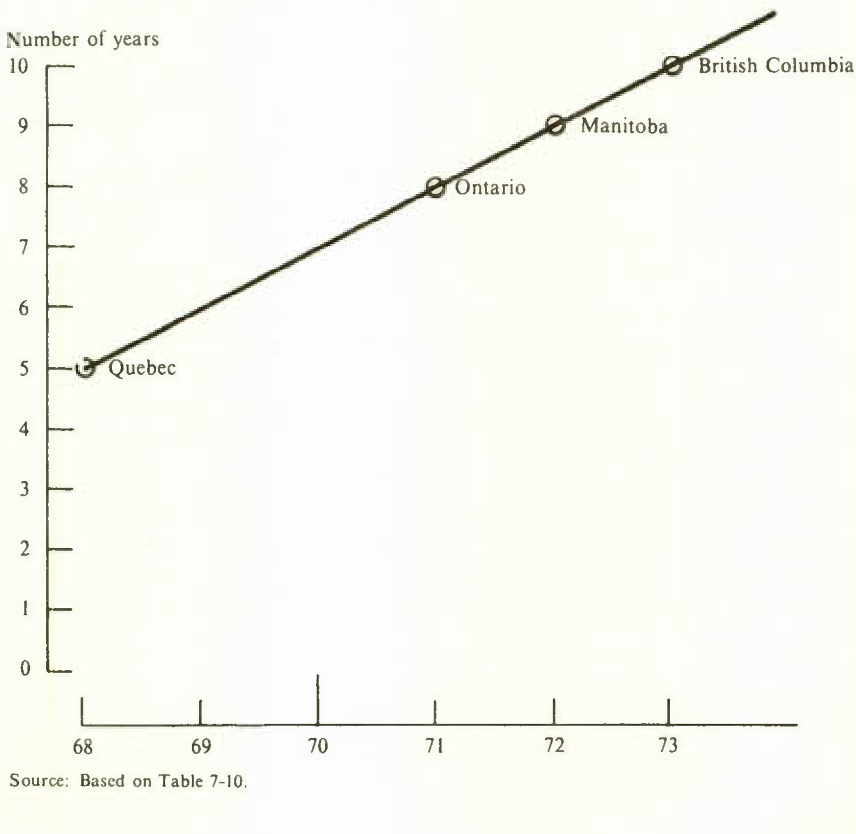
	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1964	0	6.81	0	0	9.20
1968	21.42	33.47	10.75	0	17.12
1972	34.13 (65.00)[1]	75.45	39.31	100	29.82

1 The data do not include two rather recent mills: McMillan-Rothesay (Saint John, N.B.) and Nova Scotia Forest Industries (Port Hawkesbury, N.S.). If these mills are equipped with special presses, then the percentage of newsprint capacity for the Atlantic region would jump to 65 per cent in 1972.

Source: Data were extracted from the questionnaire used by S. Globerman, "New Technology Adoption in the Canadian Paper Industry," *Technological Diffusion in Canadian Manufacturing Industries*, Department of Industry, Trade and Commerce (Ottawa: Information Canada, 1974). Furthermore, these data were revised by an expert on the industry. Since this revision was made from memory, the results have only an indicative value.

Chart 7-2

Regional Lags in Attaining 33 Per Cent of Capacity Accounted for by Fourdrinier Machines Equipped with Special Presses or by Twin-Wire Machines, 1968-73



Source: Based on Table 7-10.

three years later than in Quebec; in the Atlantic region, four years later;[7] and in British Columbia, five years later.

Factors Pertaining to the Diffusion of Innovations

At first glance, it would appear that the diffusion of innovations in the newsprint industry proceeded in a wavelike pattern according to distance from the central provinces; Quebec and Ontario were the regions of initial adoption of the innovations we have examined, and the other regions followed later. However, this may not be a significant explanation since, in the early part of the century, the location of foreign markets, the state of technology, and government policies meant that the western and Atlantic provinces were scarcely represented in the industry. It is important to distinguish here between the lag in availability and the lag in acceptance of an innovation.[8] Prior to 1930, new technology was not available in the western and Atlantic regions in the sense that these regions had not been opened up to the industry. Once they were opened, however, they were subject to the same criteria and measures of diffusion as the central provinces, and lags in the adoption of technology thereafter were lags in acceptance.

Consequently, in the case of newly installed Fourdrinier machines, the rate of acceptance is more clearly determined from the time trends of product capacity, speed, and width (see Tables 7-2, 7-4, and 7-5) and the rankings of each in the regions (see Table 7-7). The Atlantic provinces had the highest rate of increase in capacity (see Table 7-6) and the second highest average capacity in 1964 (see Table 7-7). The western provinces ranked first in adoption of technology in the early years (as indicated by the constant term in Table 7-4) and retained the highest average capacity in 1964 (see Table 7-7). This refutes the hypothesis that a wavelike pattern of diffusion of innovations regarding Fourdrinier machines emanated from the central regions, and so geography in its simplest dimension, distance, does not seem to play a role.

An economic mode of diffusion would therefore seem to give a more appropriate explanation of the observed pattern. Data, however, are not complete enough to differentiate between the mode of dealing with the economic and institutional environment of firms and the mode emphasizing the internal characteristics of firms, as described in Chapter 2 above. It appears obvious, however, that there was no long-run lack of access to new technologies in the installation of completely new Fourdrinier machines.

7 The position of the Atlantic provinces may be different if the two mills referred to in the note to Table 7-10 are equipped with special presses.

8 Z. Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, vol. 25, no. 4 (1957), p. 507.

Diffusion of twin-wire machines and special presses differs from that of Fourdrinier machines. Other studies have shown that, at the national level, the mode of diffusion of special presses depends upon the internal characteristics of firms.[9] What remains to be determined here is whether these explanatory variables operate at the regional level.

The age of machines may be a factor in the regional diffusion of twin-wire machines and special presses since it is technologically possible to keep old machines in operation almost forever by replacing old parts with new. It seems reasonable to expect the region with the most outdated stock of equipment to be the earliest and fastest adopter of new technology. This is only partially true, however. Quebec and Ontario both had less modern stocks of machines than other provinces immediately after the introduction of special presses and before the first installation of twin-wire machines. But whereas Quebec was the first and most rapid adopter of both twin-wire machines and special presses,[10] Ontario had no twin-wire machines and was quite late to adopt special presses. Ontario's backwardness in this regard may be due to its limited supply of wood since new technology is often introduced only when there is a concomitant expansion of production capability. Another factor may be the switch from newsprint to specialty papers as the dominant sector of the paper industry in that province. Or pollution regulations, which apparently have been stricter in Ontario than in most regions, may have forced Ontario companies to invest in pollution control equipment rather than in production equipment. Conversely, in the Atlantic region, the absence of twin-wire machines in New Brunswick and Nova Scotia is explained by their modern stock of Fourdrinier machines, which were the most modern of any province.

Size of firms does not seem to be a regional factor in this regard. The newsprint industry does not tolerate small inefficient firms for long and there is no particular concentration of them in any region. The industry is dominated by large firms in all regions. Those with an annual capacity of 400,000 tons or more accounted for 72.7 per cent of total output in 1973. Some of the remaining firms are branches of multinational firms and together with the large firms made up 93.1 per cent of total output in 1973. They also accounted for all of the capacity in Manitoba, the Atlantic

9 L. Nabseth and G.F. Ray, *The Diffusion of New Industrial Processes: An International Study* (Cambridge, Mass.: Cambridge University Press, 1974), p. 65: in this work, most of the explanatory variables of the diffusion process are either "company variables" or "attitude variables." See also S. Globerman, "New Technology Adoption in the Canadian Paper Industry," *Technological Diffusion in Canada Manufacturing Industries*, Department of Industry, Trade and Commerce (Ottawa: Information Canada, 1974), p. 105; this author also uses variables of the same nature.

10 We should note, however, that superficially this finding may be in contradiction with Nabseth and Ray's finding of a negative relationship between age of machines and probability of adoption; see Nabseth and Ray, *The Diffusion of New Industrial Processes*, p. 63.

provinces, and Ontario as well as 92.3 per cent of capacity in British Columbia and 87.5 per cent of capacity in Quebec in 1973. Moreover, because many large firms own mills in several regions, these regions must be deemed to have equal access to information. This equality of access is further promoted by information available from the technical section of the Canadian Pulp and Paper Association and from the Pulp and Paper Research Institute and by competition among large and/or multinational firms present in the same regions for improvements in production. Therefore, any barriers to local adoption of innovations, which lead firms to introduce innovations in uneven patterns across Canada, must be due to other reasons.

Ownership, whether Canadian or foreign, similarly cannot be said to be one of these regional barriers since some regions have roughly the same mixture of ownership of newsprint mills. In the Atlantic region, 40.3 per cent of capacity is foreign-owned; in Quebec, 38.1 per cent; in Ontario, 43.8 per cent; although, in Manitoba, 0 per cent is foreign-owned; and, in British Columbia, the figure is 27.1 per cent. In terms of decision-making, foreign-owned firms in general may be early or late adopters of new technology, but this aspect of the total phenomenon does not account for any regional gap, which is the focus of this study.

Another variable that encompasses management attitudes and other internal characteristics of firms as a factor influencing diffusion is profitability. This is theoretically important because a good rate of return is expected to be a condition for access to financial resources for modernization and expansion. The question is whether there are regional differences in profitability of different firms in the newsprint industry. Information is hard to come by, especially from foreign-owned firms, although some selected data are available on certain large Canadian-owned firms (see Table 7-11).

Table 7-11

Average Net Return on Invested Capital by Major Newsprint Producers, 1963-72

	Percentage returns on capital
MacMillan Bloedel	10.69
Canadian International Paper	8.71
B.C. Forest Products	8.23
Domtar	7.23
Abitibi	6.98
Consolidated-Bathurst	6.54
Price	5.23

Source: Computations performed on raw data published in "Les usines tournent à plein régime mais pendant combien de temps encore?" *La Presse*, 8 January 1974, p. C-1.

On the surface, British Columbia-based companies seem to fare better, although results are not conclusive. First, MacMillan Bloedel and Canadian International Paper, which both had better-than-average performances during the 1963-72 period, also operate mills in other regions. Second, although Ontario-based companies seem to score lower, as indicated by the lower level of performance of Abitibi during this period, there are many other companies operating in Ontario about which we know little if anything, and so comparisons cannot be made with certainty. Third, the profitability of British Columbia-based companies, according to experts, is linked not mainly to modernization of mills but rather to the quality of natural resources and to more generous provincial government policies regarding cutting rights, transport costs of wood, and so forth.

Another aspect of profitability, as explained in Chapter 2 above, is the way in which it affects the speed of adoption of an innovation. Obviously, innovations are adopted only if they are profitable. But they are more likely to be adopted quicker if the relative profitability can be easily computed or if the degree of risk can be clearly seen. The case of synthetic fabrics is a good illustration of this point: synthetic fabrics were adopted much faster than twin-wire machines because their profitability was easier to calculate, they did not require a large expenditure, and they had a longer life than the equipment they replaced. But because data about the regional diffusion of synthetic fabrics are lacking, we cannot say whether this aspect of profitability has a regional dimension.

The Regional Factor

According to the evidence presented in the previous section, the regional factor does not seem to have played a large role in the diffusion of innovations in the newsprint industry in Canada. An important exception, however, concerns the lack of diffusion of twin-wire machines in Ontario and the relatively long lag in adopting special presses in that province, which are definitely due to regional factors such as limited wood supply and local government regulation regarding pollution. On the other hand, in the peripheral regions, the later installation of Fourdrinier machines has not been a technological disadvantage in that, in general, when they were opened up for exploitation, they were endowed with machines embodying the technology current at the time. Finally, although we have no data and must therefore rely on secondary sources, basic regional characteristics such as government policies regarding forest exploitation have been instrumental in the late opening of the territories of the peripheral regions to the production of newsprint.

8 Shopping Centres

Shopping centres[1] have had a profound impact on shopping habits of Canadian consumers by filling an increasingly larger proportion of the consumer's regular shopping basket during the past two decades or so. They are a major retail innovation and account for a very high proportion of new retail space.[2]

The first Canadian shopping centre was opened in Vancouver in 1950. By 1956, there were 67 shopping centres across Canada. By 1973, they numbered 664 and together they accounted for 17.6 per cent of all retail trade in Canada. This share reached one-quarter of all retail trade excluding that of automobile dealers, fuel dealers, and general stores, which are rarely found in shopping centres. Included in this share for shopping centres are more than half of all department store sales and nearly one-third of chain store sales, including supermarket chains.

Innovations specific to shopping centres—the physical design of facilities, the strategic configuration of retail outlets, adjacent parking areas,

1 As defined in Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, annual "A group of stores are planned, developed and designed as a unit, containing a minimum of five retail establishments (or four retail establishments and a restaurant) in operation during any part of the current year. The centre must have a minimum of 20,000 square feet of usable parking area adjacent to it, and the parking facilities must be free of charge to customers. For shopping centres with paved parking areas of 20,000-50,000 square feet, the ratio of parking area to gross floor area must be 1.5 to 1 or better. The merchandizing development must contain either a grocery and combination store (that is, a grocery store with sales of fresh meat accounting for 20 to 40 per cent of total sales), a department store, or a chain variety store. While a shopping centre is usually designed as a single project, all establishments do not necessarily have to be leased from a single (private or collective) ownership. A retail establishment may own the building and the land on which it is situated and still be fully integrated with the centre. A shopping centre usually bears a name and, as a rule, matters of common interest to the tenants, such as children's playgrounds, community activities, parking, etc., originate from one authority." This definition excludes most downtown malls and a number of planned multi-store, multi-level shopping plazas because they do not allow free parking (even though parking may be conditionally free — that is, contingent upon a minimum purchase), or they fail to meet the requirements of the foregoing definition in some other way.

2 See, for example, Metropolitan Toronto Planning Department, *Shopping Centres and Strip Retail Areas, Metropolitan Toronto Planning Area, 1969* (Toronto: The Planning Department, 1970), p. 3: Toronto shopping centres accounted for almost 90 per cent of the total increase in retail floor space between 1953 and 1969.

covered walkways, centralized management, and so on—have economic implications that allow us to treat the shopping centre as a major technological change, much as we treat changes in the production process of manufactured goods. This innovation can be viewed as affecting both the supply and demand sides of the retail market. On the supply side, shopping centres produce certain kinds of economies of scale and agglomeration. For example, while overhead and operating costs may not be lower than at free-standing locations,[3] economies may be achieved in advertising as individual retailers launch joint advertising campaigns and as customers become more responsive to a given amount of expenditure on advertising by establishments in shopping centres in comparison with free-standing retail outlets. Additional efficiencies may be gained as increased volume of sales allows a more assured in-stock position on wanted merchandise and as retailers substitute convenience of shopping for personal service. On the demand side, shopping centres reduce consumers' time and possibly also monetary costs of travel and parking while carrying out their regular shopping. The physical design of facilities seems to have the intended effect of increasing a customer's propensity to shop and to buy on impulse on a given shopping trip. In addition, the larger or regional shopping centres extend the variety of goods that can be purchased on one shopping trip as well as facilitate comparison shopping by housing similar types of shops at the same location.

The rise of shopping centres coincided with the growth of the service sector in the Canadian economy, which is relatively labour-intensive. Therefore, advances in productivity in service industries depend to a large degree upon efficient organization of production, rather than upon technology embodied in specific job skills or capital goods. The modern shopping centre is a prime example of such an organizational innovation where the design of facilities brings retail establishments and customers together in larger numbers and with greater efficiency. Shopping centres combine several earlier innovations in retailing—notably, extensive use of the self-service principle, which is analogous to automation in that it is labour-saving, and an increase in size of retail firms and concentration of ownership to capture economies of scale. As one researcher in the field has put it, "The planned shopping centre is aimed at gaining the benefits from the economies of planned agglomeration."[4]

3 According to one economist in the industry, C.R. Luft, Assistant to V.P. Operations, The Eaton Co. Ltd., in a private communication, "More often than not, a tenant could operate a stand-alone facility of similar size at much lower cost," and "There are usually a large number of merchants common to competing centres in a given market....
If they could get away with one outlet instead of two, would their costs not be more likely to fall?"

4 Y.S. Cohen, *Diffusion of an Innovation in an Urban System*, University of Chicago, Department of Geography, Research Paper 140, Chicago, 1972, p. 28.

The first retailers to adopt shopping centre marketing innovations were the supermarket chains that grew up in the early 1950s. They took advantage of the opportunity to serve regular consumer needs by situating near their markets in the rapidly expanding suburbs or urban centres. Other retailers — for the most part, independent local entrepreneurs — joined in this move to the suburbs and located near the food stores, which at the time were the primary attraction to customers of shopping centres. This was unlike the experience in the United States, where chain department stores provided the initial focus of shopping centre development.

The success of these early developments along with the accumulation of shopping centre expertise from the United States quickly convinced retailers and developers of the tremendous potential for retail development in suburban areas of Canadian cities. Today, retailers involved in this shopping centre development are among the largest developers of shopping centres in Canada.[5]

During the same time, the dominant focus of shopping centres changed as large-scale regional and national food store chains gave way to department stores as the primary drawing cards in typical shopping centres. Grocery store sales fell from approximately 45 per cent of shopping centre sales in the late 1950s to 33 per cent in 1973. Department store sales rose from 18 per cent in the early 1960s to 33 per cent by 1973, thus more than offsetting the loss in food sales. This change was also accompanied by an increase in the variety and quality of the service mix available in the collection of stores in a given shopping centre, a process known as deepening.

Shopping centres, like most services, are nontradable, in the sense that a shopping centre in Winnipeg cannot serve consumers in Bathurst. The nontransportability of the product dictates that the sizable investment required to establish a shopping centre must be made on site. There is thus ample room for regional factors to enter into the diffusion process.

From the literature on the diffusion of innovations come hypotheses concerning modes of diffusion that possibly have variables related to regional characteristics and may then suggest the presence of a regional factor.

For example, we might argue that the urban phenomenon is a key to the explanation of the diffusion of shopping centres. One reason for this belief is the location of shopping centres offering a diversity of goods and services near large numbers of customers who require the services they offer and who are most likely to be found in urban and suburban areas. Another reason is the market potential of shopping centre locations, which depends upon distance from competitors offering similar assortments of goods and services. The fringes of urban areas, away from traditional city-core retail

5 Statistics Canada, *Shopping Centres in Canada, 1961-73*, Cat. No. 63-527, 1976.

locations, have been the prime spawning ground for shopping centres. In addition, the suburban growth that occurred in the 1950s and 1960s has meant an expanding retail market in precisely the non-core areas suited to the shopping centre. The relationship between the move to the suburbs and the establishment of retail facilities near these new concentrations of population follows as a corollary to central place theory, which predicts that retail centres will locate where they can minimize distribution costs or consumer travel.[6] And these phenomena vary regionally, which is our prime interest here.

Diffusion of shopping centres may alternatively follow the mode that emphasizes the economic and institutional environment of the firms. The "wheel of retailing" theory from the marketing literature predicts that market development entails two interrelated phenomena: market penetration, in terms of both number of shopping centres and shopping centre sales as a proportion of retail sales; and changes in types of business carried on in shopping centres.[7] As the basic innovation is extended to new markets, it is also deepened by adding a variety of new or different retail stores and/or by using department stores as alternative anchors of the shopping centres. If the extent of market penetration and the pattern of the deepening of the service mix both have regional characteristics, then our case for identifying a regional factor in the diffusion of shopping centres is strengthened.[8]

The Pattern of Canadian Diffusion

Theoretically, in order to measure the diffusion of shopping centres in Canada, we must indicate the proportion of potential adopters that have introduced the innovation. Thus we are primarily interested in knowing the share of all retail sales that takes place in shopping centres in those urban or suburban markets that are suited to this form of retailing. We are also interested in various dimensions of the deepening of the process of diffusion, such as the size of shopping centres and the type of trade in shopping centres.

6 B.L. Berry and William L. Garrison, "Recent Developments of Central Place Theory," *Papers and Proceedings of the Regional Science Association,* Philadelphia, 1958, pp. 107-20.

7 See Ronald R. Gist, *Retailing: Concepts and Decisions* (New York: John Wiley and Sons, 1968), Chap. 4, for a summary of literature on institutional life cycles in retailing.

8 See M.S. Moyer, "Shopping Centres in Canada: Their Impact, Anatomy and Evolution," *The Business Quarterly,* vol 58, no. 2 (1973), p. 24: this author uses both the degree of penetration and the pervasiveness of penetration (which we have called deepening of the service mix) to assess the impact of shopping centres on retail trade.

Table 8-1

Increase in Number of Shopping Centres, Canada, 1956-73

	Number of shopping centres	Percentage increase in number of shopping centres
1956[1]	67	
1957[1]	95	41.8
1958[1]	125	31.6
1959[1]	193	54.4
1960[1]	231	19.7
1961	281	21.6
1962	305	8.5
1963	346	13.4
1964	369	6.6
1965	386	4.6
1966	420	8.8
1967	461	9.8
1968	480	4.1
1969	499	4.0
1970	541	8.4
1971	—	—
1972	599	10.7
1973	664	10.9

— Not available.

1 Data before 1961 include a few "strip" developments, which were eliminated by a definitional change for the 1961 survey.

Source: Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, 1968, 1972, and 1973.

From 1956 to 1973, the number of shopping centres in Canada increased nearly tenfold—from 67 to 664. The increase was most rapid in the initial years of development, when it was usually more than 20 per cent per year (see Table 8-1). Since the early 1960s, the growth in numbers of shopping centres has moderated but has remained above the general growth rate of the economy and retail trade industry.

Retail sales in shopping centres increased between 1956 and 1973 by a factor of 28, which reflects the increased share of retail trade taking place in shopping centres, the general growth in the retail trade industry, and price inflation (Table 8-2, column 1). Sales in shopping centres as a proportion of the total retail trade industry grew from 2.6 per cent to 22.4 per cent during this period (Table 8-2, column 2). As with the growth in numbers of shopping centres, sales in shopping centres increased most rapidly before the early 1960s (Table 8-2 column 3); however, there has been no continuing downward trend to support the contention of some observers that the era of further diffusion of this innovation is at an end.[9]

9 See, for example, Statistics Canada, *Shopping Centres in Canada, 1961-73*, Cat. No. 63-527, 1976, Introduction.

Table 8-2

Increase in Shopping Centre Sales, Canada, 1956-73

	(1) Total retail sales in shopping centres	(2) Shopping centre sales as a proportion of retail trade[1]	(3) Annual increase in (2)
	($ Million)	(Per cent)	
1956	238.0	2.6	
1958	468.4	4.5	36.5
1960	790.0	6.8	25.6
1961	994.2	7.9	16.2
1962	1,172.1	9.3	17.7
1963	1,340.2	9.6	3.2
1964	1,607.9	10.8	12.5
1965	1,865.3	11.6	3.9
1966	—	—	—
1967	2,552.2	13.7	9.1
1968	2,873.2	14.4	5.1
1969	3,320.6	15.5	7.6
1970	3,866.3	17.2	11.0
1971	—	—	—
1972	5,466.7	20.1	8.4
1973	6,736.5	22.4	11.4

— Not available.
1 Excluding goods not usually found in shopping centres.

Source: Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, annual; and *Retail Trade*, Cat. Nos. 63-517 and 63-519.

The size of shopping centres can be measured in two main ways: the number of stores in a given shopping centre, and the total amount of sales by all the stores in the shopping centre.

The number of stores can vary greatly, from the small neighbourhood strip developments with 5 to 15 stores, to community shopping centres with 16 to 30 outlets, to the larger regional centres containing up to 100 or more retail establishments, and even to the newer urban core developments that combine shopping facilities with office, hotel, convention, or other commercial facilities. Most of these latter developments are excluded from the analysis in this paper by our definition, however. For many years, the average size of shopping centres in Canada fluctuated within a fairly narrow range of between 12.4 and 13.2 retail outlets per centre. Beginning in the late 1960s, however, the opening of a greater number of larger centres increased the average number of stores per centre to 16.4 by 1973 (Table 8-3, column 1).

Average retail sales per shopping centre also increased during this period, from $3.6 million in 1956 to more than $10 million in 1973 (Table 8-3, column 2). The rate of increase of sales in shopping centres depends upon price increases as well as upon increased volume of trade, so

Table 8-3

Size of Shopping Centres Using Two Measurements, Canada, 1956-73

	Average number of retail outlets per shopping centre	Average sales per shopping centre
		($ Million)
1956	12.4	3.6
1957	12.8	—
1958	13.0	3.7
1959	12.2	—
1960	13.2	3.4
1961	13.2	3.5
1962	13.2	3.8
1963	12.6	3.9
1964	12.7	4.4
1965	12.9	4.8
1966	13.3	—
1967	13.6	5.5
1968	13.8	6.0
1969	14.0	6.7
1970	14.6	7.1
1971	—	—
1972	15.6	9.1
1973	16.4	10.1

— Not available.

Source: Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, annual.

that the figures cannot be used as a direct measure of the increase in size of centres. It is apparent, however, that the increase in sales per centre was well above the general rate of inflation over the period.

The size distribution of shopping centres can be further examined by disaggregating these averages into three size classes (see Table 8-4). During the late 1950s, when the total number of shopping centres increased most rapidly, the number of neighbourhood shopping centres of 5 to 15 retail establishments increased faster than that for the larger community and regional centres. In the early 1960s, these centres accounted for nearly 75 per cent of all shopping centres in Canada. However, while they have continued to increase in absolute numbers during the past decade, they have increased less rapidly than larger centres and their proportion in the total has therefore fallen to slightly more than 60 per cent. Community shopping centres increased slightly in proportion to all centres after the mid-1960s, reaching 22 per cent in 1973. In the same period, we can see a doubling of the proportion of the largest-size class in the total number of shopping centres from 8 to 16 per cent. Not only has there been a trend towards more of the largest-sized shopping centres but also, since 1968 (the first year in which the appropriate data have been available), there is evidence that shopping centres in this class are growing larger. The average number of retail outlets in regional shopping centres increased from 41 in 1968 to 48 in 1973.[10]

The long persistence of a broad range of sizes of shopping centres suggests that their success does not depend upon scale of operation alone. The shopping centre concept has proven adaptable to a variety of environments or markets, which determine the most appropriate scale. In fact, in terms of sales per retail outlet, neighbourhood centres did as well in 1973 as the average of all shopping centres. Neighbourhood centres comprised 29.7 per cent of all retail outlets and 29.5 per cent of all sales in shopping centres.[11] This does not deny, however, that, over the past decade, there has been a distinct (although not overwhelming) trend towards a greater proportion of large centres. Moreover, the data on sales in shopping centres indicate that a growing proportion of sales in regional centres takes place at the expense of the community centres and, since the mid-1960s, also of neighbourhood centres, as a result of the gradual deepening of shopping centres at the Canadian level.

Since this deepening has accompanied the penetration by shopping centres of the Canadian retailing field, it may have been instrumental to this penetration. This is, of course, an hypothesis, but some people[12] have

Table 8-4

Distribution of Shopping Centres, by Size Class, Canada, Selected Years, 1956-73

	1956	1959	1964	1968	1972	1973
Total number of shopping centres	64	193	369	480	599	664
Distribution of shopping centres by size class			(Per cent)			
Neighbourhood (5-15 retail outlets)	57.8	73.6	73.2	69.8	65.1	62.8
Community (16-30 retail outlets)	32.8	18.7	19.0	20.6	20.9	22.0
Regional (more than 30 retail outlets)	9.4	7.8	7.9	9.6	14.0	15.7
Distribution of sales, by size class						
Neighbourhood (5-15 retail outlets)	25.9	30.6	34.8	33.2	30.2	29.5
Community (16-30 retail outlets)	51.1	39.0	29.0	28.8	22.8	23.4
Regional (more than 30 retail outlets)	23.0	30.4	36.2	38.0	47.0	47.1

Source: Statistics Canada, *Shopping Centres in Canada, 1951-73,* Cat. No. 63-527, Tables 25, 26, and 31.

10 Statistics Canada, *Shopping Centres in Canada,* Cat. No. 63-214, annual.

11 Statistics Canada, *Shopping Centres in Canada, 1961-73,* Cat. No. 63-527, 1976.

12 Moyer, "Shopping Centres in Canada."

expressed it more forcefully by stating that the deepening of the service mix provided the shopping centres with one approach to enable them to continue to penetrate the retail field after more than two decades of substantial growth in Canada. This view also agrees with the view of marketing experts who offer the life-cycle theory or evolutionary theory of development of retailing institutions as an explanation of the gradual increase in the size of shopping centres. For them, the trend to larger centres is the result of not only an increase in scale but also a shift to more broadly based and service-heavy types of business and to an enrichment of the service mix through the addition of a greater variety of smaller retail outlets. The shift in primacy from the supermarket to the department store typifies the diversification from "proximity-sensitive" or "convenience-sensitive" commodities associated with neighbourhood centres to more "assortment-sensitive" goods found in department stores. These trends are concurrent with the further development of sophisticated design techniques that more fully integrate the shopping centre into a total environment shopping complex.[13]

The Pattern of Regional Diffusion

In order to regionalize our analysis of the national trends in diffusion of shopping centres, we must first construct regional diffusion curves for them. That means relating effective adoptions of innovations to regional potentials. Here we divide Canada into six regions rather than the customary five as is done in the other chapters of this study, because it became evident at the outset of our research that the process of diffusion in Alberta was acutely different from that in Saskatchewan and Manitoba, the other two Prairie provinces.

The extent of diffusion or degree of market penetration can be quantified using two measures: the number of shopping centres per urban area in each region, and shopping centre sales as a share of total retail sales in the regions.

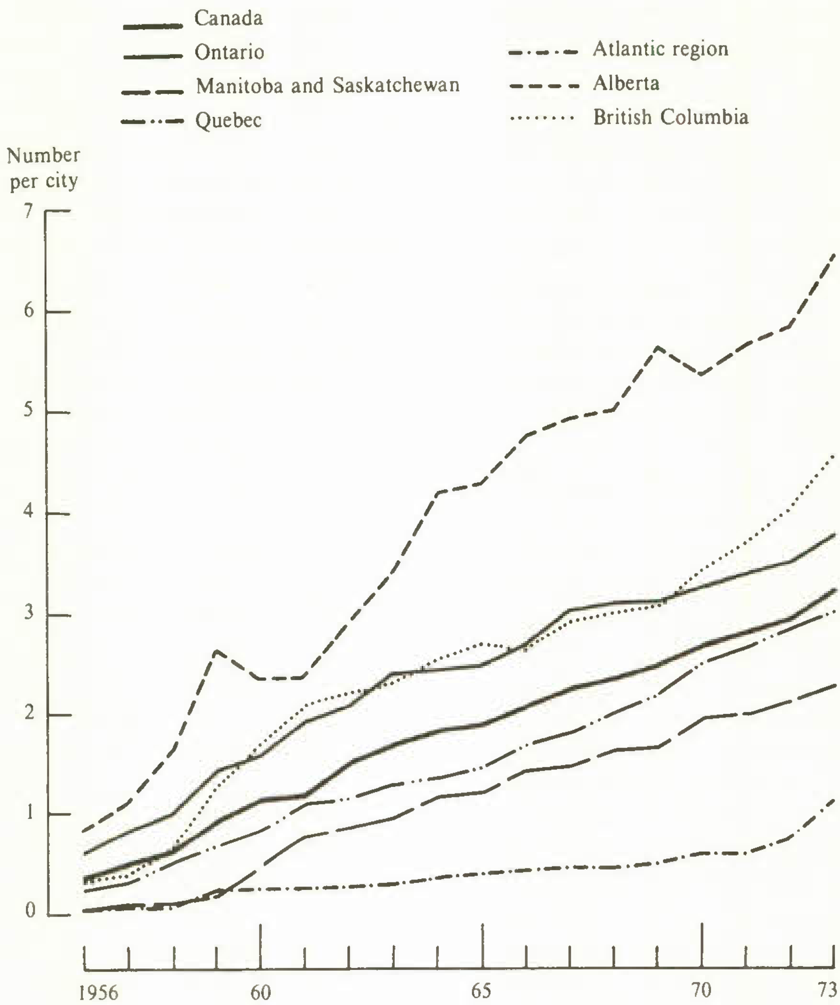
The first measure can be computed directly, in that numbers of both shopping centres and urban centres in each region are readily available for the 1956-73 period. The largest provinces had the most shopping centres in 1973: Ontario had 266; Quebec, 154; British Columbia, 91; Alberta, 72; and the smaller provinces had fewer. Because shopping centres are an urban phenomenon, the appropriate denominator for indicating regional potential is the number of urban areas with populations of 5,000 or more.[14]

13 Graham Fraser, "The Smothering Embrace of the Giant Plaza," *Globe and Mail*, 27 December 1975, p. 4.

14 Urban areas are defined according to the 1971 Census definitions. Therefore, any urban area that grew to a population of 5,000 or over by 1971 is taken as a potential adopter in all years.

Chart 8-1

Average Number of Shopping Centres per Urban Area of 5,000 and Over, by Region, 1956-73



Source: Statistics Canada, *Shopping Centres in Canada,* Cat. No. 63-214, annual.

Relating the two numbers for each year gives us ratios indicating the relative progress of this innovation in the six regions (see Chart 8-1). By this measure of diffusion, Alberta was the leader in all years, having, on average, one shopping centre per urban area in 1957 and more than 6.5 by 1973. The numbers of shopping centres per urban area in Ontario and in British Columbia have historically been very similar; however, the rate of increase was more rapid in British Columbia than in Ontario from 1957 to

1961[15] and again from 1969 to 1973. Quebec, Manitoba and Saskatchewan, and the Atlantic region lagged significantly behind the other regions in the growth in number of shopping centres per urban area. The gap between Alberta and the rest of Canada in the diffusion of shopping centres increased more rapidly during the early 1960s, and this lead remained approximately constant during the latter part of the period. Two exceptions were British Columbia, which tended to catch up to Alberta in the period since 1969, and the Atlantic region, which fell even further behind since the late 1960s.

Because shopping centres vary in size and because the distribution of large metropolitan areas varies across regions,[16] the number of shopping centres per urban area is not in itself a sufficient measure of the degree of regional diffusion of this innovation. Important aspects of the regional diffusion of the shopping centre innovation in Canada are better appreciated by comparing shopping centre sales as a share of a region's total retail trade (see Chart 8-2). The graph shows that market penetration of shopping centres increased in all regions, with Alberta again the leader, followed by Ontario, British Columbia, Quebec, Manitoba and Saskatchewan, and, finally, the Atlantic region. The ranking of the regions[17] by this measure of diffusion is very similar to the one above with the exception that Ontario now clearly leads British Columbia, while Quebec is more closely comparable to Manitoba and Saskatchewan, at least since the late 1960s.[18] Once again, the gap between the fastest and slowest

15 British Columbia had, of course, both fewer shopping centres and fewer urban centres; nevertheless, in the period 1957-61, the absolute number of shopping centres in British Columbia increased sixfold (from 7 to 42) while the number of shopping centres in Ontario increased by a factor of 1.4 (from 57 to 136).

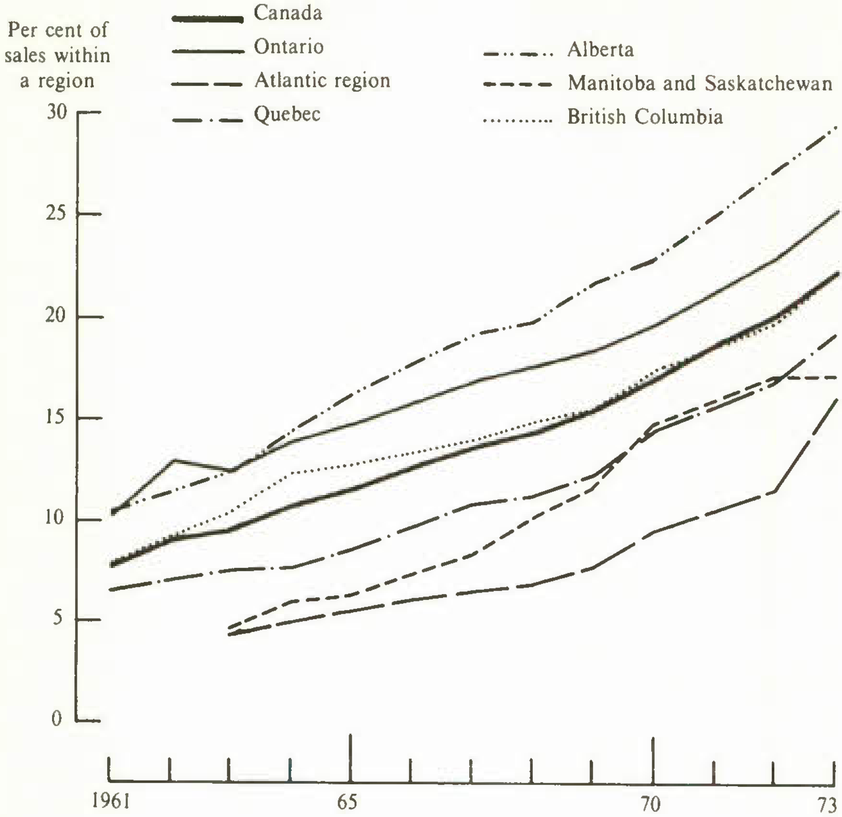
16 The influence of the distribution of large cities may be illustrated by comparing two regions such as Ontario and the Atlantic provinces. The former is endowed with large urban centres such as Toronto. The weight given to these centres in the denominator of the index of shopping centres per urban area will be the same as that given small urban centres like Bathurst in New Brunswick. Yet we would expect to find more shopping centres within the boundaries of metropolitan agglomerations such as greater Toronto—especially as a consequence of the rapid growth of suburban areas, which are most conducive to the adoption of this particular innovation. As a result, the shopping centre per urban area index is biased in favour of regions possessing a greater number of large urban agglomerations, which are counted as one whatever the number of individual cities present in the agglomerations.

17 Approximate only; as in the case of the number of shopping centres per urban area, it implicitly takes into account the growth in population and purchasing power in the potential adopter areas.

18 It has often been thought that Quebec's relatively poor performance is due to its greater number of downtown malls and plazas excluded from the shopping centre definition employed here. Statistics Canada has collected data on these malls for 1973 and inclusion of their sales with regular shopping centre sales shows that "Quebec's percentage of Canadian shopping centre sales is still lower than its percentage of Canadian retail trade as a whole in 1973," see *Shopping Centres in Canada*, Statistics Canada, Cat. No. 63-214, 1973, p. 8.

Chart 8-2

Sales in Shopping Centres as a Percentage of Total Retail Sales,[1] 1961-73



1 Excluding goods not usually found in shopping centres.

Source: Statistics Canada, Cat. Nos. 63-214, 63-517, and 63-519, annual.

adopters has not closed over time; however, there has been some convergence in recent years as the proportion of shopping centre sales in total retail sales has increased more rapidly in lagging regions.[19]

Although the measure of shopping centre sales as a share of retail sales is marginally preferable, it cannot completely replace the measure of centres per urban area as an index of diffusion because the available data do not exclude rural areas and centres of population under 5,000 from total retail trade. Despite this, the rankings of regions obtained from the two methods

19 The slight downturn shown for Manitoba and Saskatchewan in Chart 8-2 is accounted for by a decline in shopping centre sales in Saskatchewan of 11.9 per cent between 1972 and 1973, while shopping centre sales in Manitoba and total retail sales in the two provinces continued to increase faster than the Canadian average. We might note, without offering a full explanation, that the decline coincides with the beginning of recovery from a rather severe contraction in the Saskatchewan economy.

Table 8-5

Average Ranking with Respect to the Extent of Market Penetration by Shopping Centres, Two Indices, by Region, 1956-73 and 1961-73

	Number of centres per urban area, 1956-73	Shopping centre sales as a proportion of retail sales, 1961-73
Atlantic region	6	6
Quebec	4	4
Ontario	2[1]	2
Manitoba and Saskatchewan	5	5
Alberta	1	1
British Columbia	2[1]	3

1 Average ranking during the period on a year-to-year basis (18 years) is exactly the same for both regions: Ontario and British Columbia.

Source: See Charts 8-1 and 8-2.

of measurement are almost identical (see Table 8-5). Alberta is clearly the leader in both measures. Next come Ontario and British Columbia, with Ontario slightly ahead because of the edge it gets from the differences between the two measurements. And the rankings of the lagging regions are the same whatever the method of measurement.

Further, from Charts 8-1 and 8-2 we can compute the time lags for initial adoption and later diffusion of shopping centres in the regions (see Table 8-6). In both initial adoption and later diffusion, the Atlantic region lagged well behind the rest of Canada. Quebec, as well as Manitoba and Saskatchewan, did not perform well either; indeed, on average, they lagged more than six years behind Alberta. Ontario and British Columbia followed more closely behind.

Table 8-6

Lags in Shopping Centre Attainment of Specific Shares of Total Retail Market, by Region, 1956-73 and 1961-73

	Initial adoption,[1] 1956-73	Later diffusion,[2] 1961-73
Atlantic region	16.0	9.25
Quebec	4.0	6.25
Ontario	1.0	.50
Manitoba and Saskatchewan	6.0	6.13
Albertà	0	0
British Columbia	2.3	3.0

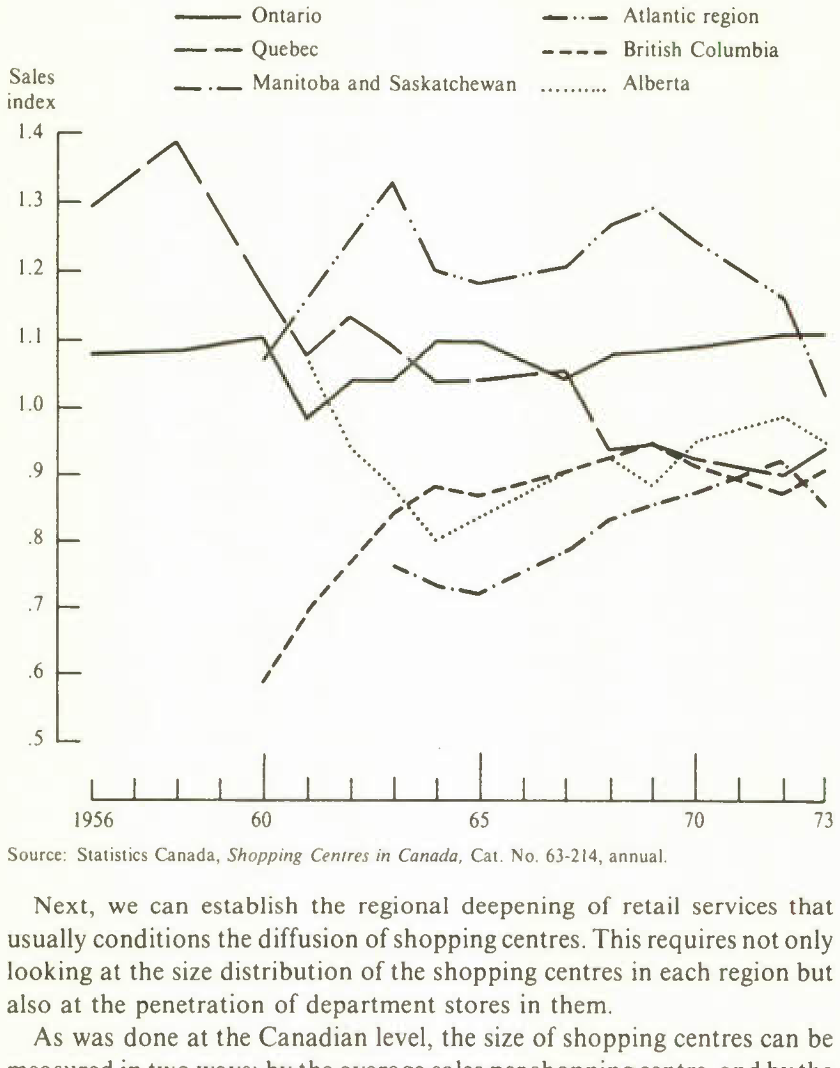
1 The time lag has been computed at the level of .81 shopping centre per urban area (Chart 8-1). The lag has been computed with reference to Alberta as the leader.

2 The average number of years that a region lagged behind the leading region, Alberta. It has been computed at two levels (11.0 and 15.0), Chart 8-2.

Source: Computed from Charts 8-1 and 8-2.

Chart 8-3

Index of Average Sales per Shopping Centre, by Region, 1956-73



Source: Statistics Canada, *Shopping Centres in Canada,* Cat. No. 63-214, annual.

Next, we can establish the regional deepening of retail services that usually conditions the diffusion of shopping centres. This requires not only looking at the size distribution of the shopping centres in each region but also at the penetration of department stores in them.

As was done at the Canadian level, the size of shopping centres can be measured in two ways: by the average sales per shopping centre, and by the number of retail outlets in the various shopping centres.[20]

There has been some convergence of the regions with respect to average sales per shopping centre (see Chart 8-3). The Atlantic region and Ontario were consistently above the Canadian average, which is represented by 1.0 in the chart. Quebec showed the highest average sales in the late 1950s but by the late 1960s had joined the provinces west of Ontario, with below average sales per centre.

20 We de not have regional data on the distribution of sales by size class as presented for Canada in Table 8-3.

To gain a measure of the dispersion of shopping centres around these averages, we must look at the size classes of centres in the regions, as we did at the national level (see Table 8-7). Ontario was the leader in the proportion of shopping centres in the largest or regional size class from 1956 until the late 1960s. By 1967, however, Quebec surpassed Ontario in the proportion of centres of this size class as well as in the overall average size of shopping centres. By the early 1970s, Alberta matched Ontario in the proportion of shopping centres of this size class; however, the average size of all shopping centres in Alberta was still smaller than that in Ontario.

Quebec had a very high concentration of mid-sized or community shopping centres relative to other regions during the late 1950s and early 1960s. For the 1956-73 period overall, however, this proportion converged to the national average as proportionally more new small and large centres than mid-sized ones were opened in Quebec in later years. The Atlantic region was also a popular location for community shopping centres. The continuing increase in numbers of mid-sized shopping centres in the Atlantic region, especially after the falling-off of construction of new ones in Quebec, gave this region the largest proportion of community centres in Canada in 1973.

Alberta, which led all regions in the number of shopping centres per urban area and in the proportion of retail sales at shopping centre locations, had a large proportion of small neighbourhood shopping centres until the late 1960s. After 1966, few new small centres were opened there, although several community and regional centres were built in Alberta during this time. Nevertheless, as of 1973, Alberta continued to lead Canada in the proportion of neighbourhood centres.

While, historically, the proliferation of small-sized shopping centres has been followed by an increase in the numbers of larger centres in all regions except Quebec, it is not true that the regions that led in the trend to larger centres were also the leaders in the number of centres per urban area or in the proportion of shopping centre sales in total retail sales. In particular, Quebec and the Atlantic region, which lagged by our measures of diffusion, were leaders in the increase in average size of centres. Alberta, which led in shopping centres per urban area and the share of shopping centre sales of total retail sales, lagged behind all regions in this trend to larger centres, except Manitoba and Saskatchewan, at various times during the period.

The decline in the primacy of grocery stores (Chart 8-4) and the increase in the importance of department stores (Chart 8-5) in shopping centre sales are major aspects of deepening in the diffusion process. While the pattern fits all regions in a general way, there are marked differences related to regional factors that influence the diffusion process. Grocery store sales as a proportion of total shopping centre sales were lower in the western and Atlantic provinces than in Ontario or Quebec and fell everywhere over the period. Meanwhile, although department store sales in shopping centres

Table 8-7

Distribution of Shopping Centres, by Size Class[1] and by Region, Selected Years, 1956-73

		1956		1958		1961		1963		1966		1968		1972		1973	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Atlantic region	A	1	100	2	100	4	57.1	5	55.6	10	76.9	9	64.3	14	60.9	21	58.3
	B	—	—	—	—	3	42.8	4	44.4	2	15.4	4	28.6	5	21.7	11	30.6
	C	—	—	—	—	—	—	—	—	1	7.7	1	7.1	4	17.4	4	11.1
Quebec	A	4	40	6	31.6	24	43.6	36	54.5	51	60.0	59	57.8	85	59.4	89	57.8
	B	6	60	12	63.1	26	47.3	27	40.9	26	30.6	30	29.4	33	23.1	32	20.8
	C	—	—	1	5.3	5	9.1	3	4.5	8	9.4	13	12.7	25	17.5	33	21.4
Ontario	A	22	53.6	47	66.2	92	67.6	122	72.6	131	69.7	153	70.5	158	64.0	161	60.5
	B	13	31.7	16	22.5	31	22.8	32	19.0	40	21.3	43	19.8	54	21.9	63	23.7
	C	6	14.6	8	11.3	13	9.6	14	8.3	17	9.0	21	9.7	35	14.2	42	15.8
Manitoba and Saskatchewan	A	—	—	2	100	13	86.7	15	78.9	23	79.3	26	81.3	31	73.8	34	75.6
	B	—	—	—	—	1	6.7	3	15.8	5	17.2	5	15.6	9	21.4	10	22.2
	C	—	—	—	—	1	6.7	1	5.3	1	3.4	1	3.1	2	4.8	1	2.2
Alberta	A	8	88.9	16	88.9	22	84.6	33	86.8	43	87.7	43	78.2	43	67.2	49	68.1
	B	1	11.1	2	11.1	2	7.7	2	5.3	5	10.2	7	12.7	10	15.6	12	16.7
	C	—	—	—	—	2	7.7	3	7.9	4	8.2	5	9.1	11	17.2	11	15.3

British Columbia	A	5	83.3	11	84.6	36	85.7	39	84.8	43	81.1	45	75.0	59	73.8	63	69.2
	B	1	16.7	2	15.4	4	9.5	4	8.7	6	11.3	10	16.7	14	17.5	18	19.8
	C	—	—	—	—	2	8.8	3	6.5	4	7.5	5	8.3	7	8.8	10	11.0
Canada	A	40	59.7	84	67.2	191	68.0	250	72.3	301	71.7	335	69.8	390	65.1	417	62.8
	B	21	31.3	32	25.6	67	23.8	72	20.8	84	20.0	99	20.6	125	20.9	146	22.0
	C	6	9.0	9	7.2	23	8.2	24	6.9	35	8.3	46	9.6	84	14.0	101	15.2

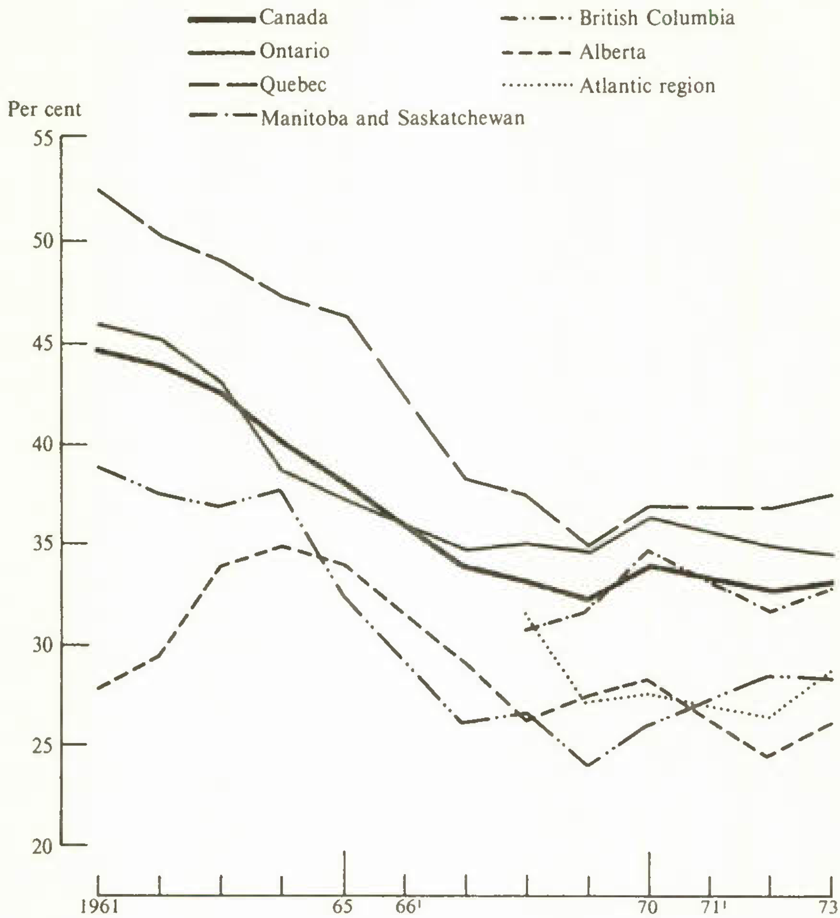
1 Class A: 5 to 15 retail outlets—neighbourhood centres.
Class B: 16 to 30 retail outlets—community centres.
Class C: 30 and over retail outlets—regional centres.

Note: These calculations are made from published data, uncorrected for definitional changes, that occurred at the time of the 1961 survey. The figures shown for Canada in 1956 thus differ from those shown in Table 8-2, where correction for the definitional change eliminated three shopping centres from the smallest size class. Since the magnitude of the correction is small and since we do not know the regional distribution of the correction, we have continued to use the uncorrected published data for years prior to 1961.

Source: Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, annual.

Chart 8-4

Grocery Sales as a Proportion of Total Shopping Centre Sales, Canada, by Region, 1961-73



1 Data not available.

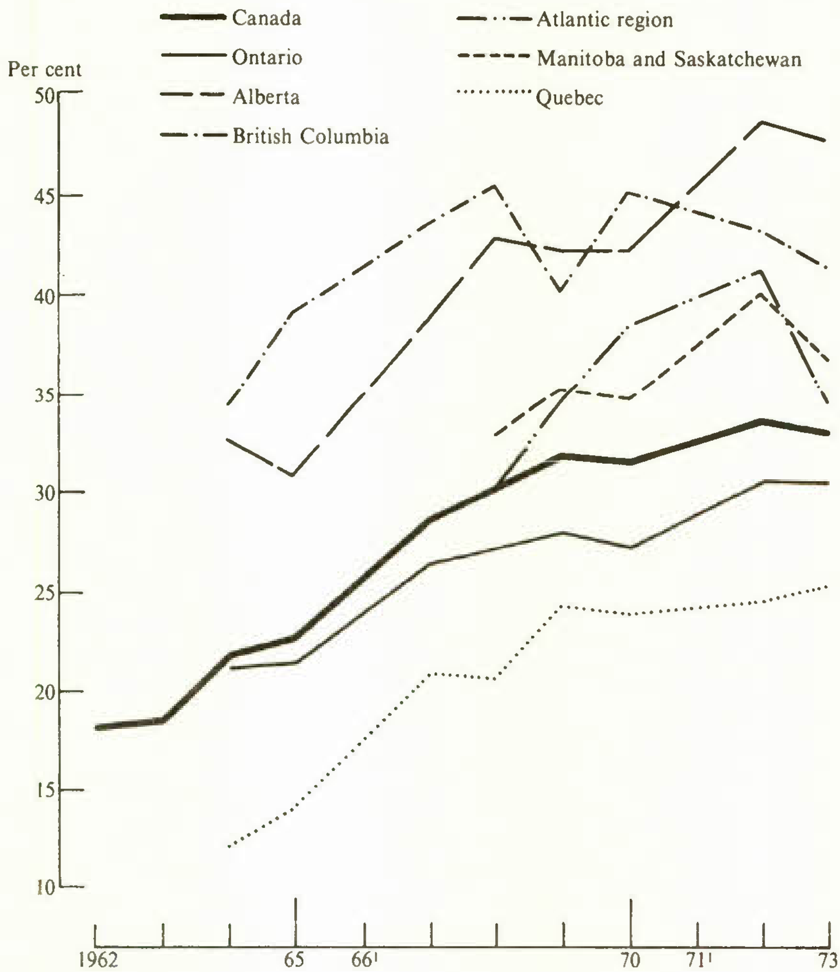
Source: Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, annual.

since 1964 have shown an upward trend in all regions, the proportion has been higher in the western and Atlantic regions, especially in Alberta and British Columbia.

Regional orderings with respect to these selected aspects of the diffusion process can be readily developed (see Table 8-8). Distinctly different regional rankings surface. Indeed Alberta, which we have seen as the leader in terms of shopping centres per urban area and the proportion of shopping centre sales of total retail sales, is first on only one account — the share of department store sales in total shopping centre sales.

Chart 8-5

Department Store Sales as a Proportion of Total Shopping Centre Sales, Canada, by Region, 1962-73



1 Data not available.
Source: Statistics Canada, *Shopping Centres in Canada*, Cat. No. 63-214, annual.

Factors Pertaining to the Diffusion of Shopping Centres

Two types of factors have prompted the diffusion of shopping centres: fundamental factors such as the rapid urban and, especially, suburban growth; and secondary factors such as the deepening of shopping centres. Appearing as intermediate means, secondary factors become operational only if fundamental factors have materialized beforehand. But their importance here is considerable because, without deepening, shopping centre diffusion would not have been very extensive.

Table 8-8

Rank in Selected Aspects of the Diffusion of Shopping Centres, by Region, 1963-73[1]

	Average position of region as to:		
	Proportion of its shopping centres classified as large (regional) shopping centres	Amount of sales per shopping centre	Department store sales as a proportion of total shopping centre sales
Atlantic region	4	1	4
Quebec	1	3	6
Ontario	2	2	5
Manitoba and Saskatchewan	6	6	3
Alberta	3	4	1
British Columbia	5	5	2

1 Excluding 1966 in Col. 2. Col. 3 covers only the period 1968-73.
Source: Table 8-7 and Charts 8-3 and 8-5.

We noted earlier that the "move to the suburbs" and hence suburban growth is expected to be a prime determinant of the increase in numbers of shopping centres and the increase in the proportion of retail sales taking place in shopping centre locations. Our shopping centre data, however, are given on a provincial rather than city or suburb level, thereby making it impossible to test this proposition directly. Nonetheless, we do know that the postwar growth of suburban areas of cities has been substantial. From 1951 to 1971, the population of fringe areas of 17 Canadian cities increased by 191 per cent while the cities proper increased 42 per cent.[21] This meant an additional 3.6 million persons became residents of these areas and potential shopping centre customers.

Table 8-9 shows the growth of urban centres[22] by region in the decade 1961-71. The ranking of regions by urban growth is almost identical to the ranking by the number of shopping centres per urban centre in Table 8-5, the rank correlation coefficient being in this case .971.[23] This means regions

21 Statistics Canada, *Shopping Centres in Canada, 1961-73*, cat. no. 63-527, 1976, Table 3.

22 Defined as all areas that had attained a population of 5,000 or over in 1971.

23 The coefficient is given by:

$$1 - \frac{6 \sum_{i=1}^{n} d_i^2}{n^3 - n}$$

where

n = the number of units to be ranked in each series;
d_i = the difference in the rank of the ith unit between series.

The coefficient may range between −1 and 1, with 0 indicating no correlation between the series and ± 1 indicating perfect agreement of the series.

that displayed the highest rate of urban growth also led in the number of shopping centres. Similarly, the ranking of regions by the proportion of retail sales taking place in shopping centre locations is also almost the same as the ranking of regions with respect to the growth of urban centres, the rank correlation coefficient here being 0.943. Thus urban growth appears to be the major explanation of the rankings of regions by both number of centres and retail sales in shopping centres.

Table 8-9

Growth of Urban Population, Canada, by Region, 1961-71

	Increase in urban population, 1961-71[1]	Rank of regions in descending order of growth of urban population
	(Per cent)	
Atlantic region	11.0	6
Quebec	20.3	4
Ontario	27.8	3
Manitoba and Saskatchewan	18.1	5
Alberta	36.6	1
British Columbia	32.7	2
Canada	24.8	

1 Based on urban areas with populations of 5,000 and over according to 1971 Census.

Moreover, urban expansion helps to interpret the fluctuations that occurred over the period covered by our data, as shown in Charts 8-1 and 8-2. In the case of British Columbia and Ontario, there was no clear leadership of one region over the other in terms of the numbers of shopping centres per urban centre, although the rate of increase in British Columbia (given by the shape of the diffusion curve in Chart 8-1) was greater than in Ontario, both during the early years of diffusion and in the most recent period. This rapid increase in the number of shopping centres is consistent with the more rapid increase in urban population in British Columbia. When we look at the sales measure of diffusion, however, Ontario is the clear leader over British Columbia (Chart 8-2). It is probably safe to conclude, in this instance, that Ontario's higher urban ratio—that is, the higher proportion of total population living in urban areas—accounts for the higher proportion of total retail sales in shopping centres. In Ontario, the urban ratio was .80 and .83 in 1961 and 1971, respectively, while in British Columbia, it was .76 and .75.

Another anomaly appears in the ranking of Quebec with Manitoba and Saskatchewan in the proportion of sales in shopping centres (Chart 8-2). The fact that Manitoba and Saskatchewan pulled ahead of Quebec in this ranking in the late 1960s is not too surprising when we note the substantial increase in the urban ratio of the two Prairie provinces. The urban ratio increased from .48 to .55 or 14 per cent in the decade 1961-71. There was an actual loss of rural population, which meant that, over time, the urban areas of this region received relatively more weight in our measure of diffusion than in other regions, such as Quebec, where urbanization proceeded at a less rapid pace.

Lack of data on shopping centres by city has prevented us from investigating the role of urban size; however, as the Ontario-British Columbia comparison shows, the level of the urban ratio apart from the growth variable does appear to have a role. We have also noted that change in the urban ratio — a measure that takes account not only of the increase in urban or "potential adopter" population but also the relative decline in the "non-adopter" population — is useful in explaining apparent anomalies in the diffusion measures.

All in all, then, we have support for the hypothesis that the diffusion of shopping centres is related, among other things, to urban growth.

As hypothesized by Moyer[24] and others, the extent of the penetration of shopping centres in the retail field is not only a function of the general surrounding conditions—that is, the growth of urbanization and, especially, suburbanization—but possibly also of the gradual changes in the form or shape of the shopping centres—that is, the gradual deepening of the services provided by the shopping centres either through an increase in the size of the shopping centres or by the presence of department stores.

From a regional point of view, it does not seem that sales per shopping centre are an important explanatory factor of size; because Chart 8-3 shows a convergent trend during the period, the regional average position as shown in Column 2 of Table 6 is not too significant.

The number of stores per shopping centre and the presence of department stores, on the other hand, are not well correlated with the diffusion process itself. The Spearman correlation indices of Column 1 of Table 8-7 with Columns 1 and 2 of Table 8-5 are only .229 and .371, respectively. Similarly, the coefficients of correlation between Column 3 of Table 8-7 and Columns 1 and 2 of Table 8-5 are .4 and .371, respectively. The low correlation of each factor, taken individually, with diffusion measures does not mean that together they do not play any role. The fact of the matter is that there are substitution possibilities between department stores and large shopping centres,[25] each, in turn, assuming a key role in different regions. For certain regions, further diffusion has been fostered by larger shopping centres while, in others, department stores have been the prime movers of the diffusion of shopping centres. Alberta and British Columbia owed their position (first and third or second in diffusion) to their position with regard to department stores (first and second). Ontario's

24 Moyer, "Shopping Centres in Canada."

25 This substitution should not be exaggerated. It is unlikely that regional shopping centres do not have at least one department store. However, not all shopping centres counting one department store need be as big as a regional shopping centre.

rank owed little to department stores per se, because large regional shopping centres have been instrumental in the further expansion of shopping centres.[26] In Quebec, the same process was at work but with less success, so that Quebec's rank was fourth.[27]

The Regional Factor

A regional factor exists if the factors that explain the diffusion of shopping centres have different regional characteristics. For instance, the close association of the ranking of regions with respect to two measures of the diffusion of shopping centres (found in Table 8-5) and the percentage increase in urban population (Table 8-9) point to the existence of a regional factor in the diffusion of the innovations. The varying regional urban ratios, such as for British Columbia and Ontario, which are regional characteristics, also explain diffusion of shopping centres. The regional factor in the diffusion of shopping centres consists then in the urbanization process peculiar to each region. Otherwise, it would have been difficult for provinces like Alberta to be ahead of Ontario.

Similarly, the size of shopping centres when measured by the number of stores in a shopping centre has played a role in the central provinces. This also is related to a peculiar characteristic of some regions, their urban hierarchy being dominated by large metropolises.

Finally, the role of department stores in the West is worth studying with respect to some institutional characteristics of the region. Indeed, four large department store chains—Eaton's, Sears, The Bay, and Woodwards—have been operating in the West and have been involved in shopping centre development for a long time,[28] compared with only two—Eaton's and Morgan's, which, until its takeover by The Bay, was not expansion-oriented—in the East. In addition, the East has had a wider variety of retailing establishments and smaller chain stores specializing in goods such as clothing, which have occupied a portion of department

26 This is logical: in older, large metropolitan areas (Toronto-Montreal), the only way for suburb shopping centres to compete with central city stores was (except in the case of food) to offer variety and style, something possible only in shopping centres with a large number of stores.

27 That does not mean that giant supermarkets as kingpins of shopping centres have done much better. According to experts, "discount operations have always had more trouble in Quebec than in the rest of Canada," see "The Bigger They Are, the Harder They Fall—Why HyperMarché Is in Trouble," *Maclean's*, November 1976, p. 63.

28 Note that our argumentation concerning the involvement of store chains in the development of shopping centres is compatible with many motivations for their activity as promoters including the one of land speculation. It is not unusual for a shopping centre to to be built as part of a larger land development project, perhaps even at a loss on retailing operations in order to increase the value of adjacent, yet-unoccupied land zoned residential. A complete work on the shopping centres in Canada would have to examine the linkage between retail and residential land markets.

stores' potential markets. What emerges from these phenomena is a picture of shopping centres in the West having received, at least in the past,[29] a significant push from the encouragement by the local stock of department stores of shopping centre development around the more service-heavy department store anchors. Because these factors reflect certain regional characteristics, they testify to the existence of a regional factor operating on the diffusion of shopping centres in Canada.

29 Recent developments, particularly the expansion of numerous smaller chain stores originating in central Canada, suggest that department stores alone are becoming a less reliable indicator of this aspect of shopping centre diffusion.

9 Conclusions

In this last chapter, we draw general conclusions regarding the state of technological diffusion in the five Canadian regions. To our knowledge, this has not been attempted before. We do so with some reservations, for we are aware that our sample of innovations is neither strictly random nor strictly representative. However, we believe it is sufficiently broad to justify a few generalizations. Their tenor is such that we hope they will tempt others to explore further this potentially fruitful area of research into problems of regional development.

We begin by discussing in greater detail than in previous chapters what we mean by speaking of a "technological lag" of a region. In a one-good world, where the good is produced in every region with steadily improving techniques, the meaning is clear. If one imagines the good as corn, one can readily conceive of corn being produced in one region by methods that are five years, ten years, or twenty years behind those in use elsewhere.

In a multiple-good world, difficulties immediately arise. If one region specializes in one commodity and another in a completely different commodity and they trade, is there any meaningful sense in which one region might lag technologically behind the other? Or, what if both regions produce the same commodity but climate, geography, or factor endowments differ in such a way as to make different technical advances appropriate in each region?

In cases where a technique is never applicable anywhere outside the region, either in the rest of the nation or in the rest of the world, it is difficult to speak of a technological lag. Clear examples may be rare and those that do exist probably depend on unique national resources. Thus, if Peru is the only nation with access to anchovies, can one speak of Peru as being behind or ahead in the technology of anchovy fishing? For there is nobody else that Peru can follow or lead. Nevertheless, with some ingenuity one might devise tests of backwardness—is sardine fishing all that technologically different?

A more likely situation is where a region applies technology that is in use elsewhere in the world but not elsewhere in the nation. Since automobile engines are only assembled in central Canada, automobile engine assembly techniques in this region neither lead nor lag those in the rest of the country, though they may lead or lag those in other countries. More common still is the case where a region has technology that, while it is not appropriate for all regions, is applicable in one or two other Canadian regions, as well as in other parts of the world. Containerization is one example. Methods used in the production of wine are another. In these cases one can speak of technological advances in one region lagging or leading those in some other Canadian regions, but not of a generalized tendency to lead or lag within Canada.

Finally, there are techniques applicable to all regions, as well as to other countries, such as the shopping centre or roof trusses. In such cases, the meaning of saying that one Canadian region lags technologically behind the others is fairly straightforward. However, reasonable scholars could still disagree about the precise way to measure the lag, and different measures could give different results. The difference between one region and the rest of Canada in the dates at which 90 per cent of potential adopters have adopted, and the dates at which 50 per cent have done so, will not likely be the same, but either is arguably a good measure of a lag. Nevertheless, this kind of problem is more readily overcome than those that arise when only one or two regions ever adopt a particular innovation.

In this latter situation, a method that could be used in principle is to compare each region, for a given innovation, with comparable adopters of that innovation outside Canada for example, in the whole of the United States, or in the whole of the United States and Europe. It would then be possible, for almost all types of innovations, to say that a given Canadian region tended to be a certain number of years behind others in adopting those innovations that happen to be applicable. If Newfoundland were typically fifteen years behind the United States in the adoption of new techniques in blueberry picking while Prince Edward Island was typically ten years behind in the adoption of new techniques in potato farming, the implication would be that Newfoundland was five years behind Prince Edward Island. The example clearly generalizes, though not in any simple fashion. If other Canadian regions also became comparable adopters, they could be included in the comparisons. The set of innovations considered in each region would differ according to differences in industrial specialization, in relative factor prices, in natural resource endowments, and so forth, but each region could in principle be compared with adopters elsewhere, inside and outside Canada, and an average adoption lag could be obtained. Interregional comparisons would then be possible.

The theoretical possibility of such a procedure gives validity to the concept of regional technological lags. The amount of empirical work required to actually implement it rules it out of consideration for the time being, but it is useful to keep in mind as we undertake the examination of intra-Canadian comparisons of the technological adoption process.

Among the six innovations we have studied, four were applicable throughout Canada—computers, roof trusses, newsprint technology, and shopping centres—while two were perfectly applicable only in three of the five major regions—electric furnaces, in Quebec, the Prairies, and British Columbia,[1] and containers in Quebec, the Atlantic region, and British Columbia.[2]

Initial Adoption

The initial timing of an innovation is one useful measure of how advanced or backward a particular region is in technological adoption. It is only one measure, because early adopters can sometimes be surpassed by those who, though late in initial adoption, exhibit very rapid rates of adoption thereafter. The definition of initial adoption needs care. An innovation whose adoption was geographically random in some accepted sense would be more likely to appear first in the larger regions. Geographically random could mean, for example, that any plant was as likely to adopt as any other in a given month. Larger regions with more plants would have a higher total probability of being leaders. To overcome this problem and to avoid assigning leadership to Ontario over the Atlantic region simply because of its size, it is perhaps better to look at the date by which some small but appreciable fraction of potential adopters in each region had adopted. That fraction needs to be large enough to eliminate, or render acceptably small, the probability that a region is first (or last, or any other position) by chance. Given the varying nature of the data for each innovation, it is necessary to be flexible in how one measures the date by which a "small but appreciable" fraction of adoption has occurred, but the principle should be clear. Difficulties in determining the lags in initial adoption also arise in some cases where a region is seen to have not yet adopted during the period under study. In these instances, we calculate the lag as the number of years between the time the leader adopts and the end of the period.[3]

The procedures that we used in determining lags in initial adoption are described below, and the results in years of lag behind the leader in each industry are shown in Table 9-1.

1 Electrical furnaces are used in all regions. But for reasons furnished in Chapter 4, they are never likely to dominate steel output in Ontario and the Atlantic provinces in the same way as they do elsewhere.

2 Ontario is a difficult case. Containers were applicable to the port of Toronto in the early years, but not to the same degree later. This point is taken up further below.

3 In so doing, we risk a downward bias in the number of years that initial adoption lags behind in certain regions. We may note, however, that this assumption does not jeopardize the ordering of regions with respect to the adoption of new innovations presented below.

Table 9-1

Number of Years that Initial Adoption Date Lagged behind the Leader, by Region

	(1)	(2)		(3)	(4)	(5)	(6)	(7)
		Furnaces						
	Computers	BOP	Electric	Roof trusses	Containers	Special presses	Shopping centres	Average lags[1]
Atlantic region	3.5	17	n.a	8.2	2	1.75	16	8.08
Quebec	.25	n.a	14	0	0	.375	4	3.10
Ontario	0	0	0	2	5	3.5	1	1.64
Prairie region	1	—	0	6.83	—	4.25	3.4	3.10
Manitoba and Saskatchewan							6	
Alberta							0	
British Columbia	2.5	—	2	4	2	0	2.3	2.13

— Not applicable.
1 The average has been obtained by dividing the sum of the lags by the number of applicable innovations.

Source: Table 3-3, Chart 4-1, and Tables 5-7, 6-1, 7-9, and 8-6.

Computers

We used two measures to determine lags in initial adoption. On one hand, we defined the date of initial adoption as being when computers per billion dollars of gross regional product reached 0.8. On the other hand, we defined initial adoption completed when the number of computers per thousand members of the labour force equaled 0.4. Both measures led to identical estimates of the lags in initial adoption for all regions except British Columbia. Our data source for these figures is Table 3-3.

Steel Furnaces

Although, quantitatively, electric furnaces may not be the most important innovation in steelmaking, they are of special interest to regional economists as they have been instrumental in the establishment of the steel industry in certain peripheral regions. Their date of initial adoption presents a problem because they existed in a complementary role relative to conventional — open hearth (OH) or basic oxygen process (BOP) — mills for forty years or more. However, it is in their basic function in the production of primary steel (the paradigm being Sidbec) that we consider them here.

From this perspective, the innovation is not applicable in the Atlantic region because it remains in a complementary role. It is clearly applicable in the Prairies, British Columbia, and Quebec where open hearth or basic oxygen furnaces do not exist to an appreciable degree. The initial lags are then established with reference to the leader of the group, the Prairies. The level attained by the Prairies in 1957 (see Chart 4-1) has been judged a reasonable initial benchmark. The case of Ontario is, however, special; it usually had more capacity (in absolute terms) in electric furnaces than any of the other regions. It is only in 1971 that Quebec, and eventually the western provinces, surpassed Ontario. Consequently, one can hardly speak of Ontario lagging.[4] This is why we attribute a position of no lag to Ontario, although in this region electric furnaces do not assume the same crucial role that they do elsewhere. The lags, determined by referring to Chart 4-1, are presented in Table 9-1.

Our interest in electric furnaces should not, however, detract us from the main new technology in large-scale production of primary steel — the basic oxygen process. Only two regions are involved, Ontario and Atlantic. It is furthermore easy to determine the leader and the lagger, because the Atlantic region never adopted this innovation. In 1956, the basic

4 Ontario actually furnished the peripheral areas with early examples of many models of electric furnaces. This experience was later transmitted to other regions by the mechanisms of the local subsidiaries of the major Ontario steel producers.

oxygen process accounted for 8 per cent of Ontario's steel capacity. Taking this as the level of initial adoption, the lag for the Atlantic region is 17 years.[5]

Roof Trusses

We used as a main index of date of adoption the one based on the share of roof truss output in sash and door shipments (Table 5-7). Lags in initial adoption are calculated when this index reaches 0.75.[6] The leader in initial adoption of this innovation was Quebec.

Containers

This is a case where an innovation is not universally adoptable by each and every region. In this respect, the Prairies are easily eliminated. Ontario, however, is more complex because, in the early days of containerization, when the ships were still small, the port of Toronto and the U.S. Great Lakes ports expected to become major handlers of container traffic.[7] The port of Toronto was also partially equipped for container service. (It was only later when the ships increased in size and the economics of container shipping changed radically that the port of Toronto was rendered less suitable for containerization.) This is a matter with which we must deal in our analysis of subsequent adoption and not, however, in our study of initial adoption. Consequently, we include Ontario in our examination of initial adoption. The source of information here is Table 6-1, and the criterion for establishing the date of initial adoption is technical; that is, it is not directly related to the proportion of total ports' volumes accounted for by containers. The date of initial adoption is taken as the year when a regular service of ships specialized in containers is introduced.

Newsprint

Several different innovations pertaining to the production of newsprint were studied in Chapter 7. Only one, the special presses, however, lends itself to the type of calculations we have to make here. It is also the one that

5 Note that, by adding basic oxygen furnaces, we are not giving more weight to furnaces than to other innovations of our study because (except for Ontario) each region is involved with only one type of furnace.

6 Initial interest in roof trusses in Canada dates back to 1956, whereas the value of .75 is attained only in 1963 by the East region.

7 See testimony of P. Normandeau, President, St. Lawrence Seaway Authority, as reported in G. Pinard, "Même si les délais de passage étaient éliminés, le trafic de la voie maritime n'augmentera pas," *La Presse*, 20 August 1977, p. A-11.

can be compared with other studies.[8] The source of data here is Table 7-9, where the value of 9.2 per cent of newsprint output produced by special presses in British Columbia is the benchmark.[9] If we had been able to use other innovations and used different time perspectives, we might have obtained somewhat different results. For instance, in a very long period, the average capacity per machine, whether measured by speed, machine width, or a combination of both, shows no significant difference among regions. Nevertheless, the introduction of special presses is an innovation that is applicable in all regions and thus warrants attention in a study of the regional aspects of the diffusion of technology.

Shopping Centres

In this instance, we have taken the date of initial adoption as being when the number of shopping centres per urban area reaches 0.81. The figures are presented in Table 8-6, and Alberta is shown to be the leader while the Atlantic provinces are seen to lag behind considerably. In Table 9-1, we present a value for the lag in initial adoption of shopping centres for the Prairie region as a whole. This is necessary in order to achieve conformability with our data on other innovations. The figure we present is a population weighted average of the lags for Manitoba and Saskatchewan together, and Alberta.

Leaders and Laggers in Initial Adoption

Table 9-1 summarizes the lags we have found in initial adoption. Ontario is seen to lead most often and has the lowest average lag. Conversely, the Atlantic region does not lead on any account and has an average lag that is more than twice that for any other region. In three out of the five innovations applicable to the Atlantic region, the region was the slowest insofar as initial adoption was concerned. Even if one introduced arbitrary upper limits upon lags of, say, 10 or 12 years and reduced the shopping centre and basic oxygen process lags in accordance, the region would still lag far behind the others. Quebec and the Prairies are seen to have average lags that are equal, while the performance of British Columbia is slightly better. Each of these regions leads in the initial adoption of at least one innovation: British Columbia, in special presses; the Prairies, in electric furnaces; and Quebec, in both containers and roof trusses.

8 L. Nabseth and G.F. Ray, *The Diffusion of New Industrial Processes: An International Study* (Cambridge, Mass.: Cambridge University Press, 1974), Chap. 4.

9 We have also made the assumption that the diffusion process is segmentally linear over the years. That enabled us to draw straight-line diffusion curves linking the values provided by Table 7-9.

Later Diffusion

A tendency to be late in initial adoption matters less if the rate of later adoption in lagging regions is much faster than elsewhere. In this instance, the lagging regions could effectively catch up with the leaders and any initial technological gaps could be narrowed if not completely closed. The average lag taken over the period as a whole would then be significantly less than that in initial adoption. In what follows, we present the methods we employed in calculating the average lags over the period for each innovation, as shown in Table 9-2. These lags were usually arrived at by taking a number of readings during the period and averaging them. Readings typically included the initial date of adoption, and a number of others, depending upon the availability of data.

Computers

The calculations are based upon Chart 3-7 and Table 3-4. We use the measure of autonomous computers per labour force member. Similar results would have been obtained using our alternative measure of autonomous computers per billion dollars of gross regional product.[10] It is interesting to point out that the lags in the adoption of computer technology between all regions and Ontario increased during the period—that is, the average lags exceed those for initial adoption.

Steel Furnaces

The regions' average lags are established for both types of furnaces, BOP and electric. For BOP, the analysis involved only two regions, Ontario and the Atlantic, one of them (Atlantic) never adopting (see Chapter 4). The Atlantic region is credited with an average lag of 17 years.

For electric furnaces, readings were taken when the index of ability of local capacity in electric furnaces to satisfy apparent needs of the local steel complex (Chart 4-1) reached levels of .47 and .70. For reasons that were spelled out in Chapter 4, we attribute Ontario with a zero lag and we exclude the Atlantic provinces from the analysis. British Columbia is also a difficult case. While its index reaches .47, the level of initial adoption, early in the period, the index subsequently declines, thus never reaching .70. We thus take the lag for this later reading as the difference between the time the leader attained this level and the end of the period. The average lag is then calculated using this lag and that for initial adoption.

10 Details of our calculations are available upon request.

Table 9-2

Average Lags in Technological Diffusion, by Region

	(1)	(2)		(3)	(4)	(5)	(6)	(7)
		Furnaces						
	Computers	BOP	Electric	Roof trusses	Containers	Special presses	Shopping centres	Average lags[1]
Atlantic region	3.63	17	n.a	4.89	1.38	2.38	12.25	6.92
Quebec	1.63	n.a	13.5	.22	1.33	.19	6.25	3.85
Ontario	0	0	0	1.03	5.0	3.32	.5	1.41
Prairie region	2.13	—	0	4.13	—	3	3.49	2.55
Manitoba and Saskatchewan	6.13							
Alberta	0							
British Columbia	2.75	—	7.5	3.97	4.5	2.25	3	4.00

— Not applicable.
1 The average has been obtained by dividing the sum of the lags by the number of applicable innovations.

Source: Table 3-4 and Chart 3-7, Chart 4-1, Table 5-7, Chart 6-2, Table 7-10, and Chart 8-2.

Roof Trusses

The average regional lag for roof trusses has been established by taking three readings on the data of Table 5-7: one at .75 per cent of roof truss shipments in the sash and door industry; the other at 1.96 per cent; and the last at 2.86 per cent. The regional averages of these readings are listed in Table 9-2. Although there was catching up by most regions, the lags have not diminished greatly, with the exception of that for the Atlantic region. It is also interesting to note that the leadership has changed during the period, from Quebec (or East) for the first two readings to the Prairies for the last reading.

Containers

First, the Prairies are excluded from the analysis. Second, it would also be tempting to do the same with Ontario if it were not for the fact that the port of Toronto is still active in container traffic and retains expectations of playing a more important role in container shipping in Canada.[11] On the other hand, as indicated in Chapter 6, the lag is not really comparable with those in other regions because sizable decreases in the total volume of overseas general cargo have occurred. Nevertheless, the interest and activity of the port of Toronto in containerization cannot be ignored, and we include it in our analysis. The average lag for Ontario is taken to be 5 years, which is the value of the lag in initial adoption. The other lags were established by taking three readings on Chart 6-2: one at 13.5 per cent of general cargo (international) being containerized; a second at 30 per cent; and a last one at 50 per cent. The position of the Quebec region is arrived at by taking the average of its two major ports, Montreal and Quebec City. A similar calculation is performed for the Atlantic region. British Columbia's position is exclusively determined by the port of Vancouver.

Newsprint

As we did previously in our analysis of initial adoption, we focus on special presses. More specifically, we are concerned with the percentage of newsprint capacity in each region accounted for by machines equipped with special presses (Table 7-10). To calculate the average lag, readings are taken at levels of 9.2 per cent and 29.8 per cent. This average is reproduced

11 According to a study of the Chamber of Commerce of Montreal, the proposed reduction from 90 cents a ton to 62 cents a ton that the St. Lawrence Seaway charges on containers would increase appreciably the competitive position of the port of Toronto; see J. Poulain, "On peut craindre un exode des entreprises si le tarif des containers est abaissé," *La Presse,* 26 August 1977, p. B-3.

in Table 9-2. The changes over the period worked in opposite ways; British Columbia, and to a small extent the Atlantic region, has worsened its position, while the Prairie provinces have ameliorated theirs. Quebec and Ontario positions remained almost unchanged.

Shopping Centres

The calculations for computing the average lags in the diffusion of shopping centres are founded upon Chart 8-2. The average lags presented below are the average of two readings, one taken at approximately 11 per cent, and the other at 15 per cent. The Prairie region's lag is obtained by taking a population-weighted average of Alberta on the one hand and Manitoba and Saskatchewan on the other. During the period, the Atlantic region and Ontario have reduced their initial lags, while those for Quebec and British Columbia have increased.

Average Lags in Later Diffusion

Our results are summarized in Table 9-2. While Ontario and the Atlantic provinces occupy first and last place, as they did in our analysis of initial adoption, the relative positions of the other regions change somewhat. In Table 9-1, the Prairies and Quebec had identical average lags in initial adoption; however, Table 9-2 reveals that the pace of later diffusion in the Prairies has been much stronger than that in Quebec, and the former now leads by a significant margin. In fact, the average lag over the period has decreased by 18 per cent in the Prairies and has increased by 24 per cent in Quebec. The ranking of British Columbia has also changed. While British Columbia's average lag in initial adoption placed it ahead of all regions with the exception of Ontario in Table 9-1, the only region having a greater lag over the period as a whole than British Columbia is the Atlantic region. Indeed, the British Columbia lag has almost doubled.

In sum, Ontario and the Atlantic provinces maintain their positions. The Prairies improve their position and are second only to Ontario in the pace of later diffusion. The positions of Quebec and British Columbia deteriorate substantially, with the latter's being the most severe.[12]

12 Some might wish to argue that a different regional ordering would result if we imposed an upper limit on certain lags (for example, shopping centres in the Atlantic region) of, say, 10 or 12 years and omitted from the analysis innovations such as electric furnaces in British Columbia, for which our index shows no clear trend. It should be noted, however, that such an approach does not, in fact, alter the ordering.

Technological Lags and Regional Disparities

For each innovation, we could identify a regional factor. In some instances, this factor has promoted the diffusion of innovations and, in others, it has had the opposite effect. If regional income disparities are linked to access to or the diffusion of innovations, some fundamental characteristics of a region (the regional factor) are then at the source of regional disparities. If such links can be established, we may hold one of the keys to explaining the sizable regional disparities in Canada. To this we now turn.

In examining whether the regional differences in technological lags (measured in Table 9-2) are related to regional disparities, we begin by noting a strong correlation between productivity and income differences already documented elsewhere,[13] and noting also that technological lags are one factor among a number of others leading to productivity gaps. It has been shown that, in the 1970-73 period, the percentage differences in labour productivity from the national average were: Atlantic region, -21,[14] Quebec, -7; Ontario, +4; Prairies, +1; and British Columbia, +10. But part of these differences can be accounted for by differences in industry mix[15] and in physical and human capital per worker.[16] The residual differences, which are not explicable by these factors, are : Atlantic, -13; Quebec, +1; Ontario, +5; Prairies, -2; and British Columbia, -6.

The ordering of these differences is close to the ordering of technology lags that we found. Ontario is well ahead in residual productivity and also in technological adoption, while the Atlantic is well behind in both. Quebec and the Prairies are close together, as they are in technology, although the ranking is reversed when we move from residuals in productivity to lags in technology. British Columbia occupies the same rank in both measures. The Spearman rank correlation coefficient between the two measures is .9, which is a good correlation.

How much of the productivity residual can be explained by technology?[17]

13 See Economic Council of Canada, *Living Together: A Study of Regional Disparities* (Ottawa: Supply and Services Canada, 1977), Chapter 5.

14 Population-weighted provincial average.

15 *Ibid.*, Table 5-3.

16 *Ibid.*, Table 5-12.

17 It has been suggested to us that regional productivity differences hinge on the total level of technology and that this is not the same as regional differences in the adoption of new technology at the margin. In our view, this comment is based upon an attractive but misleading analogy with how physical capital affects productivity. With physical capital, regional differences in the flow of new investment need have no connection, at least in the short to medium term, with regional differences in capital stock and, hence, no connection with regional differences in productivity attributable to capital. However, as Appendix C shows, under reasonable assumptions about how technical change enters the production function, regional differences in lags in adoption—a marginal concept—do determine regional differences in the total level of productivity, provided the regional adoption lags are averaged over all industries. And, in principle, we are carrying out such a process, though we would be the first to admit that we have a perilously small sample to do it with!

If we suppose technical change accounts for about 1.25 per cent a year of productivity growth (in Denison's sense) and make the very strong assumption that these average lags apply to the whole of each regional economy, they would lead to a productivity lag behind Ontario of about 6.9 per cent in the case of the Atlantic region, 1.4 per cent in the Prairies, 3.1 per cent in Quebec, and 3.3 per cent in British Columbia.[18] Since the actual regional differences with respect to Ontario in the unexplained residuals are 18 per cent[19] for the Atlantic region, 7 per cent for the Prairies, 4 per cent for Quebec, and 11 per cent for British Columbia, technology lags could account for a substantial portion of the residual productivity gaps between Ontario and the other provinces. The proportion would be over one-third of the gap in the case of the Atlantic region, somewhat under one-third for British Columbia and the Prairies, and most of the gap for Quebec. While the "pilot survey" nature of the data precludes strong reliance being placed upon these conclusions, they are nevertheless suggestive. The order of magnitude of the productivity differences, which our analysis suggests may be attributable to technical lags, is the same or larger than those attributable to regional differences in industry mix, or to differences in human capital, or to differences in regional unemployment rates.

Since there is a link between regional lags in technology and regional lags in productivity (as shown above), there might be room for policy action. Can regional policies be of some help to correct undesirable situations? Among many things, the answer to this question is that it depends upon the nature of the regional factors that are instrumental in causing the various technological lags depicted in Chapters 3 to 8. Table 9-3 summarizes the pertinent information necessary to form an opinion.[20]

The list of regional factors (in Table 9-3) enables us to identify the cases where policies might be feasible and practical. That means that, in certain cases—for example, where geographical distance is the main factor—not much can be done, or if so, at great expense. Yet, even there, it shows what kinds of policies are feasible: transport subsidies, amelioration of the road network, increase in quality of air services, and so forth—anything that can reduce the costs of distance to decision-makers. Some other cases are more likely to be ameliorated by local regional policies; they are cases where urban growth and planning, local entrepreneurship and local industrial structure are the main regional factors. That does not mean that the policies are easily devised or implemented in all cases. If, for instance, we are dealing

18 These figures are arrived at by multiplying the average yearly lag of each region behind Ontario (Table 9-2) by 1.25 per cent.

19 The figures are arrived at as follows: the difference between the unexplained residuals in the Atlantic region (-13) and those in Ontario (+5) is 18; see Economic Council, *Living Together*, p. 78, Table 5-12.

20 Because Table 9-3 is a summary, many refinements in the concepts and diagnoses are absent.

Table 9-3

Factors of Diffusion, Principal Mode of Diffusion, and Regional Factors Regarding Innovations, Various Economic Sectors

	Innovation	Access to information	Factors of diffusion	Principal mode of diffusion	Regional factors
All sectors	Computers	No problem	Size of firms Type of economic activity Government activities	Economic environment	Local industrial structure Federal government implantations
Primary steel	BOP furnaces	No problem	Distance from central Canadian markets	Epidemiology	Physical distance
	Electric furnaces	No problem	Distance from BOP and OH production facilities	Epidemiology (in reverse)	Physical distance
Construction	Metal plates Roof trusses	No problem Some problem	Steel complex Economies of scale Dwelling mix	Economic environment Urban hierarchy	Local industrial structure Large metropolitan areas Type of urban growth and planning
Transport	Container ports	No problem	Changes in container ships' economics and establishment of commercial connections between sea-shipping companies and railways	Economic environment Internal characteristics of firms	Local entrepreneurship (private and public)

Newsprint	Special presses	No problem	Age of machines Size of firms	Internal characteristics of firms	Quality of resources Anti-pollution regulations (to a small extent) Regional forestry policies
Commerce	Shopping centres	—[1]	Rate of growth of cities Deepening of service mix in shopping centres	—[1]	Urban growth and planning Degree of urbanization Local stock of department stores

1 Although we are sure that the urban phenomenon is the key to the explanation of the diffusion of shopping centres, we cannot propose urban hierarchy as the mode of diffusion for shopping centres because a lack of data in some areas precludes relating certain characteristics of shopping centres to urban size.

Source: See Chapters 3 to 8.

with an innovation that prospers mainly in large metropolitan areas, there is not much that can be done in the short run by local authorities. But at least they will know why they cannot have it as early as central Canada and/or that they should not count on it. The matter is, of course, much different if local entrepreneurship is the main factor. Finally, the federal government should also recognize that in certain cases it can and does play an important role in the diffusion of innovations.

Appendices

A Appendix to Chapter 3

Table A-1

Growth of the Stock of Computers, Canada, by Region, 1956-73

	Atlantic region	Quebec	Ontario[1]	Prairie region	British Columbia	Canada
1956[2]		2	2			4
1957		4	5	1		10
1958	1	7	13 (1)	3		24
1959	1	11	22 (2)	5		39
1960	1	18	35 (3)	8	2	64
1961	2	44	73 (4)	20	5	144
1962	6	83	146 (8)	40	14	289
1963	10	117	239 (16)	61	37	464
1964	11	126	257 (19)	67	41	502
1965	27	204	330 (27)	97	52	710
1966	35	280	443 (39)	120	70	948
1967	44	332	664 (55)	166	93	1,279
1968	56	410	811 (58)	229	107	1,613
1969	84	485	1,045 (62)	281	142	2,037
1970	131	603	1,361 (98)	381	224	2,700
1971	178	764	1,814(167)	501	290	3,547
1972	228	939	2,279(188)	601	358	4,405
1973	321	1,271	2,809(213)	833	499	5,733

1 Data in brackets refer to installed computers for the federal government services in Ottawa.

2 Having no information for the period 1952-55, except for the first adoption of computers in Canada in 1952, we begin the series in 1956.

Notes: Data cover:
- — January to December for 1956 to 1963;
- — January to March for 1964;
- — April 1964 to June 1965 for 1965;
- — July 1965 to June 1966 for 1966;
- — July 1966 to April 1967 for 1967; and
- — May of the previous year the following May for all other years.

The 1956-64 data were established on the basis of later censuses.

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table A-2

Computer Distribution According to Size, Canada, by Region, 1965-73

	1965	1967	1969	1971	1973
			(Per cent)		
Atlantic region					
Small (0-31 K)	81.5	84.1	79.8	82.6	84.1
Medium (32-255 K)	18.5	15.9	19.0	16.3	14.3
Large (256 K and over)	—	—	1.2	1.1	1.6
Total	100.0	100.0	100.0	100.0	100.0
Quebec					
Small (0-31 K)	84.3	82.2	71.3	70.5	77.0
Medium (32-255 K)	15.7	17.5	23.3	24.5	18.2
Large (256 K and over)	—	.3	5.4	5.0	4.8
Total	100.0	100.0	100.0	100.0	100.0
Ontario					
Small (0-31 K)	83.9	78.3	71.8	76.0	80.0
Medium (32-255 K)	15.8	19.6	22.3	18.4	15.1
Large (256 K and over)	.3	2.2	5.9	5.6	4.8
Total	100.0	100.0	100.0	100.0	100.0
Prairie region					
Small (0-31 K)	85.6	72.9	74.7	76.8	80.8
Medium (32-255 K)	14.4	25.3	20.6	19.4	16.1
Large (256 K and over)	—	1.8	4.6	3.8	3.1
Total	100.0	100.0	100.0	100.0	100.0
British Columbia					
Small (0-31 K)	88.5	81.7	73.3	77.9	80.6
Medium (32-255 K)	11.5	17.2	19.0	19.0	16.8
Large (256 K and over)	—	1.1	7.7	3.1	2.6
Total	100.0	100.0	100.0	100.0	100.0
Canada					
Small (0-31 K)	84.5	79.0	72.5	75.4	79.7
Medium (32-255 K)	15.4	19.5	21.9	19.8	16.0
Large (256 K and over)	.1	1.5	5.5	4.8	4.2
Total	100.0	100.0	100.0	100.0	100.0

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table A-3

Computer Diffusion, Major IBM Series, Canada, by Region, Various Periods, 1960-73

(Cumulative percentages and number of installed computers)

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada
IBM 1620						
1960			8			4
1961		20	29	13		19
1962	20	30	46	25		31
1963	40	80	63	50	40	48
1964	60	100	83	75	80	81
1965	60		92	88	100	92
1966	60		96	100		96
1967	80		96			96
1968	80		100			98
1969	80					98
1970	100					100
Installations	5	10	24	8	5	52[1]
IBM 1401						
1960			1			0
1961		10	9	5	4	8
1962	13	26	31	19	9	25
1963	33	51	49	36	35	46
1964	40	71	69	55	57	66
1965	47	82	80	69	78	78
1966	53	92	88	81	83	87
1967	73	95	90	93	87	91
1968	93	99	94	93	96	96
1969	93	99	96	95	96	98
1970	100	100	100	100	100	100
Installations	15	73	134	42	23	287

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada
IBM 360/20						
1965		2	1	4		1
1966	19	11	17	19	12	16
1967	35	33	41	42	36	39
1968	54	46	53	53	58	52
1969	65	70	75	70	70	73
1970	77	85	90	89	85	88
1971	96	94	95	96	94	95
1972	100	100	98	100	97	99
1973			100		100	100
Installations	26	111	271	53	33	494
IBM 360/30						
1965		5	3	6	3	4
1966	29	29	32	27	26	30
1967	50	58	63	58	60	60
1968	50	80	78	77	71	77
1969	57	84	81	88	86	82
1970	79	88	84	90	89	86
1971	86	91	89	98	91	90
1972	100	94	93	100	100	95
1973		100	100			100
Installations	14	106	209	52	35	416

Table A-3 (cont'd)

(Cumulative percentages and number of installed computers)

IBM 1130	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada
1966	8	17	11	14	7	12
1967	38	53	46	36	14	43
1968	69	73	63	64	57	65
1969	92	93	76	82	71	81
1970	92	97	88	96	81	91
1971	92	100	96	100	100	97
1972	100		99			99
1973			100			100
Installations	13	30	100	28	14	185

IBM 360/40	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada
1965		2	1			1
1966		17	13	16	8	14
1967		37	26	28	29	29
1968	25	59	40	40	42	44
1969	75	76	64	56	83	68
1970	100	87	86	72	92	85
1971		93	94	92	92	93
1972		98	97	92	96	96
1973		100	100	100	100	100
Installations	4	46	97	25	24	196

Canada

	IBM 360/25	IBM 360/50	IBM 370/145 and 379/155
1966		6	
1967		20	
1968		41	
1969	42	62	
1970	78	82	
1971	95	89	32
1972	95	96	86
1973	100	100	100
Installations	106	109	111

1 Approximately 60 per cent of total installations. We were unable to determine with accuracy the installation date for all the installations of this series.

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table A-4

Computers Used for Production Control, by Region, 1960-73

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1960					
1961			1		
1962		1	1		
1963		1	1		
1964	1	2	1		
1965	1	2	2		
1966	1	4	3	1	
1967	1	8	9	3	2
1968	1	9	10	19	2
1969	2	9	24	23	2
1970	2	15	49	33	6
1971	9	30	91	39	15
1972	11	64	120	59	25
1973	14	105	213	80	47

Note: The data for the years 1960-68 are based on the 1968 census except in the case of Ontario for the years 1961-63, in which case the 1971 census was used.

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table A-5

Number of Computers Used for Production Control per Billion Dollars of Value Added in Goods-Producing Industries, by Region, 1960-73

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia
1960					
1961			0.1		
1962		0.2	0.1		
1963		0.2	0.1		
1964	0.9	0.4	0.1		
1965	0.9	0.3	0.2		
1966	0.8	0.6	0.3	0.2	
1967	0.8	1.2	0.8	0.7	0.8
1968	0.8	1.5	0.9	4.3	0.8
1969	2.1	1.4	2.0	5.0	0.7
1970	1.4	2.4	4.2	7.5	2.5
1971	6.4	4.6	7.5	8.1	5.3
1972	7.5	9.3	9.2	11.4	8.1
1973	8.0	14.1	14.8	12.2	12.0

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table A-6

Number of Computers Connected to One or Several Others, Canada, by Region, 1965-73

	Atlantic region	Quebec	Ontario[1]	Prairie region	British Columbia	Canada
1965		7	5 (1)	2	1	15
1966		26	31 (2)	7	6	70
1967			Incomplete data			
1968		27	76 (8)	26	6	135
1969	3	49	94(12)	38	8	192
1970	13	75	189(16)	57	21	355
1971	25	118	226(21)	61	24	454
1972	29	110	309(29)	80	45	573
1973	43	160	395(38)	115	64	777

1 Numbers in parentheses indicate the number of computers of the federal government in Ottawa equipped with data transmission lines to other computers.

Notes: Data cover:
- — July 1965 to June 1966 for 1966;
- — July 1966 to April 1967 for 1967; and
- — May of the previous year to following April for 1968 to 1973.

Data for 1965 include data for previous years.

Source: Calculations based on data from CIPS, *Computer Census*, annual.

Table A-7

Estimates of Provincial Gross Domestic Product, Canada, by Region, 1956-73

	Atlantic region	Quebec	Ontario	Prairie region	British Columbia	Canada[1]
1956	2,138	8,686	12,824	5,935	3,430	33,013
1957	2,209	8,888	13,762	5,641	3,641	34,191
1958	2,280	8,982	13,727	6,200	3,719	34,908
1959	2,391	9,413	14,167	6,335	3,856	36,162
1960	2,499	9,792	14,500	6,689	3,976	37,456
1961	2,603	10,264	15,180	6,431	4,056	38,534
1962	2,732	10,968	15,883	7,365	4,320	41,268
1963	2,875	11,429	17,099	7,766	4,577	43,746
1964	3,083	12,413	18,277	7,786	4,975	46,534
1965	3,265	13,201	19,698	8,378	5,350	49,892
1966	3,725	13,992	21,279	8,964	5,768	53,728
1967	3,568	14,601	21,970	9,016	6,051	55,206
1968	3,792	14,991	23,297	9,705	6,383	58,168
1969	4,024	15,601	24,884	10,023	6,939	61,471
1970	4,209	15,893	25,848	9,941	7,072	62,963
1971	4,409	16,600	27,039	10,745	7,708	63,501
1972	4,715	17,539	28,961	11,395	8,250	70,860
1973	4,977	18,535	30,533	12,454	8,894	75,393

1 The data for 1956, 1957, and 1958, as well as those for Saskatchewan, are estimates based on personal income.

Source: See R. Beaudry, "Les aspects régionaux de la technologie au Canada: le cas des ordinateurs," Economic Council of Canada, Discussion Paper 50, Ottawa, 1976.

Table A-8

Distribution of Computers in Use in Canada, by Industrial Sector, 1971

	Computers	Rental value
	(Per cent)	
Agriculture	.5	.4
Forestry, pulp and paper	1.3	1.1
Mining	1.1	1.1
Manufacturing	22.0	17.6
Construction	1.3	.4
Transport	4.0	5.1
Data processors	8.6	15.3
Hospitals	1.6	.9
Education	16.0	13.6
Federal administration[1]	11.6	10.5
Provincial administration[2]	4.6	8.5
Local administration	2.8	2.0
Finance	7.7	11.5
Other services	11.7	7.6
Other	5.2	4.4
Total	100.0	100.0

1 Including Crown corporations.
2 Including provincial companies.

Source: *Branching Out*, Report of the Canadian Computer/Communications Task Force, Ottawa, 1972.

B Appendix to Chapter 4

In analysing the forces of geographical association in the steel industry, researchers have shown that metal-working industries form an industrial complex heavily dependent on iron and steel mills, an industry external to the group. Note here that we are using the term "complex" as Roepke *et al.* did.[1] But this leads to some confusion. A better terminology is the one of Czamanski:[2] the term "cluster" covers industrial sectors that are associated in economic space — that is, in an input-output table covering, for instance, a whole country — while the term "complex" covers the industrial sectors that are not only associated in economic space, but also in geographical space, for instance, in a Standard Metropolitan Statistical Area. Furthermore, industries that are part of a complex often, but not always, associate geographically.[3]

Economic linkages are one kind of force of geographical association. "Leontief would consider two sectors as linked if one sells $1/n^{\text{th}}$ or more of its output to the other or if one purchases $1/n^{\text{th}}$ or more of its inputs from the other (where n stands for the number of sectors in the input-output table). The former is a demand linkage, the latter a supply linkage."[4] Let us note that Leontief's measure has no direct spatial implications. As we shall see later, the economic links of Standard Industrial Classification 291 (Iron and Steel Mills) can be established all over Canada.

General agglomeration economies are another kind of force of geographical association. They are taken into account by the manufacturing industry as a whole. Its spatial distribution thus measures "the general locational advantages of various parts of the country."[5]

Because there are two sets of forces at work, the process of geographical association follows complex rules, so that the phenomenon will present

1 H. Roepke *et al.*, "A New Approach to the Identification of Industrial Complexes Using Input-Output Data," *Journal of Regional Sciences*, vol. 14, no. 1 (1974), pp. 15-31.

2 S. Czamanski, *Regional Science Techniques in Practice* (Lexington, Mass.: D.C. Heath, 1972).

3 H. J. Richter, "The Impact of Industrial Linkages on Geographic Association," *Journal of Regional Sciences* (April 1969), p. 26.

4 *Ibid.*, p. 22.

5 M. E. Streit, "Spatial Association and Economic Linkages between industries," *Journal of Regional Sciences* (August 1969), p. 180.

itself in many forms and shapes depending upon the relative importance of each of the two forces. For instance, the strength of economic linkages is not always a good indicator of the degree of spatial association of economic activities: "there is the case of an industrial activity which, for technological reasons, depends heavily on locational proximity to another industry without obtaining the most of its inputs—in value terms—from the latter industry."[6] On the other hand, "some nonlinked sector pairs (in Leontief terms) may locate in the same areas because they are linked to a common market or source of materials."[7] However, in the case of steel, because of important transport costs, the strength of the economic linkages should decrease with distance.

Furthermore, the attraction of two industries may be bidirectional; for instance, steel mills attract steel users, and steel users sometimes attract steel mills. The latter attraction may be small. In the United States, "primary iron and steel manufacturing" is negatively correlated with linked sectors, while "metal-working machinery and equipment, etc." is positively correlated.[8] In Germany and France, the location of iron, steel sheet, and metal product industries is more influenced by agglomeration factors (expressed by the presence of all manufacturing industries) than by economic linkages.[9] Yet, in the case of electric furnaces, it is unlikely that they would be installed without a modicum of local demand; that is, local demand must cross a threshold before it attracts electric capacity. On the other hand, large BOP and OH facilities are more capable of existing independently of direct demand of local steel users; their location is more dependent upon the level of general manufacturing activity.

A final factor that makes our understanding of the relationships of geographical association difficult is the constraint implied in making the demands of local steel users the only norm to establish the ceiling of the diffusion curve. The difficulty arises from the facts that local users do not always wait for local supply of steel before beginning operations, and that steel mills do not depend exclusively on local markets to operate. Consequently, local demands do not absorb all local primary steel outputs.

The Canadian situation reflects these two facts. There are steel users in every region of Canada, but their numbers are not in direct proportion to each region's primary steel production capacity. This proportion is measured indirectly by our index of the competitive ability of local steel mills to satisfy local needs in primary steel (see Chapter 4).

On the other hand, all regions export steel to all other regions of Canada and abroad. For instance, Quebec, which accounted, in 1967, for 9 per cent of all Canadian shipments (in value terms) of the Iron and Steel Mills

6 *Ibid.*, p. 169.
7 Richter, *The Impact of Industrial Linkages*, p. 24.
8 *Ibid.*, p. 26, Table 1.
9 Streit, *Spatial Association*, p. 181.

Industry (Standard Industrial Classification 291), used only 39 per cent of its own production, exported the rest to other regions, including Ontario, which absorbed 38 per cent, and foreign countries, which absorbed 15 per cent of its production. At the same time, Quebec satisfied only 26 per cent of its own needs, importing 63 per cent from Ontario (not counting foreign imports). Similarly, Ontario absorbed 67 per cent of its own production, exporting the rest to other regions (22 per cent) or abroad (11 per cent). Nova Scotia sells all across Canada, and there are even small shipments from British Columbia to Newfoundland.[10]

There are two main reasons for the cross-hauling of steel in Canada. Steel is not an homogeneous product. There exist special steels not produced by every region. And economies of scale force producers to sell to other regions or abroad; local markets are not always sufficient.

In any case, the proportion of local demand for primary steel apparently satisfied by local supply through electric furnaces can be viewed as an index (in ordinal numbers) of the competitive ability of the electric process over other processes. Remembering that geographical association works through two sets of forces (one that stems from direct economic linkages, and the other through the presence of all manufacturing industries), we shall use both concepts to assess the ability of local electric steel furnaces to satisfy local demands.

The two concepts are illustrated in Streit's model, which relates spatial association to two sets of explanatory variables. Streit's model employs linear regression equations of the following form:[11]

$$r_{kj} = a_0 + a_1 L_{kj} + a_2 r_x + e$$

where

r_{kj} = spatial association between industry k and industry j;

L_{kj} = the strength (in Leontief's sense) of economic linkages; and

r_x = agglomeration factor $1/2\ (r_{kx} + r_{jx})$;

where

r_{kx} = spatial association between industry k and industry as a whole (x);

r_{jx} = spatial association between industry j and industry as a whole (x); and

e = an error term.

10 Statistics Canada, *Destination of Shipments of Manufacturers, 1967,* Cat. No. 31-504.
11 Streit, *Spatial Association,* p. 180.

The formula for our index of competitive ability is a cross between the location quotient and the coefficient of geographical association. It is expressed as follows:

$$\text{Index} = \frac{C_{ij}}{C_{i\cdot}} \Big/ \frac{P_{kj}}{P_{k\cdot}}$$

where

C_{ij} = capacity of electric furnaces i in region j;

$C_{i\cdot}$ = total capacity of all types of furnaces in Canada;

P_{kj} = total cost of materials used by industry k in region j. Industry k takes on the meaning of: (a) industries of the steel complex, or (b) all manufacturing industries in the two versions of the index; and

$P_{k\cdot}$ = total cost of materials used by industry k in Canada.

The formula produces an index number not linearly transformable into a measurement of the effective satisfaction of local steel needs by local steel mills. For instance, according to Statistics Canada, Quebec satisfied (in 1967) only 26 per cent of its own needs,[12] while our index suggests 30 per cent for the same year (see Table 4-3). The discrepancy is probably due to the fact that Statistics Canada figures do not take into account foreign imports, or that Quebec exports a very large proportion of its output. Some of the Quebec's capacity is geared to the demands of other regions. Cardinal measurement is not necessary, however, because our purpose is simply to develop a ranking among regions, especially Quebec and the West, to determine which has been the relatively faster adopter of electric furnaces.

Since Ontario has considerable OH and BOP capacity, the index is not relevant to the most important portion of Ontario's ability to satisfy apparent local needs. In this case, the index measures some competitiveness and some complementarity of the electric process with other processes in Ontario. Because of the lack of OH and BOP in the West and Quebec, the index is probably very significant for those regions.

The index can be calculated for each region, for each year, in two versions. The first makes the local attractiveness of the region for steel producers commensurate with the purchases of the local industries that are part of the steel complex. For computation purposes, the industries of the steel complex have been taken to be the following Statistics Canada

12 Statistics Canada, *Destination of Shipments*, p. 207.

Standard Industrial groups: No. 13—Metal Fabricating Industries (except machinery and transportation equipment industries); No. 14—Machinery Industry (except electrical machinery); and No. 15—Transportation Equipment Industries.

The second version makes the local attractiveness commensurate with the level of purchases of all the local manufacturing industries. This version is different from the first one in the sense that the emphasis is on the satisfaction of the mutual needs of both steel producers and manufacturing in general. One of the needs of the steel producers is agglomeration economies. We have previously established (from Streit's model) that they are commensurate with the purchases of all local manufacturing industries. On the other hand, these same purchases accounted for local demands for steel not taken into account by the purchases of the industries of the steel complex. The purchases we are talking about include not only raw materials and semi-finished products, but also supplies and so forth.

The index appears to be based on some implicit premises that require justification.

The first premise is that the same proportion of steel input to total inputs exists in all regions. This proportion surely exists for industries of the steel complex. The Machinery Industry, for example, should consume roughly the same proportion of steel whatever its location. The case for all manufacturing industries requires different proportions of steel in their inputs. Consequently, different regional manufacturing activities would be expected to have different relative needs for steel. However, one must note that Streit's model uses industry as a whole. At this level of aggregation, regional differences are much less pronounced, so that local steel needs are roughly proportionate to the general level of manufacturing activity.

In this study, to increase the degree of diversity of the regional industrial structure, we even provide a measurement (see Tables 4-3 and 4-4 and Charts 4-1 and 4-2) for a region that we called West, which includes both the Prairies and British Columbia. We also provide measurements for the Prairies and British Columbia separately. We could not do the same thing for the Atlantic region because Quebec is a region by itself.

The second premise seems to be that location of steel mills is determined by local demand. We have already said that this is not strictly true, especially for large BOP and OH mills. The fact of the matter is that all steel installations require a threshold of local demand. This threshold is relatively small for electric furnaces, but quite large for BOP and OH processes. However, once this condition is satisfied, any further increase in local demand may or may not lead to proportionate increases in local supply. As will be seen below, this is partly due to the fact that steel is not a homogeneous product. In fact, our model does not need a one-to-one relationship between local demand and local supply; it just requires that thresholds be satisfied.

The third premise might appear to be that the index requires steel to be a homogeneous commodity produced equally easily by any kind of furnace — that is, that the electrical process is a perfect substitute for other purposes. This is a false impression. The measurement power of the index does not require this type of homogeneity. Suppose that the demand for primary steel is in fact the sum of three demands for technologically nonsubstitutable products — billets (low-quality) for bars and rods; billets (high-quality) for certain construction steel products; and ingots for flat-rolled products — where the proportions of the general steel market accounted for by different products are as follows: bars and rods, 25 per cent; construction steel products, 20 per cent; and flat-rolled steel, 55 per cent. Suppose, furthermore, that the electric furnaces can produce only low-quality billets, and that the breakdown of the general demand is the same for all regions, although this is not always true because, in practice, steel users needing flat-rolled steel are unlikely to locate in regions where suppliers of this type of product do not exist.

In this case, it can be predicted that, in regions endowed with only electric furnaces, the value of the index will not exceed .25 (except when bars and rods are exported outside the region). This can be shown in the following manner. Rewriting the index in the following form,

$$C_{ij} \Bigg/ \left[C_{i\cdot} \left(\frac{P_{kj}}{P_{k\cdot}} \right) \right]$$

the denominator measures the local needs for all types of steel, and the numerator measures only the capacity to produce billets of low quality. Since the denominator also includes products that account for the other three-quarters of the needs, the ratio can never exceed .25. However, to the extend that exports are allowed and that the proportion of general local steel demand in the form of flat-rolled steel is allowed to decrease, as noted above, the ratio can exceed .25.

The ratio then measures the capacity of local electric furnaces to satisfy local needs from whatever source. It reflects also the degree to which electric furnaces are imperfect substitutes for other processes, especially in Ontario.

Table B-1

Steel Furnace Capacity, by Process — Open Hearth (OH), Electric, or Basic Oxygen Process (BOP) — Canada, by Region, 1956-75

	Atlantic region		Quebec		Ontario			West			Canada
	OH	Electric	OH	Electric	OH	BOP	Electric	OH	BOP	Electric	Total
					(Tons of steel)						
1956	615,000	38,000	49,000	195,900	3,413,200	350,000	617,600	50,000	—	190,200	5,518,900
1957	750,000	39,500	49,000	223,750	3,470,000	525,000	507,600	50,000	—	198,400	5,813,250
1958	897,000	37,500	49,000	291,900	3,550,000	710,000	511,700	50,000	—	221,000	6,318,100
1959	897,000	36,000	49,000	249,000	3,550,000	1,110,000	522,700	50,000	—	222,800	6,686,500
1960	927,000	36,000	45,900	223,800	3,500,000	1,440,000	521,300	50,000	—	256,700	7,000,700
1961	927,000	36,000	45,900	445,600	3,500,000	1,580,000	556,600	50,000	—	430,300	7,571,400
1962	970,000	36,000	45,900	437,200	4,025,000	1,870,000	557,050	50,000	—	439,600	8,430,750
1963	970,000	33,000	45,900	462,800	4,025,000	2,100,000	421,350	50,000	—	496,700	8,604,750
1964	970,000	33,000	45,900	538,450	4,400,000	2,550,000	411,990	50,000	—	479,900	9,479,240
1965	970,000	53,000	61,500	575,450	4,900,000	3,100,000	634,790	50,000	—	564,096	10,908,836
1966	1,070,000	45,000	61,500	593,400	5,150,000	3,550,000	709,350	50,000	—	568,520	11,797,770
1967	1,070,000	113,000	—	628,200	5,400,000	3,550,000	671,026	—	80,000	669,000	12,181,226
1968	1,070,000	113,000	—	655,900	5,900,000	3,550,000	835,350	—	80,000	689,825	12,894,075
1969	1,070,000	83,000	—	645,700	5,900,000	3,720,000	927,850	—	80,000	687,825	13,114,375
1970	1,070,000	113,000	—	658,900	5,900,000	3,720,000	915,250	—	80,000	785,225	13,242,375
1971	1,070,000	113,000	—	873,900	5,900,000	4,320,000	866,450	—	80,000	860,025	14,083,375
1972	1,070,000	113,000	—	1,493,900	4,310,000	6,610,000	898,000	—	80,000	886,225	15,461,125
1973	1,220,000	103,000	—	1,508,100	4,610,000	6,650,000	917,000	—	80,000	886,225	15,974,325
1974	1,025,000	57,000	—	1,789,900	3,100,000	9,950,000	1,224,200	—	—	1,188,600	18,334,700
1975	1,025,000	57,000	—	1,850,300	3,100,000	10,216,000	1,225,200	—	—	1,365,000	18,838,500

Source: Statistics Canada, *Iron and Steel Mills*, Cat. No. 41-203, and *Primary Iron and Steel*, Cat. No. 41-001. Figures for 1956-64 are for December 31 of the preceding year. Those for 1965-75 are for January 1 of the current year.

Table B-2

Steel Furnace Capacity, by Process — Open Hearth (OH), Electric, or Basic Oxygen Process (BOP) — Western Region, by Province, 1956-75

	Manitoba		Saskatchewan	Alberta	British Columbia	
	OH	Electric	Electric	Electric	BOP	Electric
			(Tons of steel)			
1956	50,000	71,000	—	39,000	—	79,300
1957	50,000	71,000	—	48,100	—	79,300
1958	50,000	71,000	—	77,300	—	72,700
1959	50,000	71,000	—	77,300	—	74,500
1960	50,000	104,200	—	79,300	—	73,200
1961	50,000	101,000	125,000	89,500	—	114,800
1962	50,000	101,000	121,600	90,100	—	126,900
1963	50,000	135,000	128,000	110,000	—	123,700
1964	50,000	135,000	121,600	112,600	—	110,700
1965	50,000	135,000	128,000	169,800	—	131,296
1966	50,000	135,000	150,000	165,300	—	118,220
1967	—	237,000	150,000	168,000	80,000	114,000
1968	—	239,225	150,000	170,600	80,000	130,000
1969	—	239,225	150,000	168,000	80,000	130,600
1970	—	239,225	210,000	183,000	80,000	153,000
1971	—	239,225	280,000	187,000	80,000	153,800
1972	—	239,225	300,000	192,600	80,000	154,400
1973	—	239,225	300,000	192,600	80,000	154,400
1974	—	237,000	600,000	196,600	—	155,000
1975	—	237,000	600,000	368,600	—	159,400

Source: Statistics Canada, *Primary Iron and Steel,* Cat. No. 41-001.

C Appendix to Chapter 6

Table C-1

Containerized Traffic as a Proportion of International General Cargo Traffic, Five Main Canadian Ports, 1969-75

	Halifax			Saint John			Quebec			Montreal[1]			Vancouver			
	International general cargo	Containerized cargo	Per cent	International general cargo	Containerized cargo	Per cent	International general cargo	Containerized cargo	Per cent	International general cargo	Containerized cargo	Per cent	International general cargo	Containerized cargo	Per cent	Canadian[2] traffic in containers
	(Thousands of tons)															
1969	842	50	5.9	1,135	50	4.4	795	92	11.6	3,617	496	13.7	2,754	130	4.7	46
1970	767	250	32.7	1,360	90	6.6	967	301	31.1	3,653	907	24.8	3,110	130	4.2	125
1971	1,203	696	57.9	1,218	138	11.3	1,242	603	48.6	3,851	1,276	33.1	3,807	473	12.4	219
1972	1,639	1,107	67.5	1,544	343	22.2	1,077	685	63.6	2,831	1,249	44.1	3,958	432	10.9	224
1973	1,788	1,311	73.3	1,554	491	31.6	1,133	850	75.0	3,193	1,718	53.8	3,925	545	13.9	263
1974	2,255	1,706	75.7	1,713	451	26.3	1,180	856	72.5	3,623	1,774	49.0	4,345	647	14.9	225
1975	2,026	1,384	68.3	1,617	526	32.5	640	501	78.3	2,530	1,313	51.9	3,479	577	16.6	243

1 In 1965, Montreal had 43,163 tons of containerized freight.

2 In the case of Vancouver, some purely Canadian container traffic is included. For instance, some asbestos going from a Yukon port to Vancouver as return freight could not be eliminated from the data.

Source: Unpublished data provided by G.B. Bisson of the National Harbours Board.

Table C-2

Containerized Traffic as a Proportion of International General Cargo Traffic, Port of Toronto, 1969-75

	International general cargo	Containerized cargo	Per cent
	(Thousands of tons)		
1969	763	44	5.8
1970	527	40	7.6
1971	600	56	9.3
1972	757	100	13.2
1973	478	53	11.1
1974	424	53	12.5
1975	400	100	25.0

Source: Toronto Harbour Commission.

D Wages and Technical Progress

It is commonly asserted that high wages force firms to adopt better methods. How does this fit in with the reverse view that high wages are a consequence of advanced technology? We argue here that, for an entire economy, there is probably a fallacy of composition in the view that high wages are an incentive to adopt technical methods that are known; despite this, wages are endogenous to technical progress for firms as a whole. Our argument is based, first, on a proof that this latter statement holds for a simple economy with perfect competition and, second, on the observation that the proof does not hinge in any fundamental way on the assumptions concerning perfect competition and the simplicity of the economy analysed.

Consider a production function at the firm level

(1) $q_i = A\, f(l_i\, ,\, k_i)$.

Let prices to the firm be given at p, and wage rates at w. We seek

(i) the demand for labour by the firm;
(ii) the response of the firm to a rise in wage rates; and
(iii) the response of wage rates to a technical advance.

The demand for labour by the firm is given by

(2) $p\, A\, f_{ei} = w$ (the wage equals the value of the marginal product).

It is well known that, if w increases, the individual firm will increase the ratio of capital to labour used and this will often involve what are called more progressive technical methods. The firm will move around the production isoquants in the direction of greater capital intensity.

Consider now the determination of the wage rate in the economy as a whole. In this particular industry, the demand for labour is given by summing the l_i's from equation (2) over all firms. That gives

(3) $L_d = \sum_i l_i\,.$

For capital, we have

(4) $p\ A\ f_{ki} = p_k r$, and

(5) $K_d = \sum_i k_i$.

Where we go from here depends on how we specify the rest of the economy. Consider a simple case in which there is only one product, in which the total supply of labour and capital is fixed.

Then we have

(6) $K_d = \bar{K}$

(7) $L_d = \bar{L}$.

The system now determines q_i, k_i, l_i, L_d, K_d, w/p, r/p, as functions of A, $\bar{K}$, $\bar{L}$. It is clear that real *income*, Σq_i, is a positive function of A, the level of technology, as is real income per capita, $(\Sigma q_i)/\bar{L}$ (it is here assumed that capital is owned by some or all of the labourers).

Why then is it often stated that high wages cause advanced technology, rather than the other way around?

Within the context of this simple model one can imagine two exogenous changes whose effects might, in practice, lead to this (erroneous) conclusion. One is an increase in $\bar{K}$. The other is an increase in A, the level of (neutral) technology. Consider the last phenomenon first.

A Rise in A

Suppose that not all firms adopt the new technology right away. As a specific example, let m firms adopt right away, and let n firms fail to adopt. Let the new value of A be $(A + \delta A)$.

Then we have

	Adopting firms	Nonadopting firms
(1)	$q_i = (A + \delta A)\, f(l_i, k_i)$ $i = l \ldots m$	$q_j = A\ f(l_j, k_j)$ $j = l \ldots n$
(2)	$p(A + \delta A) f_{li} = W$	$p\ A\ f_{lj} = W$
(3)	$L_d = n\ l_i + m\ l_j = \bar{L}$	
(4)	$K_d = n\ k_i + m\ k_j = \bar{K}$	
(5)	$p(A + \delta A)\, f_{ki} = p_k r$	$p\ A\ f_{kj} = p_k r$

It is clear from (3) and the top left-hand part of (2) that the demand for labour at a given real wage will be higher now than it would be if δA were zero. As compared with $\delta A = 0$, demand by the m adopting firms is higher and it is unchanged in the nonadopting firms. But that increase in demand will force a rise in real wages, since $\bar{L}$ is fixed. With that rise in real wages, nonadopting firms will cut back their demand for labour, moving along and up their unchanged marginal product schedules. Labour then shifts from nonadopters to adopters. From equation (5), we see that the same thing is true for capital. Thus, adopting firms grow at the expense of nonadopters. That will mean lower or negative profits for nonadopters, a strong incentive to adopt. Thus, it will appear that high wages are causing adoption. Yet, in fact, adoption is causing high demand for labour by adopters, which raises wages, which, in turn, forces nonadopters to adopt. It is adoption that forces nonadopters to adopt, with high wages being only the intervening mechanism, not the basic cause.

An Increase in K

An increase in $\bar{K}$ will, in the first instance, reduce $p_k r$, the rental on capital per physical unit. That will induce all firms to use more capital. As they do so, the marginal product of labour will rise and firms will demand more labour. Since the total supply of labour is fixed, wages will rise. That will be an additional force making for greater capital intensity. Thus, a process of increasing capital intensity is likely to be accompanied by rising wage rates, and it will look as though rising wage rates cause the greater capital intensity (which will look like technical advance), especially in firms that are slow to adjust, whereas the reverse is true.

This is a very simple competitive economy, but the basic results would not be sensitive to complications such as increasing the number of products, having more than one type of labour, introducing oligopolistic elements, and so forth. The key feature that generates the results is really that the total labour supply is exogenous to the economy, so that the wage rate is endogenous. In the model, exogenous means "fixed," but it could equally well mean "increasing exogenously through time." These assumptions on endogeneity and exogeneity seem reasonable for each Canadian region. The very existence of regional problems is equivalent to the assertion that labour is not mobile enough to equilibrate wages between regions — that is, labour supply is exogenous with respect to the wage in each region, and the wages are endogenous.

We conclude that it is not reasonable to ascribe backward technology in low-wage regions like the Atlantic region to low wages. Rather, backward technology, if it exists, will cause wages to be low.

There is one serious problem about determining in practice whether backward technology exists.

If rental rates are the same in the two regions, because of capital and goods mobility, but wages are not, because the production function is different for reasons other than technology—for example, resource endowment and human capital—then the region with lower wages will adopt a less capital-intensive technology. This situation is

Region 1	Region 2
$q = a\,f(k, l, r)$	$Q = A\,f(K, L, R)$

$$a < A \quad , \quad r > R$$

$\dfrac{\partial q}{\partial k} \Big/ \dfrac{\partial q}{\partial l} = \dfrac{w}{p_k r}$	$\dfrac{\partial Q}{\partial K} \Big/ \dfrac{\partial Q}{\partial L} = \dfrac{W}{p_k r}$

$$w < W.$$

Region 2 is both more advanced ($A > a$) and more capital-intensive (because $W > w$). Since a more capital-intensive technique will usually seem more technically advanced, we shall never be quite sure that the observation of "better techniques" in 2 is not due to wages that are high for reasons other than technology, forcing a more capital-intensive technology. Technology is not more backward at any given wage rental ratio, but may appear so because wage rental ratios are different. This problem faces all studies of technology diffusion, and we have no new solutions to it. But there is nothing here to distinguish between the study of international differences in technology and interregional differences in technology. This particular form of the "high wages cause high technology" argument has not inhibited researchers from drawing conclusions about the international diffusion of new technology, and it should not inhibit similar conclusions concerning the interregional spread of technology.

E The Mean Technological Lag in a Multi-Product Economy

The purpose of this appendix is to derive appropriate weights for the average technological lag for one simple kind of multi-product economy.

Suppose there are goods purchased in each of two regions, with output per unit time denoted

$q_1, q_2 \ldots q_n$ in region 1, and

$\bar{q}_1, \bar{q}_2 \ldots \bar{q}_n$ in region 2.

Define the technological lag of region 2 behind region 1 as r_i time units, such that, assuming neutral technical progress at rate λ_i in the production of good i,

$$q_i = e^{\lambda_i r_i} \bar{q}_i .$$

(If r_i is negative, region 2 is ahead of region 1.)

In region 2, the loss of output of good i attributable to the technological lag is

$$\simeq \frac{q_i - \bar{q}_i}{\lambda_i r_i \bar{q}_i} .$$

Thus the loss of value added is

$$\lambda_i r_i \bar{q}_i \bar{P}_i$$

where P_i is the price of good i in region 2.

The total loss of value added because of technological lags in all products is

$$\sum_i \lambda_i r_i \bar{q}_i \bar{P}_i .$$

Consequently, the fraction of output lost in region 2 by virtue of technological lags behind region 1, which we call Λ, is given by

$$\Lambda = \sum_i^n \bar{\omega}_i \lambda_i r_i ,$$

where $\bar{\omega}$ is the fraction of gross regional product in region 2 accounted for by product i.

The last expression may be decomposed as follows:

$$\Lambda = \lambda \sum_i \bar{\omega}_i r_i + \sum_i \bar{\omega}_i r_i (\lambda_i - \lambda),$$

in which λ can be any number, but which may usefully be taken as the national average rate of technological progress. One might plausibly assume, with λ so defined, that the second term on the right of the last equation would be much smaller than the first, since for some λ_i, $\lambda_i > \lambda$, but for other $\lambda_i < \lambda$, and since the average rate of technological progress in region i is likely to be very close to λ. If so, we have

$$\Lambda \simeq \lambda \sum_i \bar{\omega}_i r_i ,$$

and the fractional annual loss of total output in a region may then be approximated as the product of the national average rate of technical change and a value-of-production-weighted average of the lags, measured in years, in the region's individual industries.

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Summary

Productivity differences among Canadian regions are large and longstanding. A possible explanation for part of them is that innovations are typically adopted later in some regions than in others, even though they are always adopted eventually. That hypothesis, and its quantitative importance, are investigated in this book. The regional diffusion of several innovations is examined: special presses and other developments in the newsprint industry; roof trusses in the construction industry; electric furnaces and other methods of steelmaking; computers; shopping centres; and containerization of ocean cargo. It is concluded that there are significant and systematic regional lags, and that a not insignificant part of regional productivity differences are attributable to them.