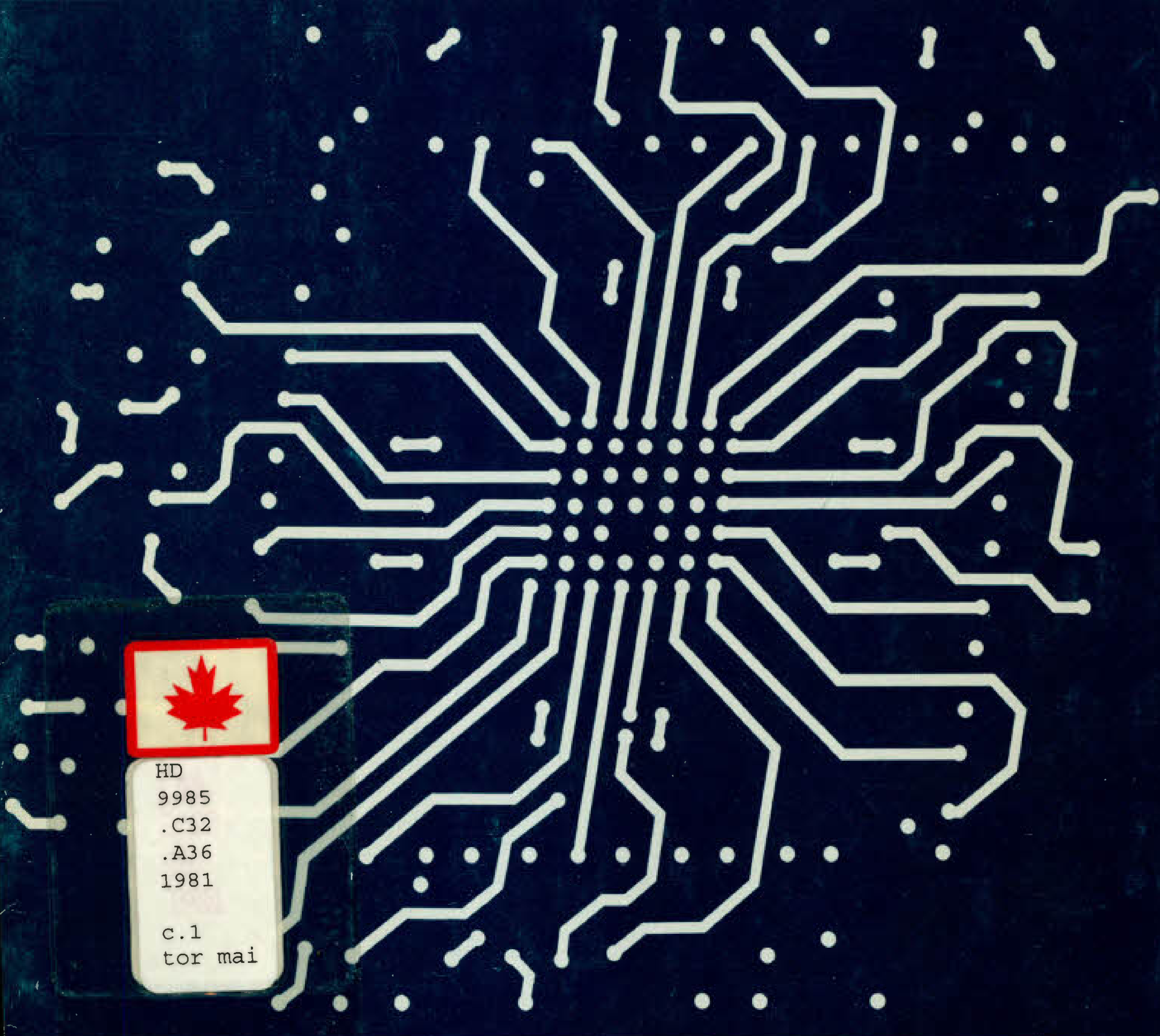
The Adoption of Computer Technology in Selected Canadian Service Industries

Steven Globerman

Case Studies of Automation in University Libraries, Hospitals, Grocery Retailing and Wholesaling, and Department and Variety Stores



A study prepared for the
Economic Council of Canada

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This study was undertaken as part of the Economic Council of Canada's series of micro-level studies on the process of technological change, productivity, and growth in Canadian industries. The purpose of the series is to improve our basic understanding of how technology is obtained, developed, and applied in the Canadian economy and of what effects this process has on the productivity, growth, and competitiveness of Canada's firms and industries.

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1 Introduction and Overview

The Policy Setting

It is widely accepted among economists and policymakers that technological change is a major factor in the promotion of increases in an economy's real output.[1] Also, the view prevails that the growth of the tertiary (or service) sector relative to the primary and secondary sectors has contributed considerably to declining productivity growth rates over the past two decades. To the extent that technological change proceeds at a slower rate in the tertiary sector, it is axiomatic that productivity growth will decline as a result of resources shifting to the service sector, other things being equal. An indication of the relative growth of the service industries in recent decades is provided in Table 1-1. Over the postwar period, employment in service industries increased from around 41.5 per cent of total Canadian employment to 65.5 per cent. Clearly, wholesale and retail trade, as well as community, business, and personal services (i.e. commercial services, education, and hospitals), are now major sectors of employment in the Canadian economy.

While there is little argument that productivity growth has been generally slower in tertiary industries than elsewhere,[2] concerns have been raised about whether conventional productivity measures are particularly biased for service sector industries. These qualifications are well-known, and it is generally accepted that problems in defining the output of service industries present a particularly severe source of bias for tertiary-sector productivity estimates.[3]

A more fundamental issue is the need to find the cause of lower productivity growth rates in service industries and to determine whether the slower implementation of new technology is a significant source of the sector's productivity problems. Numerous hypotheses have been offered in this regard. One is that the labour-intensive nature of most service activities inhibits the implementation of new technology, since new technology is often embodied in new or modified pieces of capital equipment.[4] A second is that the small, poorly capitalized firms – including those of the "mom and pop" variety – that populate service industries are ill equipped to implement new technology. Another is that many services are provided by government or other nonprofit organizations presumed to be especially inefficient.[5]

Table 1-1

Employment in Canada, by Industry, Selected Years

	1946	1961	1976
		(Per cent)	
Goods:			
Agriculture	24.8	11.3	5.0
Fishing, trapping, and forestry	2.3	1.7	.9
Mines, quarries, and oil wells	1.5	1.3	1.5
Manufacturing	25.3	24.0	20.3
Construction	4.7	6.2	6.7
Total	58.6	44.5	34.4
Services:			
Transportation, storage, and communications[1]	7.9	9.3	8.7
Wholesale and retail trade	12.0	16.9	17.3
Finance, insurance, and real estate	2.6	4.0	5.2
Commercial services, education, hospitals, and church institutions	18.9	19.4	27.1
Public administration		5.9	7.2
Total	41.4	55.5	65.5

1 Includes utilities.

SOURCE B. W. Wilkinson, *Canada in the Changing World Economy* (Montreal: C. D. Howe Research Institute, 1980), Table 3, p. 20.

While hypotheses abound, there have been relatively few studies of the process of technological change in service industries. This is particularly so, considering the large number that have been done for manufacturing industries.[6] The broad purpose of this study is to shed additional light on the adoption of new technology, or technological diffusion, in four service industries: libraries, hospitals, retailing, and wholesaling. The specific process analysed is the adoption of electronic data processing (EDP) and related computer applications. Two empirical issues were of particular interest: how rapidly firms in Canada have automated specific applications, and the factors that have contributed to faster or slower adoption in each instance. One important factor in this regard is the public policies that directly or indirectly influence adoption behaviour. Brief consideration is given to the employment implications of the process studied, although our primary focus is on the determinants of the adoption process itself.

Innovation and the Sample Industries

It has been suggested that the introduction and diffusion of the computer is the most prominent innovation in all of the service industries.[7] Thus a focus on computer automation, while hardly representative of the broad technological-change process in the service sector, affords a thorough opportunity to explore hypotheses raised about diffusion in service industries. It is also of contemporary interest to policy-makers, since opportunities to improve productivity in the service sector through computer automation are still quite substantial. Hence a successful attempt to identify barriers to faster computer adoption offers a direct policy pay-off.

Commercial applications of computer technology are numerous and varied. The most straightforward and institutionalized use of EDP has been the automation of various accounting functions such as payroll, accounts receivable and payable, and general ledger. The computer is also being utilized in production and process control applications (e.g. materials planning, production scheduling, inventory management); finance functions (e.g. costing, cash-flow analysis); marketing functions (e.g. sales analysis, ordering, site analysis); and planning (e.g. forecasting, critical path scheduling).[8] Over time, many companies have become involved in integrating computer procedures for their main company functions, to provide a total management information system. The components of such systems have one central purpose: to equip management with better information and an enhanced ability to quantify the factors upon which decision making depends.

For our sample of service industries, we attempted to identify the extent and nature of computerization.[9] Time and other resource constraints prevented us from being comprehensive in our data gathering and analysis of computer applications. For example, our survey questionnaire on EDP use in retailing and wholesaling functions concentrated on only a few specific applications in each of the broad functional areas that together constitute managements' agendas.[10] Furthermore, no explicit attempt was made to identify the precise nature of computerization – e.g. batch processing versus service bureau versus minicomputer.[11] Our empirical focus is, therefore, somewhat select in that we consider aspects of an extremely atypical innovation; however, our choice of innovation provides unity to the study and enables us to focus on a reasonably well defined set of observations. As noted above, one of the barriers to studying technological diffusion in service industries is the difficulty in clearly identifying technological innovations. Computerization provides the diffusion researcher with an extraordinarily rich set of opportunities to examine the process of technological change in industries hitherto largely ignored.

Our sample of industries, while not strictly representative, is responsible for a substantial share of employment and output in the service sector. Moreover, our sample encompasses both nonprofit organizations (i.e. hospitals and libraries) and profit-oriented organizations (i.e. retail and wholesale firms), thereby covering the major organizational hierarchies found in the sector.

Some additional insight into the coverage of the sample is provided by Table 1-2. Clearly our sample of service industries excludes a number of major tertiary industries, most notably public administration. Given the organizational and technological differences that exist between the various service industries, including the difference in capital/labour ratios exhibited in Table 1-2, caution must be exercised in generalizing our findings outside the confines of our sample. Moreover, coverage is incomplete even within the sectors studied. For example, university libraries comprise a specialized subset of the library population (public and private), which includes commercial libraries, special government libraries, municipal and provincial public libraries, and libraries affiliated with educational institutions at all levels. No estimates of the total Canadian library population are readily available. However, some perspective on the relative significance of university libraries is provided by the following data. For the year 1976/77, Statistics Canada included 77 parent university libraries in its annual report on university and college libraries in Canada.[12] Including affiliated colleges of the reporting universities, there were 110 university-affiliated libraries in 1976/77. For the same year, there were 145 college libraries and 752 public provincial and municipal libraries in Canada.[13]

University-affiliated libraries are substantially larger than college or provincial and municipal libraries. For example, total personnel costs in 1976 for university-

Table 1-2

Distribution of Capital and Labour, by Service Industry, 1976

	Proportion of total	
	Employment	Capital stock
	(Per cent)	
Transportation and storage	11.7	15.2
Communications		9.8
Finance, insurance, and real estate	8.1	8.5
Wholesale and retail trade	26.9	7.4
Commercial services	42.2	8.1
Education, hospitals, and church institutions		16.6
Public administration	11.2	34.4

SOURCE Calculated from data in B. W. Wilkinson, *Canada in the Changing World Economy* (Montreal: C. D. Howe Research Institute, 1980), Tables 3 and 6.

affiliated libraries were $90.5 million, while they were $115.7 million for all college and provincial and municipal libraries in the same year. Thus, while university libraries constitute a relatively small percentage of all public libraries, they account for the bulk of total personnel expenditures. No precise estimates of the number and aggregate size of commercial and special government libraries are readily available. A very rough estimate might place the total number of volumes housed in commercial and special government libraries at around 8.5 million, or somewhat less than 25 per cent of the volumes held in university-affiliated libraries.[14] University libraries, therefore, account for a substantial share of all library activity in Canada.

Our coverage of wholesale and retail trade is restricted to wholesaling and retailing activities in the food industry and in department and variety stores. More specifically, our sample consists of supermarket and variety chain stores, group wholesalers in the food industry, and department and variety store retailers. Our sample choice was dictated, in large measure, by pragmatic considerations; i.e. some comparable data on automation in U.S. food stores and department stores were available in the published literature. Also, opportunities to enhance productivity through automation have been particularly generous in food retailing and wholesaling.

It is difficult to establish precisely the extent of our coverage of the wholesale sector, since the wholesaling activities that we consider also include activities undertaken by integrated retailers. Statistics Canada, on the other hand, reports data on wholesaling services for wholesale merchants operating establishments primarily engaged in buying or selling goods on own account. Table 1-3 indicates, however, that food wholesaling trade comprises about 20 per cent of overall wholesaling trade. To the extent that the automation experience of independent wholesalers of apparel and dry goods and of household furniture and furnishings is similar to that of department and variety stores, our analysis of the automation of wholesaling functions would potentially bear upon almost a quarter of Canada's wholesale trade. From Table 1-4, it can be seen that food store, as well as department and variety store, sales accounted for about 38 per cent of all retail sales in Canada in 1980.

Table 1-3

Estimates of Wholesale Sales, by Sector, 1979

	Estimated sales
	($ Millions)
Food	14,617
Apparel and dry goods, and household furniture and furnishings (including floor coverings)	3,238
Motor vehicles, and automotive parts and accessories	5,767
Machinery and equipment	19,087
Building materials (including hardware, plumbing, metal, and lumber products)	14,102
Other	15,763
Total	72,574

SOURCE Statistics Canada, *Wholesale Trade, January 1980,* Wholesale Trade Section, Merchandising and Services Division (Ottawa: Supply and Services Canada, April 1980).

Table 1-4

Estimates of Retail Trade, by Sector, 1980

	Estimated sales
	($ Millions)
Food stores	19,389
Department and variety stores	9,418
Motor vehicle dealers, and distributors of automotive parts and accessories	32,264
Clothing stores	4,147
Hardware, furniture, and appliance stores	2,717
Pharmacies	2,374
All other stores	6,534
Total	76,843

SOURCE Statistics Canada, *Retail Trade, January 1980* (Ottawa: Supply and Services Canada, 1980).

Our analysis of automation in hospitals concentrates primarily upon public general hospitals. Hospitals in Canada can be basically classified into four broad categories: public general, public special, private (or proprietary), and federal government.[15] Public special hospitals include rehabilitation centres, extended care units, psychiatric hospitals, and the like. Private hospitals are primarily rehabilitation and extended care facilities, including nursing homes. In 1974, public general hospitals comprised about 69 per cent of all Canadian hospitals and accounted for approximately 78 per cent of all hospital beds in Canada. Hospital expenditures represent more than half of Canada's projected total health care expenditures in 1981.

In summary, while the scope of this study is necessarily restricted, our sample provides significant coverage of several major segments of the Canadian service sector.

A Summary of the Diffusion Literature

The literature on the adoption of new technology permits certain broad conclusions to be drawn about the diffusion process.[16] One is that for a given innovation, adoption rates can vary significantly across countries. In this regard, there is some fragmentary evidence that the adoption of innovations in Canadian and manufacturing industries proceeds at a slower rate, on average, than in similar industries in the United States and Western Europe.[17]

A second and related observation is that the rate of adoption of technological innovations ordinarily varies among firms, even within the same domestic industry. This finding is at odds with microeconomic models that assume homogeneous production functions (including homogeneous levels of managerial efficiency) across firms in narrowly defined industries; however, it is consistent with recent models of firm behaviour that emphasize that the adoption of new technology is conducted largely by trial and error methods and that, at any point in time, firms in a given industry will have differing incentives to depart from established ways of operating.[18] It is also consistent with the notion that information about new technology is uncertain and costly to obtain, and that firms differ in their efficiency at gathering and processing this information, as well as their attitudes towards risk.

A third observation is that innovations will vary in their speed of adoption. A representative finding in this regard is provided by Mansfield's (1968) study of the spread of innovations from enterprise to enterprise in four industries: bituminous coal, iron and steel, brewing, and railroads. Diffusion of new techniques in these industries was generally a slow process. Measuring from the date of the first successful commercial application, it took twenty years or more for all the major firms to install four of the twelve major innovations studied. Only in the case of three sample innovations did it take ten years or less for all the major firms to install them. The rate of imitation varied widely, however. Sometimes it took decades for firms to install a new technique; in other cases, they imitated the innovator quite rapidly. The number of years elapsing before half the sample firms had introduced an innovation varied from 0.9 to 15.

Econometric models suggest at least four characteristics of innovations that significantly condition their speed of adoption: the extent of their economic advantage over older methods or products; the extent of the uncertainty associated with using the innovation when it first appears; the extent of the commitment required to try out the innovation; and the rate of reduction of the initial uncertainty regarding the innovation's performance.

Conclusions regarding the factors that cause certain firms to adopt an innovation sooner than others are somewhat more tenuous. The bulk of relevant studies available are for manufacturing innovations. These studies generally conclude that, other things being equal, large firms tend to adopt innovations sooner than small firms. Of course, one would expect this result if large and small firms had the same propensity to adopt innovations; i.e. if one firm has 90 per cent of the market and a second firm, 10 per cent, the first firm should be observed to adopt sooner than the second about nine times out of ten, ceteris paribus. The more interesting and relevant question is whether large firms adopt innovations sooner than small firms, beyond the rate that might be anticipated solely because of normal statistical probabilities. In other words, are there economies of scale in innovation adoption? In this regard, a judicious interpretation of the available evidence might maintain that large companies are generally, but not always, leaders in the early adoption of innovations, largely owing to the fact that for most innovations there is a significant threshold level of expenditure required for successful adoption.[19] The likelihood that large firms will be the earliest adopters of an innovation is positively related to the requisite threshold expenditure level.

The speed at which firms begin to use a new technique is one aspect of the overall rate of innovation adoption. The other is the rate at which firms (having adopted an innovation) substitute the new technique for older methods. Evidence on the relationship between firm size and intrafirm diffusion is somewhat ambivalent. On balance, the few available studies of the relationship suggest that, having initially adopted an innovation, small manufacturing firms are quicker than their larger rivals to substitute new techniques for older ones.[20]

Attitudes towards risk, profit expectations, and organizational slack constitute an interrelated set of factors that (along with firm size) are presumed to explain differences across firms in rates of new technology adoption. While a number of observers claim, however, that managerial outlook and aggressiveness are crucial factors influencing new technology adoption,[21] their influence has been extremely difficult to identify statistically. This may, in part, be due to the difficulty in quantifying managerial propensities to innovate. Proxy measures such as the average age and the average education level of top management have been used to measure (indirectly) the degree of organizational receptivity towards innovation adoption. They have generally been statistically insignificant variables in econometric models of the diffusion process.[22] On the other hand, there is abundant evidence that manufacturing innovations are adopted more rapidly in less concentrated industries.[23] To the extent that industrial concentration ratios adequately measure competitive conditions, one might infer from this result that where competition is weak, organizational slack is, indeed, a significant deterrent to the adoption of innovations.

Evidence from Romeo (1975) and from Beardsley and Mansfield (1978) indicates that there is a fairly high correlation between firms' estimates of the profitability of using an innovation and the actual profitability of the investment. This result is consistent with findings that information about the "objective" characteristics of an innovation tends to be fairly widespread among potential adopters.[24] A significant element of risk apparently remains in most innovation-adoption decisions, however. This is attested to by the fact that late initial adopters frequently substitute a new technique for older techniques at a faster rate than earlier adopters.[25] Apparently the experience of earlier users of the innovation significantly lowers the perceived risks of innovation adoption for the later users.[26] While it is, therefore, quite plausible that varying degrees of risk-aversion contribute to differences in interfirm and intrafirm diffusion rates, direct evidence of the significance of this factor is difficult to find in the literature.

The relatively limited evidence available on technological diffusion in service industries tends to be consistent with some of the major findings from studies of manufacturing innovations. In particular, there is evidence of a tendency for earlier adoption to be related to firm size. In one study, Peterson, Rudelius, and Wood (1972) traced the diffusion of three life insurance innovations through the industry. They concluded that earliness of adoption is significantly related to insurance in force, with large firms tending to adopt sooner than small firms. Since the three innovations were relatively costless and low-risk, the authors interpret their results as suggesting that large firms may be more aware of what the competition is doing or better able to evaluate innovations.

Simon and Golembo (1967) studied the spread of the "January White Sale" among U.S. department stores. The data showed considerable variation in adoption across cities, with stores in larger cities generally being quicker to adopt. Since the "January White Sale" is virtually a costless innovation, Simon and Golembo hypothesize that executives in bigger stores are keener merchandisers and quicker to act. A related hypothesis is that there is more competition among stores in larger cities. That competition is a relevant spur to diffusion is evidenced by the fact that once the innovation was used by one store in a city, the second (and other) stores responded without delay, regardless of the size of the city.

Baldridge and Burnham (1975) examined the innovation behaviour of schools in a number of school districts in the San Francisco Bay area and in Illinois. The innovations were curricular changes (e.g. a new reading program) and organizational changes (e.g. new teaching methods). The authors hypothesized that in most situations increased organizational size and complexity would lead to increased innovation. One reason is that with increased size, there is an increase in specialists who handle specialized subtasks and initiate search procedures for more efficient techniques to accomplish their goals. Another is that increased size produces critical masses for certain problems that stimulate adoption of innovations to handle them. For their sample of schools, Baldridge and Burnham found that increased size and complexity were positively related to innovation; that is, the larger the school, the more innovations it adopted.

Oster and Quigley (1977) attempted to identify the determinants of differences between communities in their probability of permitting four particular innovations in building codes. They found, among other things, that the probability of adoption is significantly related to the average size of construction firms in the local housing market. They also found that jurisdictions that permit one of these innovations are more likely to permit the others, other things being equal. The latter finding is particularly interesting, since it suggests that durable differences in the propensity to adopt innovations may exist across service organizations. As noted above, studies of the diffusion of manufacturing innovations have failed to provide evidence that early adopters of one innovation are generally quicker to adopt other innovations.

Several studies have been done on the diffusion of new technology in hospitals. In one study, Russell (1979a) analysed the factors contributing to differences in the 1975 levels of intensive-care beds and of three prestige technologies – cobalt therapy, open-heart surgery, and renal dialysis – for a sample of 2,772 U.S. metropolitan hospitals. She also analysed the speed of diffusion of four other technologies – intensive care, respiratory therapy, the diagnostic use of radio-isotopes, and the electroencephalograph – using subsets of the sample. Russell concludes that the scale of a hospital's activities, approximated by the number of beds in it, was uniformly important to the diffusion of these technologies. Large hospitals adopted a given innovation sooner, on average, than small hospitals, and they were also more likely to have one of the prestige technologies. She found, however, no relationship between the percentage of beds in the four largest hospitals in a metropolitan area (i.e. an inverse potential measure of competition) and diffusion, except in the case of open-heart surgery.

Rappoport (1978), conversely, found that U.S. hospitals in a competitive environment (i.e. with more hospital beds per capita) tended to adopt the radio-isotope innovation earlier than other hospitals. He also found that larger hospitals spent more on the initial radio-isotope facility than smaller hospitals adopting at the same time. In the case of the various hospital innovations, the sample innovations were relatively costly, and differences in the availability of capital funds is one factor that undoubtedly conditions the relationship between firm size and speed of adoption.

There is only very limited evidence available on the determinants of intrafirm rates of diffusion in service industries. In one study, Globerman (1978) found no significant relationship between the number of gasoline stations operated by a company and the rate at which the company converted to self-service stations.[27] In another relevant study, McQueen and Savary (1977) concluded that with respect to placing savings accounts "on-line," small trust and loan companies were ahead of the major chartered banks in Canada.

In summary, the diffusion literature points to both similarities and differences in adoption patterns for manufacturing and service sector innovations. In both sectors, larger firms are generally quicker to adopt an innovation once it has been introduced into an industry, although it is not always true that it is more profitable for larger firms to adopt sooner. The evidence is much more ambiguous regarding whether innovations, once adopted, spread more rapidly within larger firms. Studies also tend to conclude that competition promotes faster innovation adoption in profit-oriented manufacturing and service firms. The evidence is less clear-cut in nonprofit service industries. Some very fragmentary evidence from service industries indicates that firms that are quicker to adopt one innovation may be quicker to adopt others; however, there is no evidence to this effect for manufacturing innovations. Neither manufacturing nor service industry studies have turned up much direct evidence that managerial propensities to innovate, or organizational slack, play a significant role in diffusion processes.

In reviewing the diffusion literature, it is possible to conclude that while studies (at least of manufacturing innovations) abound, a number of important issues have not been addressed satisfactorily. For example, there is a strong *a priori* notion among organizational behaviourists and many economists that differences in managerial motivation strongly affect the relative degree of innovativeness across firms. Leibenstein (1979), in particular, has argued that managers may not try to maximize profits and/or that an organization's structure may not permit certain options to come to the attention of decision-makers, either of which could contribute to organizational inertia and "x-inefficiency."

Leibenstein and others acknowledge that sheltering a firm from competition allows organizational inertia to persist. The general finding that the speed of adoption of new technology is positively related to competitive conditions is, therefore, perfectly consistent with most organizational models of the firm. Nevertheless, the lack of more direct evidence documenting the influence of organizational structure on innovative behaviour is surprising in view of its presumed *a priori* importance. Surely, there are very few industries in which competition is so ruthless as to eliminate all marginally inefficient managers. It seems valid to presume, therefore, that diffusion models seeking to identify the empirical relevance of organizational slack have largely failed to incorporate appropriate organizational variables into the estimating equations. As noted above, the management variables that have been tested are generally peripheral and, in some cases, irrelevant to the way in which organizational decisions are reached. Given the importance of the managerial efficiency issue from both a positive and a normative standpoint, the unsatisfactory empirical treatment of the issue, to date, represents an important shortcoming in the literature.

Another aspect of the diffusion literature that can be criticized is the relatively superficial treatment accorded the issue of technological specificity. More specifically, a new technology may be appropriate (or profitable) for only a subset of firms in an industry at any point in time. For any normative policy conclusions to be drawn from observed adoption behaviour, it is necessary to identify differences across sample firms in the ex ante profitability of adopting new technology. In practice, this is ordinarily an extremely difficult task and it is therefore possible to argue that many extant studies of technological diffusion do not provide unbiased estimates of the determinants of early innovation adoption. We give further attention to this issue in a later section.

A Policy Perspective

The preceding review of the diffusion literature identifies a number of important policy issues, some of which are particularly relevant to Canadian policymakers. One is the respective roles of large and small firms in promoting the adoption of new technology. A number of policy institutions in Canada have advocated promoting larger average sizes of domestic firms as a way of encouraging domestic innovation;[28] however, their focus on innovation ignores the potential impact of larger firm size on the subsequent diffusion of innovations. While the available literature suggests that interfirm diffusion rates are positively related to firm size, the evidence for service industries is relatively limited. The available evidence is somewhat contradictory regarding the relationship between firm size and intrafirm rates of diffusion; hence, there is some uncertainty about the overall impact of larger average firm size on the rate of technological diffusion, particularly in service industries. This uncertainty is accentuated by findings that strongly support the position that increased competition promotes faster adoption of new technology, both among and within firms. The evidence in this regard is not as robust for service industries as for manufacturing industries. To the extent that additional evidence confirmed the importance of competitive forces in promoting technological diffusion in service industries, a further caution would be raised against consolidating service organizations as a way of promoting technological change.

Concern has also been expressed about the contribution of diffusion gaps to interregional differences in productivity and per capita income levels. In particular, there is concern that geographic differences in managerial skill levels and that organizational slack may cause long-run disparities in productivity levels across provinces. A study of the interregional diffusion of technology, undertaken for the Economic Council of Canada, concluded that interregional differences in the diffusion of new technology do indeed exist but that they may be largely ascribed to significant differences in regional economic characteristics.[29] Only in the case of containerization of international ocean cargo did authors find any evidence that regional differences in managerial attitudes and entrepreneurship per se affected interregional diffusion patterns.

The bulk of the innovations studied by Martin et al. affected the operations of profit-oriented manufacturing companies. Interregional differences in management attitudes and organizational slack should be less frequently observed for innovations affecting profit-oriented companies, which are presumably subject to the discipline of corporate takeovers, than for innovations affecting nonprofit service organizations. Hence evidence of regional diffusion differences for service innovations would provide complementary evidence to the findings of Martin et al. Evidence of organizational slack in the adoption of service innovations would also have important implications for management policy in the public sector. Specifically, it would heighten the importance of finding ways to reward differential productivity performances, rather than treat all public institutions as identical; for example, budgeting procedures based on size or other formulas might be amended to reward innovation (or to penalize organizational slack). It should be noted that the relationship between organizational slack and innovation is an empirical one. A number of authors argue that slack resources promote organizational innovation.[30] A finding of this nature for our sample of service industries would profoundly alter any suggestions to institute incentive-based budgeting systems for nonprofit service organizations.

An important and controversial issue of particular relevance in the Canadian context is whether foreign ownership of domestic assets affects the domestic rates of technological change. According to conventional wisdom, foreign ownership speeds the adoption of new technology in the host economy but retards domestic innovation. Since our sample of service industries is, by and large, wholly domestically owned, our study will shed no additional light on this issue. An industrial-structure policy issue that is explicitly addressed in this study, however, is the relationship between vertical integration and technological diffusion. Although vertical integration has not been a prominent issue in Canadian competition policy, a recent investigation by the Restrictive Trades Practices Commission of the vertical ties between Bell Canada and Northern Telecom Ltd. raises the possibility that the issue will be of greater importance in the future.[31] Some recent research has argued quite strongly in favour of the efficiency advantages of vertical integration. More specifically, it has been argued that vertical integration enhances the ex ante profitability of innovation and the early adoption of new technology, particularly when the new technology potentially affects both the "upstream" and "downstream" portions of the industry.[32] A generalized finding in support of this position would constitute an argument in favour of the social efficiency of vertical mergers. The automation experiences of integrated and nonintegrated food companies provide a limited set of observations bearing on this issue.

A very fundamental issue that has been largely ignored in the diffusion literature is the influence of government legislation and regulation on the speed of adoption of new technology. Government regulation is a particularly significant potential factor conditioning technological change in nonprofit, government-supported institutions, such as hospitals and libraries. In the case of hospitals, for example, laws setting up a process whereby hospitals must get government approval before acquiring certain kinds of equipment could significantly affect the rate at which new hospital technologies spread through the population of potential adopters. In the specific case of automation, provincial governments in Canada have influenced the development of hospital computer technology from its earliest stages. The policy initiatives undertaken by these governments affected the degree to which different hospitals would find automation to be a cost-saving organizational change. Indeed, one tentative conclusion of this study is that government policies may have retarded the spread of computer technology among hospitals (and possibly, libraries as well) by discouraging market forces aimed at "scaling down" computer technology for efficient use by smaller organizations. Government funding policies which fail to reward (in a systematic way) efficient management of public-sector organizations may also act as an indirect barrier to the adoption of cost-saving innovations. In this regard, a finding that managers of public sector organizations constitute a heterogeneous set (with respect to their attitudes towards innovation) would accentuate the importance of designing nonmarket efficiency incentives for nonprofit industries.

Some Methodological Issues

Before presenting our individual case studies, there are several methodological issues that should be addressed. One relates to the meaningfulness of observed interfirm differences in adoption behaviour, either on an international or intranational basis. The implicit premise of most diffusion studies is that a new process or product represents a significant improvement over existing processes or products. The failure of some firms to adopt an innovation as quickly as others is, therefore, ascribed to two potential sets of factors: adoption of the innovation is more profitable for the earlier users, and/or managerial attitudes towards risk, organizational slack, and comparable factors influencing management propensity to innovate differ between earlier and later adopters.

Conceptually, the advantages of adopting a process innovation (such as computer technology) can be calculated in a fairly straightforward way. If an innovation makes it possible to produce a given amount and quality of output at a lower operating cost, compared to existing technology, the present value of this operating-cost saving (evaluated over the entire projected range of output for the productive life of the innovation) constitutes the benefit derived from the adoption of the innovation. The purchase price of the innovation, plus any capital losses associated with the premature scrapping of existing process equipment, represents the cost of its adoption. The net benefit of innovation adoption at any time period (t) can therefore be estimated as the difference between these two aggregates. Presumably firms will allocate their scarce financial capital by investing in those activities offering the greatest expected net benefits. If all firms in an industry confront a reasonably similar set of investment alternatives, we would expect that those firms anticipating the greatest net benefit from adopting an innovation would, in fact, be the earliest adopters of the innovation, other things being constant.

Most studies try to evaluate the anticipated economic benefits of an innovation and limit the sample of potential adopters to those firms that would benefit economically from innovation adoption; however, it is often difficult to establish whether a given innovation represents an economic, as well as a technical, improvement over existing techniques, particularly in the early stages of the diffusion process. Furthermore, it is extremely difficult to identify with any precision ex ante differences among firms in the net benefits of adopting a given innovation.

Another complication is raised by the possibility that firms may have different perceptions about the profitability of adoption and/or about the impact of delaying adoption on the profitability of adoption. For example, while all firms may perceive the adoption of an innovation to be profitable at a given point in time, a subset of firms might consider it even more advantageous to delay adoption until a later time period.[33]

An implication of the foregoing considerations is that observed time differences between firms in adopting new technology do not, by themselves, identify technological "leaders" and "laggards." The observed diffusion gaps have policy relevance only if the expected profitability of adoption (over time) is identical for all organizations being compared or if any differences that exist can be accounted for empirically, either by direct measurement or by satisfactory proxy variables. As noted above, most studies attempt to standardize for interfirm differences in the ex ante profitability of innovation adoption at discrete points in time, usually at an early stage in the adoption process.[34] Proxy independent variables, such as firm size, geographic location, and the like, are usually employed in this exercise. It is unlikely, however, that these proxies are perfect, or that they are even necessarily unbiased estimates of the ex ante profitability of innovation adoption. Nevertheless, they are usually the best estimates available. In this study, we rely upon proxy measures of ex ante profitability to standardize for differences in the anticipated net benefits of automation among Canadian and U.S. firms. While a substantial effort was made to qualify the merits of the various proxies used, it does not obviate the caveat that our "diffusion gap" measures are imprecise and therefore not very meaningful in instances where differences in adoption behaviour are relatively small.

Another issue, also bearing on the relevance of observed diffusion gaps, arises from the possibility that the degree of success associated with innovation adoption varies systematically across firms. For example, while U.S. firms may adopt an innovation sooner than Canadian firms, the U.S. firms may have greater difficulties integrating the innovation into their organizations and may therefore realize much smaller benefits per dollar of investment. In this case, the policy implications of the observed diffusion gap are less obvious than if the degree of success in innovation adoption had been constant across the sample firms. While we reviewed the available trade literature to determine whether significant ex post differences in the profitability of innovation adoption existed among comparable firms, our review was not definitive.

Notwithstanding the foregoing disclaimers, we feel safe in making the following observations. The bulk of available evidence supports the contention that the innovations considered in this study represent real economic improvements over pre-existing techniques. Furthermore, profitable adoption was not necessarily restricted to a small subset of firms. While the ex ante profitability of EDP adoption may (in its earliest stages) have been positively related to firm size, access to service bureaus and other shared computer facilities enabled small firms to benefit significantly from automation as well. The fact that a number of sample EDP applications, particularly the automation of accounting functions, had been implemented in the manufacturing sector well before their adoption by most service industries provides an additional argument that our sample service organizations were aware of the advantages of EDP. Thus there is a basis for the belief that observed interfirm differences in EDP adoption reflect, to some degree, the influence of organizational and managerial differences and not merely "unexplained" differences in the ex ante profitability of EDP adoption.

2 Innovation in University Libraries

A number of industry experts argue that apart from the application of photographic technology (e.g. copying machines, microfilming of records, and so forth) automated library systems represent the first major breakthrough in library technology since the invention of printing by movable type.[1] The concept of automated library systems is imprecise; for example, in the trade literature it has been applied to systems as widely diverse as electronic tabulating machines and on-line, minicomputer-based systems. If the definition of automation is restricted to computerized data processing, thereby excluding equipment such as electronic typewriters and bookkeeping machines with data storage capacity, pioneer library computer systems can be dated back to the mid-1960s. Early approaches to library automation were typically piecemeal in nature and utilized batch-processing technology; that is, individual library operations were automated separately over time rather than as an integrated system of operations.[2] Circulation and the ordering and acquisition functions were typically the earliest activities to be computerized, as they were relatively straightforward record-keeping processes, in contrast to activities such as cataloguing or serials control.[3]

Since the introduction of the early automated systems, a number of important changes inside and outside the industry have expanded the sophistication and potential scope of library computer applications. For example, the development of the MARC format (i.e. machine-readable catalogue tapes) by the Library of Congress in the late 1960s was an event of major importance in the automation of cataloguing. Advances in communications technology, particularly the improved speed and accuracy with which digital information can be carried over conventional telephone lines, have facilitated on-line and networking systems. The latter, which involves on-line use of a common computer by multiple libraries, promotes the capturing of economies of scale at the central processing level.

At present, there is a wide spectrum of library systems: some on-line and some batch-processing, in-house systems, and networks. The existence of a broad spectrum of systems reflects not only the influence of previous automation decisions but also a diversity of opinion regarding the relative economic advantages of different automation techniques. Indeed, while most general library functions in university libraries have been at least partially automated,[4] there is no consensus on the expected cost savings associated with the various available automated systems. This is partly the result of inadequate data to enable comparison between automated systems and the manual or semi-automated systems being replaced. Also, automation obliges the systems designer and senior librarians to reassess existing operating procedures in order to facilitate the implementation of new systems. These reviews frequently uncover potential operating efficiencies not necessarily tied to automation. It is unclear whether these efficiency gains should be credited to automation per se. Finally, automation ordinarily changes the nature of the services provided and facilitates the introduction of new services. While it is seldom difficult to show that improved standards of service have resulted from automation, it is a different matter when it comes to attaching a dollar value to such improvements; consequently it is difficult to demonstrate that the value of improved services outweighs any additional costs.

For the foregoing reasons, it is impossible to conclude that computerized systems represent an unambiguous economic, as well as technical, improvement over manual and semi-automated systems in Canadian university libraries. It should be noted, however, that individual case studies,[5] as well as the author's review of a number of annual reports of Canadian university libraries,[6] tend to report that automation imparted net economic benefits. Specifically, while comparatively few staff savings were made possible immediately upon mechanization, library business was thereafter able to grow quite rapidly with only a small increase in effort by the library staff.[7] Furthermore, after some initial "teething" problems, the quality of service was deemed by most library managers to have improved substantially.

In summary, while the benefits and costs of library automation cannot be quantified precisely, the balance of largely anecdotal evidence available suggests that computerization, particularly of the more easily automated activities such as circulation and the preparation of subject indexes, does represent an economic improvement over pre-existing methods. The perceived net benefits vary by user and by system. For example, there are indications that off-line, computerized circulation systems begin to have lower unit costs than manual systems, in academic libraries issuing something in the range of 250 or more items daily, and that unit costs for on-line circulation systems can be up to twice those for off-line systems.[8] The existence of economies of scale in library automation is evidenced in other library operations as well. For example, the more frequently a holdings list is updated, reordered, or reclassified, the greater the advantage of a computer system. The greater ex ante economic advantages from automating larger library systems must be recognized in attempting to evaluate interfirm differences in automation adoption.

Automation in Canadian University Libraries

Information on the automation of university libraries is available from two published surveys. One survey, undertaken for the American Library Association, drew its sample from a comprehensive list of North American libraries and information centres that could conceivably have been users of data processing equipment.[9] Statistical results were based on returns from 6,150 libraries. The survey found that a total of 79 four-year college and/or universities in the United States were using computers in one or more library applications in 1966. The total increases to 82 if community colleges are included; with the inclusion of all other automated academic libraries, primarily medical school libraries, there were 95 automated academic libraries in the United States in 1966. In contrast, the survey identified only five Canadian university libraries using computers in 1966 for one or more library applications.[10]

To compare the relative level of adoption in U.S. and Canadian university libraries, we must standardize for differences between the two samples in the potential number of adopters. One relevant consideration in this regard is whether a critical threshold was necessary for a university library to automate economically one or more functions as early as 1966. As noted in the preceding section, several factors suggest that early library automation was characterized by economies of scale. Specifically, the potential benefits of computerization in a number of important library functions were positively related to the volume of output or the repetitiveness of a task. Furthermore, the presence of on-site computer expertise, usually drawn from the data processing centres of larger universities, was essential for successful automation in the 1960s, given that very few outside sources of library computer expertise were available;[11] however, the information available is insufficient to define the precise extent and magnitude of these scale economies. Nor is it possible to identify a size cutoff for economical versus noneconomical automation.

If one makes the extreme assumption that all university college and junior (or community) college libraries, regardless of size, were potential adopters of automation as early as 1966, the population of potential adopters in the United States and Canada equaled 2,163 and 235, respectively.[12] The ratio of adopters to potential adopters in 1966 would, therefore, equal 0.038 (i.e. 82 divided by 2,163) for the United States and 0.021 (i.e. 5 divided by 235) for Canada. If one assumes, alternatively, that the size "cutoff" for economical adoption excludes community and junior colleges, an alternative estimate of relative adoption levels would be obtained.[13] One might also want to recognize that some colleges included in the total of 235 Canadian university and college libraries are actually affiliated colleges of a parent university. It might be argued that most of these affiliated colleges are too small to constitute potential adopters or, equivalently, that their decisions to automate could only be economically justified if they were tied to ongoing automation in main university libraries.[14] If we redefine the population of potential adopters to include only four-year college or university libraries and exclude affiliated and junior and community colleges, our prior findings would be reversed. Specifically, the 1966 adoption ratio for Canada would increase to 0.083 (i.e. 5 divided by 60), while the ratio for the United States would increase to only 0.055 (i.e. 79 divided by 1,442).[15]

The latter estimate must be treated with great caution, since it undoubtedly leaves the U.S. sample with a substantially higher percentage of small, independent regional colleges that serve the same function as affiliated "satellite" colleges in Canada. The estimate of 60 main college and university libraries in Canada excludes regional colleges, as well as art colleges, community colleges, public colleges in Alberta, colleges of applied arts and technology, colleges of agricultural technology in Ontario, private colleges in Quebec and collèges d'enseignement général et professionnel (CEGEP). The number of libraries in these excluded colleges is not reported for the 1966/67 academic year; however, in 1971/72, regional college libraries and the like were approximately 75 per cent of the number of main college and university libraries listed. If one assumes that the same percentage held in 1966/67 and if one redefines the set of potential adopters in Canada to include regional colleges and the like, the 1966 adoption ratio for Canada decreases to 0.052.

Differences in the number of departmental and special libraries in the university systems of the two countries could also contribute to the observed differences in adoption ratios. Specifically, a greater number of volumes located in departmental libraries might encourage the main library to automate specific functions earlier than otherwise – particularly those of acquisition, serial control, and information dissemination. The number of departmental and special libraries associated with main university or college libraries in Canada is unavailable for 1966. Recent data suggest, however, that departmental libraries constitute a higher proportion of all university and college libraries in Canada than in the United States.[16] If this were true for 1966 as well, it would help to explain the apparent higher adoption ratio for the Canadian sample of potential adopters restricted to main universities and colleges.

To summarize, given the difficulty in unambiguously defining a comparable set of potential adopters in the two countries, one cannot draw any strong conclusions about early adoption patterns in Canada and the United States. Different measures lead to somewhat different conclusions. A prudent assessment might therefore maintain that any differences in early adoption were not marked. This, by itself, does not imply that the rate of automation in Canada was "optimal," since diffusion rates in U.S. university libraries may have been slower than could be economically justified.[17] Conversely, significantly slower rates of diffusion in Canada, given comparable ex ante benefits of adoption, would be some indirect evidence of a diffusion gap in Canada.

The similarity of early automation experience in Canada and the United States is further underscored by available evidence on the number of computer applications relative to the number of adopting firms. Table 2-1 reports the number of computerized activities among automated main college and university libraries in Canada and the United States.[18] It can be seen that the relative emphasis on adoption, by library application, differs between the two countries. For example, greater relative emphasis was placed on early circulation automation in Canada, while U.S. libraries placed a relatively greater emphasis on automating serials and periodicals and managerial activities.[19] The average number of computer applications per adopting library, however, was quite comparable. The 79 four-year college and university libraries in the United States that had automated at least one library function by 1966 had, on average, 2.4 automated applications; the 5 automated main university libraries in Canada had, on average, 2.0 automated applications in 1966.

Table 2-1

Automation in College and University Libraries, by Selected Activity, Canada and United States, 1966

	Number of applications	
	Canada	United States
Acquisitions	1	18
Cataloguing	2	24
Circulation	3	18
Serials and periodicals	2	46
Administration and management	1	29
Abstracting and indexing	—	8
Bibliography and special catalogues	—	16
Dissemination	—	6
Information and retrieval	—	13
Miscellaneous	1	15
Total	10	193

SOURCE Author's calculations based on data in Creative Research Services Inc., *Use of Data Processing Equipment by Libraries* (Chicago: American Library Association, 1966).

A more recent survey of library automation was undertaken by the LARC Association. The LARC survey was based primarily upon a comprehensive review of the library automation literature along with select follow-up surveys. Data on automation in U.S. libraries are provided for 1971,[20] while comparable data for Canadian libraries are available for 1972.[21] The 1971 survey identified 176 four-year U.S. college or university libraries having at least one automated library activity. The total rises to 195 academic libraries if community college and medical school libraries with automated library applications are included. The 1972 survey identified 15 Canadian university libraries having one or more automated library applications; however, there is reason to argue that the number of automated Canadian libraries is underestimated in the LARC survey, since a study done by the Commission on Post-Secondary Education in Ontario identified a number of university libraries in Canada that were automated by the end of 1971 but were not cited as being automated in the LARC survey.[22]

As noted earlier, a good deal of uncertainty exists, even among librarians, about what constitutes automation, and even a fairly detailed survey would fail to obviate this ambiguity.[23] We attempted to reconcile differences between the LARC survey and the Commission's study by contacting the systems librarians at those Canadian libraries mentioned as being automated in the latter survey but not in the former survey. Since not all of the resident systems librarians were knowledgeable about their library's automation status as far back as 1972, annual reports of the libraries in question were also consulted. Our follow-up efforts suggest that at least eight Canadian university libraries not indicated as being automated by the LARC survey were, in fact, automated by 1972. Including these 8 as part of the group of adopters raises to 23 the total number of Canadian university libraries automated by 1972.

The question once again arises as to the definition of "potential adopter." If the population is defined as all university, college, and junior college libraries, the 1972 adoption ratio for Canada equals 0.11; the 1971 adoption ratio for the United States equals 0.07. The LARC survey may have also underestimated the number of automated U.S. university libraries, however, and there was no convenient way to evaluate the potential magnitude of any such bias. If the relative extent of underreporting is assumed identical for the U.S. and Canadian populations, the estimated number of U.S. adopters would increase to 270,[24] and the 1971 U.S. adoption ratio would approximate 0.11.

Given our ignorance about the precise bias in the LARC survey of U.S. university libraries, as well as the potential incomparability between U.S. and Canadian samples for any single definition of potential adopter, a conservative conclusion about interfirm diffusion patterns is appropriate. Specifically, it does not appear that Canadian university libraries lagged behind U.S. university libraries in implementing automated library techniques. This conservative conclusion is reinforced by the observation that the 23 automated Canadian libraries had, on average, 3.73 automated applications, while the 176 automated U.S. libraries had, on average, 2.10 automated applications.[25]

Anecdotal evidence also tends to support the contention that early automation of university libraries in Canada proceeded somewhat faster than in U.S. university libraries. The Commission on Post-Secondary Education in Ontario undertook a rather informal survey of library computer application in the United States and concluded that, if anything, U.S. library automation projects were lagging behind those in Canada.[26] The Commission ascribed this lag to the U.S. practice of funding automation projects by special grants rather than by operating grants, which, in turn, leads to funding inconsistencies and the resulting termination of many promising projects. Representatives of the University of Toronto Library Automation Systems group (UTLAS) expressed their belief (in a meeting with the author) that while the U.S. library profession might have been slightly ahead of their Canadian counterparts in terms of technical approach in the mid-1960s, Canada achieved comparability fairly quickly.

The lack of any strong evidence that Canadian university libraries lagged significantly behind U.S. university libraries in the early automation of library functions is encouraging, given evidence from the manufacturing sector suggesting that, on balance, diffusion in Canada is slower than in the United States. There is a basis, however, for arguing that Canadian university libraries should have been significantly faster adopters of automation. Specifically, the average Canadian university library is larger than the average U.S. university library.[27] To the extent that profitability of adoption is positively related to library size, the average Canadian university library would find automation more profitable than the average U.S. university library. Thus, other things being equal, one would have anticipated Canadian university libraries to have enjoyed a lead over U.S. libraries in adopting computerization.[28] The possibility raised by this observation is that organizational and "market-related" factors may have discouraged the adoption of computer technology in Canada relative to adoption in comparable U.S. libraries. To explore this possibility further, a cross-sectional model of computer adoption was specified and estimated, in which various factors, including proxies for the ex ante profitability of automation, were included as explanatory variables.

An Empirical Model of Library Automation

In order to determine the distinct influences of size and other factors on the automation decision, multivariate regression analysis was employed. Given the very small number of automated Canadian libraries in 1966, the dependent variable was initially specified as a binomial variable (A_i), taking a value of 1 if the i^{th} library had one or more automated functions by 1972 and 0 otherwise. Theoretical considerations, as well as anecdotal evidence, suggest a number of relevant independent variables to consider. One is the size of a university library. Given presumed economies of scale in library automation, one would expect larger libraries to automate sooner than smaller libraries, other things being equal. Statistical results reported below are based on total library expenditures in 1970/71 (E_i) as the size measure. Total expenditures are a fairly comprehensive "flow" measure of a library's overall activities; however, substantial correlation between "flow" measures such as total expenditures and stock measures such as total volumes of books and periodicals and total staff left our results fairly insensitive to the precise measure chosen.

Holding the ex ante profitability of adoption constant (as proxied by the expenditure variable), the decision to automate should be conditioned by competitive pressures and similar factors influencing management's receptivity to change. While profitability considerations do not constrain the behaviour of library managers, librarians are, for various reasons, desirous of demonstrating increased patronage of their institutions. For one thing, librarians' claims for increased public funding may depend upon their ability to demonstrate an increased demand for services; for another, librarians may pursue larger size as a prestige motive. While no direct measure of potential competition exists for our sample of Canadian university libraries, a plausible proxy measure is the number of institutions providing comparable services in the market served by a given library. It is not obvious how to define the "relevant market" for university libraries. One can reasonably argue that it is a provincial, local, or (in some cases) national market. The nature of the data available suggested a convenient measure of potential competition: a Herfindahl index (H_i) based upon the relative volume holdings of university libraries in their respective provinces.[29] The dependent variable should be negatively related to the Herfindahl index.

A number of observers have argued that libraries are ordinarily characterized by slack or operating inefficiencies and that library managers are concerned with promoting greater efficiency only when their work volume increases relative to available labour resources.[30] Budget tightening is, therefore, alleged to be an important factor promoting library automation.[31] On the other hand, researchers such as W. J. Baumol and M. Marcus (1973) claim that efficiency in libraries is extraordinarily high. Thus the question of whether libraries operate with significant slack appears to be an empirical one. It has obvious importance for policy in that if organizational slack is a relevant constraint on innovation, the adverse impact of budget reductions on real output in the sector could be mitigated in part, or entirely, by increased efficiency in the sector. A variable (S_i), included to test the empirical relevance of the "slack" argument, is the percentage growth in salary expenditures minus the percentage growth in total library volumes over the period 1967-71. A slower growth in salary expenditures relative to library volumes is taken to be a measure of increased work volume relative to available manpower.[32] Presuming significant "x-inefficiency," this should (by reducing slack) encourage library automation.

Another variable (F_i), included to capture the potential impact of organizational slack, is the ratio of total professional librarians to total full-time equivalent staff in 1970/71. Since automation of most library activities is designed to economize on labour input and improve the quality of service, it might be organizationally easier to automate when nonprofessionals comprise a substantial percentage of the library's staff. For one thing, the implicit promise of "permanent" employment is much weaker in the case of nonprofessional librarians. For another, professional librarians may be important participants in the automation decision. To the extent that they see automation as a long-run threat to their economic or professional security, they are in a position to directly oppose the automation process. We therefore anticipate a negative relationship between F_i and the dependent variable. It should be noted that F_i may also be influenced by whether a library automates. That is, where automation occurs, and assuming it primarily replaces mainly nonprofessional labour, F_i would tend to rise. Such simultaneity would work against the presumed negative relation from F_i to A_i.

Several studies have attempted to identify a firm's propensity to innovate by constructing a summary index of its past innovation-adoption behaviour.[33] In other words, they have attempted to measure any durable differences between firms in managerial receptivity towards innovation by positing an empirical relationship between historic and current innovation-adoption behaviour. It is not surprising that such studies (which have largely focused on profit-oriented firms) do not reveal the existence of perpetual adoption leaders and laggards. Where adoption of new technology was an important element of competitive strategy, chronic laggards would realize permanently lower rates of return, ceteris paribus. Given equal capital costs across firms, laggards would either be bought out by more efficient competitors or forced to leave the industry. This need not be the case, however, for nonprofit organizations receiving public subsidies. Nonprofit organizations do not necessarily face a market survival test of efficiency; hence there may be no market check on persistent delay in implementing new technology. To test the hypothesis that some libraries are more inclined to adopt new technology than others, we employ data for one relevant historical innovation: the adoption of microfilm, microfiche, and microcards.[34] Specifically, we identify a library's receptivity to innovation adoption (M_i) as the ratio of its total holdings of microfilms, microfiche, and microcards to its total holdings of all volumes (printed or micro-coded) as of the 1970/71 academic year. To the extent that there is organizational persistence in delaying innovation adoption, we anticipate a positive relationship betweem M_i and the dependent variable.

Two other independent variables were included in the initial estimating equation. One variable (L_i) is the ratio of salary expenditures to total library expenditures in 1970/71. Since library automation is primarily designed to effect labour savings, L_i should be positively related to A_i, to the extent that a higher value of L_i denotes a greater potential opportunity to introduce computerization of library functions. However, there is a potential simultaneity problem here as well. That is, early adoption (by reducing part-time employment) could reduce the ratio of salary expenditures to total expenditures, if reductions in part-time employment expenditures were not redistributed (directly or indirectly) to full-time employees. Such simultaneity would impart a negative bias to the L_i coefficient. The second variable (C_i) equals the total number of book volumes in all libraries in the city in which the i^{th} sample library is located divided by the total population of the city.[35] The presumption here is that the C_i variable serves as a rough proxy measure of the overall demand for library services in the local market area served by the i^{th} university library. A greater demand for library services (including new or improved services) in the immediate market area served by a sample library should, other things being equal, promote the library's decision to automate.

The foregoing discussion can be summarized by the following functional-form equation, where the i subscript denotes each individual sample library:

1 $$A_i = f(E_i, H_i, S_i, F_i, M_i, L_i, C_i).$$

For estimation purposes, the function was specified to take a linear form, thereby converting equation 1 into a linear probability function. The equation was estimated by ordinary least squares (OLS) over a sample of 43 Canadian university libraries, for which full information on all variables was obtainable. Results are reported in equation 1(a) below:[36]

1(a) $$A_i = 0.8983 + \underset{(2.59)}{0.0001E_i} - \underset{(-1.51)}{0.3849H_i} - \underset{(-1.90)}{0.0519S_i} - \underset{(-1.18)}{1.732F_i} + \underset{(1.35)}{0.2450M_i} - \underset{(-0.96)}{0.0692L_i} + \underset{(0.82)}{0.0034C_i}$$

$$\bar{R}^2 = 0.265 \qquad F = 2.82$$

The E_i variable is statistically significant at the 0.01 level, confirming our prior notion that economies of scale did exist in the earlier stages of the automation process. The S_i (slack) variable is significant at the 0.05 level. This result supports the hypothesis that resource constraints provide a motivation for library managers to adopt automated technology. The H_i variable takes the expected negative sign but is significant only at the 0.10 level. The M_i variable is also significant at the 0.10 level. The statistical insignificance of the F_i variable could reflect a potential simultaneity problem as described above, as could a negative sign for the L_i variable. Summarizing our results, while all coefficients take their expected signs, most are statistically insignificant. Taken as a whole, the results support the view that (holding ex ante profitability constant) differences in managerial propensities to adopt cost-saving innovations, which are in turn related to organizational and environmental factors conditioning efficiency incentives, are significant determinants of library automation.

Several other independent variables were included in estimating equation 1(a). One was the age of the university library. A previous study by Globerman and Book (1974) found some evidence that older arts organizations were less efficient than younger ones. The age variable was, however, statistically insignificant when included in equation 1(a), and its inclusion reduced the overall goodness-of-fit statistics. A set of regional dummy variables was also included, identifying libraries by province.[37] Only the dummy variable for British Columbia was remotely robust: it was positive and statistically significant at the 0.15 level. All the estimated coefficients remained essentially unchanged with the inclusion of the regional dummies. The adjusted coefficient of determination, of course, declined.

Several points should be made about equation 1(a). The use of OLS estimation with a binomial dependent variable raises two statistical concerns. One is that some estimated values of the dependent variable may fall outside the zero/one range for forecast values of a probability function. The other is that residuals may be heteroscedastic. While estimation techniques are available that constrain forecast values of the binomial dependent variable to lie within a zero/one range, their results are difficult to interpret and, moreover, are not clearly superior to ordinary least squares.[38] In any case, less than 10 per cent of the forecast values from equation 1(a) fell outside the zero/one interval. Problems of heteroscedasticity are also suggested to be minor, particularly when the variance of the dependent variable lies between 0.2 and 0.8.[39] In the case of equation 1(a), the variance of the dependent variable was approximately 0.37. Moreover, a parametric test enabled us to reject the hypothesis of heteroscedastic residuals at the 0.01 level.[40] Thus there is reason to believe that the variances of the estimated coefficients would not be affected by employing more complex, generalized least-squares estimation.

We were also interested in determining whether variables identified in equation 1(a) were capable of explaining the extent of automation in individual libraries. For this purpose, the dependent variable N_i was defined as the number of library applications automated by 1972. All independent variables remain as defined above. Results of OLS regression are given in equation 1(b):

$$\text{1(b)} \quad N_i = 2.4040 + \underset{(1.74)}{0.0004E_i} - \underset{(-1.63)}{2.834H_i} - \underset{(-1.58)}{0.1494S_i}$$

$$- \underset{(-1.20)}{5.231F_i} + \underset{(2.63)}{1.813M_i} - \underset{(-0.56)}{0.1691L_i} + \underset{(0.26)}{0.0002C_i}$$

$$\bar{R}^2 = 0.329 \qquad F = 3.34$$

The basic results of the two equations are quite similar. Specifically, the signs of all variables are identical, and goodness-of-fit statistics are comparable. One difference is that the statistical significance of the M_i variable increases markedly (to the 0.01 level) in equation 1(b), while the significance of the E_i variable decreases to the 0.05 level. The H_i variable remains significant at the 0.10 level. Thus the basic set of factors determining whether a library had been automated by 1972 appear relevant for determining the extent of automation.[41]

Summary and Policy Implications

Available information on the automation experience in Canadian and U.S. university libraries admits a guarded conclusion that diffusion rates in the two countries did not differ markedly in the early stages of the diffusion process. This does not, however, provide a basis for concluding that the diffusion rate in Canada was socially optimal. Economies of scale in the earlier stages of library automation should have contributed to faster automation of Canadian libraries, given that Canadian college and university libraries were larger, on average, than their U.S. counterparts. Thus the actual rate of diffusion in Canada provides some cause for concern about the existence of greater organizational slack in Canada.

Many observers argue that library management is characterized by a significant degree of slack or "x-inefficiency."[42] Our limited statistical analysis lends some empirical support to this argument. Specifically, an increase in the workload relative to available labour resources promoted automation. Moreover, potential competition among libraries encouraged automation. Some additional evidence that slack or "x-inefficiency" can persist in this sector is suggested by the observation that the extent of adoption of a prior innovation (i.e. micrographics) was positively and significantly related to the extent of computer adoption. Finally, the greater the ratio of professional librarians to total staff, the slower the rate of automation. This suggests that cost savings may not constitute a prominent objective of professional library managers.

The policy implications of the foregoing findings are not obvious. Some of the important factors influencing automation exert contradictory influences. For example, encouraging a concentration of library resources in a smaller number of larger libraries would, among other things, reduce competition in the sector. Reduced incentives to adopt new technology attending a reduction in competition could more than offset any benefits associated with greater scale economies. Attempting to encourage greater efficiency by periodic tightening of operating budgets could have unintended consequences if libraries are left with insufficient resources to make the necessary investments in new technology.

Several broad policy suggestions may, however, be advanced, based on the evidence at hand. One is the imperative to instil greater incentives of efficiency in libraries.[43] Incentive budgeting, whereby libraries are assured of keeping some (perhaps an escalating) percentage of cost savings in their future budgets, is one possible approach along these lines.[44] Another suggestion confronts the economies-of-scale/level-of-competition conundrum. Specifically, responsible government agencies might attempt to do more to spur the "scaling down" of new technology. In the case of libraries, for example, only the very largest libraries could afford the heavy costs of developing, maintaining, and operating complex, localized computer-based systems. The opportunity to join networks or to purchase turnkey minicomputer systems from commercial vendors offered an expanded opportunity for small libraries to automate economically. Criticism has been raised that inappropriate emphasis was placed by the federal and provincial governments on developing library networks in Canada. This emphasis, in turn, delayed definition and the solution of systems problems at the local level through, for example, minicomputer automation.[45] The centralization of automation decisions in provincial ministries and the heavy emphasis on networks has been criticized as delaying the more rapid development and implementation of minicomputer technology in hospitals as well. While a full examination of the validity and relevance of these criticisms is beyond the scope of our study, there is some *a priori* reason for concern that government policies discourage the "scaling down" of capital-embodied technology in nonprofit service industries.

3 Innovation in Hospitals

As noted in the preceding chapter, apart from the application of photographic technology, library technology was relatively static prior to the introduction of computer applications. Conversely, technological change in hospitals has been quite marked over time, even prior to computer automation. In particular, new surgical and diagnostic techniques have been implemented, as well as improved patient-care procedures. It is neither possible nor necessary to review these innovations in this report.[1] Several of the more significant recent advances will be briefly cited, however. Recent major innovations in the health services industry encompass both organizational and operational changes. For example, the hospice concept, whereby critically ill patients and their relatives are provided with health services and psychological guidance on an ongoing basis, represents a major new direction in hospital treatment of the dying patient. Specialized facilities for in-patient treatment, such as intensive care units and inhalation therapy departments, have become widespread over time. More prosaic, but nonetheless significant, changes have taken place in operational areas such as the laundry and food services departments of hospitals. Innovations in hospital laundries include larger and more productive equipment and automatic materials handling. Mechanization in hospital kitchens include the formation of central commissaries, more extensive conveyorization, and the use of microwave ovens. The use of disposable products to replace items that require cleaning, sterilization, or other reprocessing is also indicated to be a source of savings in supply and manpower costs.

One main point to note is that new medical technology is frequently embodied in expensive capital equipment, and in many cases it is not clear that the associated expense is justified by the increased effectiveness of the new equipment.[2] Since one basic presumption of diffusion studies is that a new technique represents an economic improvement over existing techniques, it is not possible to draw normative welfare conclusions about many new hospital technologies. Nor is it possible to interpret slower adoption of new technology as evidence of managerial slack. Indeed, bureaucratic hospital models provide a theoretical basis for presuming that hospitals may consistently purchase new "prestige" pieces of equipment before the purchase can be economically justified. In this regard, Russell (1979b) notes that the belief that hospitals adopted technologies too slowly gave way to the belief that they adopted them too quickly and that too many hospitals adopted them.

Hospitals began implementing computer systems in the early 1960s. Prior to 1960, electronic computers were not in general use in hospitals. Early use of computers focused on administrative applications, particularly payroll systems, and was batch-processing oriented. A few hospitals experimented with the development of fully integrated systems designed to meet all hospital information requirements, both administrative and clinical; however, most were unsuccessful, and the failure to develop "total" medical information systems has led to the division of the medical data base into manageable components. For example, subdata bases exist, dealing with such problems as drug and pharmacy orders, doctors' orders, patient history information, and so forth.

The major advance in computer technology during the 1970s has been the availability of on-line systems that provide hospital personnel direct access to computerized data files through communications terminals and the development of minicomputers. With the appearance of the micro-processor, automation is now possible in virtually any existing type of clinical equipment found in the hospital. For example, computers are being used along with closed circuit TV, EKG machines, blood pressure indicators and other devices to monitor patient condition. They are also being used as automated diagnostic and decision aids (e.g. planned radiation therapy). Computers and related equipment are being introduced in clinical labs to process on-line data from lab test equipment and in clinics to undertake multiphasic patient examinations.

While some recent applications of computer technology in hospital practice have been technologically spectacular (e.g. computerized trans-axial tomography (CAT) scanners), the net economic benefits of many medical applications of computer technology have not been convincingly demonstrated to date. Real cost savings are, however, demonstrable for the more prosaic applications of computers, particularly for hospital payroll and patient billing systems. These simple accounting systems represent the earliest applications of electronic data processing in hospitals and, to date, constitute the areas of greatest penetration of EDP, notwithstanding the expansion of other accounting-related functions such as inventory, pharmacy records, purchasing, and logistics.[3]

Only a small minority of hospitals have undertaken formal studies to evaluate the effectiveness of their EDP systems. The few available case studies provide evidence that computerization has saved costs in financial and accounting applications.[4] Furthermore, surveys of hospitals indicate that EDP users are generally pleased with the results realized. The overwhelming majority claim that automation has enhanced their overall operations and that the money spent was clearly or marginally worthwhile. The greatest benefits claimed are money savings, followed by greater overall control, better accounts receivable, and improved accuracy.[5] Major variations exist, however, in the benefits received per dollar of EDP investment. For example, while some economic success has been claimed for computerization of medical records and data bases, the evidence available is not as impressive as for the previously cited automated accounting functions. In summary, it would seem justified, in focusing on administrative applications of computers in hospitals, to presume that faster adoption promised an improvement in overall sectoral efficiency.

Automation in Canadian Hospitals

The benefit potential of computerization of information handling in hospitals was recognized as early as 1960; however, as was true for libraries, the automation of information storage and processing systems in hospitals lagged well behind comparable efforts in profit-oriented sectors.[6] For example, only 30 U.S. hospitals reported on-site computer installations in 1962.[7] Medicare and Medicaid legislation in the mid-1960s, however, prodded many U.S. hospitals and other health care organizations into the use of computers to handle their financial and accounting processes.

Two major surveys of the use of computer-based information systems in U.S. hospitals are available. One study, done by the Hospital Financial Management Association (HFMA), is based on a survey questionnaire mailed to approximately 7,000 American hospitals. Analysis and results were based on 2,300 returned questionnaires. This study reports a striking rate of EDP adoption: around 90 per cent of respondents had used some form of electronic data processing for at least one of their applications by 1976. While a large group of hospitals (approximately one-third) are members of organizations of data-processing users and hence may do no data processing on their own premises, the extremely high rate of reported computer users is remarkable in light of the relatively slow start made by hospitals in the automation process. It is also troubling in light of a more recent and equally comprehensive survey conducted by the American Hospital Association (AHA), which indicates a substantially lower level of EDP use. Specifically, the 1979 AHA survey was also based on a questionnaire mailed to over 7,000 hospitals; about half responded. Results indicated that only 65.4 per cent of all respondents had used computers in one or more applications by 1979. This overall percentage reflected a weighted average of 52.3 per cent for public hospitals and 73.1 per cent for private hospitals.[8]

The contradictory results cannot be easily reconciled, as they reflect the only available comprehensive surveys of hospital automation in the United States. It has been estimated that 846 U.S. hospitals had on-site computer installations in 1970, while an additional 2,041 employed the services of off-site computer facilities.[9] Given that there were around 6,800 hospitals in the United States in 1970, the imputed adoption ratio for that year is around 42 per cent. Thus the HFMA result implies a substantially faster rate of adoption by nonusers than does the AHA estimate. One might argue that the AHA results are more reliable since they are based on a larger set of respondents. Also, responding hospitals may have been more careful in providing accurate information to their own association headquarters than they would have been for an independent research organization. In any case, the differences between Canadian and U.S. adoption ratios are sufficiently large that the discrepancy between the two U.S. studies is not of critical importance.

The most comprehensive source of information about computer use in Canadian hospitals is the publication, *Health Computer Applications in Canada*, the first volume of which appeared in December 1974.[10] This annual survey provides information on current and prospective users of computer systems in three major application areas: clinical, administrative, and research. The information is provided on a voluntary basis; that is, hospitals and service bureaus that wish to be included in the publication for a given year must (on an unsolicited basis) submit a description of their computer systems to the editors. This ad hoc method of information gathering can be expected to result in some underreporting of computer use.[11] An additional problem arises from the fact that the publication frequently fails to cite the number of hospitals belonging to a particular service bureau identified in the report. In other instances, an unidentified number of hospitals will be indicated as sharing computer facilities housed in a single hospital, further complicating efforts to identify automated and nonautomated Canadian hospitals.

In order to complement the data provided in the publication, we undertook a limited supplementary survey. This consisted primarily of contacting the major hospital computer service bureaus in Canada and asking them to identify subscribing hospitals, as well as the computer applications provided subscribers. Hospitals providing computer services for other hospitals were also contacted for similar information. Finally, all hospitals that indicated in the Canadian Hospital Association's *Canadian Hospital Directory* that they had a data processing department or a systems analyst on staff, but that were not listed in *Health Computer Applications in Canada*, were contacted directly for information about their use of EDP equipment. In most cases, the latter inquiry resulted in reclassification of a hospital from a nonautomated to an automated station. This supplementary survey undoubtedly reduces, but does not eliminate, the underreporting bias cited above.

The various data sources indicate that around 260 Canadian hospitals (excluding nursing homes, medical clinics, and the like) used data processing for either clinical or administrative applications in 1974.[12] Given that there were 1,379 Canadian hospitals listed in the *Canadian Hospital Directory* in 1974, approximately 19 per cent of all Canadian hospitals were computerized in one or more major applications by 1974. A more comparable approximation to the 1979 AHA estimate of U.S. hospital automation is provided by our estimate of EDP use in Canadian hospitals for 1978.[13] Information supplementary to the data provided in *Health Computer Applications in Canada* was gathered in a manner similar to that described for 1974. We estimate that the number of Canadian hospitals using EDP for clinical or administrative applications increased to 404 in 1978. The total number of Canadian hospitals listed in the 1978 *Canadian Hospital Directory* equaled 1,356. Hence the 1978 ratio of adopting hospitals to total hospitals was around 30 per cent. This ratio lies well below the AHA's estimate of EDP adoption by U.S. hospitals in 1979. Even acknowledging the possibility that EDP use by Canadian hospitals (as estimated above) is underreported, the discrepancy between the Canadian and U.S. adoption levels seems too substantial to be attributable to data errors.

One cannot necessarily presume from the foregoing observations that Canadian hospitals were slower than U.S. hospitals to adopt automation, holding ex ante profitability of adoption constant.[14] As was the case for libraries, a critical size threshold must presumably be reached before a hospital would find it profitable to automate. No precise estimate of this threshold is available. Some industry participants argue that with access to service bureaus, any sized hospital could have justified automation as early as 1970. Others argue that evaluation of systems and the ability to justify computer expenditures to provincial ministries require a hospital to be a minimum size (having, perhaps, as many as 200 beds).[15]

The average-sized Canadian hospital in 1978 had 144 rated beds; by comparison, the average-sized U.S. hospital had 198 rated beds. One implication of this observation is that relatively more Canadian hospitals may find themselves falling below the critical size threshold for economical automation. To the extent that larger size is a significant factor in earlier adoption, the observed differences between Canadian and U.S. adoption levels may be attributed, in some measure, to size differences between Canadian and U.S. hospitals; however, the argument that economies of scale exist in the hospital automation activity is a contentious one. At least one study concludes that small hospitals have a greater incentive to automate because they cannot afford to pay for additional personnel to perform tasks that are similar to those handled on a noncomputerized basis by larger hospitals.[16]

Some preliminary indication of the importance of size in the adoption decision is provided in Table 3-1. The table shows the average size of adopting and nonadopting Canadian hospitals in 1974. The results reported in the table are somewhat ambivalent with respect to the size/computerization relationship. In all cases, the average size of adopting hospitals is significantly greater than that of nonadopting hospitals; however, the average size of adopting hospitals in some provinces is comparable to the average size of nonadopting hospitals in other provinces. This observation suggests a number of possibilities. One is that the size/computerization relationship differs across provinces; another is that the observed size/computerization relationship is influenced by other factors whose effects must be held constant in order to identify the true relationship. In the following section, we report the results of a multivariate statistical analysis designed to identify the influence of hospital size and other relevant factors on the automation decision.

Table 3-1

Average Size of Hospitals Adopting or Nonadopting Automation, by Province, 1974

	Average number of admissions	
	Adopters	Nonadopters
Atlantic provinces	6,232	2,222
Quebec	12,546	5,874
Ontario	13,349	4,811
Manitoba	2,876	650
Saskatchewan	5,911	647
British Columbia	6,716	1,203

SOURCE Calculations based on data provided by the Health Computer Information Bureau, in *Health Computer Applications in Canada*, and supplemented by author's survey.

Before turning to this task, we should note that the difference in average hospital size is not the only potential factor accounting for the observed Canada/U.S. differences in hospital automation. The more detailed, itemized reporting requirements for health insurance claims are suggested to provide U.S. hospitals with a stronger incentive to automate. An alleged advantage in batch-processing expertise in the United States may also have contributed to the U.S. lead in early automation. It has also been suggested that the United States has a more developed hospital industry computer service group than Canada, although Canada enjoys an advantage in terms of more advanced interactive computer software.[17] Industry observers have expressed concern that hospital administrators in both Canada and the United States are risk-averse and have trouble defining their computer needs. Hospital administrators may have weak incentives to cut expenses if they fear that any resulting savings will lead to subsequent budget cuts. In this regard, the greater percentage of private hospitals in the United States might mitigate, to some degree, efficiency disincentives in the U.S. hospital sector.

In summary, the diffusion gap between Canada and the United States in hospital automation cannot be attributed unambiguously, in part or in whole, to greater "x-inefficiency" in Canadian hospitals, given the variety of other possible causes; however, the influence of organizational slack and managerial propensities upon innovation may be identified through a direct modeling approach, in the manner undertaken for university libraries.

An Empirical Model of Hospital Automation

Our dependent variable was again specified as a binomial, taking a value of 1 if a sample hospital had one or more automated administrative (or clinical) functions by 1974 and 0 otherwise.[18] Hospital size is one independent variable ordinarily included in a model of hospital innovation. While there is uncertainty about the empirical relevance of economies of scale in recent automation activity, there is less doubt that economies of scale were relevant in the early period of in-house, batch-processing computing. Furthermore, there is a basis for arguing that administrators in large hospitals found it easier to convince provincial health authorities that automation was a good idea for their institutions. Provincial governments have been continually concerned about redundant automation and have consequently separated the planned computer expenditures of hospitals from other expenditures for careful evaluation. While the degree of centralization and formality of the approval process varies from province to province, a review of government initiatives in the early stages of automation suggests that health officials were convinced that scale economies existed in the automation process.[19] As noted above, even systems experts disagree on the relative advantages of centralized data processing versus decentralized distributed processing; however, the fact that the relevant regulatory agencies apparently believed that economies of scale existed in automation undoubtedly increased the receptivity of larger hospitals to the idea. Finally, it was indicated to us that hospitals under a minimum size (having around 150 to 200 beds) are unlikely to have competent systems people on staff and may have difficulty articulating their system requirements to outside consultants. For these and other reasons, we would expect a positive relationship between the size of a hospital and the likelihood that it was automated by 1974.

Previous studies by Russell (1979) and Rappoport (1978) indicated that teaching hospitals were quicker to adopt new techniques for diagnosis and treatment than nonteaching hospitals. This is suggested to reflect, in part, prestige motivation on the part of teaching hospitals. Also, to the extent that new equipment attracts patients with "unusual" ailments, the adoption of new equipment promotes a hospital's teaching function. The automation of administrative activities is not likely to augment the prestige of a hospital, at least in the view of the lay public. Hence, stress on enhancing prestige at the expense of economic efficiency could cause teaching hospitals to overlook EDP for other forms of new technology. This possibility was investigated by including a dummy variable, T_i, taking a value of 1 if a hospital was a teaching institution and 0 otherwise.

The decision to automate is also potentially influenced by factors affecting managements' receptivity to change. One such factor is the degree of competition facing hospital administrators. While it is unlikely that automating a hospital's administrative functions would directly increase the hospital's patient load, it could help to reduce operating inefficiencies, thereby allowing the hospital to operate at a higher level of capacity.[20] Perhaps a more important factor is that government health officials may be loath to reject the funding demands of hospitals that provide the sole source of patient care over a substantive geographic area. In regions where a number of hospitals service the community, administrators may be less vulnerable to claims that budget cuts threaten the availability of medical services in a given region. If this phenomenon operates to any significant extent, it could promote increased slack in hospitals that essentially have a monopoly on hospital care in a given region. Consequently, we would expect early automation to be positively related to the level of competition that a hospital faces. An indirect reason for anticipating a positive relationship between automation and competition is that local monopoly positions are generally enjoyed by hospitals in rural areas. Since there are presumably some external economies in using shared computer facilities, smaller hospitals in urban areas are in a better position to utilize central processing units located off premises than are their rural counterparts.[21]

Our measure of competition facing a sample hospital is similar to the Herfindahl index employed in the library model. In the case of hospitals, however, the relevant market area is the town or city in which the hospital is located.[22] It is reasonable to presume that the relevant market for hospitals is much smaller than that for university libraries. For one thing, doctors will refer and admit patients to their affiliated hospitals, and ordinarily these will be close to where their practices are located; for another, acute cases will generally go, or be taken to, nearby hospitals. To be sure, local monopolies may exist in subregions of a large city. Hence, our measure of a hospital's relevant market may be too broad in some cases; no convenient alternative measure was available, however. Our Herfindahl index (H_i) is therefore calculated as the squared value of the ratio of total beds in a hospital to the total number of hospital beds in the town or city in which it is located, summed over all hospitals in that town or city for 1974.

An explicit proxy for organizational slack, found to be statistically significant in the estimating equations for libraries, was included as an independent variable in the hospital model. The variable S_i was measured as the percentage growth in hospital admissions minus the percentage growth in personnel over the period 1970-74.[23] A larger value of S_i is taken to indicate greater demands on the resources of an organization and, therefore, greater pressure on hospital administrators to adopt innovations that promise to conserve scarce resources. Another variable included to capture a hospital's propensity to innovate was a dummy variable (M_i), taking a value of 1 if the sample hospital had converted to metric measurement by 1974 and 0 otherwise. While metrication is not the most prominent indicator of prior-to-adoption behaviour that might have been chosen, it was the only measure for which data were available.[24]

Two other independent variables were specified to capture organizational differences in innovation propensity. One was a dummy variable (R_i), taking a value of 1 if a hospital had a religious affiliation and 0 otherwise. While there was no suggestion in our discussions with industry representatives that lay administrators were more receptive to organizational change than clerical administrators, the organizational behaviour literature would suggest that organizational change is more difficult to introduce in more highly structured hierarchies.[25] Our presumption is that the managerial hierarchy is more highly structured in religious hospitals. A related notion is that lay administrators are more likely to possess either formal or occupational exposure to accounting and management information systems and are, therefore, more favourably disposed to implement automation, other things being equal. While the theoretical justifications for including the R_i variable are somewhat speculative, they appeared as interesting propositions to test.

Another independent variable included (G_i) was the age of the sample hospital in 1974. Older hospitals are typically located in the downtown core of an urban area. For a number of reasons, we would expect urban-core hospitals to be under greater pressure than hospitals elsewhere to automate their administrative functions. One reason is that the postwar migration of educated middle-income Canadians to suburban areas is likely to have increased the difficulties faced by urban-core hospitals in attracting skilled, clerical employees. Another is that downtown urban hospitals are more likely to be confronted with constraints on storage space, further increasing the incentive to convert record-keeping functions from manual filing systems to more space-efficient computerized systems.

Estimation Results

The functional form of the empirical relationship is given by equation 2 with the variables defined as above:

$$2 \quad A_i = g(Z_i, T_i, H_i, S_i, M_i, R_i, G_i).$$

Table 3-1 which reports the average size of adopting and nonadopting hospitals, by province, gave some preliminary indications that the adoption/size relationship might vary between provinces. This possibility is enhanced by the fact that provincial policies towards hospital automation differed somewhat. Specifically, while all provinces were essentially centralist in their administration of hospital computer budgets, some provincial governments allowed hospitals greater freedom in their computer expenditure decisions than did others.[26] Given these *a priori* differences, it seemed appropriate to test whether data pooled across provinces constituted a homogeneous cross-section. A covariance test, owing to Chow (1960), enabled us to reject the hypothesis that the coefficients estimated in equation 2 were equal among provinces; thus equation 2 was estimated across hospitals, segmented by province.[27] In all cases, the sample sizes (fixed essentially by the availability of data for all relevant variables) were large enough so that segmenting hospitals by province did not raise concerns about degrees of freedom.

Table 3-2 reports results for the linear estimation of equation 2, employing four size measures: admissions (Z_{1i}), beds (Z_{2i}), staff (Z_{3i}), and expenditures (Z_{4i}). The equation can again be interpreted as linear probability functions, with the estimated coefficients representing the marginal probabilities of automating associated with each variable. Potential problems associated with the use of a binomial dependent variable were noted earlier; however, as with the library model, violation of zero/one boundary conditions was relatively infrequent, and the hypothesis of heteroscedastic residuals was rejectable. Several other points must also be noted. Since it was felt that there were too few teaching hospitals in Manitoba and Saskatchewan to permit reliable estimation of the T_i coefficient, the variable was dropped from equations 2(m) to 2(w). Furthermore, the Herfindahl index (H_i) was redefined in equations 2(m) to 2(p) as a binomial variable equal to 1 if a hospital was located in Winnipeg and 0 otherwise. Since Winnipeg was the only city or town in our sample of Manitoba hospitals to have more than one public general hospital, a continuous specification of the H_i variable seemed inappropriate. This respecification would lead us to expect the H_i variable to have a positive coefficient in the Manitoba equations.

The results reported in Table 3-2 are somewhat perplexing in that the signs and significance levels of the estimated parameters are not consistent across provinces. For example, while the size coefficients are all positive and significant at the 0.05 level in a majority of cases, they are insignificant in the British Columbia and Manitoba samples. The finding that larger hospitals were generally first to automate, ceteris paribus, is consistent with evidence from other studies of service sector diffusion, including the studies of hospital automation cited earlier. It is also consistent with the notion that the observed gap between U.S. and Canadian hospital automation levels is partly explicable by the larger average size of U.S. hospitals.

The teaching variable is, by and large, statistically insignificant. This result, while at odds with the findings of previous hospital innovation studies, is not unexpected, since (as noted earlier) automation of administrative functions is unlikely to be seen as a "prestige" innovation. The Herfindahl index provides mixed results. The variable has the anticipated negative sign for the Quebec and British Columbia samples and the anticipated positive sign for the Manitoba sample, although it is statistically robust only in the Quebec sample. In our other three samples, the observed sign is perverse and is statistically significant in two equations for the Ontario sample. Thus our results provide mixed support for the hypothesis that increased concentration retards diffusion of new technology among hospitals. We would point out, however, that the impact of competition on the propensity to innovate should be more marked when the innovation is clearly tied to improved patient care.

The statistical performance of the "slack" variable (S_i) is disappointing, particularly in light of its relatively strong performance in the library automation model. It takes the expected positive sign in four of the six provincial samples, but is never significant at the 0.05 level. It is possible, of course, that our specification of the variable does not directly capture a hospital's need to automate the personnel function, which was the first administrative application of computers; however, the only other variable that it made sense to use in its stead – i.e. the growth in personnel over the period 1970-74 – did not provide markedly better results.

The metrication variable (M_i), taken to be an index of managerial propensity to innovate, tends to

Table 3-2

Regression Results for Hospitals

			Variables											
Equation	Province	Constant	Z_{1i}	Z_{2i}	Z_{3i}	Z_{4i}	T_i	H_i	S_i	M_i	R_i	G_i	$\bar{R}^2$	F
2(a)	Ontario	-.4514	.0001				-.2123	.2991	-.0011	.2487	-.0283	.0021	.453	14.91
	(142 hospitals)		(5.80)				(-1.38)	(2.16)	(-.40)	(3.39)	(-.31)	(1.66)		
2(b)	"	-.4437		.0016			-.2700	.2925	-.0009	.2644	-.0242	.0016	.479	16.50
				(6.34)			(-1.77)	(2.23)	(-.34)	(3.72)	(-.27)	(1.32)		
2(c)	"	-.1881			.0005		-.3962	.1169	-.0010	.2787	-.0254	.0018	.379	9.80
					(4.20)		(-1.63)	(.78)	(-.35)	(3.58)	(-.26)	(1.27)		
2(d)	"	-.0544				.0299	-.0873	.0199	-.0011	.2557	-.0388	.0019	.327	8.02
						(3.01)	(-.49)	(.13)	(-.37)	(3.06)	(-.39)	(1.25)		
2(e)	Quebec	.1926	.0000				.0057	-.2310	-.1970	.0668	-.1615	.0002	.291	5.92
	(105 hospitals)		(2.89)				(1.50)	(-2.25)	(-1.46)	(.75)	(-2.02)	(.17)		
2(f)	"	.2412		.0005			.0057	-.2470	-.1944	.0622	-.1610	.0002	.274	5.54
				(2.54)			(1.48)	(-2.38)	(-1.42)	(.69)	(-1.99)	(.15)		
2(g)	"	.2282			.0002		.0047	-.2131	-.1528	.0650	-.1537	.0002	.305	7.16
					(3.30)		(1.25)	(-2.06)	(-1.14)	(1.74)	(-1.95)	(.16)		
2(h)	"	.1915				.0218	.0047	-.1905	-.1612	.0724	-.1360	.0003	.328	7.83
						(3.73)	(1.28)	(-1.86)	(-1.23)	(.83)	(-1.74)	(.18)		
2(i)	British Columbia	.8464	.0000				-.0543	-.3101	.0396	.1959	-.2530	-.0021	.179	3.43
	(79 hospitals)		(1.57)				(-.17)	(-1.39)	(.32)	(1.74)	(-1.69)	(-1.07)		
2(j)	"	.8576		.0004			-.0713	-.3213	.0499	.2997	-.2645	-.0020	.174	3.35
				(1.43)			(-.22)	(-1.44)	(.37)	(1.78)	(-1.72)	(-.99)		
2(k)	"	.9299			.0001		-.0381	-.3913	.0448	.2261	-.2796	-.0018	.161	3.13
					(.91)		(-.107)	(-1.81)	(.362)	(2.02)	(-1.80)	(-.904)		
2(l)	"	.9266				.0119	-.0521	-.3965	.0518	.2254	-.2840	-.0017	.160	3.13
						(.89)	(-.14)	(-1.85)	(.42)	(2.01)	(-1.84)	(-.83)		
2(m)	Manitoba*	.6576	.0000					.3627	.0842	-.0861	-.2307	.0016	.025	1.24
	(56 hospitals)		(.407)					(1.30)	(.97)	(-.61)	(-1.20)	(.392)		
2(n)	"	.6545		.0002				.3999	.0828	-.0938	-.2303	.0021	.023	1.21
				(.204)				(1.50)	(.878)	(-.65)	(-1.19)	(.49)		
2(o)	"	.6463			.0003			.2829	.0797	-.0963	-.2465	.0017	.021	1.16
					(.363)			(1.42)	(.782)	(-.71)	(-1.24)	(.43)		
2(p)	"	.6521				.0086		.3225	.0811	-.0940	-.2445	.0017	.021	1.16
						(.472)		(1.48)	(.82)	(-.66)	(-1.23)	(.43)		
2(q)	Saskatchewan	-.1349	.0001					.2867	.1201	-.0172	.0257	.0059	.447	13.44
			(5.24)					(.63)	(1.01)	(-.178)	(.27)	(2.71)		
2(r)	"	-.4657		.0023				.3286	.1225	-.0188	.0598	.0057	.464	12.11
				(4.19)				(.86)	(1.04)	(-.20)	(.63)	(2.68)		
2(s)	"	-.4182			.0037			.2526	.1268	.0101	.0479	.0051	.458	11.82
					(4.62)			(.58)	(1.05)	(.15)	(.48)	(2.59)		
2(t)	"	-.3455				.0925		.200	.136	.0170	.0671	.0071	.423	10.41
						(3.36)		(.48)	(1.12)	(.17)	(.67)	(3.28)		
2(u)	Atlantic provinces	-.2040	.0001				.2835	.2447	.2036	.0241	.2061	-.0008	.272	4.37
	(64 hospitals)		(2.99)				(1.34)	(.85)	(1.13)	(.19)	(1.73)	(-.28)		
2(v)	"	-.1476		.0012			.2811	.2001	.2033	.0834	.2149	.0005	.221	3.55
				(2.17)			(1.26)	(.67)	(1.10)	(.66)	(1.74)	(.17)		
2(w)	"	-.1076			.0004		.2884	.2211	.2143	.1196	.2195	.0012	.204	3.30
					(1.85)		(1.26)	(.72)	(1.13)	(.96)	(1.76)	(.43)		
2(x)	"	-.1013				.0330	.2946	.2171	.2015	.1389	.2230	.0014	.201	3.27
						(1.79)	(1.29)	(.71)	(1.06)	(1.13)	(1.78)	(.51)		

NOTE A t-statistics is shown in parentheses below each coefficient. $\bar{R}^2$ is the overall coefficient of determination adjusted for degrees of freedom. In the Manitoba regression equation, the Herfindahl variable is defined as a binomial, taking a value of 1 if the sample hospital was located in Winnipeg, and 0 otherwise.

reaffirm the findings of our library model; i.e. there may be organizational persistence in propensities to innovate among nonprofit organizations. This conclusion is tempered, however, by the negative findings for the Manitoba and Saskatchewan samples. In the case of hospitals, early automation is generally associated with early metrication; however, the relationship is statistically robust only for the Ontario and British Columbia samples. Another index of the propensity to innovate (R_i) was a surprisingly strong variable. In four of the six provincial samples, it had the anticipated negative sign and was statistically significant (at the 0.05 level) in the Quebec and British Columbia equations. Our earlier hypothesis as to why lay administrations might be quicker to automate their hospitals is admittedly speculative. Furthermore, it does not account for the opposite experience of hospitals located in the Atlantic provinces. Resolution of this apparent inconsistency requires further study.

Summary and Policy Implications

Our empirical model of hospital automation, by and large, supports the finding that large service-sector organizations are quicker to implement an innovation than small organizations. Unfortunately, it was not possible to test a corollary hypothesis – i.e. that innovations spread more quickly through large service organizations than through small ones. Our attempt to identify the impact of competitive pressure on automation adoption, as well as the impact of managerial attitudes towards innovation, had mixed success. More specifically, while there was some indication that these factors are relevant, statistical results were inconsistent across provincial samples. This inconsistency suggests that the relevant independent variables may be imprecisely specified in given samples. Unfortunately, economic and organizational information on individual hospitals is extremely limited, and the set of variables selected represented virtual exhaustion of the data available.

Our tentative statistical examination prohibits drawing any firm policy conclusions; however, the finding that certain organizational characteristics are associated with faster or slower adoption has interesting policy implications. Specifically, universal-funding approaches that fail to acknowledge differences in organizational efficiency implicitly penalize efficient administrators and allow inefficient organizational behaviour to persist. There is nothing startling or new in the observation that the nonprofit status of hospitals is a significant obstacle to efficiency. Fraser (1975), among others, has argued that the absence of personal property rights, which necessarily implies that the hospital trustees and administrators have no claim to any residual wealth that might be generated, is most likely the prime cause of weak incentives to minimize costs. Our finding that organizational and environmental incentives to automate may differ between hospitals suggests that there is some possibility for funding agencies to identify efficient and inefficient organizations and implement appropriate financial incentives to induce laggards to emulate leaders more quickly. The design and implementation of such policies would undoubtedly be fraught with contention and would be severely circumscribed by the need to maintain a minimal quantity and quality of care in existing hospitals; however, there would appear to be some urgency in addressing this issue.

The finding that large hospitals automated earlier than small hospitals is not necessarily a recommendation for hospital mergers, since such mergers would also be likely to increase concentration in relevant markets, thereby potentially mitigating incentives to innovate. A broader and potentially more promising policy approach is to attempt to promote the "scaling down" of new technology, thereby improving access of small units to new technology. In this regard, there has been criticism that Canadian health authorities have not created an environment that will attract many top computer professionals. A particular problem is the excess of bureaucracy in the hospital/government interface. The isolation of health professionals from any substantive knowledge of computing was suggested in a number of interviews as being a major barrier to computerizing the health care system. At a minimum, it seems relevant to suggest that government administrators be careful not to perpetuate an economies-of-scale bias in the development and adoption of new technology. For example, it is possible to argue that in the case of hospitals, provincial ministries remained overly committed to the networking or service bureau concept, thereby retarding efforts to implement minicomputer technology in medium-sized and smaller hospitals.

4 Innovation in Grocery Retailing and Wholesaling

Grocery retailing has undergone a marked transformation over time in both marketing and production techniques. Perhaps the most fundamental marketing change in food retailing was the appearance of the supermarket. The planned shopping centre, anchored by a "flagship" supermarket and department store, represents another fundamental marketing innovation.[1] Other significant organizational changes affecting grocery retailing include the co-operatively owned and voluntary groups and, more recently, box stores and superstores. Co-operatively owned groups are characterized by multi-unit and single-unit store owners who own and direct a wholesale company, while a voluntary group comprises single and multi-unit retailers affiliated with an independent, profit-seeking wholesaler. Co-operatives and voluntary chains made their appearance in the United States before they emerged in Canada. Box stores (adapted from the European prototype) made their initial appearance in Canada in 1978. The box-store concept limits selection to the 500 or so most commonly purchased items, whereas a standard supermarket carries 8,000 or more items. The customer in box stores also bags his or her own groceries.[2]

Numerous other technological innovations that have taken place in food retailing over the past 20 years should be mentioned. Table 4-1 provides a summary list of selected innovations in food retailing over approximately the past 20 years. To this list might be added the fairly recent introduction of generic food products,[3] energy control devices, digital electronic meat and produce scales, and flexible grocery shelving systems.

Notwithstanding this impressive list, it can be argued that the adoption of computer technology represents the most important breakthrough in grocery retailing operations to date. The potential impact of automation on the industry's operations is becoming even more dramatic with the recent advances in micro-processing technology and the intersection of computer and telecommunications technologies.

The initial application of computer technology in food retailing was, as elsewhere, the automation of routine bookkeeping operations at head office level. These early applications included payroll, accounts receivable and payable, and inventory control. Subsequently, head office use of computers was extended to financial activities such as cash flow projection and to marketing activities such as sales analysis. The emergence of the minicomputer has, however, effected the most dramatic potential improvement in retailing management information systems by facilitating, among other things, the transmission of store level data to a central processing unit for sophisticated marketing analysis.[4] The rapid reporting of store-level transaction data for

Table 4-1

Selected Technological Innovations in Food Retailing since about 1960

Checkout innovations:
Stamp dispensers
Change makers
Basket-checkout design modifications
Display and handling innovations:
High-rise freezers
Back-stocking dairy cases
Warehouse-to-store-floor containers
Bottle return systems
Procedures innovations:
Store-ordering entry devices
Short-interval scheduling procedures
Space allocation systems
Perishable product innovations:
Centralized preparation
Weighing/pricing equipment
Specialized fixtures
High-efficiency freezers/coolers

SOURCE Leonard L. Berry and Ian H. Wilson, "Retailing: The Next Ten Years," *Journal of Retailing* 53, no. 3 (Fall 1977), p. 16.

central processing has obvious implications for improved inventory management, stock ordering, credit authorization, and related functions. At the other end of the retailing process, computerized purchase-order management enables the store manager to keep a more accurate and comprehensive control over merchandise moving into the store. In-store minicomputers are also being used for energy control systems in retail outlets.

Electronic point-of-sales (POS) systems cover a range of hardware and software features and functions. At one end are the low-priced electronic cash registers with memory units, available at prices ranging from $1,500 to $6,000 per unit;[5] at the other extreme are the more powerful and more costly POS systems, linked to an in-store minicomputer, offering a broad range of data on inventory movement, coupon redemptions, accounting functions, and the like. The most advanced POS systems incorporate optical scanning systems that key in data to the in-store computer through one or another electronic scanning unit.[6] The cost savings associated with scanning are debatable, partly because source marking of the Universal Product Code (UPC) by manufacturers has progressed more slowly than anticipated. Also, the continued need to item-price in many jurisdictions reduces the potential cost savings from scanning. It is extremely difficult to quantify the benefits of scanning, since realized benefits will partly depend upon how effectively management utilizes the information generated by the system. Many observers believe that optical scanning at the present time can only be justified by large chains with broad stock requirements. Nevertheless, several small independent chains claim that they have realized net cost savings from their scanning systems.

Grocery wholesaling has also enjoyed significant technological advances over the past several decades. Head office functions have been the focus of computerization, along the lines of the retail-store head office activities. A substantial amount of new technology has also been introduced into the warehouse proper. Mechanical improvements include: narrow-aisle equipment, pallet fork-lift trucks, stacker cranes, specialized conveyor systems, improved packaging (including plastic containers), unitized loads and containers, and shrink or stretch-wrap pallets.[7]

Warehousing changes are increasingly centred around computerization, and it is fair to say that automation has profound prospects for revolutionizing warehouse activities. Administrative functions that have been automated at the warehouse level include inventory accounting and control functions such as the recording of withdrawals and receipts, stock locator systems, maintenance of inventory balances, and identification of damaged and obsolete merchandise. Automated warehousing procedures include the preparation and identification of location transfers, and loss and damage claim support. The most advanced distribution technology is the automated order selection system, or computerized warehouse batch picking.[8] The "fully automated warehouse" encompasses computerized batch picking, along with automated storage and retrieval vehicles (which are supplanting traditional fork-lift trucks) and automated sortation systems. Fully automated warehousing systems cost from $2.5 million to $4 million and are restricted primarily to new structures designed to handle a high volume of uniform products such as dry groceries and frozen foods. At present, fully automated warehousing is in its infancy; however, it represents a new distinct direction for the future. Another computer-based technology on the horizon is direct on-line ordering from retail stores to plant warehouses.

Computerization of in-house accounting and inventory control tasks has substantially improved managerial efficiency over a range of control functions. For example, automation has improved the speed and accuracy of management information systems and has enabled managers to process a greater amount and variety of information without concomitant increases in personnel. As was the case for libraries and hospitals, the issue of whether a critical size threshold was required for efficient automation in food retailing and wholesaling is relevant. While there is no clear consensus on this issue, it can be argued that access to service bureaus and original equipment manufacturers brought profitable computerization of routine bookkeeping functions within the reach of even relatively small firms.[9] It is less evident that small firms could undertake computerized planning activities such as site analysis and new product analysis or that they could profitably undertake advanced automation applications such as POS systems, particularly those linked to scanners, and automated warehousing. Automation of sorting and distribution processes at the retail and wholesale levels appears to be characterized by greater economies of scale than the automation of in-house accounting functions.

Automation in Food Retailing and Warehousing

Published information on the extent of computerization in food retailing and wholesaling is unfortunately sadly lacking. The Retail Council of Canada notes that published information on retail Management Information Systems (MIS) has emphasized technical systems rather than an assessment of the extent and nature of implementation.[10] Nevertheless, the Retail Council suggests that retailers are lagging significantly behind manufacturers in the use of MIS technology.[11]

To obtain some information on the extent and nature of automation in Canadian food stores, we undertook a mail survey of food retailers and wholesalers in Canada. The initial step in the surveying process was to interview a number of EDP specialists in order to establish the scope and content of information that could be reliably obtained through a mail survey and to clarify technical terminology. The next step was to draft a preliminary survey questionnaire and draw up a list of sample firms. The list was compiled from the survey of food chains and groups reported in *The Canadian Grocer*, August 1979. Initially, subsidiaries were aggregated to the highest reporting unit; however, subsidiaries were treated as separate observations if an autonomous computerization decision was undertaken by subsidiary management.

An initial list of 66 firms was compiled. The preliminary questionnaire was mailed to a randomly selected sample of ten firms, six of whom responded. A final questionnaire, which reflected slight changes to the preliminary questionnaire, was mailed to all the remaining firms on the list.[12] In total, 70 questionnaires were mailed out, and 39 usable responses were received – representing a response rate of approximately 56 per cent. This response rate is relatively high, as mail surveys go, and it should be noted that the questionnaire was designed to elicit information at minimal cost and inconvenience to the respondents.[13] For example, the survey did not request information on the precise nature of computerization – e.g. in-house computer versus service bureau membership. Nor did it request the firm to identify operating and financial information such as sales, profits, and so forth. Thus the survey was designed more to acquire information about the extent of computer use than to compile details about the nature of computer use and the characteristics of adopting and nonadopting firms. Since the initial sample was drawn from a list of food chains and co-operative groups,[14] our sample is quite clearly biased towards the exclusion of independent retail stores and independent warehouses. If significant economies of scale exist in the automation activity, this bias will lead to overstating the extent of computer adoption across all food retailing and wholesaling firms in Canada.

Respondents can be grouped into three broad categories: 1/ those indicating ownership of retail stores but not ownership of warehouses; 2/ those indicating ownership of both retail stores and warehouses; and 3/ those indicating ownership solely of warehouses. The latter group would encompass wholesalers with affiliated retail outlets. The greatest number of responses (21) was received from the second group; 10 were received from the first and 8 from the third.

The earliest that computers were used for head office functions by firms in group 1 was 1978,[15] eight of the ten companies responding had at least one head office activity computerized by 1979. The earliest that computers were reported to have been used in the head offices of firms in group 2 was 1956; only two of the twenty-one firms in this group had not computerized at least one head office function by 1979. The earliest that computers were used in head offices of firms in group 3 was 1966; seven of the eight responding wholesalers had at least one head office function computerized by 1979.

Table 4-2 reports the distribution of responses to specific automation applications; that is, it reports the number of companies indicating automation of selected applications by 1974. The results suggest that the automation of head office functions was implemented both earlier and more extensively by group 2 firms. Group 2 firms are substantially larger, on average, than firms in the other two groups. Specifically, the average number of employees for the seventeen group 2 firms reporting data equals 8,331. The average number of employees for the five group 1 firms and the six group 3 firms that reported equals 115 and 448, respectively. Thus the more extensive and earlier automation of the group 2 firms is consistent with the existence of economies of scale and economies of vertical integration in the automation process; other factors, however, need to be held constant when relating size and vertical integration to automation. In a latter section, we present a multivariate model of the automation process, where the relationship between adoption behaviour and firm size is examined within a ceteris paribus framework.

It is impossible to compare the automation experiences of Canadian and U.S. food retailers and wholesalers, since comparable data on automation are unavailable for U.S. companies. As noted above, approximately 40 per cent of all U.S. wholesale firms had computerized their in-house accounting and inventory tasks by 1972. Considering our sample of group 2 and group 3 firms (i.e. those food companies performing warehousing functions), approximately

Table 4-2

Automation of Head Office Functions up to 1974, by Food Retailers and Wholesalers Surveyed

	Number of companies automated		
	Group 1 (8 companies)	Group 2 (20 companies)	Group 3 (7 companies)
Area of automation:			
Payroll	—	13	4
Accounts receivable	—	9	4
Accounts payable	—	12	
General ledger	—	8	
Inventory control	—	9	5
Expense ledger	—	6	
Sales audit and reporting	—	9	2
Price changes	—	12	1
Average number of applications	—	3.9	2.3

SOURCE Author's survey.

73 per cent had at least one automated activity by 1972. Several caveats must be raised, however. One is that the U.S. statistic encompasses results for all types of wholesalers, while the Canadian statistic is for food wholesalers only. There is some evidence that food companies pursued automation more aggressively than other retailing and wholesaling groups.[16] This factor would contribute to biasing upward the Canadian adoption rate relative to the U.S. rate. Also, the Canadian sample is biased towards the inclusion of large wholesaling firms. To the extent that economies of scale exist in the automation activity, our comparison has an additional bias in favour of observing a higher level of automation adoption in Canada. Data are unavailable to permit a Canada/U.S. comparison, holding size and other determining factors constant; however, if our statistical model reveals that firm size is an insignificant variable in the automation decision, the foregoing comparison might be taken as stronger evidence that (holding ex ante profitability constant) Canadian wholesalers were quicker than U.S. wholesalers to automate head office functions.

Our survey also provides information on the computerization of warehousing functions by food companies operating warehouses – i.e. firms in groups 2 and 3. The earliest reported warehousing automation for group 2 firms was 1955; for group 3 firms, the earliest was 1966. Seventeen of the twenty-one integrated food companies had automated at least one warehousing function by 1979, while only one of the nonintegrated wholesalers had failed to automate at least one warehousing activity by 1979.

Table 4-3 shows the number of firms that indicated automation of specific warehouse applications. The average number of warehouse computer applications reported by eighteen group 2 companies was 4.1, while the average for the seven group 3 companies reporting was 3.9. One can conclude that while large integrated food companies may have been the first to automate warehouse activities, intrafirm diffusion

Table 4-3

Automation of Warehouse Activities up to 1974, by Food Companies Surveyed

	Number of companies automated	
	Group 2 (18 companies)	Group 3 (7 companies)
Collecting orders from retail outlets	8	3
Batching orders	11	5
Production of billing and picking documentation	11	5
Inventory control and reporting	10	5
Picking orders	8	3
Preparing bills of lading	6	1
Preparing accounts receivable and payable	10	1
Purchase order management	10	4
Average number of applications	4.1	3.9

SOURCE Author's survey.

rates did not differ significantly between integrated and nonintegrated wholesalers, at least through 1974.

Our survey also sought to obtain some data on automation in retail outlets – specifically, whether scanning equipment was being used at point of sales and also whether retail outlets were using computerized cheque or credit authorization. Again, the integrated food stores were faster to implement new technology. Only one of the group 1 companies was using scanning equipment by the end of 1979, and none were using computerized chequing or credit authorization; in contrast, eight group 2 stores were using scanning and one was using computerized cheque or credit authorization.

As was the case for wholesaling firms, there is very little information available to facilitate the comparison of automation speed between U.S. and Canadian food retailers. The first scanning store in the United States was Marsh Supermarkets in Troy, Ohio, in 1974.[17] The first scanning application in Canada was in 1975. By Fall 1978, it was estimated that there were 318 scanner installations in the United States and 16 in Canada.[18] The estimated number of food stores in the United States is approximately 189,300, compared with approximately 31,310 in Canada. Thus, while there are approximately six times the number of food stores in the United States, there was approximately twenty times the number of scanners in use there by Fall 1978.

It should be noted that the average size of U.S. food stores is larger than that of their Canadian equivalents. This, by itself, would encourage faster adoption of scanning in the United States, since the benefits of scanning are presumably related to a store size and the diversity of merchandise it carries. The average size of the four largest chains in Canada is actually larger than that in the United States, however. Thus, for at least some sectors of food retailing, the ex ante profitability of scanning might be higher in Canada than in the United States.[19] It is impossible, however, to isolate scanning adoption for only the largest chains in Canada and the United States. Given these considerations, as well as the relatively small percentage of stores in either country using scanners, one should not draw overly strong conclusions from the relative adoption levels for scanning equipment. The finding is, however, consistent with the previously discussed evidence suggesting that retailing innovations are introduced sooner, and adopted more rapidly, in the United States than in Canada.

An Empirical Model of Automation in Food Retailing and Wholesaling

Our survey results suggested that large, integrated food companies were the earliest and most intensive adopters of automation. In this section, an empirical model of the diffusion process is specified and estimated in order to identify the statistical influence of firm size and vertical integration on automation adoption, holding other factors constant.

The first set of equations focuses on the adoption experience of firms owning retail stores – i.e. group 1 and group 2 firms. The initial dependent variable (A_{1i}) is a dummy variable, taking a value of 1 if at least one head office function was computerized by 1974 and 0 otherwise. Alternative size measures were used in various estimating equations, including total sales, total employment, and total number of retail stores. The results were quite similar for all size measures, although goodness-of-fit statistics were slightly better using the "total number of stores" measure. Hence results reported below are for size (S_{1i}), measured as the total number of retail stores owned by the i^{th} company. The vertical integration variable (VI_{1i}) is a binary variable equaling 1 if a company owns one or more warehouses and 0 otherwise.

As in the models of library and hospital automation, we were interested in determining whether adoption behaviour was correlated for all innovations. In the initial equation, our measure of managerial receptivity to new technology (M_{1i}) was a dummy variable, taking a value of 1 if scanning equipment was used by the company and 0 otherwise. Clearly, the use of a single innovation, particularly one biased towards adoption by larger companies, is a crude measure of receptivity towards innovation. Unfortunately, it was the only measure available in this context. A set of dummy variables was also included in the equation to test directly for the existence of interregional differences in diffusion rates. Four regional dummies were specified: G_{1i} (Quebec); G_{2i} (Prairies); G_{3i} (Atlantic); G_{4i} (British Columbia).[20] Companies were classified regionally by the location of their head office.

We had no strong prior expectations about the signs of the regional dummies. Discussions with industry representatives had led us to believe that information about available hardware and software was well disseminated, although the central provinces may enjoy a relatively greater abundance of skilled systems analysts and programmers; however, to the extent that large food chains are less efficient than other food retailers (holding scale effects constant), faster adoption might be anticipated outside Ontario, since all of the chain store head offices in our sample are located in Ontario.[21] Furthermore, the concentration of total food store sales among the leading chain stores is highest in Ontario;[22] however, simple four-firm concentration ratios may be misleading indicators of competition in this context. For one thing, only Ontario enjoys the competition of all four major chains. The Quebec market can be characterized as a duopoly, while the other regions are esentially served by one of the four leading chains. For another, regional concentration ratios may fail to reveal important pockets of concentration at local levels. In this regard, Mallen (1976) concludes that concentration in urban markets is greatest in the Prairie provinces. Thus our regional dummy variables cannot be construed as necessarily reliable indexes of the competitive pressure on retail firms to automate. Any significant differences observed in interregional diffusion patterns may therefore reflect the influence of one or more unspecified factors.

Empirical results of OLS estimation are reported in equation 1, Table 4-4. Vertical integration is positively and significantly related to the dependent variable, as is the M_{1i} variable. While size is positively related to the dependent variable, it is statistically insignificant. None of the regional dummy variables are statistically significant.

The second dependent variable (A_{2i}) is specified as the number of head office functions computerized by 1974. This variable is taken to be a measure of intrafirm diffusion. The set of independent variables is identical to the set in equation 1. Statistical results are reported in equation 2. Only the VI variable is statistically significant at acceptable levels in equation 2, although all factors apparently exert the same directional influence on interfirm, as well as intrafirm, adoption patterns – i.e. in equations 1 and 2.

A third dependent variable (A_{3i}) is the number of head office functions computerized by 1979. This measure of adoption permits expansion of the sample from 19 to 26 firms,[23] thereby providing greater degrees of freedom. Employing the same specification as equation 2 and estimating by ordinary least squares gives the results reported in equation 3. Equations 2 and 3 are quite comparable. All signs are identical, and VI is statistically significant in both equations. One observed difference is the Atlantic region variable, which is statistically significant in equation 3.

Summarizing the results to this point, regression analysis confirms that size and vertical integration are positively related to the speed and intensity of automation of head office functions in retail food companies; however, only the vertical integration variable is statistically significant. There is weak evidence that organizations favourably disposed towards automating one type of function are quicker to automate other functions.[24] There is little evidence of significant interregional differences in the speed or extent of automation, although there is some evidence that firms headquartered in the Atlantic region were slower to automate their head office activities.[25]

Another innovation examined at the retail level was also specified as a dummy variable (A_{4i}) taking a value of 1 if a company was using scanning equipment in one or more of its stores by the end of 1979 and 0 otherwise. All independent variables are specified as in equations 1 to 3 with the exception of

Table 4-4

Regression Results for Food Companies (Retailers)

		Variables								
Equation	Constant	S_{1i}	VI_{1i}	M_{1i}	G_{1i}	G_{2i}	G_{3i}	G_{4i}	$\overline{R}^2$	F
1 (19 firms)	.0493	.0006 (1.36)	.5007 (3.24)	.3163 (2.18)	.1827 (.91)	.2715 (1.14)	-.2209 (-1.38)	-.1394 (-.45)	.635	8.24
2 (26 firms)	.4192	.0017 (.51)	2.160 (1.90)	1.782 (1.58)	2.075 (1.38)	2.470 (1.40)	-.9143 (-.762)	-1.5560 (-1.04)	.438	3.78
3 (26 firms)	2.031	.0007 (.23)	2.796 (2.73)	.7481 (.73)	1.274 (.94)	1.774 (1.12)	-2.473 (-2.29)	-.4690 (-.35)	.493	4.47
4 (20 firms)	-.1433	.0002 (.31)	.0739 (.19)	.5522 (1.78)	.1872 (.61)	.0561 (.87)	.2216 (.72)	.5172 (1.06)	.136	1.60
5 (26 firms)	-.0077	-.0001 (-.17)	.0422 (.23)	.0334 (1.65)	.0226 (.85)	.0681 (2.14)	.0189 (.67)	.0278 (1.30)	.229	2.48

M_{1i}, which is specified as a dummy variable equaling 1 if the company's head office was automated by 1974 and 0 otherwise. Results of OLS estimation are given in equation 4. Only the M_{1i} variable is statistically significant at the 0.05 level, confirming our earlier finding that automation efforts tend to be correlated in different retailing activities. Total size (as measured by the number of retail outlets) is statistically insignificant. An alternative size measure (i.e. average sales per store) was also statistically insignificant. The insignificance of the two size measures in equations with scanning adoption as the dependent variable is somewhat surprising, given strong prior expectations that the profitability of scanning adoption is positively related to the volume and diversity of merchandise sales. One possible explanation is that collinearity between the various size measures and the Quebec dummy variable confounds reliable estimation of the size parameter.[26] Of course, it is also possible that economies of scale in scanning adoption have been overstated.

The relationship between the extent of scanning adoption (A_{5i}), measured as the average number of scanners per store, and the independent variables specified in equation 4 is reported in equation 5. Once again, there is no evidence of any significant relationship between size or vertical integration and the extent of scanning adoption. One unexpected result is the statistically significant positive coefficient observed for the Prairie region dummy variable. We have no ready theoretical explanation for this result; however, in a relatively small sample such as that in equation 5, statistical results are extremely sensitive to individual observations, taking extreme values. In the case of equation 5, a retailer located in the Prairie region was an especially intensive user of scanning equipment. The coefficient for the Prairie variable undoubtedly reflects the heavy influence of this statistical outrider. On balance, therefore, it seems reasonable to conclude that the adoption of scanning equipment is not significantly related to regional dummy variables.

Our second set of equations focuses on the adoption experience of firms owning warehouses – i.e. group 2 and group 3 firms. One dependent variable (A_{6i}) was specified as the number of headquarter functions computerized by 1974.[27] Various size measures were employed in preliminary estimations. Results are reported for total employment (E_{1i}), which provided the best overall results. The initial measure of innovation "propensity" (M_{2i}) was a dummy variable equaling 1 if a company had one or more warehouse functions computerized by 1974 and 0 otherwise. The other independent variables are specified identically to those in Table 4-4. Results employing the A_{6i} dependent variable are reported as equation 1 in Table 4-5.

The results indicate that the extent to which head office functions were computerized by 1974 is negatively and significantly related to the size variable. Automation of head office functions is positively and significantly related to the automation of warehousing functions. While vertical integration is positively associated with the dependent variable, it is not statistically significant. All regional dummy variables are insignificant.

A second dependent variable (A_{7i}) was defined as a dummy variable, taking a value of 1 if a firm had automated one or more warehousing functions by 1974 and 0 otherwise. All other variables are defined as in equation 1 with the exception of M_{2i}, which is redefined as the number of headquarter functions automated by 1974. Results of OLS regression are reported in equation 2. The positive, statistically significant coefficient for the size variable provides the only evidence, to this point, of larger firms being

Table 4-5

Regression Results for Food Companies (Wholesalers)

		Variables								
Equation	Constant	E_{1i}	VI_{1i}	M_{2i}	G_{1i}	G_{2i}	G_{3i}	G_{4i}	$\overline{R}^2$	F
1 (21 firms)	-1.006	-.0001 (-2.31)	1.8411 (1.53)	5.358 (4.65)	.3751 (.35)	-.8754 (-.44)	-.8183 (-.68)	-2.341 (-1.03)	.560	4.63
2 (21 firms)	.2769	.0001 (2.48)	-.1602 (-.85)	.1165 (4.06)	.0393 (.24)	.4882 (1.52)	-.1084 (-.37)	.4882 (1.52)	.644	6.17
3 (21 firms)	4.1851	-.0172 (-.22)	-.4206 (-.33)	.2376 (1.78)	1.605 (1.40)	-.3757 (-1.74)	.7170 (.59)	1.340 (.56)	.250	2.11

quicker to automate than smaller firms. The results for all other estimated parameters are generally consistent with preceding results.

A final dependent variable (A_{8i}) is specified as the number of warehousing functions computerized by 1979. Equation 3 reports results from regressing this dependent variable against the set of independent variables specified in equation 2. The size variable is once again statistically insignificant, as is the vertical integration variable. The coefficient for the Prairie regional dummy variable is significant at the 0.10 level; however, this result is strongly conditioned by one specific observation.

Summary and Policy Implications

Our examination of automation in food retailing and wholesaling companies does not permit any clear comparison of Canadian versus U.S. experience. Some tentative evidence suggests that our particular sample of Canadian food wholesalers automated headquarter functions sooner than U.S. wholesale firms; however, the relevance of this comparison is obscured by the fact that food companies have generally been quicker to adopt automation than other wholesale companies, as well as by the fact that our sample of Canadian firms is biased towards the inclusion of large wholesalers. Equation 1 suggests that the extent of automation of headquarter functions is negatively related to firm size. Thus the nature of any sampling bias created by the focus on large Canadian wholesalers is uncertain.

Somewhat firmer grounds exist for concluding that scanning equipment was adopted more quickly in the United States than in Canada and that this difference is not necessarily attributable to differences in average firm sizes between the two countries; however, other factors influencing the relative profitability of scanning adoption in the two countries, such as the costs of scanning equipment, are not necessarily constant. Hence it is not necessarily appropriate to conclude that Canadian retailers have lagged behind U.S. retailers in adopting scanning technology, holding ex ante profitability of adoption constant.

Our results provide no firm basis for making strong prescriptive policy suggestions to speed the diffusion of new technology in this sector; however, certain policy cautions should be raised. The main disclaimer is that increased average firm size, with concomitant increases in concentration, does not promise to stimulate the adoption of new technology in food retailing and wholesaling. Thus our evidence provides no empirical basis for assuming a "technological efficiency/concentration" trade-off, as has been suggested in Good (1979), Mallen (1976), and others. For at least certain activities of retail food companies, there is some basis for arguing that vertical integration encourages faster technological diffusion.

It is not possible, based upon the evidence available, to evaluate the empirical relevance of other suggested barriers to faster automation. For example, some observers suggest that difficulties in co-ordinating manufacturer and retailer co-operation in implementing universal product codes has slowed the adoption of scanning. Tariffs on specific types of automation equipment, as well as requirements for price labeling, are also suggested to be potential impediments to the diffusion process.[28] A number of industry spokesmen indicated to us that the shortage of systems analysts with applied business backgrounds was a major factor hampering faster automation in this sector. All of the foregoing are plausible conjectures; however, further study is required to evaluate their empirical significance.

5 Innovation in Department and Variety Stores

Changes in the structure and operation of department and variety stores have been evolutionary rather than revolutionary in nature. Indeed, some observers have criticized department stores for exhibiting built-in organizational rigidities, for a slowness to act, and for a lack of receptivity to new ideas.[1] Notwithstanding these criticisms, a number of important innovations have been introduced into the industry.

The conventional department store of today is essentially a regional chain, with one or more stores in the downtown section of a city and a number of outlying stores, all being managed and operated by one group of executives. The movement of department stores to suburban shopping centres constituted one innovative response to the declining share of department store sales in total retail sales over the period 1930-65. Another was the appearance of the discount department store in the 1950s and, more recently, the promotion of fashion and boutique-type marketing, along with increased provision of services such as financial planning, insurance, and income tax preparation.[2]

Several other, more recent changes in the operations of department and variety stores are worth noting. Microfilming has substantially improved the availability of information to managers at different locations and levels in chain store sales, as well as to counter customers purchasing stock in multi-line stores. The introduction of credit cards represent another important marketing innovation; however, computerization probably represents the most significant opportunity, to date, to improve productivity in this sector, according to industry experts.

The nature of automation in this sector is quite similar to that in food retailing. Initially, routine bookkeeping operations at head office level were automated. Subsequently, automation was extended to financial, marketing, and planning activities. Minicomputer technology provides opportunities for department stores to introduce point-of-sales systems. The most elaborate of these systems have optical character recognition (OCR) scanning, or wanding, options. Minicomputers also facilitate the introduction of computerized cheque and credit authorization, as well as computerized purchase order management.

Warehousing activities are also subject to automation along much the same lines as for food wholesalers. Automation of warehousing procedures such as preparing of documentation and bills of lading, inventory control and reporting, preparing accounts receivable and payable, and collecting orders from retail outlets are well under way. More advanced distribution technology, encompassing the "fully automated warehouse" concept is still in its infancy. This technology will be more difficult to introduce in department stores than in food warehouses, given the wider diversity of merchandise handled by department stores.

Since the automation of department and variety stores represents a close analogue to automation in food retailing and wholesaling, we shall not re-examine the potential advantages and disadvantages of automating specific activities. Rather, we shall merely reassert the contention that automation of in-house accounting and financial functions undoubtedly represented a cost-effective technological improvement that was accessible to small as well as large firms, although the accessibility of the technology to small firms undoubtedly increased over time. Specific automation applications at the retail store level (such as point-of-sales systems) or at the warehouse level (such as automated batch picking) undoubtedly offer significant potential benefits. For example, point-of-sales systems with wanding capacity offer the benefits of continuous inventory updating and stock-out signaling. The information captured at point of sales can be used to update and revise marketing strategies, to change credit terms, and to make other strategic decisions on the basis of the very latest marketing information; however, the relatively high costs of the requisite equipment make the net benefits of adopting these more advanced systems somewhat conjectural, particularly for smaller firms.

Automation in Department Stores

At least one major study of the use of EDP is available for the U.S. retail industry.[3] The number of firms contacted for information was not indicated in the report; however, analysis was based on 608 responses. Results indicated that almost 76 per cent of respondents were using EDP in some capacity by 1968. The most prominent computer applications were in accounting functions such as accounts receivable and payable, payroll, general ledger, and inventory. Given the number of applications reported for all responding firms, the number of computer applications per user equaled 4.7. A similar survey conducted for 1958 indicated that 27 of the 105 responding firms (or approximately 26 per cent) were automated.[4]

Since no comparable data on automation were available for Canadian department and variety stores, we undertook a survey comparable to the survey of food companies. An initial list of 71 department stores and 13 variety stores was drawn up from the *Canadian Key Business Directory* (1980) and a preliminary questionnaire, similar to the one developed for food retailers, was sent to a 10 per cent subsample of firms.[5] A revised questionnaire was subsequently mailed to all remaining firms. Usable returns were received from 44 companies, yielding an effective response rate of 52 per cent. Twenty-six of the responding firms were integrated into the wholesaling function, while the other 18 respondents were specialized in the retailing function. Total sales of the responding firms constituted a projected 60 per cent of all department store sales in 1979.[6] Our respondents therefore represent a major portion of the industry.

The earliest date indicated by our respondents for the use of computers was 1955. Eight of the responding firms failed to indicate a specific date for computerization. Of the remaining 36, 12 indicated computerization of one or more functions by 1968. This 33 per cent adoption level is well below the 76 per cent adoption level reported above for U.S. general merchandisers. Some data are also available on the relative use of POS systems in Canada and the United States. These data also indicate slower automation in Canada, although the differences observed are much less marked than those observed for automated head office functions. Specifically, about 14 per cent of U.S. department stores have POS systems with wanding capacity.[7] Our survey revealed that five responding firms (or around 11 per cent of the sample) were "wanding" by 1979.

It should be noted explicitly that the U.S. and Canadian samples are not precisely comparable in terms of store mix. To the extent that establishments other than department stores were quicker to automate than department stores, the U.S. survey can be expected to show a higher level of automation, since it includes all general merchandise stores. Furthermore, U.S. department and variety stores are larger than their Canadian counterparts. For example, the 40 largest department-store company divisions in the United States had an average sales volume of around $333 million (U.S.) in 1979; our sample of Canadian department and variety stores had an average sales volume of approximately $181 million that year. To the extent that economies of scale exist in the automation process, U.S. stores would find automation more profitable and could be expected to automate earlier than their Canadian counterparts, ceteris paribus. Therefore, the apparently slower rate of interfirm adoption for Canadian department stores is suggestive, but certainly not conclusive evidence, of laggard adoption behaviour. This disclaimer is reinforced by the observation that the domestic tariff makes automation equipment more expensive in Canada than in the United States.[8]

Table 5-1 presents a breakdown of responses, by specific head office automation application; more specifically, it shows the number of companies with head office automation by 1974. It can be seen that integrated stores (i.e. the group 2 firms) automated sooner or more extensively than nonintegrated stores

Table 5-1

Automation of Head Office Functions up to 1974, by Department and Variety Stores

	Number of companies automated	
	Retailers only	Integrated retailers
	Group 1 (14 companies)	Group 2 (22 companies)
Area of automation:		
Payroll	2	11
Accounts receivable	5	11
Accounts payable	2	9
General ledger	3	6
Inventory control	1	7
Expense ledger	2	7
Sales audit and reporting	3	5
Price changes	—	4
Average number of applications	1.29	2.73

SOURCE Author's survey.

(i.e. the group 1 firms). This finding is consistent with results from our sample companies. It is also consistent with the presumed existence of economies of scale in the automation activity, since the average size of group 2 firms is $254 million, while the average size of group 1 firms is $11.7 million.

Table 5-2 shows the distribution of responses, by specific warehouse automation application, for group 2 firms. The average number of warehouse computer applications reported by the 19 group 2 companies that supplied data was 1.0 – well below the average number reported by group 2 and group 3 food companies. It is also interesting to note that integrated food companies were more extensive automators of head office functions than integrated department stores, although when comparing nonintegrated retailers, department stores were earlier and more extensive automators than food stores.

Table 5-2

Automation of Warehouse Activities up to 1974, by Department and Variety Stores (Integrated Retailers) Surveyed

	Number of companies automated
	Group 2 (19 companies)
Collecting orders from retail outlets	2
Batching orders	3
Production of billing and picking documentation	3
Inventory control and reporting	4
Picking orders	2
Preparing bills of lading	1
Preparing accounts receivable and payable	3
Purchase order management	1
Average number of applications	1.0

SOURCE Author's survey.

Our survey results tend to support the conclusion that department stores lagged behind food companies in adopting computer technology. While slower automation of some department store warehousing activities might be expected, given the greater heterogeneity of merchandise carried, this would not necessarily account for the slower automation of headquarter activities or of basic accounting functions at the warehouse level. Given our earlier finding that size and automation of food stores are not significantly related, size differences between department stores and food stores are not a compelling explanation of the differences observed. Nor are differences in internal funds available for reinvestment in new technology. Over the postwar period, profit rates in the two sectors were quite comparable; however, significant differences in concentration levels in the two sectors suggest that competitive conditions may have been an important factor conditioning the relative speeds of adoption in the two sectors.[9] In order to investigate these presumptions further, a statistical model of automation in department and variety stores was specified and estimated.

An Empirical Model of Department Store Automation

The models estimated for department store automation are quite similar to those for automation in food retailing and wholesaling. The initial dependent variable (A_{1i}) is a binary variable, taking a value of 1 if one or more head office functions were computerized by 1974 and 0 otherwise. A variety of size measures were employed; however, results are reported only for the size variable S_{1i}, defined as the number of retail outlets owned by the sample firm.[10] A vertical integration variable (V_{1i}), as specified in the food store equations, was included as an independent variable, as were the four regional dummy variables G_{1i} through G_{4i}. Our measure of managerial receptivity to new technology (M_{1i}) was defined as a dummy variable, taking a value of 1 if computerized cheque authorization was in place by 1979 and 0 otherwise. Results of OLS estimation are reported in equation 1 of Table 5-3. The size variable is statistically significant at the 0.05 level. The dummy variables G_{2i} and G_{3i} for the Prairie and Atlantic regions, respectively, are significant at the 0.01 level.

The second dependent variable (A_{2i}) is defined as the number of computerized head office applications as of year-end 1979. All independent variables are defined as in equation 1. Data for all independent variables were available for 27 sample firms, and the results of OLS estimation are reported in equation 2. Quite clearly, equation 2 provides a very poor "explanation" of the intensity of automation adoption among sample firms. Only the size variable is statistically significant. Sign differences between equations 1 and 2 can be noted for the M_{1i}, V_{1i}, G_{1i} and G_{4i} coefficients.

A third dependent variable (A_{3i}) is defined as a dummy variable equaling 1 if a company had com-

Table 5-3

Regression Results for Department and Variety Stores

		Variables								
Equation	Constant	S_{1i}	V_{1i}	M_{1i}	G_{1i}	G_{2i}	G_{3i}	G_{4i}	$\bar{R}^2$	F
1 (36 firms)	.6353	.0021 (1.80)	.0001 (.57)	.2721 (1.35)	.0526 (.19)	-.3660 (-1.93)	-.5681 (-2.09)	-.3609 (-1.18)	.164	2.14
2 (27 firms)	4.7244	.0161 (1.80)	-.0008 (-.68)	-.4094 (-.41)	-1.2879 (-1.04)	-1.038 (-1.08)	-.9890 (-.91)	.2289 (.16)	.049	1.19
3 (33 firms)	.1842	-.0034 (-1.82)	.0005 (2.56)	.0275 (.85)	-.1909 (-.74)	-.1740 (-.85)	.0971 (.42)	-.2405 (.91)	.023	1.09
4 (23 firms)	-.0488	-.0001 (-.56)	.2752 (.65)	.1282 (3.23)	.3876 (1.57)	-.2360 (-1.62)	.2815 (1.21)	.3906 (.43)	.518	4.38

puterized cheque authorization by the end of 1979 and 0 otherwise. All independent variables are defined as in equation 2 with the exception of the M_i variable, which is defined as the number of head office applications automated by 1979. Ordinary-least-squares regression over 33 observations is reported in equation 3. Like equation 2, the overall statistical fit for equation 3 is quite poor. The size coefficient is negative and statistically significant, notwithstanding its positive sign in equations 1 and 2. The strong statistical performance of the *VI* variable is also somewhat surprising, given its insignificance in the preceding equations. It might be conjectured that the sharp collinearity between the S_i and V_i variables in equations 1 to 3 accounts for the sampling instability of the coefficients and contributes to making the reported statistical results somewhat unreliable.[11]

Our fourth dependent variable (A_{4i}) equals 1 if at least one warehouse function was computerized by 1979 and 0 otherwise. Results are reported in equation 4, where the size variable is redefined as total company sales (in thousands of dollars) and the M_i variable is defined as in equation 3. Results are estimated for 23 department and variety stores that operated their own warehouses. Equation 4 provides strong confirmation of the finding that organizations favourably disposed towards the adoption of one type of automation are quicker to automate other functions. There is no evidence that large size or vertical integration contributes to the earlier automation of warehousing functions. Equation 4 also supports the pattern observed in equations 1 to 3: firms headquartered in the Prairie region are slower to adopt than firms headquartered in Ontario; however, no consistent pattern emerges for the other regional dummies.

Summary and Policy Implications

It must be candidly acknowledged that our estimated equations for department and variety store automation are far from being statistically robust. Furthermore, statistical results are not consistent across equations. For example, in certain cases, larger firm size is associated with earlier automation; in others, the converse is true. There is some tendency, as noted in our other sectoral studies, for automation of various activities to be correlated; however, the strength of this relationship in the department store sector varies between equations. In most instances, the relationship is statistically insignificant.

No direct evidence is cast on the importance of competitive pressures in stimulating faster automation in this sector; however, suggestive indirect evidence is provided by the finding that firms headquartered in the Prairie region were generally slower to automate than firms headquartered elsewhere. Department stores have enjoyed their greatest success in terms of market share primarily in the Prairie provinces of Manitoba and Alberta and in British Columbia. One possible explanation of this phenomenon is that junior department stores concentrated on entering the Canadian market in Ontario and Quebec. Junior department stores have become dominant factors influencing retail competition in Ontario, Quebec, and the Maritime provinces; however, they are much less substantial competitive forces in the western provinces.[12] To the extent that the entry of new organizations into the department store field motivated department stores to become more innovative, the slower automation of stores headquartered in the Prairies is consistent with the existence of less competitive pressure in that region.

One can, of course, posit other explanations for interregional differences in automation. For example, the availability of skilled systems analysts and programmers may be relatively greater in Ontario and Quebec than elsewhere. Another possibility (albeit of limited significance) is that transportation costs make the purchase of scanning and other equipment more expensive in the Prairie region than elsewhere. In short, the hypothesis that differences in competition underlie differences in adoption behaviour is plausible but not necessarily convincing.

Our tentative statistical results prohibit drawing any strong policy conclusions apropos promoting technological change in department and variety stores. By the same token, they offer no persuasive support to a call for increasing average firm size as a means of stimulating diffusion. Indeed, the evidence is somewhat supportive of a policy approach to reduce concentration as a way of stimulating technological change. Unfortunately, our results can provide no insight into the quantitative significance of a number of frequently cited barriers to faster automation in this sector, including domestic tariffs on EDP equipment and a shortage of business-trained systems analysts.

6 Overall Summary and Conclusions

This study examined the adoption of computer technology for a number of specific applications in four broad service sectors: libraries, hospitals, retailing, and wholesaling. There were two empirical issues of primary interest: how rapidly had firms in Canada automated the specific applications; and what factors contributed to faster or slower automation? And, relative to the second question (based upon the automation experience), what public policies might promote faster adoption of new technology?

Information on automation adoption in the sample sectors is available only for specific points in time; hence it is not possible to express the diffusion rate as a continuous mathematical function. The estimates of automation for discrete points in time are more correctly viewed as adoption levels rather than adoption rates. In this regard, comparison of adoption levels in Canada and the United States provides somewhat ambivalent results. For comparable time periods, adoption levels were higher in the United States for hospital and department store automation. Data were insufficient to permit a detailed comparison of automation levels in food stores; however, for at least one major automation application in food stores (i.e. scanning equipment), adoption levels were higher in the United States than in Canada. The library sector provided a somewhat different conclusion; Canadian university libraries, if anything, appeared to be faster automators than their U.S. counterparts.

In the absence of explicit estimates of the ex ante profitability of automation in the two countries, it is hazardous to ascribe slower adoption levels in one or the other country to organizational slack or other aspects of inefficiency. Likewise, the fact that automation in service industries commenced later and proceeded at a slower pace than in manufacturing is not necessarily evidence of laggard adoption behaviour on the part of service firms. Exogenous factors may have contributed to a lower ex ante profitability of automation in service firms – especially Canadian service firms. Therefore, slower automation would not necessarily be inconsistent with efficiency.

While it was impossible to estimate the ex ante profitability of automation, a number of major factors conditioning it were considered on either an informal basis or as part of a multivariate statistical analysis. This evaluation suggested that in the hospital and, to a lesser extent, in the retailing and wholesaling sectors, the ex ante profitability of automation may well have been higher in the United States than in Canada, although the magnitude of any differences is highly uncertain. An argument can be made that the reverse conclusion is appropriate for libraries. Therefore, differences in adoption levels potentially reflect differences in structural factors conditioning the net benefits of automation, as well as behavioural differences in managements' receptivity to new technology.

Our attempts to identify these influences as more precise statistical variables met with indifferent success. In the nonprofit sectors, there was some statistical evidence that organizational slack played a significant role in determining adoption behaviour. Apparently, competition also made management more receptive to new technology, and this receptivity tended to extend across various forms of innovation.

In the case of retailing and wholesaling, we were unable to provide direct statistical evidence of the influence of behavioural factors, such as organizational slack, on adoption behaviour. Some evidence was found that the firms quickest to automate one set of activities were generally quickest to automate other activities. This pattern is consistent with the proposition that managers may differ in their receptivity to new technology. Alternatively, it may merely reflect the fact that computerization was generally more profitable for some firms than for others.

A number of potentially important structural factors, particularly firm size, did not show any consistent relationship to adoption behaviour. The inconsistent relationship between firm size and automation was somewhat surprising, given the expectation of economies of scale in the automation process. Several conclusions are plausible. One is that the presumed economies of scale in automation have been overestimated. Another is that slack in larger organizations offsets the higher ex ante profitability of automation. In any case, our results do not provide strong support for the recommendation that amalgamation of service organizations should be encouraged (or even tolerated) to promote the faster diffusion of new technology. The adverse impact of reduced competition and larger firm size on the propensity to innovate may more than offset any increases in the profitability of adopting innovations characterized by some amount of indivisibility.

The need to reconcile indivisibilities in new technology with increased pressure on organizations to innovate presents something of a dilemma for policymakers, since promoting increases in average firm size may have undesirable effects in terms of reduced competition and increased organizational slack. One promising policy approach is to stimulate a faster "scaling down" of new technology. The automation experience in all of our sample industries demonstrates a pronounced pattern for market forces to increase the accessibility of new technology to smaller firms. The technicalities and welfare implications of such policy approach are beyond consideration in this study; however, there is some evidence that government agencies may impose an economies-of-scale bias on the process of new technology adoption, at least in regard to public sector organizations. At a minimum, a more neutral posture might encourage a more rapid development and diffusion of "scaled-down" technology.

The study also underscores the urgency in reconciling the universality of service considerations with efficiency-incentive requirements for public sector organizations. This is an extremely difficult task, to be sure. Ongoing experiments in incentive budgeting in the U.S. hospital sector bear close watching in this regard. A number of other policy guidelines might help to promote faster diffusion as well. For example, the budgeting process should facilitate a reasonable planning horizon for administrators. Year-to-year uncertainty in an organization's budgetary position is not conducive to making commitments to new technology that might involve a fairly lengthy duration of planning time. This concern is of particular relevance to public sector organizations, whose budgetary positions are almost entirely dependent on government funding policies. A related suggestion is to allow individual administrators greater latitude in making innovation decisions within an incentive-budgeting framework. Concern about nonoptimal decisions (from a group perspective) being taken might be offset by reductions in bureaucratic delay associated with new investments.

An important social concern about automation is its impact upon employment opportunities. This study did not treat the issue of "technological unemployment" as an explicit focus. Nevertheless, several of our case studies did provide some insight into the relationship between employment conditions and automation. In hospitals and libraries specifically, the primary impact of automation (to this point) appears to have been on the growth of clerical jobs; i.e. automation has facilitated growth in output without a concomitant increase in clerical employees. Since automation was generally implemented earlier and more extensively in organizations facing greater constraints on expanding employment, however, the aggregate impact of automation on actual employment opportunities for clerical staff may not have been too marked. That automation has the potential to alter job mix significantly is clear. Besides increasing demand for computer-related skills, automation has the potential to alter demand for other skill categories. For example, automation in retailing and wholesaling has the potential for decreasing employment opportunities for bookkeepers, traffic dispatchers, and so forth; however, it has the potential to increase employment opportunities in occupations using the output of automated processes – for example, market research. Our rather cursory consideration of this issue did not indicate that any significant changes had taken place along these lines, to date, in the retailing and wholesaling sectors.

Weaknesses noted in most diffusion studies are the use of indirect measures of the ex ante profitability of innovation adoption and the imprecise specification of organizational characteristics in the form of proxy variables. These weaknesses generally derive from constraints on the availability of data, and in this regard our study was no exception. Unfortunately, published data are ordinarily insufficient to permit precise measurement of the relevant variables. While original surveying offers the prospect of obtaining the required data in a satisfactory form, there is ordinarily a trade-off between the depth and breadth of information obtained. In an exploratory study such as this, it was felt that a broad coverage of the service industries was desirable. Our survey was consequently designed to obtain maximum information on some basic issues related to automation, including its timing and extent.

Having established some necessary background and perspective, we feel it is possible, in future studies, to focus on more detailed empirical issues relating to diffusion in service industries. In particular, it would be appropriate to gather information facilitating more explicit measurement of the ex ante profitability of innovation adoption, as well as a broader and more precise set of measures of organizational and managerial characteristics. We intend to pursue this task in future research.

Notes

CHAPTER 1

1 The precise contribution of technological change and other components of the productivity "residual" has been the subject of an intense debate that need not concern us here. For a perspective on the issue and some recent evidence, see F. Gollop and D. Jorgenson (1980).

2 Exceptions to this assertion can, of course, be cited. One notable exception is the data processing service industry.

3 For a thorough review of these issues, see Victor Fuchs (1969).

4 The importance of embodied research and development in promoting industrial productivity is demonstrated by Nestor Terleckyj (1980).

5 For a review of these hypotheses, see Joan Bodoff (1975).

6 This bias is partly due to the greater availability of data for manufacturing processes and the fact that manufacturing innovations are frequently easier to identify, since they are often embodied in new capital equipment.

7 See Bodoff (1975).

8 For a comprehensive description of computer technology applications, see Humphrey Sturt and Ronald Yearsley, eds. (1969).

9 Accounting applications (particularly payroll) constituted, by an overwhelming margin, the most prominent use of EDP.

10 However, the applications chosen constitute, by and large, the most prominent uses of EDP in each sample sector.

11 The array of computer systems found in the typical organization is ordinarily fairly heterogeneous. Any attempt to sort out all of the various hybrid systems used by organizations in our sample industries would have required the dedication of substantially greater resources. For reasons elaborated upon later in the study, it is not clear that the expenditure of additional resources would be justified by the benefits anticipated.

12 See Statistics Canada (March 1979).

13 See Canadian Library Association (1979).

14 These estimates are calculated from data provided in Jacques Cattell Press, ed. (1979).

15 This is the classification used by the Canadian Hospital Association.

16 We do not attempt any comprehensive survey of the extensive diffusion literature in this report. For more thorough reviews, see Edwin Mansfield (1968) and L. S. Nasbeth and G. F. Ray (1974).

17 For a discussion of this evidence, see D. J. Daly and S. Globerman (1976) and S. Globerman (1979).

18 For an example of a recent model of this type, see R. R. Nelson and S. G. Winters (1980).

19 It is generally the case that this threshold level of expenditure declines, in real terms, over time. It might also be noted that the existence of such threshold expenditure levels might be overstated in the literature, owing to a research emphasis on "significant" innovations.

20 On this point, see Edwin Mansfield (1963), S. Globerman (1976), and A. A. Romeo (1975).

21 A strong defence of this proposition is offered by J. S. Metcalfe (1970) and G. S. Maddala and P. Knight (1967).

22 See, for example, S. Globerman (1975). Their insignificance is not too surprising, since many of the relevant decisions to adopt or not adopt new technology are made by line managers.

23 See Romeo (1975), Maddala and Knight (1967), and P. Swan (1973), among others.

24 For some further evidence on this point, see J. A. Martilla (1970) and J. A. Czepiel (1974).

25 However, see S. Globerman (1978) for some contrary evidence.

26 A factor contributing to this phenomenon is that improvements to the innovation generally take place over time, which makes more extensive adoption more profitable at a later date.

27 He also found that interfirm and intrafirm rates of adoption are positively related to levels of price competition in retail markets.

28 The Science Council is a particularly noteworthy exponent of this policy. While most of the attention of "industrial strategists" has been paid to manufacturing industries, consideration is being given to consolidating service institutions, particularly in public sector activities such as education and health services.

29 See F. Martin et al. (1979). In the case of computer technology, surveys have shown that new developments tend to occur in central Canada and then to spread to the other provinces, although these surveys do not hold constant significant differences in regional economic characteristics. On these results, see J. Chevreau (1981).

30 See, for example, H. S. Dordick and R. J. Goldman (1978).

31 There has been a long-standing concern in the United States about the competitive implications of vertical integration. It should be noted that the Bell Canada/Northern Telecom inquiry involves vertical integration between a regulated monopoly and an unregulated equipment supplier. It therefore raises a variety of issues different from the more traditional vertical-integration issues. These need not concern us here.

32 For an overview of this literature, see D. J. Teece (1976).

33 Such expectations may be based, for example, on a view that the innovation will be "scaled down" over time for more efficient use by smaller firms.

34 The economics literature conventionally dates the start of the diffusion process at the point where 10 per cent of all potential adopters are utilizing an innovation.

CHAPTER 2

1 See, for example, R. T. Kimber (1974).

2 In university libraries, most typically, the central university computer was used to process information stored on cards or tape.

3 For a comprehensive outline of the history of library automation, see Richard DeGennaro (1972) and various papers in J. L. Divilbiss, ed. (1977).

4 These functions include circulation, acquisitions and purchasing, cataloguing, reference, information retrieval, and authority files.

5 The economics of library automation, including case study evaluations, is considered in Kimber (1974), Divilbiss, ed. (1977), and S. Martin and B. Butler, eds. (1975).

6 They include: Acadia University, University of Alberta, Bishop's University, Brandon University, University of British Columbia, University of Calgary, Concordia University, University of Guelph, Laurentian University, Mount Allison University, and Memorial University. This sample is relatively broad both in its geographic coverage and in the size distribution of sample libraries.

7 These staff savings are primarily in clerical functions. Demand for other skilled inputs, such as indexers, translators, and abstractors may, in fact, have increased as a result of the increasing rate of production of new records owing to automation. See Ben Ami Lipetz (1970).

8 See Kimber (1974), p. 25.

9 See Creative Research Services Inc. (1966).

10 They were Simon Fraser University, University of Windsor, University of Alberta, University of British Columbia, and University of Toronto. To be precise, Canadian universities give both three- and four-year Bachelor degrees. We use the term "four-year" for convenience.

11 The complexity of library automation functions was frequently beyond the experience and competence of academic computing centres as well.

12 These estimates were obtained from P. B. Steckler and W. E. Wright, eds. (1966).

13 The insignificant number of adopters from this group in both countries supports the relevance of this assumption.

14 To provide some perspective on this point, in 1966 the main library at the University of Toronto held about 1.46 million volumes. Four affiliated colleges – Erindale, Scarborough, St. Michael's, and Victoria – together held less than 400,000 volumes in their libraries.

15 The number of main college and university libraries in the United States and Canada was obtained from Steckler and Wright (1966) and from Dominion Bureau of Statistics (1968), respectively. Were sufficient data available it would be preferable to define the population of potential adopters explicitly according to size of student body and/or volume of library books rather than type of college.

16 See Jacques Cattell Press, ed. (1977).

17 In this regard, evidence suggests that library automation in the United States commenced earlier and proceeded faster than in the United Kingdom. See Commission on Post-Secondary Education in Ontario (1972).

18 The activities chosen follow the classification used by the American Library Association for the aforementioned survey.

19 The relatively low number of administration and management automation applications reflects the fact that most libraries are part of a larger organization that employs a computer-based accounting system.

20 The LARC Association (1971).

21 The LARC Association (1972).

22 See Commission on Post-Secondary Education in Ontario (1972).

23 For example, some libraries suggested in their annual reports that the use of electronic typewriters with memory capacity constituted automation.

24 This estimate is derived as the product of 176 (the estimated number of adopters in the LARC survey) and 1.533 (the scaling factor, equal to 23 divided by 15).

25 These estimates of intrafirm adoption rates were calculated from data provided in the LARC surveys.

26 See Commission on Post-Secondary Education in Ontario (1972), p. v-5.

27 For all four-year colleges and universities in the United States in the Fall of 1971, the average number of library volumes was 146,504; see R. M. Shaffner (1975). By comparison, the estimated average number

of volumes for 43 main college and university libraries in Canada for the academic year 1970/71 was 529,000. See Dominion Bureau of Statistics (1973). This difference would obviously be smaller if regional and satellite colleges were included in the Canadian total.

28 In discussions with library systems analysts, several specific disadvantages to automation in Canadian libraries were cited. One was higher telecommunication rates in Canada, compared with the United States, which reduces the economic advantages of network and other computer time-sharing arrangements in Canada. Another was the failure of library school curricula to focus on library systems education; however, in the subjective opinion of the library systems analysts whom we consulted, these disadvantages were not thought to be significant determinants of differences in Canada-U.S. automation rates.

29 More specifically, the value of H is calculated as the sum of the squared values of the relative volume holdings of each individual university library in each province. These values ranged from a low of 0.168 for Ontario university libraries to a high of 1 for Prince Edward Island and Newfoundland. A lower value of H may be taken to represent a higher degree of potential competition.

30 For example, D. S. Price, in Divilbiss (1977), p. 84, states: "having been shielded from the competition of the marketplace, librarians have, until recently, had little or no incentive to examine their costs of operation."

31 On this point, see D. V. Black in G. L. Smith and R. S. Meyer, eds. (1969).

32 Another, possibly more precise stock variable that might have been used is the difference between growth rates in salaries and percentage growth in library volumes circulated. Unfortunately, the latter variable was not as readily available as total volumes. In any case, we would anticipate a reasonably constant relationship between total volumes and total volumes circulated across libraries.

33 See, for example, R. A. Peterson, W. Rudelius, and G. Wood (1972) and Mansfield (1963).

34 It is difficult to identify and collect data for other library innovations.

35 Data for all independent variables (except C_i) are from Dominion Bureau of Statistics, *University and College Libraries in Canada*, various issues. The C_i variable is constructed from data provided in Jacques Cattell Press, *American Library Directory*.

36 The bracketed coefficients are t-statistics. $\bar{R}^2$ is the overall coefficient of determination, adjusted for degrees of freedom. F is the ratio of explained to unexplained variance, adjusted for degrees of freedom.

37 More specifically, libraries in Ontario were taken as the base and were assigned 0 values. All other libraries were assigned values of 0 or 1, depending upon whether they were located in one or the other of four regions: Atlantic region, Quebec, Prairies, or British Columbia.

38 For a discussion of this point, see L. B. Russell (1979a), pp. 169-70.

39 This argument is defended in D. R. Cox (1970).

40 The test is described in S. Goldfield and R. Quandt (1965).

41 Regional dummy variables were all statistically insignificant when included in equation 1(b).

42 This criticism is clearly not directed only at Canadian libraries.

43 It is of interest to note that library-like organizations such as book wholesalers and jobbers, which must make a profit from their services, are generally further ahead than libraries in their adoption of computer-based systems. See Kimber (1974), p. 27.

44 The approach raises issues about maintaining quality of service and other related concerns that will not be dealt with here. Suffice to note that a number of state hospital administrations in the United States are experimenting with incentive-budgeting programs.

45 See David Batty (1977).

CHAPTER 3

1 For an extensive review of changing medical technology, see S. J. Reiser (1978).

2 For a full discussion of this point, with specific reference to a number of recent hospital innovations, see L. B. Russell (1979b).

3 See G. F. Groner et al. (1974) and C. A. Austin and B. R. Greene (1978) for reviews of computer applications in health care delivery.

4 See various issues of *Computerworld* and *Hospital Administration in Canada*.

5 See Hospital Financial Management Association (1976).

6 This is the conclusion of Austin and Greene (1978).

7 See Bureau of Labor Statistics (1976).

8 These data from the 1979 AHA survey were provided to the author on a confidential basis by the American Hospital Association. The responses are purported to be an unbiased representation of the population of respondents and therefore should not bias the estimated adoption ratio. It should be noted that the study from which these data are taken was not yet completed at time of writing.

9 See Bureau of Labor Statistics (1976).

10 See Health Computer Information Bureau, various years. I am indebted to John Louth, of the Toronto General Hospital, for bringing this publication to my attention.

11 In a personal interview, Colin Shanks, Director of the Hospital Computing Services of Ontario, the largest hospital service bureau in Canada, suggested that underreporting was not a serious problem for Ontario hospitals but could be more serious for hospitals outside Ontario.

12 The bulk of these were administrative applications. Specifically, we identified only seven hospitals indicating the use of data processing for clinical but not for administrative applications.

13 At the time of writing, the most recent data available reported 1978 computer usage.

14 There is anecdotal evidence that automation in British and Swedish hospitals proceeded at a much faster rate than in North American hospitals. This evidence, however, does not necessarily demonstrate that North American hospitals were inefficiently slow in automating, since all other factors were not explicitly held constant.

15 The author thanks Colin Shanks for providing a perspective on economies of scale in hospital automation.

16 See B. Garcia (1976). The essential thesis of this article is that small hospitals have less scope for "x-efficiency" than large hospitals.

17 This assessment is based on the author's discussions with Colin Shanks and Ron Hebert of MAI Ltd.

18 Reliable data on the number of computerized applications implemented by each sample hospital were not available.

19 For example, the Ontario Ministry of Health promoted the formation of regional computing centres for hospitals in the early 1970s, while hospitals in British Columbia started automating through a central service bureau in the late 1960s. Hospitals in Alberta, Saskatchewan, and Manitoba are all on group systems run by provincial health ministries.

20 Several hospitals have indicated that automated patient registry systems increased efficiency in the use of available bed space.

21 Proximity to the central processing unit permits lower data transmission costs as well as easier access to programming resources and other inputs.

22 The hospital location is taken as the town or city reported in the *Canadian Hospital Directory*.

23 To be more precise, the variable is actually the inverse of the stock variable specified in the library model. This inconsistency was not intentional and presents no problem in comparing the hospital and library equations. One should merely expect the S_i coefficients to take opposite signs in the two sets of equations.

24 All independent variables are constructed from data found in the *Canadian Hospital Directory*, unless otherwise stated.

25 See, for example, P. R. Lawrence and J. W. Lorsch (1967).

26 For example, in some provinces, hospitals were allowed the flexibility to expand computer applications once one application was in place; in others, hospitals had to seek continuous approval on a project-by-project basis. This assessment was conveyed to us in discussions with provincial computer service groups.

27 The exception is the sample of Atlantic hospitals, where the homogeneity assumption was supportable. Estimation was restricted to public general hospitals to avoid introducing heterogeneity by hospital type.

CHAPTER 4

1 Both the supermarket and the planned shopping centre had their origins in the United States and subsequently were introduced in Canada. For an overview of innovation in North American marketing organizations, see M. S. Moyer and G. Snyder (1967).

2 The "no-frills" store implemented somewhat earlier by several chains is similar in concept to the box store in that the customer packs and carries his or her own groceries; however, the no-frills store is closer in merchandise scope to the supermarket.

3 A recent study showed that generic products accounted for about $1.7 billion a year of sales across Canada. Generics were originally marketed in France and were introduced in the United States in 1977. The first Canadian chains moved into generics early in 1978. See *Canadian Grocer* (April 1978), p. 41.

4 Such systems are identified under the broad heading, "point-of-sales systems."

5 The more advanced and expensive electronic registers are upgradable to full POS systems.

6 Mel Dobrin, President of Steinberg's Ltd., has termed the electronic checkout with code scanning "the most significant development in food retailing." See W. S. Good (1979), p. 41.

7 Many of these innovations are described in E. J. Budill (1979) and F. R. Denham (1978).

8 Batch picking involves filling orders for 10 to 20 stores simultaneously.

9 Original equipment manufacturers generally buy equipment from a manufacturer and add value to it by designing a software package that fits the clients' needs. The service bureau basically supplies consulting services and rents the client a terminal hooked into its host computer.

10 See Retail Council of Canada (1978), p. 125.

11 One study, by D. F. Martin (1973), reports that computerization of in-house accounting and inventory tasks, which was introduced in the early 1960s, was extended to nearly two-fifths of all U.S. wholesale firms by 1972 and probably to one-half by 1974.

12 Additional questionnaires were mailed to subsidiaries when a parent firm indicated that its responses excluded subsidiary results.

13 More specifically, our preliminary survey indicated that a very sharp trade-off existed between breadth and depth of survey coverage. Thus an emphasis on obtaining information about the extent of computerization and the cost saving associated with it would have substantially reduced our response rate. Since our priority in this study was to obtain basic information in an area where very little is known, our questionnaire was designed to encourage a high response rate. A copy of the questionnaire is available from the author upon request.

14 In Canada, a chain is defined as four or more food stores under common ownership.

15 It should be pointed out that two firms in group 1 indicated that they were computerized by 1979, but they did not report the date of initial automation.

16 This evidence will be discussed in the following chapter.

17 See *Chain Store Age* (August 1978).

18 See C. D. Stevens (1978).

19 Presuming that all other things are constant. This presumption may not be tenable, however. It was pointed out to us that Canadian firms face particular disadvantages in implementing point-of-sales systems. One is the tariff on the equipment.

20 The Ontario region was therefore the "normalizing" observation.

21 The remaining firms in the sample are primarily voluntary or co-operative groups. A study by B. W. Marion et al. (1979) concludes that large food chains are characterized by higher retail costs and other inefficiencies.

22 See Stevens (1978).

23 Seven firms did not indicate the precise date of automation, although they did indicate that they were automated by 1979.

24 This finding is consistent with other surveys reporting that firms find it easier to automate a particular function when some automation of other functions has already taken place. See, for example, H. Braun and R. Bartlett (1978).

25 A study by W. Good (1979) concludes that differences between stores located in Newfoundland and Ontario in the use of electronic cash registers is attributable primarily to size; i.e. stores in Newfoundland are, in the aggregate, much smaller than those in Ontario.

26 The simple correlation coefficients between the variables exceed 0.6.

27 Most firms in the sample had computerized at least one headquarter function by 1974.

28 In this regard, equation 4 in Table 4-4 indicates that scanning was adopted sooner in British Columbia (a "prices off" province) than in Ontario (a "prices on" province), although the coefficient is not statistically significant. Unfortunately, it was not possible to evaluate the empirical significance of tariffs in the diffusion process.

Chapter 5

1 See, for example, E. G. May and M. P. McNair (1977), p. 57.

2 An overview of major changes in the structure and activities of department stores can be found in Moyer and Snyder (1967), and Statistics Canada (1979).

3 See Retail Research Institute (1969). The respondents to the survey encompass general merchandisers, including department stores.

4 This total included firms owning or renting computers or using service bureaus.

5 Miscellaneous general merchandise stores were excluded from the sample on the grounds that they represented an extremely heterogeneous group. It should be noted, however, that the survey conducted by the Retail Research Institute (1969) included general merchandise stores.

6 The department store sales reported in Statistics Canada (1979) were for 1951 to 1977, inclusive. Sales estimates for 1979 were extrapolated linearly from the series.

7 The U.S. estimate is from Braun and Bartlett (1978).

8 There was no evidence, however, that lack of information or unavailability of equipment was a problem for potential Canadian adopters. Indeed, it was indicated to us that information on automation practices in the United States was readily available to Canadian stores.

9 By way of comparison, the ten largest department store organizations in Canada accounted for 96 per cent of total department store sales in 1976. The ten largest supermarket chains accounted for about 51 per cent of total supermarket and grocery store sales in the same year.

10 Overall and individual goodness-of-fit statistics were generally higher for this size measure than for the others utilized.

11 The simple correlation coefficient between the two variables ranges from 0.7 to 0.82 in the three equations.

12 See Statistics Canada (1979), p. 35.

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