AUTOMATIC RATE ADJUSTMENTS AND SHORT-TERM PRODUCTIVITY OBJECTIVES FOR BELL CANADA

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ABSTRACT

A general approach to the specification of realistic short-term productivity objectives and price guidelines is presented. Desirable characteristics for an Automatic Revenue Adjustment Clause (ARAC) are discussed. Rate adjustments represent the difference between maximum allowed input price increases and minimum required productivity gains. Attention is focused on the specification of the productivity objective. Since the potential for productivity improvement is not the same in different companies, a realistic objective can only be set by examining the past performance of Bell Canada. However, simple averages of historic productivity gains are inappropriate. After studying the Bell Canada production process, a short-term productivity forecasting model (which can be used to check the consistency of revenue and cost estimates in a budget view) is specified. Minimum required productivity gains calculated using this model are consistent with past performance under similar circumstances. It is concluded that an ARAC could be implemented within the framework described.

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CHAPTER I

INTRODUCTION

During the last decade, a rapidly expanding body of literature has developed with regard to production theory. The explanation of productivity change has been studied at both a macro and micro level. Several investigations of the sources of productivity change under restrictive assumptions have been made. In addition, increasingly sophisticated production functions have been estimated. Estimation problems have led some researchers to fit derived relationships. For example, an input requirement model can be derived from the production function if cost minimization is assumed. Debate has also arisen over the validity of estimating any aggregate equation. Although the final impact of this developing literature is not yet evident, new approaches to growth theory at an aggregate level and to the theory of the firm at a micro level have been encouraged.

In surveying the literature, it is evident that a great deal of the research in this field has been built upon a weak data foundation. Comparison of the different approaches is complicated by the fact that different researchers have used different data sources.

In this thesis, the nature of the Bell Canada production process will be investigated and some of the approaches mentioned above will be compared using a consistent and reliable data base. The objective is to develop a short-term productivity forecasting model for Bell Canada.

Bell Canada is a regulated company and all rate changes must be approved by the Canadian Transport Commission. In a time of accelerating inflation, the need for more frequent rate adjustments is expressed and the increasing frequency of rate cases puts severe pressure on the whole regulatory process. As a result, increasing interest in Automatic Rate Adjustment Clauses (ARAC) has developed. The specification of an ARAC involves two main problems. First, given the level of output, a maximum allowable input level must be specified. In other words, a minimum required productivity level must be set. Research on the production model is useful in specifying a realistic productivity goal to be built into the ARAC. Secondly, the maximum allowable price increase on each input must be determined. Depending on whether increases in interest expense are included, the automatic rate adjustment can be calculated so as to maintain a given rate of return on either average total capital or on equity capital. The second goal of this study is to develop an automatic revenue adjustment clause for Bell Canada. Particular attention will be directed at the determination of an appropriate minumum required productivity improvement in each year and the analysis of the production process can be interpreted as leading up to the specification of this minimum required productivity gain.

Chapter II contains a description of the historical development and present institutional environment of Bell Canada. Some major technological developments occurring in the past are discussed. An outline of the services offered and the current organization of the company is given. The regulatory environment in which the company operates is also discussed. This background information is required if the specification of either a production model or an automatic adjustment formula is to be understood.

Chapter III introduces the concept of an automatic rate adjustment clause. This concept is not unlike the guidelines of the Prices and Incomes Commission in the United States. The need for such a clause in an inflationary and deflationary environment is explained. In fact, the regulator, the company and the public can all benefit from such an approach if appropriate provisions are made.

As pointed out above, two decisions are required to determine the size of any automatic adjustment. First, maximum allowable input requirements must be specified given the output level. Secondly, maximum allowable price increases for each of these inputs must be specified. Particular attention must be focused on the problem of building an incentive for efficient management into any automatic rate adjustment clause. Some of the alternate proposals which have been developed elsewhere are discussed within this framework in the second section of Chapter III. A discussion of the theoretically desirable properties of any automatic rate adjustment mechanism is given in the third section. Finally, the underlying accounting framework and the general procedures necessary to calculate an automatic rate adjustment for Bell Canada are described. Further research regarding the production process, the nature of technological change and the cyclical behaviour of productivity gains for Bell Canada are required before the ARAC can be fully specified. These topics are treated in subsequent chapters.

The procedures used to calculate various productivity measures are outlined in Chapter IV. After a discussion of aggregation and index number problems, a detailed description of the development of all input and output data is given. Some readers may prefer to bypass this discussion. However, since the merit of the following chapters rests on the appropriate definition of inputs, output, price and factor prices, I felt that this topic required a detailed discussion within the main body of the text. The actual data are presented in Appendix A (Tables A-1 to A-26).

A theoretical discussion of production function and input requirement models is contained in Chapter V. The relationship between productivity measures and shifts in an aggregate production function are discussed. It is pointed out that a production function can be used to determine expected productivity trends as well as to answer other questions concerning the characteristics of production. The implicit assumptions of alternate aggregate production functions are stated in terms of the basic characteristics of any technology. Next, a method for investigating the nature of technological change directly is described. This entails examining the relationship between factor prices and various input and output variables under the assumptions of constant returns to scale, cost minimizing behaviour and exogenously determined input and output prices. Of course, any conclusions which might be drawn using this approach are dependent on the validity of the three assumptions made. However, this method is also outlined in Chapter V in the hope that preliminary evidence on the nature of technological change might aid in the search for a satisfactory aggregate production function. Methods used to estimate each type of production function with the explicit specification of technological change are described. Finally, given the form of the production function and the adjustment mechanism for each input, an input requirement model is developed under the assumption of cost minimization. This type of model can be used to predict both the long-term level and cyclical pattern of productivity gains.

Estimates of alternate production function and input requirement models are presented in Chapter VI. Evidence from the preliminary investigation of technological change is discussed first. Empirical estimates of Cobb-Douglas, Constant Elasticity of Substitution and some nonhomogeneous production functions are then described. Estimated input requirement models are also shown. To the extent that a unique production function or a compatible set of production functions is found, general conclusions are drawn regarding the characteristics of the Bell Canada production process, the type of technological change, the productivity trends expected in the future and the cyclical pattern of productivity gains.

A model for the specification of minimum required productivity gains is developed in Chapter VII. Since the opportunity for productivity improvements vary from industry to industry, valid productivity objectives for Bell Canada cannot be set by studying the performance of some other company or industry. It is more realistic to base the minimum required productivity gain on improvements achieved by Bell Canada in the past under similar conditions. In this case, productivity improvements required by the ARAC will be at least as high as those required under the present regulatory mechanism. The production process in the telecommunications industry is very capital intensive and changes in capacity utilization from year to year lead to large oscillations in potential and actual productivity improvements. However, the model estimated in Chapter VII yields very accurate predictions of productivity gains over the sample period.

The determination of maximum allowed price increases on input factors is illustrated in Chapter VIII. Automatic rate adjustments are calculated by combining these results with the minimum required productivity gains calculated in the previous chapter. Over the period 1954 to 1972, automatic adjustments and comparable historic adjustments are examined. Finally, further considerations regarding the implementation and timing of an ARAC are discussed.

The last chapter summarizes the main results of this study. Applications of the proposed ARAC are discussed and areas requiring additional research are pointed out.

Chapter II

BELL CANADA - HISTORICAL DEVELOPMENT AND PRESENT OPERATIONS

A. Introduction

Bell Canada operates as part of an integrated communications system in Canada. Other members of the Trans-Canada Telephone System are the following:

1. British Columbia Telephone Company
2. Alberta Government Telephones
3. Saskatchewan Telecommunications
4. Manitoba Telephone System
5. Maritime Telegraph and Telephone Company
6. New Brunswick Telephone Company
7. Newfoundland Telephone Company.

Each member provides the telephone plant in its own operating territory. Revenues from communications carried into, out of or across the territory of a particular member are shared by that member. Calls can also be routed out of Canada through the facilities of the Canadian Overseas Telecommunications Corporation which is also an associate member of the Trans-Canada Telephone System.

Although Bell Canada is only one of the eight Trans-Canada Telephone System members, it occupies a dominant position. About two-thirds of all the telephones in Canada are operated by Bell Canada. The operating territory includes Ontario, Quebec and parts of Labrador and the Northwest Territories. About two million square miles of territory are covered and communications facilities extend as far north as Ellesmere Island (about 650 miles north of the Arctic Circle).

Before investigating either the production process of Bell Canada or the feasibility of an automatic adjustment mechanism, it is necessary to gain some knowledge of company operations and the institutional framework within which the company operates. First, I will look at the historical development and major technological innovations which have taken place within the industry. Next, I will examine the ownership and the organizational structure of Bell Canada at present. Bell Canada services and their pricing are also described. The most important section for our purposes concerns a description of the production processes necessary for the provision of these services. Finally, the regulatory environment in which the company operates is described.

B. Historical Development and Major Technological Innovations Within the Industry[1]

Strictly speaking, the telephone industry originated in 1874 when Alexander Graham Bell conceived the idea of a telephone in Brantford, Ontario. He made the first call in 1876 and received patent rights in 1878. In the following year, the rights were sold to the National Bell Telephone Company of Boston. This company organized the Bell Telephone Company of Canada which was granted a charter in 1880. The first prospectus claimed that there were 2,000 customers. Thus, the present telephone industry in Canada has developed within the last 100 years.

When the Bell Telephone Company was formed, the first task was to bring some order to the chaotic telephone business. Some cities even had competing exchanges with no interconnection between them. The American Bell Telephone Company put up approximately one-third of the required funds and most of the major existing companies were bought. In 1882, a department was set up to manufacture telephones. This eventually developed into the Northern Electric Company.

The Bell Telephone Company had been created to serve the whole of Canada. Because of the difficult

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[1]A general description of the history and operation of Bell Canada and the telecommunications industry is contained in the booklets <u>This is Bell Canada</u> and <u>Canada's Telephone Industry In Perspective</u> which have been prepared by Bell Canada and the Trans-Canada Telephone System respectively.

terrain, existing transportation system and sparse population, this proved impractical. Operations in the Maritimes and the Prairies were sold. By 1909, the operations of the Bell Telephone Company were confined mainly to Ontario and Quebec.

Today, the telephone industry is engaged in much more than the transmission of telephone conversations. A more accurate description of the role of the industry would be "the electrical transmission of intelligence". This view of the industry's role has not developed overnight. It developed as a result of major technological developments and changes in the communications requirements of society. Some idea of the rapid technological progress made in this industry may be gained from the following paragraphs.

Early telephones each had their own battery which had to be recharged. The first improvement was to establish common batteries located at the central office to serve all telephones. Long distance service also improved. By 1890, a 200-mile long distance call could be made. Ten years later, it was possible to place a 1,000 mile call. With the advent of the vacuum tube repeater in 1915, it was possible to place calls from Montreal to Vancouver. In 1920, it was feasible to call most points in Canada and the United States. Trans-Atlantic service via New York was established in 1927 and in 1932 a direct Montreal to London route existed.

Technological innovations took place in switching as well as transmission. Originally, all calls were switched or connected manually. Today, Bell Canada would need over 500,000 operators to fulfill this role. Automatic switching machines were developed to connect the originating and the terminating telephones. The first dial office was established in Toronto in 1924. This permitted operators to simply dial the terminating telephone number to connect a long distance call.

The growth in the number of telephones was extremely rapid during the twenties. However, after the stock market crash in 1929, growth slowed down. In fact, during 1931 more phones were disconnected than were connected by the Bell Telephone Company. Demand for communications continued to grow slowly during the thirties. However, technical progress continued especially with regard to long distance transmission. In 1931, the Trans-Canada Telephone System was established. World War II created a heavy requirement for telecommunications services, but there were limited resources available to satisfy the demand.

Following the Second World War, two decades of expansion and modernization have occurred. Telephone companies were faced with a surging demand and with a shortage of equipment in place. During this period, the population of Canada nearly doubled (12 million to 20 million) and the number of telephones increased at an even faster rate (2 million to 7.5 million). The Bell Telephone Company only spent 14 million dollars on construction in 1945. By 1955, annual construction expenditures were 128 million dollars and by 1965, this figure had climbed to 242 million dollars.

The fifties also saw further technological developments. In 1958, the Bell Telephone Company started to introduce direct distance dialing whereby a customer could dial the terminating telephone number himself. This was a logical extension of operator dialed switching systems. Today, it is possible to direct dial over 100 million telephones in Canada and the United States. Future plans are to extend this service to overseas areas and a world-wide telephone numbering scheme has been established. Developments in switching machines have also made it possible to provide many new types of services to customers. The trend of technological developments toward automatic switching has made it necessary for telephone companies to employ more capital per unit of labor used, i.e., to become more capital intensive.

Transmission technology also continued to develop during the fifties. In 1958, the Trans-Canada Microwave System was opened. This made it possible to provide nationwide television and radio. Service has been extended northward by radiotelephone and by tropospheric scatter systems. The first commercial tropospheric scatter system was established in 1958. In the future, satellite communications will also be used to provide service to the north.

During the sixties, the rate of growth of basic telephone service had become more stable. However, the scope and variety of new communications services is increasing very rapidly. Long-term growth of the industry hinges largely on diversification since the growth potential of basic telephone service has declined.

In 1968, the Bell Telephone Company changed its name to Bell Canada. This is indicative of the changing role of the company. In the future, data transmission is expected to form a larger share of revenue than voice transmission. The Trans-Canada Telephone System has recently announced the opening of a coast-to-coast data transmission network which will be dedicated solely to data transmission. In addition, the varieties of basic telephone service have proliferated during the sixties. This is an expected development in an increasingly affluent society.

C. Ownership and Organizational Structure of Bell Canada[1]

Bell Canada is a privately owned corporation with more than 250,000 shareholders. More than 98 per cent of

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[1]Much of the information contained in this section is available from the Annual Reports of Bell Canada and subsidiary companies.

the shareholders are resident in Canada and less than 5 per cent of the shares are owned by foreigners. The American Telephone and Telegraph Company owns less than 2 per cent of the shares of the company. With more than four billion dollars of assets, Bell Canada ranks as the largest Canadian company on this basis. There are about 40,000 employees and total sales are in excess of one billion dollars.[1]

Bell Canada owns approximately 50 per cent of the New Brunswick Telephone Company, 99.7 per cent of the Newfoundland Telephone Company and 52 per cent of the Maritime Telegraph and Telephone Company. However, Bell does not have voting control in the Maritime Telegraph and Telephone Company. The Island Telephone Company is in turn owned by the Maritime Telegraph and Telephone Company. This company serves Prince Edward Island but is not a member of the Trans-Canada Telephone System.

Bell Canada has an agreement with the American Telegraph and Telephone Company (A.T. and T.) by which A.T. and T. agrees to provide advice and assistance on technical and operating matters. Nine major telephone organizations have a similar agreement with Bell Canada.

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[1]These comments regarding assets, employees and total sales apply to the year 1972.

Bell Canada also owns Northern Electric.[1] An agreement exists requiring Northern to manufacture materials upon Bell's request. However, the company also sells in other markets and has been a major exporter. Recently, Northern has continued the trend towards concentration on fewer product lines. In the past, Northern has had a reciprocal agreement with Western Electric (the manufacturing subsidiary of A.T. and T.) regarding the exchange of information relating to the development and manufacture of telephone equipment.

The Bell-Northern relationship has been the subject of much study. In the 1969 rate case, conclusions of an audit of Northern selling prices were presented.[2] It was reported that "in the case of all items examined by us, with the exception of minor clerical errors, the prices charged to general trade customers were as high as or higher than, the equivalent Bell prices. Exhibits B-60 and B-61 presented further evidence to the effect that Bell Canada pays lower prices to Northern than would be charged by alternative Canadian or United States suppliers. In this thesis, no further examination of this issue will be made.

An integrated system of companies has developed in the telecommunications field. These developments have been

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[1]Recently, a public offering of shares has been made. Bell Canada will retain about 90 per cent ownership of Northern.

[2]Canada, Canadian Transport Commission, Telecommunications Committee, Bell Canada Application, April 1969, Exhibit B-56 to B-61.

encouraged by the highly integrated technology involved. With growth of the entire industry, specialized functions have expanded to the point where they are managed most efficiently as separate companies within an integrated system. Examples include Bell-Northern Research, Microsystems International and Tele-Direct.

In this thesis, I am only concerned with the Bell Canada production process. Thus, the organization of companies engaged in research and development is not directly relevant. Consolidated date for Bell Canada and Teledirect are used so that the splitting off of the directory advertising business will not affect the mix of inputs and outputs. This will make aggregate input and output series more reliable. Bell's official share of total Trans-Canada Telephone System revenues are taken on the assumption that the methods used to distribute revenues have remained fairly constant and provide a reasonable share of revenues to Bell Canada.

A knowledge of the internal organization of Bell Canada is useful in studying the production process of the company. Since population density is an important variable in determining the cost of providing service, disaggregation on a geographical basis may be a useful step. Bell Canada itself is divided into two operating regions. Western Region contains Toronto Area, Western Area and Central Area. Eastern Region contains Montreal Area and Eastern Area. In addition to these two regional groups, three other major divisions exist on a functional basis. Computer Communications and Network Services include the provision of data and long distance voice services which are not provided by a particular geographical region. Operations include headquarters engineering, systems and operational staff. A final division encompasses administrative functions at headquarters. It includes departments, such as treasury, accounting, public relations, law, regulatory matters and personnel.

D. Services and Methods of Pricing[1]

Bell services may be divided into three main categories - local, toll and miscellaneous. Other income such as dividends from subsidiary companies, dividends from other investments and interest from other investments minus interest on plant under construction is also received by Bell Canada.

A breakdown of local service revenues and the value in millions of dollars for each category in 1972 is shown below.

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[1]The classification of Bell Canada services is described in detail in the Bell Canada Memorandum, "System of Accounts", General Circular, 101.15.

Contract Charges	568.2
Non-Recurring Charges	28.9
Message Charges	1.6
Public Telephone	18.1
Service Telephone	.1
Local Private Line Service	12.8
Total Local Services	629.7

Contract charges are the basic monthly charges paid by business or residence customers while non-recurring charges are based on installation of service, termination and restoration of service, initial charges for color or Princess telephones, etc. Message charges include revenue from messages in excess of the allowance covered by the regular monthly contract charges for hotel private branch exchanges or mobile radio telephones, etc. Public telephone revenues accrue from coin operated telephones. Service telephone revenues arise when Bell only provides the switching facilities and the terminal telephone equipment and lines are provided wholly or in part by others. Both local message charges and service telephone charges are relatively small. A final category of local service is local private line revenue. These are services which provide communication between points within the same telephone exchange and do not require central office switching. These private lines may be used for voice, teletypewriter or program transmission.

Cost is one of the factors considered in the pricing of local service. However, this is not the only factor. The value of service concept has been used to support the hypothesis that the price should vary with the number of telephones which can be called toll free. It is also claimed that to insure an equitable and fair rate schedule, all customers who can call the same number of telephones toll free should pay the same monthly rate. This obviously means that the rate table discriminates in favor of rural customers where the cost of providing service is higher. The costs of providing service have become a more important factor in the pricing of some types of non-recurring service charges in recent years. Another point of debate concerns charging on a flat monthly basis rather than charging on a per message basis. This is the basic issue involved in the introduction of Extended Area Service.

Bell Canada has enlarged the number of telephones which individuals in many communities can call toll free. Since monthly charges are based on the number of telephones which can be called toll free, the monthly rate is increased. Another result is that the number of conversations between points which were not in the local calling area increase several times over. Extended Area Service has been questioned on the grounds that it may not lead to an efficient use of resources and may be used to increase prices unduly. In spite of this criticism, most customers appear to favour introduction of the scheme in each instance and it does lead to reduced billing expense.

Some people predict that flat rate pricing will be extended to larger and larger areas in the future. This would be in contrast to developments in Europe and the United States where charges are levied on a per message basis by many companies.

A recent trend has been to broaden the scope of local services which are offered. Residence customers can now purchase touchtone service. In the future, it is expected that the touchtone set may be used for the transmission of data. However, the present role is usually restricted to conversation transmission. Contempra and color telephone sets represent modifications in design and style and might be classed as new services. Business customers now have access to an even greater variety of terminal equipment. Speakerphones, automatic dialers and call referral systems are increasingly popular. A wide range of PBX and centrex office switching equipment is also offered. These new services illustrate the trend towards product diversification which is occurring in the provision of basic telephone service.

In the future, planners foresee the development of a wired city. Each dwelling would have one line through which would pass voice and data communications. Merchandise could be displayed on a screen for home shopping. Newspapers or library reference material would be instantly available. Money would play a minimal role in such a society as the credit system would be almost completely computerized. This conception may not materialize in the near future, but it does indicate that the demand for local service may be far from exhausted.

The value in millions of dollars for each category of toll service revenue in 1972 is shown below.

Message Toll	
Telephone	369.9
Other	4.3
Wide Area Telephone Service	27.6
Toll Private Line	62.8
Other	.3
Total Toll Services	464.9

Telephone message toll revenues include charges for all toll services furnished on a message charge basis. It includes revenues from toll calls made from regular exchange or toll telephone stations to transmit data over the switched network. Other message charges include local and toll messages charged on a per message basis which originate at teletypewriter (TWX) stations. Other TWX revenues from installation, move and change charges and monthly charges are also included. Wideband data services, such as Multicom, are another type of other message toll service. Wide Area Telephone Service (WATS) includes revenues from services and facilities furnished for the transmission of voice communications over the general toll switching network charged for on either a flat rate or measured basis without regard to the number of messages. Toll private line services provide communication (voice, teletypewriter, signal, etc.) between points in different telephone exchanges and do not require central office switching operations. Telephone toll private line services refer to private line services furnished for voice transmission (it includes foreign exchange, off-premises extensions and tie line service). Other types of toll private line services include private lines furnished for teletypewriter communications, message switching of data, radio and television programme transmission, Telpak, signalling, telephotograph, remote control and data processing services. Other toll service revenues include all toll revenues not provided for elsewhere.

The pricing of long distance telephone messages is based on the length (in minutes) and distance of the call, the day and the time of day when the call is made and the type of call (direct distance dialed, operator handled station-to-station or person-to-person). The actual determination of rates is based on a consideration of the costs involved. This implies a relationship between price and distance. Initial conversation minutes are priced higher. Charges also depend on usage of the network at the time that the call is made. Although costs are considered, no exact determination of prices can be made on this basis alone. An equitable and easily understood rate table must also be developed. On the basis of these criteria, all calls over the same distance are priced at the same level even though the costs may not be equal given the existing structure of the network.

Flat rate pricing has also been extended into the toll service field. Businesses may purchase Wide Area Telephone Service (WATS) which enables them to make long distance calls within a certain area. The largest area which can be purchased would include all of Canada.

At this time, I want to point out that many of the revenue categories which have been discussed include both voice and data communications. Data communications may fall under the heading local contract, message toll, WATS, local or toll private line revenue, etc. Bell Canada does not monitor the use of communication lines and hence no exact estimate of revenue from data transmission is available. However, it is estimated that data transmission may rise from about 20 per cent of total communications to over 50 per cent within the next five years. A separate organizational division (Computer Communications and Network Services) has been set up and the Trans-Canada Telephone System has recently opened a digital transmission network solely for the transmission of data.

The growing importance of data transmission has been accompanied by an expanding variety of terminal equipment. The main development has been Data-Phone sets. These telephones transmit the electrical signals produced by machines into voice frequency signals which can be transmitted over the entire telephone network. Other data communications services are: Telescript - to transmit hand-written messages; Phone-fax - a facsimile system integrated with the telephone network; and Dataspeed - a. 1,000-word-per-minute paper tape transmission system. Transmission lines of higher capacity have been made available through private line offerings. Bell now offers modulators (MODEMS) which will interface with machines requiring higher transmission speeds. The company hopes to expand this business and even to provide the front-end of computer installations in the future. A service known as Message Switching Data Service has been developed to provide a means whereby a firm's private lines and regular telephone facilities may be co-ordinated to facilitate the exchange of traffic. The system will be capable of collecting and storing large amounts of data which can then be forwarded as a bulk transfer later on.

Miscellaneous revenues are the final type of services which will be considered. The value in millions of dollars for each category for the year 1972 is shown below. These figures represent a consolidation of Bell Canada and Tele-Direct Revenues.

Directory Advertising and Sales	45.7
Rents	7.1
General Services and Licences	2.2
Other	2.6
Total Miscellaneous Revenue	57.6

Since Tele-Direct was only formed July 1, 1971, we calculated 1971 and 1972 revenues to be consistent with earlier data. Directory Advertising services include local white and yellow pages advertising, national white and yellow pages advertising, commissions received for selling advertising in other companies directories and any revenue arising from the sale of directories. Rents include revenues from the rental of telephone plant such as circuits, space in conduct, pole attachements, building space and equipment. Premise rental paid by Tele-Direct to Bell is deducted. Tele-Direct revenues from the leasing business are not included as these did not compose part of Bell Canada operations in the past. Amounts accruing for services rendered to other companies under a license agreement and general service contract are shown separately. A final category, other miscellaneous revenues, includes all miscellaneous operating revenues not provided for elsewhere. Bell records Tele-Direct commissions in this category but these must be eliminated from a consolidated income statement.

E. Production Process

Many of the services described above use the same equipment. The same network can be used for voice or data transmission although a separate network for serial transmission of data is being built. Similarly, terminal equipment, such as a simple telephone set, is used for both long distance and local calls. Disaggregation of production by service would make little sense because the majority of costs are joint. A more promising approach is to investigate the four basic steps involved in the provision of most types of communications service.

The first step is the provision of terminal equipment. As described above, an increasing variety of terminal equipment is becoming available to residence and business customers. Services are often identified by the type of terminal equipment since this is the most visible aspect of the service to the customer. However, this is only part of the service offering.

The second step is to transmit the analogue or digital signal to the local switching centre or central office. In the past, all data has been transmitted in analogue form but plans are now underway to provide digital transmission. This usually means wideband lines which can be used for serial transmission of several channels of digital information as compared with one channel of analogue information.

There have been no dramatic innovations in the provision of local looping. However, facilities and methods have improved. It has become possible to use finger gauge wire and to reach out further from a central office with the same gauge of wire. Cables are gradually replacing steel wire in rural areas. Better quality cable is now available and more cable is being buried. This results in more reliable service as well as a more aesthetic environment.

One method which has been used to cut the cost of providing local lines of communication involves the concept of dedicated plant. A cable is permanently attached from each address to the switching centre. The dedicated method results in virtual elimination of line and station transfers, reduction in man-made troubles and improved loop transmission.

A second method of cutting costs is the use of concentrator equipment to serve telephones which are a considerable distance from the central office. The lines of many customers feed into the concentrator but a reduced number of lines lead to the central office. Although there are cost savings which result from the reduced number of lines going to the central office, the concentrators themselves are relatively expensive. A similar concept is to actually distribute the switching operation which is usually carried on at the central office. This technique has not been used in Canada yet.

At some point, the message must be routed so that it will eventually arrive at the correct destination. This function is known as switching and it is the third major step in the production chain. Actually, the communications network can be thought of as one large computer making millions of logical decisions every second so as to interconnect the continent's telephones. Switching machines have replaced the manual process of connecting incoming and outgoing lines. Today, three main types of switching machines exist.

Step-by-step equipment uses a number of separate switches to complete each call. As the customer dials each digit, the machine follows step by step until a pathway to the desired telephone has been established. One disadvantage of this type of machine is that the number of switches and their arrangement are tied directly to the numbering plan. This means that the equipment is difficult to modify as cities grow or as Extended Area Service is introduced.

Crossbar switching machines are more versatile and flexible. They operate using common control. As the customer dials each digit, this information is stored. An appropriate path through the switching network is found. When this path is found, the appropriate switches are activated and the common control equipment becomes free to handle another call. Advantages of this machine are that it can easily be adapted to changing local numbering plans, it is faster and it is more economical since the number of switches required is not directly linked to the number of digits. Many new services can be provided using crossbar switching. These include pushbutton dialing, Wide Area Telephone and Centrex services.[1] Crossbar equipment is gradually replacing older step-by-step installations. Fewer moving parts result in a major

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[1]Extension numbers can be dialed directly with Centrex service.

reduction in maintenance expense with crossbar switching machines.

Even more flexible switching machines exist. Electronic Switching Systems (E.S.S.) use stored programs and hence are very easy to monitor and modify. Maintenance expense is reduced since the number of moving mechanical parts is reduced. Many new services, such as the automatic transfer of incoming calls, abbreviated dialing and conference calling are possible with E.S.S. equipment. The first E.S.S. office for regular use was established in Montreal in 1967. These machines will become more common in the future, especially in local switching offices.

A distinction should be made between local and toll switching. Local switching occurs at the customer's first point of contact with the switching network. Toll switching machines are capable of examining the area code and the switching unit code. A world wide plan for the assignment of area codes has been agreed upon. Both switching unit codes and area codes have been assigned at random throughout North America. A heirarchy of switching offices enables a customer to dial over 100 million telephones directly on this continent. In the future, direct distance dialing will be extended overseas.

Automatic billing has been developed in conjunction with automatic switching machines. Equipment is attached to the circuit and the required information is produced in the form of punched holes on paper tape. Information on this tape is transferred to punched cards or magnetic tape for computer processing. At some centres, it is still necessary for an operator to record the number from which the call is being placed. However, this human function has also been eliminated in many centres. In the future, calls which are currently operator handled will be dialed directly by the customer (person-to-person calls, collect calls, credit card calls, etc.). The operator's role will be eliminated almost to that of an observer and the present card type switchboards will disappear.

The final step in the provision of communication service is transmission of the information. Technological progress has been as remarkable in this field as in switching. Carrier techniques are now used. This is an electronic technique which makes it possible to transmit a number of voice conversations along a single pair of wires. Costs are reduced and transmission quality is improved. Cables and microwave systems are being used extensively to take full advantage of this technology. Open wire lines have a lower carrying capacity and are susceptible to storm damage. Although the Trans-Canada Telephone System has a microwave network, coaxial cable is now competitive with microwave for some short haul routes. It is expected that more coaxial cable will be installed in the future.

In Northern regions, high frequency radio is another transmission device. Climatic conditions make it uneconomic to build and maintain transmission systems used in the south. Tropospheric scatter systems are also used. Radio-telephone signals are beamed from a ground station and reflected back to earth by the troposphere at an altitude of about 50,000 feet. Another possibility in the near future is satellite communication. Research is going on in this area and the telephone system has rented communications channels from Telesat. One disadvantage of high altitude synchronous satellite systems for two-way voice communication is that the half second inherent delay in the signal returning from the satellite produces echo problems. Medium altitude satellites overcome this problem but require tracking equipment and a larger number of satellites. In the distant future, laser beams and wave guide systems provide the best potential for development. At present, wave guide systems can only be used over a few hundred feet to connect microwave equipment with the antenna.

Regardless of the type of transmission system used, the network must be constructed with certain principles in mind. Messages are grouped at toll centres before they are transmitted to the next grouping point. Direct high usage trunks only link offices between which a large volume of traffic exists. Switching equipment is programmed to try to complete a call using the most direct route. If this route is busy, an alternative route is tried. This type of network results in higher utilization and lower costs than if all points were linked directly.

The network is also engineered to provide maximum reliability in the event of disaster. Bypass routes are constructed around major cities. Major routes always have an alternate path and these are separated geographically. Key lines of communication receive additional protection. Network management essentially involves the balancing of circuit and switching capabilities on a nationwide basis to reduce congestion. This function becomes more important during an emergency and emergency operation centres are maintained in strategic locations.

It has been pointed out that transmission quality has been increased significantly in the past. However, a degree of noise and delay distortion still remains. This leads to problems in the rapid communication of data where distortion of the message results in data errors. The solution is to make higher quality transmission lines available for data transmission. Wider band widths have also been provided through such services as Multicom and Telpak. A network is being developed which will transmit data in digital rather than analogue form, thereby reducing errors and significantly lowering the cost of data transmission.

This completes the description of the four main production processes which are the provision of terminal equipment, local loops, switching and transmission service. All four processes are capital intensive and have been subject to rapid capital-using technological change. The jointness of costs for particular services and the relationship between technological change and the introduction of new services have been indicated.

F. Regulatory Environment

No description of Bell Canada's operations would be complete without mention of the regulatory environment within which Bell operates. In this industry, the size of the market is small in relation to the capital investment which is required to provide service. It is in the public interest to limit the number of firms in the industry and to regulate the operations of these firms. The telephone industry is an extreme case, in that each firm is a natural monopoly within its operating territory.

Bell Canada operates under a Federal charter and is regulated by the Canadian Transport Commission under the Railway Act. The essential behavioral aspects of the regulated communications industry in Canada have been described as follows:

1. Large segments of the industry are regulated in the public interest.

2. The industry estimates the amount of output that will be required for some period in the future, and then sets about to provide this output in the most efficient way possible.

3. Anticipated demand determines the size of the capital stock required, and this in turn determines the amount of current investment.

4. Pricing under regulatory constraint is geared primarily to ensuring that the industry can marshal the financial resources required to finance necessary capital expansion.[1]

This description would also apply to the environment within which Bell Canada has operated.

With the growing importance of the telecommunications industry, the federal government created the Department of Communications in 1969. This department is impowered to

1. co-ordinate, promote, and recommend national policies and programs with respect to communications services including the Post Office,

2. promote the establishment, development, and efficiency of communications systems and facilities,

3. assist Canadian communication systems and facilities to adjust to changing domestic and international conditions,

4. plan and co-ordinate telecommunications services for departments, branches and agencies of the Government of Canada,

5. complete and keep up-to-date detailed information in respect of communications systems and facilities and of trends and developments in Canada and abroad relating to communications matters, and to

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[1]R. Dobell et al., "Communications in Canada: A Statistical Summary", Telecommission Study 2 (b) (i), prepared for Department of Communications, Information Canada, Ottawa, 1971, p. 8.

6. take such action as may be necessary to secure, by international regulation or otherwise, the rights of Canada in international communication matters.[1]

One of the first tasks of this department was to initiate a series of Telecommission studies which examined many aspects of the industry. A Green paper outlining the federal government's present thinking on National Telecommunications Policy has been prepared. The basic proposal is for one agency to carry out some of the functions of the Canadian Transport Commission (regulating common carriers) and of the Canadian Radio and Television Commission (regulating broadcasting). Such an agency will be authorized to take a much closer look at the operations of common carriers. For example, detailed long range construction plans will have to be submitted. A split of authority between Federal and Provincial governments will have to be worked out. Negotiations and discussion will occur in the near future. In the meantime, the Department of Communications is assuming an active role in such matters as the management of the frequency spectrum and the international aspects of telecommunications regulations.

The Canadian Transport Commission itself has also adapted a new attitude toward regulation. A cost inquiry has been appointed to take a detailed look at specific questions, such as the allocation of costs and the rates

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[1]Ibid., pp. 16-17.

charged for particular services. Accounting practices with regard to deferred income taxes and depreciation are also being investigated. Other questions, such as interconnection and the Bell-Northern relationship, may be investigated. The above developments and the formation of provincial government departments in Ontario and Quebec to deal with communications all indicate that simple rate of return criteria may not be the pattern for regulation in the future.

An understanding of the characteristics of the production process is necessary for the investigation of many specific questions which arise in the regulatory arena. The answers to these detailed questions are only available from a somewhat disaggregated model of the Bell production process. Such a model would also be useful for internal management purposes. Of course, obtaining answers to more general questions (such as the extent of overcapitalization or undercapitalization) might not require the same level of disaggregation.

In this thesis, a Bell Canada production model is used to analyze a specific regulatory problem, i.e., the determination of an appropriate rate adjustment in an inflationary economic environment. When all prices and costs are rising in the economy, it will usually be necessary to raise the prices of regulated firms. The difficulty lies in determining to what extent the cost increases should be offset by productivity gains. In order to set a reasonable productivity goal, it is necessary to understand the characteristics of the production process. The frequency of rate applications has increased during the last decade as inflation has accelerated. A full scale rate application represents a costly and time consuming solution. However, any move toward an automatic rate adjustment mechanism would make it necessary to determine a quantitative productivity goal and a model of the production process would be essential.

The next chapter describes the need for an automatic rate adjustment mechanism in more detail. Theoretical advantages and disadvantages of proposed schemes are discussed and a conceptual outline for a Bell Canada automatic rate adjustment mechanism is proposed. In subsequent chapters, a Bell Canada production model is developed and integrated with the proposed automatic rate adjustment mechanism.

Chapter III

AUTOMATIC RATE ADJUSTMENT CLAUSES

A. Problems of the Present Regulatory System in an Inflationary Environment

An increase in the price of any input may be offset if less of that input is used to produce a unit of output. If the dollar value of increasing input prices is greater than the dollar value of productivity gains, either the price of outputs must be increased or the rate of return to capital must fall. During the fifties, Bell Canada was able to offset the increases in labor and intermediate input prices with productivity gains. There were relatively few rate cases and the prices of some services actually declined. However, the accelerated pace of inflation in recent years has meant that more frequent rate applications have been made.

Although total factor productivity gains have been higher during the period 1962 to 1972 than in the previous decade, this source of funds has not been sufficient to counter the increase in costs. On the assumption that demand for telephone service is price inelastic, applications for price increases have been made to prevent a decline in the rate of return to total average capital. In addition, the cost of capital raised through debt instruments has increased as a result of the inflationary premium built into interest rates. This additional cost must also be covered if earnings per share are not to decline.

A rate application involves a formal legal procedure with the presentation of evidence by the telephone company and intervenors. Witnesses are cross-examined after the presentation of their written testimony. There has been a tendency for a larger number of intervenors to take part and this has countered any attempt at speeding up procedures. Each application becomes a general examination of company operations and is usually long and costly. In any case, the decision of the Canadian Transport Commission is subject to revision by the cabinet. Direct costs incurred by the carrier, by the intervenors and by the government, have been growing rapidly as a result of the increasing frequency and complexity of rate cases and the presence of a larger number of intervenors.

Indirect costs associated with the present method of regulation are also high. As mentioned in Chapter II, the basic argument made in any rate application is that without a price increase, the company will be unable to raise sufficient money to meet service commitments. It is possible that investors might be overly impressed by this argument. In this case, the prophecy of a rising cost of capital is self-fulfilling. Also, the outcome of a rate case is not known in advance. Any added uncertainty associated with the present regulatory process may add to the cost of capital if investors demand an additional return to cover the additional risk.

Another disadvantage of the present system is that the public may never know if a particular rate change is the result of a purely political compromise or is based on a fair consideration of the facts presented. It is possible that the general public would have a better understanding of the rationale for rate changes found by implementing existing guidelines than by implementing decisions reached under the present system.

If guidelines for the short-run adjustment of rates were specified, the frequency of rate cases would be reduced. This would decrease the direct and indirect costs of regulation mentioned above. Of course, the problems associated with the short-run adjustment of rates in an inflationary environment are not uniquely related to Bell Canada. Several techniques which have either been proposed or used by regulatory authorities in the United States are discussed below.

B. <u>Solutions Which Have Been Proposed</u>

The first alternative has simply been to bypass or speed up the formal rate case mechanism whenever possible. In addition to simple changes, such as dropping the requirement that written testimony be read into the record, more fundamental changes have been proposed. The increased use of 'issue stipulations' has been suggested. This involves a prehearing agreement between the regulated utility, key intervenors and the regulatory commission. All parties agree that testimony will be directed at certain key issues. Redundant debate on either nonpertinent issues or issues on which opinions have not changed are avoided. It has also been suggested that rate applications be made in two parts. The first application would be based on the rate of return allowed in the previous case, while the second application would be based on any proposed change in the rate of return. Theoretically, the first application might be considered more quickly than if only one application were made. A third alternative involves the presentation of forecast data as testimony. The utility would in fact receive a preliminary rate adjustment partially based on forecasted cost and productivity performance. However, additional debate is often generated on the merit of the company forecasts. Finally, in cases where a rate adjustment is clearly needed immediately, an interim award has often been made subject to the final decision of the authorities.

None of these techniques aimed at streamlining the rate case mechanism have met the need for timely short-term rate adjustments in an inflationary environment. Instead, rate cases have grown longer and more costly. Many people would argue that the right of the public to a full investigation and discussion of company performance should not be jeopardized. Indeed, more adequate representation of the viewpoint of some groups is necessary. What is required is not an elimination of the present rate case procedures, but that they be made more effective. This would occur if full scale rate cases (although held less frequently) considered only long-term policy guidelines and performance rather than the short-term adjustment of rates. Another mechanism for the short-term adjustment of rates in line with prior rate case decisions on the allowable rate of return and performance standards is needed.

Many gas utilities have automatic purchased gas adjustment clauses in their tariffs. These permit changes in unit costs which are due to changes in the purchased price of gas to be passed on, usually on a month-to-month basis. This type of Automatic Revenue Adjustment Clause (ARAC) applies to about 40 per cent of the company's total costs. Several electric utilities have automatic fuel adjustment clauses in their tariffs. Changes in unit costs due to changes in fuel costs are passed on to customers, usually on a quarterly basis. Fuel adjustment clauses usually apply to about 20 per cent of the company's total costs.

Fuel and purchased gas clauses were actually initiated before World War I in the United States. They were not widely used until the 1950's. Although they have been effective in passing on part of the cost increases arising from the general increase of prices in the economy, they are rather naive techniques and have been criticized on several grounds.

Another method of offsetting the effects of general price increases in the economy is the repricing of plant in service to take account of changing price levels. Much discussion has taken place regarding the differences between current market value, replacement cost and trended original cost. Regardless of which method is used to restate the value of plant, recorded depreciation expense would be increased during an inflationary period. This increase in expense would lower the recorded rate of return. Provided that the allowable rate of return was not lowered, the regulator might eventually approve higher rate levels than if the value of plant in service were not restated. This is not really an automatic rate adjustment mechanism since a rate case would still be required before any effect on the tariff structure could take place. If the allowable rate of return were stated on a net plant rate base (rather than on the money actually invested by shareholders), the effects of restating the value of net plant would be greater since depreciation expense would be higher and at a given rate of return the dollar value of allowable net income would also be higher. However, even with a net plant rate base, this type of mechanism would still not be automatic.

Another type of ARAC which has been proposed is to allow increases in municipal or indirect taxes to be passed on to the customer.

Each of the above techniques is specific to one component of cost and provides no direct incentive for productivity improvement.

The price guidelines used by the Cost of Living Council in the United States take account of increases in the costs of all inputs resulting from inflation. They set a productivity goal and determine the allowable price increase only after allowance for productivity gains has been made. These guidelines might be used as a model for any ARAC proposed for the regulated sector. An ARAC of this type has recently been put into effect in the State of New Jersey.[1]

None of the above techniques for the short-term adjustment of prices are entirely satisfactory. In the next section, properties which would be desirable in any ARAC proposal are outlined in more detail.

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[1]United States, State of New Jersey, Department of Public Utilities, Board of Public Utility Commissioners, "Investigation of a Proposed Comprehensive Adjustment Clause: Decision and Order", Docket No. 732-134, December 13, 1973.

C. Desirable Properties of an Automatic Rate Adjustment Clause (ARAC)

1. Provision for the Achievement of Other Regulatory Goals Associated with the General Level and Structure of Rates

An ARAC should not interfere with the pursuit of other goals associated with the general level or structure of rates. Periodic reviews of regulatory policy have already been used successfully in the banking sector. It can be argued that a separate consideration of short term pro rata price adjustments and of the long term level and structure of rates would lead to better decisions in both areas. However, consideration of the allowable rate of return on capital and the relative prices of services would be necessary at more frequent intervals than revision of the Bank Act. Three years is probably the maximum time which should elapse between full scale rate cases. Of course, either the company or the regulator could always initiate a formal rate case at any time. In fact, the ARAC would serve as nothing more than a convenient bypass for a full scale rate case which would only be used when both the regulator and Bell Canada were satisfied with the adjustment proposed. If the ARAC provisions were considered reasonable, this bypass might be used often. However, both parties would still have the option of a formal rate case open to them. It would also be desirable if the provisions of the ARAC were reviewed formally at least every three years. This would increase the likelihood that the rate adjustment calculated using the ARAC would be acceptable to both parties.

In order not to impede the achievement of other regulatory goals associated with the general level and structure of rates, the following provisions are necessary.

(a) A full scale rate case should be held at least every three years to determine the allowable rate of return and the relative price of different services.

(b) The automatic adjustment should be applicable on an equal percentage basis to the price of all regulated services.

(c) If the regulator is not satisfied with the calculated automatic adjustment in a particular year, a full scale rate case can be initiated. Bell Canada should also have this privilege.

(d) The terms of the ARAC should be reviewed formally at least every three years.

2. Creation of the Maximum Incentive for Efficient Management

The delays and inconvenience associated with the present regulatory system in fact may serve as an incentive for efficient management. Certainly, if all cost increases were automatically passed on, any incentive for cost reduction would be eliminated. However, I will argue that given certain provisions, the incentive for efficient management can actually be increased by establishing an ARAC.

Arms-length regulation is the cornerstone of the present system. Individuals responsible for day-to-day management decisions are not given the responsibility for price adjustments. It is to be hoped that regulators will demand good productivity performance before approving any rate increase. If this condition is not met, then the increase allowed by a rate case judgment will simply be subsidizing inefficient management. However, there is no theoretical reason why a rate adjustment calculated using an ARAC cannot be conditional on an equally good productivity performance.

Any adjustment mechanism should apply equally in both an inflationary or deflationary environment i.e., both rate increases and decreases should be possible. Also, the measured price increases of inputs should refer to industry or national averages where they are indicative of input prices in a particular market. In this way, an indication of the truly uncontrollable element of cost increases can be found. This would avoid the problem of a regulated company granting an overly generous wage settlement. If a national average of wage rate increases is being used in the ARAC calculations, the company will have to make up any additional wage offer entirely out of additional productivity gains. Unless productivity gains are higher than the productivity gains used in the ARAC calculations, the offer of an overly generous wage rate settlement will tend to push the rate of return below the level protected by the ARAC. This argument applies to other inputs as well.

However, there is a tradeoff between finding an indicator of cost increases which is representative of the particular input market and finding an indicator which is not subject to the control of the company. For example, the national average of wage settlements is beyond the control of the company but may not be indicative of the wage increases which Bell Canada has to pay in particular labor markets. Alternative price indicators for each input are outlined in Section D of this chapter.

A major problem in formulating any ARAC is the determination of how much of the cost increases should be offset by productivity gains. This decision requires a detailed knowledge of the production process of the company involved. The productivity gain should be set high enough to provide a reasonable challenge to management but must still be accepted as an attainable objective. Because productivity gains are affected by changes in utilization rates resulting from short-term changes in demand, the rate of growth of demand must be considered when setting the productivity gain objective for each year. Changes in the quality of service could also affect the measured productivity gain. Also, if a realistic productivity improvement is to be forecast, it is necessary to ensure that the productivity level is not at an unacceptably low level in the base year. These problems are considered in more detail in Section D of this chapter. One of the aims of the research on a Bell Canada production model is to find an appropriate quantitative value for expected productivity gains.

It is possible to strengthen the incentive for efficient management in any ARAC by allowing the company to keep some of the profits earned by superior performance. These profits could arise because productivity gains were higher than the value specified in the ARAC or if input price increases were less than the value specified. One method of increasing the incentive for efficient management would be to use the ARAC to protect the rate of return within some permissable range. Within this range, company profits would be directly dependent upon whether management succeeded in meeting the terms of the ARAC. In this approach the concept of a permissable range for the rate of return is being coupled with an ARAC. A second alternative would be to use a graduated application of the ARAC around the permitted rate of return. As the actual rate of return deviated more from the allowable rate, a higher proportion of the differential would be covered by the calculated rate adjustment. The principle would be the same as that used in progressive income tax and the rate of progression could be varied. It should be pointed out that both of these schemes would not allow the company to keep any profits generated by increased efficiency until they had met productivity objectives and kept input price increases below limits specified in the ARAC.

In order to create the maximum incentive for efficient management, the following provisions are necessary.

(a) An ARAC should be operative in both a positive and negative direction.

(b) Subject to the condition that the indicators of price increases for each input are truly representative of that input market, indicators should be chosen which are not affected by specific decisions of the regulated company.

(c) A reasonable improvement in productivity performance should be expected (given changes in utilization rates and the quality of service) and the dollar value of these gains should be deducted from the dollar value of allowable input price increases.

(d) To the extent that management holds the price increases of inputs below expected rates or exceeds productivity objectives, some of the additional profits should be left with the company.

3. Absence of Implied Bias for Resource Allocation Decisions

A bias would be caused if the price increases of different inputs are not considered in an equitable way. If wage rate increases were taken into account but rising interest rates were not, a bias toward labor use would be created. In addition, the productivity objective should be specified with regard to the use of all inputs and should be deducted from the total allowable cost increase on all inputs.

In order not to create a bias with regard to resource allocation, the following provisions are necessary.

(a) Allowable cost increases should be determined for every input used and allowable expenses for a particular input must not be overly generous when compared with allowable expenses on other inputs.

(b) Productivity objectives should be set with regard to the use of all inputs.

4. Creation of an Easily Understood and Conveniently Administered Mechanism

One of the criteria used in choosing between alternate methods should be the ease of calculation. I have also mentioned that the ARAC should be applied across all services equally. If this were the case, a single entry could appear at the bottom of each customer's bill showing the increase due to the automatic rate adjustment. When the calculations yielded a very small rate adjustment it might be advisable to neglect the increase or to carry it over into the next year. It is possible that the public would feel more comfortable with a rate increase calculated by a simple formula than with a seemingly arbitrary judgment made by a regulatory or political body. At this point, I would add the following provision.

(a) The procedures used to calculate the actual rate adjustment should be kept as simple as possible, given the other provisions mentioned on the preceding pages.

5. Adjustment of Rates Based on Recent Cost Trends

The fifth general property listed was that the adjustment of rates should be based on recent cost trends. If the calculated rate adjustment is to be relevant in a period of rapidly changing business conditions, it is crucial that recent data on input price changes be used. The following provision is necessary.

(a) The indicators of unit cost increases on each input should be chosen so that reliable data will be available with a minimum delay.

6. Consideration of the Political Environment in Which an ARAC Would be Implemented

The specific provisions mentioned above should make all parties better off. The general public would have a clear understanding of why rates were being adjusted and the cost of regulation would be reduced. The regulator would have more time to spend on other long-term investigations and would be faced with an evener workload. The company would know exactly how rates were to be adjusted, would maintain the principle of arms-length regulation and would escape from the costs associated with frequent rate cases. The reduction of uncertainty with regard to government policy could also lower the cost of capital. Neither the company nor the regulatory agency could be worse off in a particular instance since they could always initiate a formal rate case.

One further provision is necessary to make any ARAC politically acceptable. It would have to be demonstrated that the application of the ARAC would not result in substantially different rate awards over the long-run than those received under the current system.

(a) Rate adjustments calculated should be similar to those granted under the current system although the timing of the adjustments would vary.

D. Accounting Framework for a Bell Canada ARAC

1. General Framework

Before an ARAC can be specified, the underlying accounting framework must be understood. Starting with the accounting identity implicit in an income statement, a price index is defined for each type of revenue and expense. The income statement identity can then be expanded and the purpose of an ARAC can be illustrated.

The basic income statement accounting identity is:

Total Operating Revenue - Employee Expense - Depreciation Expense - Other Expense - Income Taxes - Other Taxes + Other Income - Interest Charges = Net Income. This identity is shown for two subsequent years by equations 3-1 and 3-2.

3-1. $$r_1R_1 - (e_1E_1 + d_1D_1 + o_1O_1) - (t_1T_1 + x_1X_1) + n_1N_1 - i_1I_1 = c_1C_1$$

3-2. $$r_0R_0 - (e_0E_0 + d_0D_0 + o_0O_0) - (t_0T_0 + x_0X_0) + n_0N_0 - i_0I_0 = c_0C_0$$

Each variable in the income identity can be represented as follows:

rR - Total Operating Revenue

nN - Other Income

eE - Employee Expense

dD - Depreciation Expense

oO - Other Expense

tT - Income Taxes

xX - Other Taxes

iI - Interest Charges

cC - Net Income.

The price of each of these variables is indicated by the uncapitalized alphabetic character and the real magnitude by the capitalized alphabetic character. Subscripts refer to the time period.

Equation 3-3 is derived by subtracting equation 3-2 from equation 3-1.

3-3. $$(r_1R_1 - r_0R_0) - (e_1E_1 - e_0E_0) - (d_1D_1 - d_0D_0) - (o_1O_1 - o_0O_0) - (t_1T_1 - t_0T_0) - (x_1X_1 - x_0X_0) + (n_1N_1 - n_0N_0) - (i_1I_1 - i_0I_0) = (c_1C_1 - c_0C_0)$$

By collecting revenue terms on the left hand side, equation 3-3 can be rewritten as:

3-4. $$(r_1R_1 - r_0R_0) + (n_1N_1 - n_0N_0) = (e_1E_1 - e_0E_0) + (d_1D_1 - d_0D_0) + (o_1O_1 - o_0O_0) + (t_1T_1 - t_0T_0) + (x_1X_1 - x_0X_0) + (i_1I_1 - i_0I_0) + (i_1I_1 - i_0I_0) + (c_1C_1 - c_0C_0)$$

Equation 3-5 is derived by expanding each term.

3-5. $(r_1R_1 - r_0R_1 + r_0R_1 - r_0R_0) + (n_1N_1 - n_0N_1 + n_0N_1 - n_0N_0)$

$= (e_1E_1 - e_0E_1 + e_0E_1 - e_0E_0) + (d_1D_1 - d_0D_1 + d_0D_1 - d_0D_0)$

$+ (o_1O_1 - o_0O_1 + o_0O_1 - o_0O_0) + (t_1T_1 - t_0T_1 + t_0T_1 - t_0T_0)$

$+ (x_1X_1 - x_0X_1 + x_0X_1 - x_0X_0) + (i_1I_1 - i_0I_1 + i_0I_1 - i_0I_0)$

$+ (c_1C_1 - c_0C_1 + c_0C_1 - c_0C_0)$

Rearranging terms in equation 3-5 yields the following expression.

3-6. $\left[(r_1R_1 - r_0R_1)\right] =$

$\left[(e_1E_1 - e_0E_1) + (d_1D_1 - d_0D_1) + (o_1O_1 - o_0O_1)\right]$

$+ \left[(t_1T_1 - t_0T_1) + (x_1X_1 - x_0X_1)\right]$

$+ \left[(i_1I_1 - i_0I_1)\right]$

$+ \left[(c_1C_1 - c_0C_1)\right]$

$- \left[(n_1N_1 - n_0N_1)\right]$

$- \left[(r_0R_1 - r_0R_0) + (n_0N_1 - n_0N_0) - (e_0E_1 - e_0E_0)\right.$

$- (d_0D_1 - d_0D_0) - (o_0O_1 - o_0O_0) - (t_0T_1 - t_0T_0)$

$\left.- (x_0X_1 - x_0X_0) - (i_0I_1 - i_0I_0) - (c_0C_1 - c_0C_0)\right]$

Equation 3-7 is obtained by rewriting equation 3-6 where the terms in square brackets are denoted by A_1 to A_7.

3-7. $A_1 = A_2 + A_3 + A_4 + A_5 - A_6 - A_7.$

The dollar value of rate increases on total operating revenues is indicated by A_1. Similarly, A_2 represents the dollar value of price increases on operating expenses and A_3 represents the value of price increases on taxes. A_4 and A_5 represent the dollar value of increases in the compensation to each unit of average total debt and equity capital. A_6 measures the dollar value of rate increases on other income. The seventh term is more difficult to interpret. It measures the increase in revenues minus the increase in all inputs when each dollar value is evaluated in terms of the previous year's prices. This is an indicator of the dollar value of productivity gains achieved by the company. Equation 3-7 can be expressed verbally as

Dollar Value of Rate Increases on Total Operating Revenues = Dollar Value of Price Increases on Operating Expense Categories + Dollar Value of Price Increases on Taxes + Dollar Value of Increased Compensation per unit of Average Total Debt Capital

+ Dollar Value of Increased Compensation per unit of Average Total Equity Capital - Dollar Value of Rate Increases on Other Income - Dollar Value of Productivity Gains

The evaluation of each term in equation 3-7 will now be considered separately.

2. Dollar Value of Rate Increases (Term A_1)

The dollar value of rate increases on total operating revenue was given by

$$r_1R_1 - r_0R_1 = \frac{r_1 - r_0}{r_1} r_1R_1$$

For historical periods, the implicit price index of Bell services can be used to determine the value of rate increases actually granted. Table 3-1 illustrates the calculation involved.[1] These dollar values can then be compared with the value of rate increases calculated using alternative automatic rate adjustment clauses.

3. Dollar Value of Price Increases on Operating Expense Categories (Term A_2)

All calculations are illustrated in Table 3-2. The price index used in each case is listed below.

Expense Category	Dollar Value of Price Change	Price Index Used
(a) Employee Expense	$e_1E_1 - e_0E_1 = \frac{e_1 - e_0}{e_1} e_1E_1$	Employee Expense per Employee
(b) Depreciation Expense	$d_1D_1 - d_0D_1 = \frac{d_1 - d_0}{d_1} d_1D_1$	Composite Bell Canada Telephone Plant Price Index (using weights based on Gross Investment)
(c) Other Expense	$o_1O_1 - o_0O_1 = \frac{o_1 - o_0}{o_1} o_1O_1$	Implicit Price Index for Gross National Product

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[1] Note that the percentage change in the price index is calculated in terms of the value of the price index <u>after</u> the price change.

Employee Expense includes wages, salaries and fringe benefits which are not considered as taxes. Labor input was stated in terms of the number of employees. It would also have been possible to measure the volume of labor input as the number of manhours paid and the price of labor inputs as employee expense per manhour paid.

Bell Canada calculates telephone plant indexes (TPI) representing the price change on different classes of plant. An aggregate TPI index is also calculated using weights based on the distribution of investment in each year. This index was used to deflate the book value of depreciation expense.[1]

Other expense encompasses a very diverse basket of goods. The implicit price deflator for Gross National Expenditure was used because it is the most broadly based price index available.

4. Dollar Value of Price Increases on Taxes (Term A_3)

The dollar value of price increases on income taxes was given by

$$t_1T_1 - t_0T_1 = \frac{t_1 - t_0}{t_1} \quad t_1T_1$$

[1]Weights based upon investment may not correspond exactly with weights based upon depreciation in each class of plant. However, the precise definition of an appropriate price index is impossible anyway, because depreciation expense is measured at book value.

However, it is very difficult to specify a price indicator for income taxes. The inputs purchased can be considered as public services and support provided by the government. One alternative is to use the implicit price deflator for Gross National Expenditure.

The dollar value of price increases on other taxes was represented by

$$x_1X_1 - x_0X_1 = \frac{x_1 - x_0}{x_1} x_1X_1$$

Once again, it is impossible to actually measure the real amount and hence the price increase of government services provided by other taxes. The implicit price index for Gross National Expenditure is used in Table 3-3 to deflate both income and other taxes.

5. Dollar Value of Increased Compensation per Unit of Average Total Debt Capital (Term A_4)

The dollar value of increased compensation per unit of average total debit capital was given by

$$i_1I_1 - i_0I_1 = \frac{i_1 - i_0}{i_1} i_1I_1$$

Total interest charges are divided by average total debt capital to develop the price index.[1]

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[1]It was assumed that all interest charges are paid as a result of debt outstanding. Only a small proportion of interest charges are not in this category.

6. Procedure Used to Calculate the Dollar Value of Increased Compensation per Unit of Average Total Equity Capital (Term A_5)

This item was represented as

$$c_1C_1 - c_0C_1 = \frac{c_1 - c_0}{c_1} c_1C_1$$

When C_1 is defined as average total equity capital, it follows that the compensation per unit of C_1 must be measured by net income per unit of average total equity capital.[1] This variable can be interpreted as the price of equity capital. The calculated series is shown in Table 3-5.

7. Dollar Value of Price Increases on Other Income (Term A_6)

In calculating eligible expense, the deduction due to price increases on other income was represented as

$$n_1N_1 - n_0N_1 = \frac{n_1 - n_0}{n_1} n_1N_1$$

Once again, it is impossible to actually define a real unit or the price of other income. In Table 3-6, the Implicit Price Index for Gross National Expenditure is used as a price deflator.

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[1]Net income is defined inclusive of extraordinary items.

8. The Dollar Value of Productivity Gains (Term A_7)

The only remaining term in equation 3-7 is the dollar value of productivity gains and this value can be determined as a residual. Table 3-7 illustrates the following calculation.

Value of Productivity Gain = Total Value of Price Increase on Operating Expense + Total Value of Price Increase on Taxes + Value of Increased Compensation per Average Unit of Debt and Equity Capital - Value of Rate Increases - Value of Price Increase on Other Income

A percentage productivity gain can be calculated by dividing the dollar value of productivity gains by total capital and labor inputs (Employee Expense + Average Total Debt Capital + Average Total Equity Capital) in the previous year. These percentage changes can then be used to develop a type of total factor productivity index.

This productivity index does not correspond to traditional productivity measures used by economists. The input and output data used here are based on accounting concepts. For example, an economist would not measure capital in terms of original book values. A more detailed description of productivity measures and the data used is given in the next chapter. As an indicator of productivity, the index shown in Table 3-5 is inferior in many respects. It is developed here simply to illustrate the purpose of an ARAC (see the next section). In Chapter IX, it will also be used to provide a reconciliation between the economist's measure of total factor productivity and the accountant's measure of the rate of return.

E. General Description of a Bell Canada ARAC

Table 3-7 provides a numerical illustration of the following accounting identity.

$$\underset{\text{Dollar Value of Rate Increase}}{A_1} = \underset{\text{Dollar Value of Price Increase on Operating Expenses}}{A_2} + \underset{\text{Dollar Value of Price Increases on Taxes}}{A_3} + \underset{\text{Dollar Value of Increased Compensation per Unit of Average Total Debt Capital}}{A_4} + \underset{\text{Dollar Value of Increased Compensation per Unit of Average Total Equity Capital}}{A_5} - \underset{\text{Dollar Value of Rate Increases on Other Income}}{A_6} - \underset{\text{Dollar Value of Productivity Gains}}{A_7}$$

A rate increase can be calculated which would guarantee that no change in the rate of return to average total capital takes place. Given the actual values of A_2, A_3, A_6 and A_7, the dollar value of A_1 is calculated under the assumption that $A_4 = A_5 = 0$, i.e., that there is no change in compensation per unit of average total debit or equity capital. An ARAC is based on a similar type of calculation. However, instead of using the actual values of price increases on operating expenses (A_2) and taxes (A_3), a maximum limit is set. Also, instead of using the actual dollar value of productivity gains, a minimum limit is set. Thus, an automatic adjustment of rates will only maintain the minimum allowable rate of return on average total capital provided that

(a) the company meets or exceeds some minimal productivity performance, and

(b) the company holds price increases on other operating expense and tax items below some maximum limit.

An additional constraint is that the rate increase will not be allowed if it leads to a rate of return on total average capital which is above some maximum allowable rate of return. The gap between the rate of return in the base year and the maximum allowable rate of return serves as an incentive for the company to achieve the highest possible productivity gains and to pay the lowest possible prices for inputs other than capital.

Since increasing interest costs are one of the major factors leading to lower returns in an inflationary period, the ARAC developed in this study will cover increases in the compensation per unit of average total debt. However, the company will have an incentive to keep increases in the price of debt as low as possible.

The minimum productivity gain should be stated in terms of a global productivity measure rather than in terms of a partial measure such as labor productivity. If a minimum labor productivity gain were specified, the company could meet this goal by increasing capital intensity rather than by increasing the overall efficiency level. In order to avoid any tendency for resource misallocation, a global productivity measure is necessary.

Productivity gains achieved at a national level might be used as the minimum requirement. However, productivity gains and the potential for productivity gains differ widely among different industries. The Cost of Living Council in the United States moved from the specification of an overall productivity goal to the specification of different productivity goals for about 400 industries in the mining, construction and manufacturing sector. Its regulations are

> For the purpose of determining whether a price may be increased under any provision of this part with respect to manufacturing activities, productivity gains shall be calculated on the basis of the average percentage gain in the applicable industrial category [italics - mine] . . .[1]

In order to specify a reasonable and appropriate long-term goal for productivity gains, it is necessary to have a quantitative understanding of the production process and the nature and rate of technological change for the particular firm or industry.

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[1]United States, Executive Office of the President, Cost of Living Council, "Phase IV Price Regulations", Sec. 150.77, July 19, 1973.

Even if an appropriate long-term trend can be specified there will be considerable variation in productivity gains from year to year. Changing business conditions lead to differences in the rate of growth of demand. The telephone industry, as described in Chapter II, is capital intensive. Also, employee expense has a large fixed component. Changes in the demand for telephone service coupled with the fixed nature of many costs result in differences in the potential for productivity gains from year to year. As a result, an ARAC should specify a different minimum productivity gain each year.

So far I have been referring to traditional accounting data and identities. However, these date do not correspond directly with an economist's concept of input and output. The next chapter describes the data and procedures used to measure productivity performance. Subsequent chapters investigate the nature of the Bell Canada production process. The purpose of this investigation is to specify a reasonable productivity goal for any given year in terms of an economist's concept of input and output. This productivity goal can then be restated in terms of the traditional accounting data described above.

F. Summary

This chapter has outlined problems associated with the present system of regulation in an inflationary environment. There is a need for an Automatic Rate

Adjustment Clause (ARAC) to provide for the short-term adjustment of rates. However, difficulties can arise through the creation of interference with other goals which the regulator might wish to achieve via the general level or structure of rates. Undesirable side effects might include the creation of a reduced incentive for efficient management, a bias in resource allocation, etc. Provisions were listed which would minimize the difficulties associated with an ARAC. A general description of a Bell Canada ARAC was made. The main stumbling block was the specification of the minimum required productivity gain in any year. Additional research is required regarding the Bell Canada production process, the nature of technological change and the short-term behaviour of productivity gains. The next chapter describes the procedures and data to be used in the measurement of productivity. Subsequent chapters deal with the development of a production model and the specification of a reasonable productivity goal in any given year.

TABLE 3-1

ACTUAL DOLLAR VALUE OF RATE INCREASES

Year	Total Operating Revenue r_1R_1 '000'	Increase in Implicit Price Index for Bell Services $(r_1 - r_0)/r_1$	Value of Rate Increase $r_1R_1 - r_0R_1$ '000'
1952	184,398		
1953	201,963	.005601	1,131
1954	219,374	-.000635	-139
1955	244,900	.007139	1,748
1956	273,975	.003244	889
1957	302,986	-.000628	-190
1958	328,818	.006864	2,257
1959	376,605	.054102	20,375
1960	404,848	.005284	2,139
1961	433,657	-.002354	-1,021
1962	470,995	-.013620	-6,415
1963	502,977	.004355	2,190
1964	542,772	.000495	269
1965	592,961	.000198	117
1966	645,047	-.008479	-5,469
1967	702,035	-.002500	-1,755
1968	758,478	-.001904	-1,444
1969	842,090	.004389	3,696
1970	936,636	.025280	23,678
1971	1,018,788	.027147	27,657
1972	1,125,416	.019659	22,125
Total	...	...	91,838

TABLE 3-2

ACTUAL DOLLAR VALUE OF PRICE INCREASES ON EXPENSE CATEGORIES

Year	Employee Expense e_1E_1 '000'	Increase in Employee Expense per Employee[a] $(e_1 - e_0)/e_1$	Value of Price Increase on Employee Expense $e_1E_1 - e_0E_1$ '000'	Depreciation d_1D_1 '000'	Increase in Bell Canada Telephone Plant Price Index $(d_1 - d_0)/d_1$	Value of Price Increase on Depreciation Expense $d_1D_1 - d_0D_1$ '000'
1952	75,334			22,500		
1953	83,048	.074667	6,201	25,343	-.018868	-478
1954	90,630	.042442	3,847	28,087	-.010727	-301
1955	101,759	.042252	4,300	31,109	-.001193	-37
1956	111,729	-.002862	-320	35,512	.015276	542
1957	121,079	.016242	1,967	48,954	.005841	286
1958	127,292	.053130	6,763	55,754	.005807	[illegible]
1959	130,983	.078819	10,324	64,874	.001160	[illegible]
1960	134,469	.072616	9,765	72,090	.004619	333
1961	136,678	.054751	7,483	78,902	-.003476	-274
1962	142,319	.047460	6,754	86,881	.010321	897
1963	150,478	.038679	5,820	97,314	.010216	994
1964	157,031	.030809	4,838	106,224	-.002275	-242
1965	165,997	.015847	2,631	116,107	.016779	1,948
1966	181,215	.033146	6,007	127,459	.045891	5,849
1967	192,577	.061352	11,815	138,943	.063000	8,753
1968	204,789	.089961	18,423	151,907	.046711	7,096
1969	226,278	.088219	19,962	170,486	.045496	7,756
1970	255,785	.096892	24,784	183,850	.067063	12,330
1971	282,123	.088110	24,858	198,438	.050766	10,074
1972	314,179	.080516	25,296	228,033	.054116	12,340
Total	...	...	201,518	...	...	68,265

[a] Average employees are based on a simple average of employees at the beginning and end of the year.

TABLE 3-2--Continued

ACTUAL DOLLAR VALUE OF PRICE INCREASES ON EXPENSE CATEGORIES

Year	Other Expense o_1O_1 '000'	Increase in Implicit Price Index for GNP $(O_1 - O_0)/O_1$	Value of Price Increase on other Expense $o_1O_1 - o_0O_1$	Total Value of Price Increases on Operating Expense '000'
1952	28,[illegible]25			
1953	30,772	-.001139	-35	5,688
1954	35,004	.015695	549	4,095
1955	40,330	.005574	225	4,488
1956	49,011	.035484	1,739	1,961
1957	50,413	.021053	1,061	3,314
1958	56,258	.013500	759	7,846
1959	60,375	.020346	1,228	11,627
1960	63,869	.012060	770	10,868
1961	66,907	.005000	335	7,544
1962	72,657	.013807	1,003	8,654
1963	78,003	.017442	1,361	8,175
1964	80,110	.024575	1,969	6,565
1965	90,214	.031136	2,809	7,388
1966	98,005	.042945	4,209	16,065
1967	98,707	.037943	3,745	24,313
1968	107,292	.031046	3,331	28,850
1969	133,436	.042254	5,638	33,356
1970	138,819	.044129	6,126	43,240
1971	159,176	.029753	4,736	39,668
1972	170,322	.043720	7,446	45,082
Total	...	...	49,004	318,787

TABLE 3-3

ACTUAL DOLLAR VALUE OF PRICE INCREASES ON TAXES

Year	Income Taxes t_1T_1 '000'	Other Taxes x_1X_1 '000'	Increase in Implicit Price Index for GNP	Value of Price Increase on Income Taxes $t_1T_1 - t_0T_1$ '000'	Value of Price Increase on Other Taxes $x_1X_1 - x_0X_1$ '000'	Total Value of Price Increase on Taxes '000'
1952	23,745	6,597				
1953	22,715	7,184	-.001139	-26	-8	-34
1954	23,697	7,734	.015695	372	121	493
1955	24,617	8,835	.005574	137	49	186
1956	26,686	9,838	.035484	947	349	1,296
1957	27,871	11,859	.021053	587	250	837
1958	29,118	12,902	.013500	393	174	567
1959	44,556	14,526	.020346	907	296	1,203
1960	48,039	16,692	.012060	579	201	780
1961	54,621	18,862	.005000	273	94	367
1962	61,441	20,160	.013807	848	278	1,126
1963	63,332	21,501	.017442	1,105	375	1,480
1964	71,160	23,121	.024575	1,749	568	2,317
1965	78,493	25,313	.031136	2,444	788	3,232
1966	81,644	29,906	.042945	3,506	1,284	4,790
1967	91,564	35,716	.037943	3,474	1,355	4,829
1968	98,322	38,796	.031046	3,053	1,204	4,257
1969	103,835	44,681	.042254	4,387	1,888	6,275
1970	126,531	45,479	.044129	5,584	2,007	7,591
1971	122,126	52,226	.029753	3,634	1,554	5,188
1972	126,808	53,880	.043720	5,544	2,356	7,900
Total	1,350,921	505,808	...	39,497	15,183	54,680

TABLE 3-4

ACTUAL DOLLAR VALUE OF INCREASED COMPENSATION PER UNIT OF AVERAGE TOTAL DEBT CAPITAL

Year	Interest Charges i_1I_1 '000'	Increase in Interest per Unit of Average Total Debt Capital $(i_1 - i_0)/i_1$	Value of Increased Compensation per Unit of Average Total Debt Capital $i_1I_1 - i_0I_1$ '000'
1952	7,092		
1953	8,653	.046155	399
1954	9,573	.010204	98
1955	10,202	-.012773	-130
1956	11,766	.013302	157
1957	13,789	.033541	462
1958	15,405	.001049	16
1959	18,681	.032817	613
1960	23,153	.076586	1,773
1961	26,661	.040016	1,067
1962	29,685	.024000	712
1963	32,467	.011757	382
1964	35,056	.016900	592
1965	37,712	.009875	372
1966	43,969	.004365	192
1967	52,750	.032021	1,689
1968	60,969	.042661	2,601
1969	72,157	.047628	3,437
1970	77,497	.018559	1,438
1971	87,194	.031757	2,769
1972	98,701	.037360	3,687
Total	...	...	22,326

TABLE 3-5

ACTUAL DOLLAR VALUE OF INCREASED COMPENSATION PER UNIT OF AVERAGE TOTAL EQUITY CAPITAL

Year	Net Income c_1C_1 '000'	Increase in Net Income per Unit of Average Total Equity Capital $(c_1 - c_0)/c_1$	Value of Increased Compensation per Unit of Average Total Equity Capital $c_1C_1 - c_0C_1$ '000'
1952	22,570		
1953	26,849	.049097	1,318
1954	28,549	-.098045	-2,799
1955	31,978	-.030329	-970
1956	34,949	-.035856	-1,253
1957	36,037	-.127456	-4,593
1958	38,899	-.001015	-39
1959	50,284	.129479	6,511
1960	53,512	.009212	493
1961	57,691	-.022315	-1,287
1962	65,285	.049342	3,221
1963	68,294	-.050292	-3,435
1964	79,495	.060907	4,842
1965	88,820	.054109	4,806
1966	94,846	.002639	250
1967	111,821	.035391	3,957
1968	118,326	.021954	2,598
1969	113,696	-.079022	-8,984
1970	133,262	.065983	8,793
1971	147,291	.032637	4,807
1972	165,696	.057388	9,509
Total	...	...	27,745

TABLE 3-6

ACTUAL DOLLAR VALUE OF PRICE INCREASES ON OTHER INCOME

Year	Other Income n_1N_1 '000'	Increase in Implicit Price Index for GNP $(n_1 - n_0)/n_1$	Dollar Value of Price Increase on Other Income $n_1N_1 - n_0N_1$ '000'
1952	2,165		
1953	2,602	-.001139	-3
1954	3,901	.015695	61
1955	3,930	.005574	22
1956	5,517	.035484	196
1957	7,016	.021053	148
1958	6,810	.013500	92
1959	7,674	.020346	156
1960	6,976	.012060	84
1961	6,666	.005000	33
1962	7,433	.013807	103
1963	8,412	.017442	147
1964	9,425	.024575	232
1965	9,695	.031136	302
1966	11,998	.042945	515
1967	20,042	.037943	760
1968	21,922	.031046	681
1969	22,480	.042254	950
1970	24,586	.044129	1,085
1971	29,787	.029753	886
1972	32,203	.043720	1,408
Total	251,240	...	7,858

TABLE 3-7

ACTUAL DOLLAR VALUE OF PRODUCTIVITY GAIN CALCULATED USING ACCOUNTING DATA

Year	Value of Rate Increase A_1 '000'	Total Value of Price Increase on Expenses A_2 '000'	Total Value of Price Increase on Taxes A_3 '000'	Value of Increased Compensation per Unit of Average Total: Debt Capital A_4 '000'	Value of Increased Compensation per Unit of Average Total: Equity Capital A_5 '000'	Value of Price Increase on Other Income A_6 '000'
1953	1,131	5,688	-34	399	1,318	-3
1954	-139	4,095	493	98	-2,799	61
1955	1,748	4,488	186	-130	-970	22
1956	889	1,961	1,296	157	-1,253	196
1957	-190	3,314	837	462	-4,593	148
1958	2,257	7,846	567	16	-39	92
1959	20,375	11,627	1,203	613	6,511	156
1960	2,139	10,868	780	1,773	493	84
1961	-1,021	7,544	367	1,067	-1,287	33
1962	-6,415	8,654	1,126	712	3,221	103
1963	2,190	8,175	1,480	382	-3,435	147
1964	269	6,565	2,317	592	4,842	232
1965	117	7,388	3,232	372	4,806	302
1966	-5,469	16,065	4,790	192	250	515
1967	-1,755	24,313	4,829	1,689	3,957	760
1969	-1,444	28,850	4,257	2,601	2,598	681
1969	3,696	33,356	6,275	3,437	-8,984	950
1970	23,678	43,240	7,591	1,438	8,793	1,085
1971	27,657	39,668	5,188	2,769	4,807	886
1972	22,125	45,082	7,900	3,687	9,509	1,408
Total	91,838	318,787	54,680	22,326	27,745	7,858

TABLE 3-7-Continued

ACTUAL DOLLAR VALUE OF PRODUCTIVITY GAIN CALCULATED USING ACCOUNTING DATA

Year	Value of Productivity Gain $A_7 = A_2 + A_3 + A_4 + A_5 - A_1 - A_6$ '000'	Total Factor Input (Employee Expense + Total Income) B '000'	Percentage Productivity Gain $C_t = \frac{(A_7)_t}{(B)_{t-1}}$
1952		104,996	
1953	6,243	118,550	5.946
1954	1,965	128,752	1.658
1955	1,804	143,939	1.401
1956	1,076	158,444	.748
1957	62	170,905	.039
1958	6,041	181,596	3.535
1959	-577	199,948	-.318
1960	11,691	211,134	5.847
1961	8,679	221,029	4.111
1962	20,025	237,289	9.060
1963	4,265	251,239	1.797
1964	13,815	271,581	5.499
1965	15,379	292,529	5.663
1966	26,251	320,031	8.974
1967	35,783	357,148	11.181
1968	39,069	384,085	10.939
1969	29,438	412,132	7.664
1970	36,299	466,544	8.808
1971	23,899	516,608	5.120
1972	42,645	578,576	8.255
Total	323,842	5,727,055	...

Chapter IV

DATA USED TO CALCULATE PRODUCTIVITY AND TO ESTIMATE PRODUCTION MODELS

A. Procedures Used to Calculate Productivity

Productivity measures can be classified as global, total factor or partial. Partial productivity measures are based on the use of only one input factor and total factor measures are based on the use of both capital and labor inputs. Global productivity measures are based on the amount of output produced given the amount of capital, labor and raw materials used. Since we are interested in the efficiency with which all inputs are used, a global productivity measure should be employed. However, the ratio of purchased materials to final output has remained fairly stable for Bell Canada. This suggests that management has little discretion regarding the amount of raw materials which will be purchased and in this case a total factor productivity measure is acceptable. The two total factor productivity indexes used in empirical research are John Kendrick's arithmetic index[1] and Robert

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[1] John Kendrick, Productivity Trends in the United States, (Princeton: Princeton University Press, 1961).

Solow's geometric index.[1]

Kendrick's measure of total factor productivity can be represented as

$$R = \frac{Y}{aK+bL}$$

where a and b are the weights used to calculate the total factor input and Y, K and L represent output, capital and labor respectively. He defines the weights used for the calculation of total factor input as the compensation per unit of capital and labor in some base year ($a = r_B$ and $b = w_B$).[2] Productivity gains (r_t) are calculated as the percentage change in R_t.

$$r_t = \left[\frac{Y_t}{(r_B K_t + w_B L_t)} \Big/ \frac{Y_t}{(r_B K_{t-1} + w_B L_{t-1})}\right] \times 100$$

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[1]Robert Solow, "Technical Change and the Aggregate Production Function," Review of Economic Statistics, XXXIX, (August, 1957), pp. 312-20.

[2]The distributional equation shown below will hold if factors are paid their marginal products and there are no excess profits in the base year.

$$r_B K_B + w_B L_B = \frac{\partial Y_B}{\partial K_B} K_B + \frac{\partial Y_B}{\partial L_B} L_B = Y_B$$

If accurate data for Y_B, K_B, L_B and w_B exist, r_B can be calculated as

$$r_B = (Y_B - w_B L_B) / K_B.$$

A Kendrick type productivity measure using the same data described in this chapter is used in the Bell Canada productivity study.[1]

Solow's measure of total factor productivity gains can be derived under the assumptions that technological change does not affect the marginal rates of substitution of capital for labor. In that case, the production function takes the general form.

$$Y_t = A(t)\ f\ (K_t L_t)$$

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}(t)}{A(t)} + A(t)\ \frac{\partial f_t}{\partial K_t}\ \frac{\dot{K}_t}{Y_t} + A(t)\ \frac{\partial f_t}{\partial L_t}\ \frac{\dot{L}_t}{Y_t}$$

Assuming that factors are paid their marginal products and that there are no excess profits, the shares of capital and labor are :

$$\pi_{K,t} = \frac{r_t K_t}{Y} = \frac{\partial Y_t}{\partial K_t}\ \frac{K_t}{Y_t}$$

$$\pi_{L,t} = \frac{W_t L_t}{Y_t} = \frac{\partial Y_t}{\partial L_t}\ \frac{L_t}{Y_t}$$

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[1]Most of the aggregate input and output data described in this chapter were presented by Bell Canada in 1973 to the Telecommunications Committee of the Canadian Transport Commission as part of testimony on total factor productivity - see "Memorandum on Productivity", Bell Canada Application, File 955.182.1, Vol. I and II, Exhibits B-73-61 to B-73-67. Many individuals have been involved in developing the Bell Canada productivity study, Bob Olley was the witness testifying on this study. Although a Solow type productivity measure is used in this thesis, relative gains in productivity from year to year are very similar to those calculated using the Kendrick approach.

It follows that

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}(t)}{A(t)} + \pi_{K,t}\frac{\dot{K}_t}{K_t} + \pi_{L,t}\frac{\dot{L}_t}{L_t},$$

$$\left[\frac{\dot{A}(t)}{A(t)}\right] \times 100 = \left[\frac{\dot{Y}_t}{Y_t} - \pi_{K,t}\frac{\dot{K}_t}{K_t} + \pi_{L,t}\frac{\dot{L}_t}{L_t}\right] \times 100$$

In discrete form, Solow's measure of the percentage change in total factor productivity (r_t) can be calculated as

$$r_t =$$

$$\left[\frac{Y_t - Y_{t-1}}{Y_{t-1}} - \pi_{K,t-1}\frac{K_t - K_{t-1}}{K_{t-1}} - \pi_{L,t-1}\frac{L_t - L_{t-1}}{L_{t-1}}\right] \times 100$$

This represents a discrete approximation to a divisia index of productivity.[1]

The Kendrick and Solow measures of total factor productivity gains will be approximately equal for small changes in outputs and inputs when the preceding year is defined as the base period in the Kendrick measure.[2] Solow type productivity measures will be used in this study. In the last chapter, the calculated percentage gains in total factor productivity could have been represented as

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[1]Divisia indexes are described in Section C of this chapter.

[2]E. Levhari, E. Kleiman and N. Halevi, "The Relationship Between Two Measures of Total Factor Productivity", Review of Economic Statistics, XLVIII, (August, 1966), pp. 345-47.

$$ra_t = 100 \times \left[\left((r_0R_1 + n_0N_1 - d_0D_1 - o_0O_1 - t_0T_1 - x_0X_1) - (e_0E_1 + i_0I_1 + c_0C_1) \right) \Big/ (e_0E_0 + i_0I_0 + c_0C_0) \right]$$

$$= 100 \times \left[\left((Y_1) - (e_0E_1 + i_0I_1 + c_0C_1) \right) \Big/ Y_0 \right]$$

$$= 100 \times \left[\left(\frac{Y_1}{Y_0} - 1 \right) - \left(\frac{e_0E_0}{Y_0} \frac{E_1}{E_0} + \frac{i_0I_0}{Y_0} \frac{I_1}{I_0} + \frac{c_0C_0}{Y_0} \frac{C_1}{C_0} - 1 \right) \right]$$

This is a Solow productivity measure calculated using standard accounting data.

Even if the same type of productivity measure is used, different estimates can be obtained depending on the definition of output and input variables. Total factor productivity gains as calculated by Dennison, Griliches and Jorgenson, Kendrick and Solow[1] have varied widely. Indeed, productivity improvement really represents the residual increase in output after increases in inputs have been defined. The rest of this chapter describes the data used as the best estimates of inputs and outputs in this study. A production model is developed using this data in Chapter V and Chapter VI. Given the production model, the implied Solow type total factor productivity measure is

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[1] E.F. Dennison, The Sources of Economic Growth in the United States and the Alternatives Before Us, (New York: Committee for Economic Development, 1962); D.W. Jorgenson and Z. Griliches, "The Explanation of Productivity Change", Review of Economics and Statistics, XXXIV, (July, 1967), pp. 249-84; J. Kendrick, Productivity Trends in the United States; R. Solow, "Technical Change and the Aggregate Production Function", pp. 312-20.

calculated in Chapter VII. A productivity forecasting model is then developed and the productivity forecasts are related back to the Solow productivity measure described in Chapter III.

B. Aggregation

As a first step towards empirical representation of Bell inputs and outputs, it is necessary to determine the appropriate level of aggregation. Usually, this decision is made only on the basis of convenience and data availability. However, the validity of aggregation has received more attention in recent literature. It has been pointed out that aggregation is only valid in restricted circumstances.

Most of the debate has involved the aggregation of heterogeneous capital units. M. Ishaq Nadiri has summarized the conditions necessary for capital aggregation as follows.

> The neoclassical approach assumes a competitive economy, perfect foresight and that the quantity of capital is independent of both relative prices and the distribution of income. The necessary and sufficient conditions for grouping variables are: (a) that the rate of substitution between capital goods of different types be independent of the quantity of labor used with them, and (b) that the marginal rate of substitution between any two types of capital must be constant.[1]

[1]M. Ishaq Nadiri, "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey", Journal of Economic Literature, VIII, (December, 1970), p. 1144. The second condition is required for the aggregate to be a simple sum of the different elements in the capital group.

Similar conditions exist for the aggregation of labor and output. Obviously, these conditions are very restrictive and, in general, would not be fulfilled.

J. Robinson has argued that the basic neoclassical assumptions are not valid and that capital is a value concept affected by relative factor prices. She also argues that different capital goods are complements, rather than substitutes. The notion that capital is a value concept has led to the current controversy on double-switching. The debate on this topic will not be pursued here.

F. Fisher[1] has examined the conditions necessary for aggregation over several micro-economic production functions given that capital, labor and output aggregates exist for each productive unit. As discussed below, these conditions are also very stringent.

We are interested in the conditions under which it is possible to write total output (Y) as determined by an aggregate production function.

4-1. $$Y = \sum_{v=1}^{n} y(v) = F(K,L)$$

where $K = K(k(1), \ldots, k(n))$

$L = L(\ell(1), \ldots, \ell(n))$.

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[1]F. Fisher, "The Existence of Aggregate Production Functions", Econometrica, XXXVII, (October, 1969), pp. 553-77.

The aggregate capital (K) and labor variables (L) are in turn functions of the capital and labor used by the vth productive unit to produce output.

The usual condition given is that an aggregate production function exists if and only if the production function of every production unit is additively separable in capital and labor, that is, if and only if every production function (f^v) can be written in the form

$$f^v(K(v),L(v)) = \mathcal{K}^v(K(v)) + \mathcal{L}^v(L(v)); \quad v=1, \ldots, n.$$

Although this condition is true, it is unduly restrictive. We actually are not interested in the condition necessary for output to always be a function of aggregate capital (K) and labor (L). A production function describes the maximum level of outputs that can be achieved if all inputs are employed efficiently. Thus, we are only interested in the conditions necessary for equation 4-1 to hold given that production has been organized to get the maximum output with the given input factors.

In some cases, these conditions may be much less restrictive. For example, if both capital and labor are homogeneous and both are also perfectly mobile, an aggregate production function will always exist under the assumption that both factors are optimally allocated among productive units. The real problem is that institutional constraints may make it impossible for both inputs to be optimally allocated to the productive units.

A more realistic approach is to assume that the capital inputs used by each productive unit are different and are not mobile. For the moment, let us assume that labor is homogeneous and optimally allocated. Under constant returns to scale, Fisher proves that the existence of capital-augmenting technical differences between the productive units is the only case in which aggregation is possible. Without constant returns to scale, the only case where aggregation is possible is when the production function of each production unit can be represented as

$$f^v(k(v),\ell(v)) = F(H^v(k(v)),\ell(v)); \quad v=1, \ldots, n.$$

The function F must be homogeneous of degree one and the function H^V must be monotonic. This means that differences in the production functions of productive units can be represented by a stretching of the capital axis. These conditions are quite restrictive and, in general, would not be satisfied.

Fisher has also examined the conditions necessary for aggregation over micro production functions when the assumption of a single optimally allocated homogeneous labor input is dropped and the amount of capital and the production function used by each productive unit is given. The necessary condition for aggregation is that the production function of each productive unit can be written in the form

$$Y(v) = f^v(k(v),\ell_1(v), \ldots,\ell_j(v)) = F^v(k(v), \phi^v(\ell_1(v), \ldots, \ell_j(v)); \quad v=1, \ldots, n.$$

where $Y(v)$ is the output produced by the vth productive unit

$k(v)$ is the capital used by the vth productive unit

$\ell_j(v)$ is the amount of the jth labor input used by the vth productive unit.

Aggregation is possible if and only if the production of the composite labor input variable is the same for all productive units. This condition is very restrictive. For example, under the assumption of constant returns, if all firms face the same set of wages, they must hire the same mix of labor types.

Despite the very restrictive conditions necessary for aggregation, "there is, after all, considerable evidence that aggregate production functions may be appropriate approximations."[1] One illustration is the fact that predicted factor shares are reasonably accurate, even though the production function is only fitted with physical input and output data. Fisher concludes that the apparent existence of a capital aggregate may be caused by firms always investing in proportion to a particular index, by firms equating the marginal rate of technical substitution to fixed factor price ratios or by some as yet unknown systematic elements.[2] If these underlying conditions break down, the aggregate production function may no longer apply.

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[1] Ibid., p. 571.

[2] Using simulation techniques, F. Fisher and R. Solow are currently studying the conditions under which an aggregate production function would appear to hold even though it does not represent the underlying technological relationships.

Although I will be dealing with data from one company, the aggregation problem is still present. After reading the above paragraphs readers should be aware of the limitations imposed by the aggregation problem. Any aggregate results should be interpreted with this constraint in mind.. I should add that the aggregation problem exists in nearly all fields of economic research.

C. Output

When only one good is involved, the separation of any increase in revenue into the proportion due to a price change and the proportion due to a quantity change only requires an exact definition of the good being sold.

Difficulties arise when several goods are being sold. Total revenue may be represented as

$$pY = p_1Y_1 + p_2Y_2 + . . . + p_nY_n.$$

Differentiating totally with respect to time, we obtain

$$p\frac{\partial Y}{\partial t} + Y\frac{\partial P}{\partial t} = \sum_{i=1}^{n} p_i\frac{\partial Y_i}{\partial t} + Y_i\frac{\partial p_i}{\partial t} .$$

Dividing both sides by total revenue (pY), we get

$$\frac{p\frac{\partial Y}{\partial t}}{pY} + \frac{Y\frac{p}{\partial t}}{pY} = \sum_{i=1}^{n} \frac{p_i\frac{\partial Y_i}{\partial t}}{pY} + \frac{Y_i\frac{\partial p_i}{\partial t}}{pY}$$

$$\frac{\dot{Y}}{Y} + \frac{\dot{p}}{p} = \sum_{i=1}^{n} w_i\frac{\dot{Y}_i}{Y_i} + w_i\frac{\dot{p}_i}{p_i}$$

where w_i is the relative share of the ith output

$$w_i = \frac{p_i Y_i}{pY} .$$

Divisia price and quantity index numbers are defined as

$$\frac{\dot{p}}{p} = \sum_{i=1}^{n} w_i \frac{\dot{p}_i}{p}$$

$$\frac{\dot{Y}}{Y} = \sum_{i=1}^{n} w_i \frac{\dot{Y}_i}{Y}$$

Rates of growth of the divisia price and quantity indexes add up to the rate of growth of revenue. This is known as the factor reversal test. Divisia indexes are also symmetric with respect to time (time reversal test). In addition, they have the property that a divisia index of technological change is equal to a divisia index of output divided by a divisia index of inputs. M. Richter[1] has shown that such an index satisfies several desirable invariance axioms.

For empirical studies, it is necessary to find a discrete approximation to the continuous divisia index. Depending on how the weights are defined, how often they are changed and whether a geometric or arithmetic average is calculated, several different indexes are available.[2]

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[1] M. K. Richter, "Invariance Axioms and Economic Indexes", Econometrica, XXXIV, (October, 1966), pp. 739-755.

[2] I. Fisher, The Making of Index Numbers, (Boston: Houghton Mifflin, 1922).

In this study, the familiar Laspeyres index will be used.

Although a direct index of output is preferable, data limitations often exist regarding the quantity of each good sold in previous years. This is the case with Bell Canada data. However, rate tables showing the price of each good do exist for all previous years. By obtaining quantity data for only a few years to use as weighting factors, it is possible to calculate price indexes and to then deflate revenues. If a Laspeyres price index is calculated for deflation purposes, a Paasche quantity index will in fact be obtained.

$$\frac{\text{Revenue Index}}{\text{Price Index (Laspeyres)}} = \frac{\sum_{i=1}^{n} p_{i,1}\, q_{i,1}}{\sum_{i=1}^{n} p_{i,0}\, q_{i,0}} \Bigg/ \frac{\sum_{i=1}^{n} p_{i,1}\, q_{i,0}}{\sum_{i=1}^{n} p_{i,0}\, q_{i,0}}$$

$$= \frac{\sum_{i=1}^{n} p_{i,1}\, q_{i,1}}{\sum_{i=1}^{n} p_{i,1}\, q_{i,0}}$$

When the Laspeyres price index is biased upwards, the deflated output series will be biased downwards, etc.

It is also necessary to update the base period and form a chained Laspeyres price index. Changing the basket of goods covered by the price index will make it possible to consider price changes on new services which have been introduced and to reduce the biases due to the index number problem itself.

In choosing the level of aggregation, each aggregate output should be defined so as to minimize changes in the mix of outputs within that aggregate group. Bell revenues have been grouped into the categories chosen for accounting purposes. Most of the change in output mix is captured as between group variation but undoubtedly some within group variation remains.

Twenty years of annual data were available. The services offered in each class have been described in Chapter II. All price indexes are calculated as described previously. More detailed comments regarding the price indexes are made in Section E. It should be noted that in every case, uncollectible revenues are not deducted since these services are produced and hence are outputs of Bell Canada. Revenue figures shown for 1971 and 1972 are prepared on a consolidated basis for Bell Canada plus Tele-Direct and a consistent series is maintained.

All data are contained in Appendix A. Table A-1 shows the current dollar value, the price index and the 1967 dollar value of local service revenue. Similar data for the three components of telephone message toll service revenue are contained in Tables A-2, A-3 and A-4. Other toll service revenue, directory advertising revenue and other miscellaneous revenues are shown in Tables A-5, A-6 and A-7. Tables A-8 and A-9 summarize the previous seven tables and show the breakdown of total operating revenue in current and 1967 dollar values. However, deflated total operating revenue is not the measure of output used for estimating aggregate production models in this study.

If inputs are taken as labor, capital and intermediate goods, the appropriate definition of output includes the total value of production. However, if only labor and capital inputs are considered, the appropriate definition of output is a value added concept. An examination of Table A-10 will show that in current dollar terms, the cost of materials has remained an almost constant proportion of total operating revenue.[1] This would indicate that the company has little discretion in making decisions on the amount of intermediate goods purchased given the level of final output. As a result, only primary labor and capital inputs have been considered and output has been defined as a value added concept.

Non-income taxes are also deducted from total operating revenue in the calculation of gross output. The problem is that no direct measure of the actual benefits received from tax payments is available. If the benefits are not included as an input, then non-income taxes must be subtracted from output and treated as an intermediate input. This procedure was used to calculate the gross output of Bell Canada.

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[1]The decline in the cost of materials, rents and supplies as a proportion of total operating revenue expressed in real terms may be due to the fact that the Gross National Expenditure implicit price index was used as an approximation for the price level of intermediate inputs.

The calculation of current dollar gross output and real gross output is shown by Tables A-10 and A-11 respectively. The implicit price index for Gross National Expenditure is used to deflate non-income taxes and the cost of materials, rent, services and supplies. It is felt that this is a reasonable assumption in view of the unknown nature of benefits purchased in one case and the wide assortment of items in the other.

Inputs and outputs should be defined in a consistent manner for use in productivity measures. One possibility is to use gross output and gross capital data. Another alternative which may be chosen if reliable depreciation data exists is to use net output and net capital data. This restriction need not apply to the data used in the estimation of a production model. For example, gross output can be specified as a function of labor and net capital inputs, while depreciation is specified as a separate function of net capital. However, in this study, the same data was used in the production models and in the productivity measures so that the residual of the production model would conceptually correspond with measured total factor productivity.

To calculate an output series consistent with the gross capital series, write-offs should be deducted. Since plant retirements are deducted from gross plant, they should also be deducted from any gross output series as an expense. In this way, write-offs are treated in the same way as depreciation expense - only the timing of the deduction has changed. A distribution of write-offs by vintage is first computed using the vintage distribution of gross plant at the beginning and end of the year. Write-offs are then repriced to current and 1967 dollar values using the composite telephone plant price index which is described in Section H. Tables A-12 and A-13 show the calculation of gross output minus write-offs.[1]

To calculate an output series consistent with the net capital series, depreciation should be deducted. These calculations are shown by Tables A-14 and A-15. The value of depreciation in current dollars does not correspond to depreciation expense used for accounting purposes since the current dollar figure shown here is based on a restatement of depreciation for each vintage of capital from original cost to current dollars. A distribution of depreciation expense by vintage was not available and it was assumed that the distribution of depreciation by vintage was the same as the distribution of gross depreciable plant. Telephone plant price indexes were used to reprice depreciation.

D. Labor Input

The aggregate measure of labor input is developed directly as a Laspeyres index of manhours worked. This

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[1]Gross output is defined without the deduction of write-off expense in most productivity studies of which I am aware.

method is preferable to using a labor cost index to deflate employee expense. It was possible to use this approach because information existed on the quantity of manhours employed for each year. Time paid for, but not worked, including vacations, sick leave, holidays and overtime bonuses were not included.

An attempt was also made to adjust hours worked to reflect differences in the quality or skill of each manhour. Twenty-eight classes of labor input were defined on the basis of seniority and type of work. Manhours worked in each class were calculated by removing hours attributable to sick leave, vacations and holidays, by taking account of the fact that overtime bonuses do not reflect additional hours actually worked and by removing the number of manhours worked which were charged to construction expense. It remained to determine quality weights for each class of manhour considered.

Quality weights were taken as the ratio of the average total hourly renumeration of each class to the average for all classes. The assumption is that total renumeration reflects the quality of each class of labor. Since there were no observed shortages or oversupplies of particular classes of labor in 1967, this year was chosen as the basis for quality weights. It was found that quality weights calculated using other years showed little variation.

An attempt was made to include all fringe benefits for each class of labor in the total renumeration paid. These fringe benefits totaled over 20 per cent of the gross payroll in 1967. The items listed in Appendix B were included. Total fringe benefits were calculated for each type of labor and distributed to each seniority class according to the relative wage payments for that seniority. A special calculation of fringe benefits was made for part-time employees.) Total renumeration for each class was calculated as the sum of wage payments plus total fringe benefits. Quality weights were then obtained by comparing the average renumeration paid per manhour worked by each class of labor. In the calculation of labor weights, no differential was made between labor charged construction and labor actually expensed. It was felt that the average renumeration per manhour in each class of labor was not affected by this factor.

Tables A-16 and A-17 show the total manhours and weighted manhours worked. Data are presented for the following labor types.

(a) Telephone operators
(b) Plant craftsmen
(c) Clerical (Non-Supervisors)
(d) Other (Non-Supervisors)
(e) Foremen and Supervisors
(f) Executive and Staff
(g) Part-Time and Occasional
(h) Total

Workers of different seniorities have been aggregated within each labor type. It was felt that the above data should be sufficient for aggregate and disaggregate models.

E. Capital Input

If capital and labor inputs are to be measured consistently, the actual flow of capital services used should be considered. Unfortunately, an aggregate capacity utilization index does not exist and it is impossible to obtain an exact measure of the actual capital stock being utilized or of the capital services flowing from the utilized capital stock. One alternative is to calculate the capital input series by multiplying the measured capital stock series by the rate of return in some base year. This method was used to calculate capital input. When utilization rates are higher than in the base year, the calculated capital input series is likely to be lower than the true capital input.

Cash, accounts receivable, and other short-term assets are excluded from the definition of capital used. These represent a relatively small proportion of the total assets of Bell Canada and vary directly with telephone plant.

The age distribution of total gross plant is developed from data on gross additions. Actual mortality data are now available for about 70 per cent of gross plant. On the remaining plant, the amount surviving is estimated using survivor curves for each class of plant. Before 1972, it was not possible to apply this method due to a lack of data. A survivor curve for total plant was developed from a census of plant in 1965. This aggregate survivor curve was then applied to total gross additions in each year since 1920 to calculate a vintage distribution of total gross plant in each year. When the distribution of gross plant is obtained, the sum over all vintages is adjusted to equal the book value of gross plant in that year by a simple proration.

Total net plant distributions are calculated using the distributions of total gross plant and the distribution of the accumulated depreciation reserve. In earlier years, this calculation was done an an aggregate basis. However, in 1972, calculations were performed for each class of plant. The vintage distribution of accumulated depreciation is calculated from the distribution of gross plant and the relevant straight-line depreciation rate. It is balanced to the total book value by prorating across all categories and vintages.

Telephone Plant Price Indexes are used to deflate both gross and net plant. These price indexes are described in Section H. As a result of the change from aggregate to disaggregate repricing, each series was linked in 1972 by multiplying previous years by an appropriate adjustment factor. Tables A-18 and A-19 show total gross and total net plant in current and 1967 dollars. Total average plant under construction is included.

F. Price Indexes for Output

The theoretical basis of different types of price indexes and concepts such as chaining have already been discussed. A description of Bell services has also been made. It remains to describe the pricing of each output and the price index that has been developed.

Local service is billed at a basic monthly rate depending on the number of telephones in the exchange and the type of customer. There are also nonrecurring charges for installation, etc. A Laspeyres price index was calculated using quantity weights from 1967. These weights were updated in 1971 and a chained price index was calculated. Due to the introduction of new services and the absence of quantity data, it was not possible to define a consistent basket of goods over the earlier periods which would include all the goods sold in a particular year. However, the coverage of the index since 1965 is close to 100 per cent. As discussed in Chapter II, the provision of Extended Area Service and the groupings of exchanges due to growth in the number of telephones are not considered to be price increases in the calculation of this index. The calculated index is shown in Table A-1.

All of the telephone message toll indexes are calculated with the same basic program and are based on a statistical sample of toll calls which was started in 1967. Quantity weights initially were chosen using the month of October 1967. Since then, the base weights have been changed to October 1970 for the Intra-Bell component and to April 1972 for the others. It is important that the number of business days, Saturdays and Sundays be adjusted to the proportion 5-1-1 to avoid any bias caused by changing the base month. Prices are based on the time of day, the type of call (Person-to-Person, Station-to-Station operator handled, Direct Distance Dialed), the day of the week and the length of call. Classifying particular components on this basis, a Laspeyres price index is calculated. The yearly price index is calculated by taking account of the month in which the price change occurred. Calculated price indexes are shown in Tables A-2, A-3 and A-4.

Other toll revenues include a very large number of services. Some of these have monthly charges for mileage and terminal equipment. There are also a large number of service charge arrangements. New products have been introduced at a rapid rate - particularly in the data transmission field. In addition to difficulties of product definition, there is a lack of data regarding quantities sold. Since most of these services are offered to business and compete with basic toll service, one alternative is to assume that their rates move in line with the business day direct distance dialed component of telephone message toll prices. This assumption was made for many of the services. It was possible to calculate a Laspeyres price index for Teletypewriter and Wide Area Telephone Service. Private line price changes were approximated by pricing the average mileage per circuit which existed in February 1973. The composite price index for other toll is shown in Table A-5.

A Laspeyres price index was also developed for directory advertising service. Due to the changing composition of the product and the availability of data, the basket of goods was redefined several times and the price index was linked whenever the basket of goods changed. Another complication was that a rate change does not take effect until a new directory is printed. Since all the directories are not printed at the same time, there exists a time span over which a rate change becomes effective. In each case, the midpoint of the application was estimated and the entire price-up effect was assumed to occur at that time. An annual price index was computed. The calculated index is shown in Table A-7.

Other miscellaneous revenue includes rents, general services, licenses and all other revenues. It was felt that the implicit price index for Gross National Expenditure could be used to deflate this category. This index is shown in Table A-7. The same assumption was made with regard to the deflation of non-income taxes and the cost of materials, supplies, rent and service in Table A-11. In view of the large number and variety of products involved, this assumption is probably reasonable.

The above price indexes can be used separately or combined to form implicit price indexes for larger aggregates. The implicit price indexes for local, toll, miscellaneous and total Bell Canada service are shown in Table A-20.

G. Price Indexes for Labor Input

The price index for labor input can be computed as employee expense per weighted manhour. In addition to basic wage payments, employee expense includes many of the fringe benefits discussed in Section D (items which are considered as tax payments are excluded). To convert this index into real terms, it is necessary to divide by the implicit price index for Bell Canada services. Table A-21 illustrates these calculations.

Data on a disaggregate basis are only available for wages and salaries paid. To be consistent with the price index used on an aggregate basis and with the actual definition of labor input used in this study, the compensation to labor should be stated in terms of employee expense. However, it is not possible to calculate employee expense for each type of labor input. As an alternative, the average wage and salary per weighted manhour received by employees of a particular type (including those engaged in construction) was estimated for 1967. It was assumed that the ratio of employee expense to wages and salaries was the same for each type of labor. For each type of labor, the average wage per weighted manhour was estimated and multiplied by the ratio of total employee expense to total wage and salaries paid per weighted manhour for all employees. This method was used to estimate employee expense per weighted manhour for each employee category in 1967. All calculations are shown in Appendix C.

Average basic wage rate data for each type of labor are only available after 1967. Applying the percentage changes in average basic wages to the estimated employee expense per weighted manhour in 1967, it was possible to derive estimates for the cost of each labor input from 1968 to 1972. The implied assumption is that the ratio of employee expense to basic wages is the same for all types of labor in all years. For the years 1952 to 1966, it was possible to obtain information on the wage rate for a particular type of operator, plant craftsman and clerk. In a similar manner, this information was used to derive the estimates of employee expense per weighted manhour from 1952 to 1966. During this period, it was assumed that the price of other labor inputs moved by the same percentage as the price index for aggregate labor input.

One underlying assumption of these calculations is that workers engaged in construction activity receive the same renumeration as other employees. Actually, we are only interested in those employees who are engaged in providing output in the current year. The wage and salary data used here apply to all Bell Canada employees.

Finally, to find the real price indexes for each type of labor input, the nominal labor price indexes were deflated by the implicit price of Bell Canada services. The final results are shown in Table A-22. Although the disaggregate labor input price indexes developed here are only estimates, two trends can be observed. First, the increase in wage rates is higher in all classes from 1962 to 1972 than from 1952 to 1962. Secondly, the increases in renumeration received by telephone operators, plant craftsmen and clerical employees was below the average Bell increase from 1952 to 1962 and above the average Bell increase from 1962 to 1972.

H. User Cost of Capital Input

1. General Formula

Taking account of the corporate tax structure, the before tax user cost of capital can be represented as[1]

$$C_{B,t} = q_t \left[\frac{(1 - u_t v_t)}{1 - u_t} \delta_t + \frac{(1 - u_t w_t)}{1 - u_t} r_t - \frac{(1 - u_t x_t)\frac{\dot{q}_t}{q_t}}{1 - u_t} \right]$$

where $C_{B,t}$ = before tax user cost of capital in period t

q_t = price of capital goods in period t

δ_t = composite depreciation rate in period t

r_t = rate of return on capital in period t (after tax rate on equity and before tax rate on debt)

v_t = proportion of depreciation deductible for tax purposes

w_t = proportion of total income deductible for tax purposes (interest expense/total income)

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[1]This formula has been used in several studies. For example, see D. W. Jorgenson, "Investment Behaviour and the Production Function", Bell Journal of Economics and Management Science, III, (Spring, 1972), pp. 220-251.

x_t = proportion of capital gains which are realized and taxable

u_t = effective corporate income tax rate realized and taxable.

Since plant is not often resold capital gains are not realized and are not taxable. As a result, x_t is equal to zero. On the assumption that capital gains are transitional and are not regarded as part of the cost of capital by decision makers, the before tax user cost of capital can be represented as

$$C_{B,t} = q_t \left[\frac{(1 - u_t v_t) \cdot \delta_t}{1 - u_t} + r_{B,t} \right]$$

where $r_{B,t}$ is rate of return on capital before taxes.

It remains to define the actual data used in the calculation of the user cost of capital for Bell Canada.

2. The Price of Capital Goods (q_t)

The composite Telephone Plant Index (T.P.I.) was used as the price of capital goods. This is a Laspeyres price index which incorporates frequent weight changes because of the changing composition of the total telephone plant. Separate price indexes are available for the following six main classes of plant.

(a) Buildings
(b) Central Office Equipment (Switching Machinery)
(c) Station Equipment (Telephone Sets, etc.)
(d) Outside Plant (Poles, wire, cable, microwave towers, etc.)
(e) Furniture and Office Equipment
(f) Motor Vehicles.

Each of these components is a chained Laspeyres price index.

The Buildings price index is derived by weighting Statistics Canada indexes for nonresidential building materials and construction wage rates in the proportions in which these expenses make up building costs - 60 per cent and 40 per cent respectively. Statistics Canada wholesale price indexes for furniture and for trucks under 5,000 pounds were used for the last two categories. Price indexes were developed for the other three categories using Bell Canada data. Five types of central office installations, nine categories of station equipment (covering most station expenditures) and twenty-five types of materials and labor used in constructing outside plant were repriced. It should be noted that these are actually indexes of the cost of construction. Since the plant is not actually sold, it is impossible to construct a true price index for these components.

To derive a composite index, different components are weighted by the amount of investment made in each class. As pointed out in Section E of this chapter, the composite T.P.I. is used to reprice average gross and net capital stock. If different categories of plant depreciate at different rates, the quantity weights used in the composite T.P.I. should refer to the surviving or undepreciated capital stock of each type. Another alternative is to reprice the capital stock by category instead of using the composite T.P.I. The distribution of plant by category is available for a few recent years and it was only possible to use disaggregate repricing in these years. The repriced total gross and net capital stock figures were very close to the values derived using the composite T.P.I. Obviously, some of the categories of plant with the highest price increases depreciate or are written off at faster rates than average and some depreciate or are written off at slower rates. The net effect is that they tend to cancel out. Similar comments apply to the aggregate and disaggregate repricing of plant write-offs and depreciation expense. Column one of Table A-23 shows the composite T.P.I. for Bell Canada.

3. The Corporate Income Tax Rate (u_t)

In each year, the composite rate of income tax is calculated as the ratio of income tax payable to taxable income. In general, this ratio will vary slightly due to special tax provisions which may be in effect at any point in time. Deferred taxes are included as taxes payable in the current year. Column two of Table A-23 shows the calculated income tax rate.

4. The Composite Depreciation Rate (δ_t)

This series is calculated as the ratio of depreciation stated in current dollars (Table A-15) to gross capital stock repriced to current dollars (Table A-18) and is shown by column three of Table A-23.

5. Proportion of Depreciation Deductible for Tax Purposes (v_t)

Total depreciation charged for tax purposes is divided by depreciation measured in current dollars to calculate v_t. The calculated series is shown in column four of Table A-23.

6. Rate of Return on Capital Before Taxes ($r_{B,t}$)

Two types of measures have been used in this study for the before tax user cost of capital. The first measure is derived by dividing net output minus employee expense by the total average net capital stock in each year. All values are expressed in current dollars or repriced to current dollars. When using gross output and gross capital, the cost of capital is defined as gross output minus employee expense divided by total average gross capital stock in each year. These definitions have the advantage that factor payments will always exhaust output in every year. The calculated series are shown in the first two columns of Table A-24.

Another method of measuring the cost of capital is to look at the opportunity cost of funds and not at what is actually made on money invested in plant. Although the economist normally would prefer this concept, difficulties arise in the actual definition of opportunity cost.[1] The cost of funds on the market will vary with the debt to equity ratio. One practical alternative is to assume that an optimal debt ratio has been determined each year by management and to proceed with an analysis of the opportunity cost of equity and debt separately. In the case of Bell Canada, the debt ratio has remained fairly stable and it is reasonable to assume that management has little discretion in the amount of debt and equity financing used.

It is very difficult to define an opportunity cost for equity capital. Different firms have different degrees of risk and face different market situations. One possibility is to use the rate of return on average common equity capital for seven Canadian Telephone companies. However, each of these companies is smaller than Bell Canada. Another alternative is to simply take the rate of return paid by Bell Canada on average total equity capital. This approach assumes that Bell is raising money in perfect

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[1]A great deal of debate has occurred concerning the theoretical and empirical definition of the rate of return or cost of capital. For example, see F. Modigliani and M.H. Miller, "The Cost of Capital, Corporation Finance and the Theory of Investment", American Economic Review, XLVIII, (June, 1958), pp. 261-97; D. Durand, "The Cost of Capital in an Imperfect Market: A Reply to Modigliani and Miller", American Economic Review, XLIX, (September, 1959), pp. 639-55, reply pp. 655-69 ; F. Modigliani and M.H. Miller, "The Cost of Capital, Corporation Finance and the Theory of Investment: Reply", American Economic Review, LV, (June, 1965), pp. 524-27, and "Some Estimates of the Cost of Capital to the Electric Utility Industry, 1954-57, American Economic Review, LVI, (June, 1966), pp. 333-91, comments and reply in same journal, LVII, (December, 1967), pp. 1258 - 1300 .

equity markets and that the rate of return on preferred and common equity can be lumped together. Since the main purpose of this paper is not the investigation of the cost of capital, these are the only two approaches which were taken. In both cases, the rate of return on equity as stated is on an after tax basis and the before tax rate of return was calculated by dividing by one minus the effective corporate income tax rate. No attempt was made to study firms in the same risk class as Bell Canada or to determine the rate of return on the market value of equity.

The opportunity cost of debt was taken either as the marginal cost of new long-term debt issued by Bell Canada or as the embedded cost of debt issued by Bell Canada. Although the former alternative is preferable on theoretical grounds, the latter measure is often used for regulatory purposes and is often quoted by company officials. These rates of return are only opportunity costs if Bell raises money in perfect debt markets. Once again, no attempt was made to study firms in the same risk class as Bell Canada or to state rates of return on debt in terms of market values. The rates of return on debt are stated on a before tax basis and no adjustment was necessary.

Using the actual debt equity ratio in each year, a weighted average of the opportunity cost of equity and debt was calculated. Four alternative measures were derived and these are shown in the last four columns of

Table A-24.

7. Deflation of User Cost of Capital

As described above, six different measures of the rate of return to capital were obtained. From these, it was possible to calculate six different measures of the before tax user cost of capital. Each of these measures were deflated by the implicit price index for Bell services and the deflated series are shown in Table A-25.

I. Proxy Variables for Technological Change

The usual procedure is to use a time trend as a proxy variable for technological change. Even if the advance in fundamental or basic knowledge followed a smooth time trend, we are more interested in the rate of technological innovations. From the description given in Chapter II, it is clear that the rate of innovation was not constant over time.

A great many innovations have been made during the period 1952 to 1972. Some of the more important changes in the four stages of production include (1) the change to switching machines requiring less maintenance (Number Five Cross-bar and Electronic Switching Systems), (2) the use of microwave transmission systems, (3) the use of buried cable and dedicated plant for local loops and (4) the development of new types of station apparatus. The newer types of station apparatus are probably indicative of new products rather than cost reducing technological advances. Data on the percentage of total wire mileage which is buried show no great reduction over the period. Also, the cost reducing properties of dedicated plant have not been clearly demonstrated. Perhaps the most important change has been the switch to more advanced switching machines. This innovation affects both local and toll traffic. At about the same time, the microwave system was built for the transmission of toll calls. A second proxy variable used for technological change in this study is the percentage of telephones which were connected to Number Five Crossbar and Electronic Switching System offices. Other innovations such as the use for microwave transmission will also be represented by this proxy variable.

The innovations mentioned above are primarily related to the management and use of capital. Improvements in the management and use of labor have also occurred, but these were more gradual and less noticeable.

To the telephone customer, the most obvious change has been the introduction of Direct Distance Dialing. Once again, this may be more indicative of a change in product, rather than a cost reducing technological innovation. In any case, the percentage of calls direct distance dialed was used as a third proxy variable for technological change. The three proxy variables are shown in Table A-26.

Chapter V

PRODUCTION MODELS FOR BELL CANADA - THEORY

A. Relationship Between Technological Change and Productivity Measures

Four characteristics of a technology have been classified by M. Brown:[1]

(a) The efficiency of a technology determines the output that results from a given level of inputs (holding the other characteristic fixed).

(b) Technological economies of scale determine the extent to which a proportionate change in inputs generates a proportionate change in output (there are also firm economies of scale which are dependent on the size of the firm).

(c) The capital intensity of a technology refers to the capital-labor ratio. (Degrees of capital intensity are reflected in the capital-labor ratio for given relative factor prices.)

(d) The elasticity of substitution (σ) is defined for a production function with only two inputs (capital and labor) as the percentage change in the capital-labor ratio divided by the percentage change in the marginal rate of technical substitution of capital for labor.

Technological change can lead to a change in any one of these characteristics. A neutral technical change will affect only the first two. A non-neutral technical change will affect the capital intensity and elasticity of

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[1] M. Brown, On the Theory and Measurement of Technological Change, (Cambridge: Cambridge University Press, 1968), pp. 9-28.

substitution as well. Geometrically, either neutral or non-neutral technological change represent a shift in the boundary of the production set and hence a shift in the production function.

Total factor productivity ratios are based on the inputs of both capital and labor. They are often used as a measure of performance and interpreted as the change in efficiency. However, this interpretation may not be correct. Kendrick's measure of total factor productivity was explained in the previous chapter. For relatively small variations in his measure of total factor productivity to be interpreted as the change in the efficiency of production, the following assumptions are required

(a) constant returns to scale
(b) neutral technical change
(c) exogenously determined factor and output prices
(d) cost minimizing behaviour.

These assumptions are not always valid and the total factor productivity ratio is a function of the level of efficiency as well as the deviation from each of the above assumptions.

By building a production model, it is theoretically possible to determine exactly which technological characteristics are changing and exactly what is causing the productivity ratio to vary. This knowledge is the first step toward specifying a reasonable productivity goal for any automatic rate adjustment clause.

B. Implicit Assumptions of Alternative Production Functions

The elasticity of substitution (σ) is an important economic characteristic and production functions are often classified on the basis of this property. Mathematically, the elasticity of substitution can be expressed as

$$\sigma = \frac{d \ln ({}^{K}/L)}{d \ln ({}^{MPP}L/_{MPP_K})} = \left[d({}^{K}/L)/({}^{K}/L) \right] \div \left[d\left(\frac{MPP_L}{MPP_K}\right) / \frac{MPP_L}{MPP_K} \right]$$

Assuming factors are paid their marginal products, if the elasticity of substitution is greater than unity, then a rising capital-labor ratio causes labor's share of factor payments to decrease.

It is possible to derive production functions which imply a constant elasticity of substitution for all ratios of factors employed and for all levels of output. Assume that an isoquant can be written as an ordinary linear second order differential equation in terms of K, L and σ. This equation can be solved to obtain the exact form of the isoquant (in terms of K and L) for any level of σ. A homogeneous production function can then be derived using the differential equation for the isoquant.[1]

If $\sigma = 0$, a Leontief production function is obtained. Equation 5-1 illustrates this type of production function.

5-1. $Y = k_1 L$ if $K/L < K_0/L_0$

$= k_2 K$ if $K/L > K_0/L_0$

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[1] Ibid., pp. 192-94.

Production must take place at the input ratio K_0/L_0. No substitution of the factor inputs is possible and if either input is present in excess amounts, the other input becomes limiting. The discussion of the production process in Chapter II pointed out that the possibility of factor substitution exists in the telephone business. Therefore, no attempt was made to estimate this type of function.

If $\sigma = 1$, a Cobb-Douglas production function is obtained. This function is illustrated by equation 5-2.

5-2. $Y = A_0 K^{\alpha} L^{\beta}; \ \alpha > 0, \ \beta > 0, \ v = \alpha + \beta > 0.$

In order for the marginal products of capital and labor to be positive, both α and β must be greater than zero. The function is homogeneous of degree v. In economic terms, v refers to economics of scale. If v is greater (less) than unity, there are increasing (decreasing) returns to scale.

The Cobb-Douglas production function has several desirable theoretical properties. When α and β are greater than zero, the marginal products of the input factors are positive. Also, when α and β are less than one, the marginal products are decreasing functions of the respective inputs. If in addition, it is true that $\alpha + \beta = 1$, the function has constant returns to scale and therefore satisfies what are called desirable properties for a neoclassical production function.[1]

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[1]K. Arrow, B. Chenery, B. Minhas and R. Solow, "Capital-Labour Substitution and Economic Efficiency," Review of Economics and Statistics, XLIII, (August, 1961), pp. 225-250.

If factors are paid the value of their marginal products, factor shares will be constant with a Cobb-Douglas production function. This relative stability of factor shares is often observed in economic data.

A Cobb-Douglas function can reflect several types of technological change. An increase in efficiency is shown by an increase in the constant term. A change in returns to scale would be shown by a change in the sum of α and β (with their relative values unchanged). An increase in α relative to β would correspond to an increase in capital intensity. Technological change leading to a change in the elasticity of substitution cannot be reflected using a Cobb-Douglas function.

The general form of a Constant Elasticity of Substitution (C.E.S) production function is shown by equation 5-3.

5-3. $$Y = \gamma \left[\delta K^{-p} + (1 - \delta)\ L^{-p}\right]^{-\frac{v}{p}} ; \ \gamma>0,\ 0<\delta<1,\ p>-1,\ v\geq 0.$$

γ = scale parameter denoting efficiency of production

δ = capital intensity parameter

v = degree of homogeneity or returns to scale

$p = \frac{1-\sigma}{\sigma}$ where σ is the elasticity of substitution

The C.E.S. function also satisfied the properties of a neoclassical production function. When the elasticity of substitution is less than unity ($p > 0$), the function has desirable asymptotic properties as well. All types of technical change can be represented.[1] A major weakness of the C.E.S. function is that it is difficult to fit empirically.

Both the Cobb-Douglas and C.E.S. functions are based on the assumption that the elasticity of substitution is invariant with respect to factor inputs. It is also possible to relax this assumption and specify Variable Elasticity of Substitution (V.E.S.) production functions.

Alternative production functions have been presented which describe the production process at a definite point in time. Assumptions with regard to each of the four technological characteristics were pointed out. My major concern is with changes in measured productivity levels and hence with changes in each of the four technological characteristics. The following sections discuss how shifts in various production functions may be specified and estimated empirically.

C. Investigating Technological Change Using Implied Relationships

Before discussing the estimation of production functions when technological change is taking place, it is appropriate to consider the direct investigation of

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[1] It should be noted that non-neutral technical change does not necessarily increase the rate of growth of output. An increase in capital intensity will increase output growth only if capital is growing faster than labor. However, an increase in the elasticity of substitution of capital for labor will always increase the rate of growth of output.

technological change under restrictive assumptions. Sato and Beckmann[1] have classified several types of technological change. Production functions can be modified to incorporate each of these types. However, nonlinear production functions are often derived and estimation is difficult. One alternative is to assume constant returns to scale, exogenously determined factor and output prices and cost minimizing behaviour. As a result, each type of technological change implies a particular relationship between factor prices and either factor proportions or input-output ratios. It is often easier to fit these economic relationships directly than to fit the implied production functions.

Table 5-1 lists the different types of technical change classified by Sato and Beckman and the implied linear or log-linear economic relationships. By estimating these economic relationships, the nature of technological change can be determined by comparing the fit of the different equations. The coefficient of multiple determination (R^2) should not be used for this purpose. Since the independent variables are different in each equation, the total variance to be explained will not be the same. Instead of comparing the proportion of the total variance which is explained, the mean residual sum of squares should be compared directly.

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[1] R. Sato and M. Beckmann, "Aggregate Production Functions and Types of Technical Progress: A Statistical Analysis", American Economic Review, XLIX, (March, 1969), pp. 88-101.

Of course, the validity of any results rests on the validity of the above assumptions. Results from this type of analysis should be regarded as tentative. However, they might be useful in the initial specification of a production function. One consistency check would be that any estimated production function should imply constant returns to scale.

TABLE 5-1

ALTERNATIVE TYPES OF TECHNOLOGICAL CHANGE AND IMPLIED RELATIONSHIPS

Type of Technological Change	Implied Relationships
1. Product Augmenting	
(a) Hicks neutrality	$R = a + bx$
$Y = A(t)\ F(K,L)$	$\log R = a + b \log x$
(b) Labor additive	$r = a + bk$
$Y = A(t)L + F(K,L)$	$\log r = a + b \log k$
(c) Capital additive	$w = a + bx$
$Y = A(t)\ K + F(K,L)$	$\log w = a + b \log x$
2. Labor Augmenting	
(a) Harrod neutrality	$r = a + by$
$Y = F(K, A(t) \cdot L)$	$\log r = a + b \log y$
(b) Labor combining	$w = a + by$
$Y = F(K, A(t)K+L)$	$\log w = a + b \log y$
3. Capital Augmenting	
(a) Solow neutrality	$w = a + bz$
$Y = F(A(t) \cdot K, L)$	$\log w = a + b \log z$
(b) Capital combining	$r = a + bz$
$Y = F(K+A(t)L, L)$	$\log r = a + b \log z$
4. Input Decreasing	
(a) Labor decreasing	$R = a + by$
$L = G(K,Y) + C(t)Y;\ \partial C(t)/\partial t < 0$	$\log R = a + b \log y$
(b) Capital decreasing	$R = a + bz$
$K = H(L,Y) + C(t)Y;\ \partial C(t)/\partial t < 0$	$\log R = a + b \log z$

Y = output	$y = Y/K$	r = return to capital
K = capital	$z = Y/L$	w = wage rate
L = labor	$k = K/L$	$R = r/w$
	$x = L/K$	

$\alpha = r/y$ = relative share of capital

$\beta = 1 - \alpha = w/z$ = relative share of labor

$A(t)$ = index of technological change.

D. Investigating Technological Change with a Cobb-Douglas Production Function

Cross-sectional data are of little use in studying technological changes which have occurred over time and which are readily available to all telephone companies in North America (see Chapter II). If sufficient time series data are available, production functions can be fitted for successive time periods. The change in the estimated parameters would indicate the nature of technological change. In theory, the time periods chosen should correspond to technological epochs, i.e., periods when technology was relatively constant. Epochs might be defined by fitting functions for different time periods and using an F test on the residuals to determine if the regressions were generated from the same structure. However, the starting point for the first epoch remains somewhat arbitrary. Another alternative is to simply specify technological epochs based on a priori information.

When a Cobb-Douglas function is fitted in each epoch, it is assumed that technological change does not alter the elasticity of substitution (the elasticity of substitution is always equal to one). Another weakness of a Cobb-Douglas function is that a change in returns to scale is not represented by a single parameter. When the estimate of α or β changes, both capital intensity and returns to scale $(\alpha + \beta)$ may be altered. Thus, it is possible that an unambiguous estimate of changes in these characteristics cannot be found using a Cobb-Douglas function.

The main difficulty in fitting a production function for each epoch is a lack of degrees of freedom. A second approach is to use dummy variables for each epoch and to fit the function over the complete time period. Using a Cobb-Douglas function, dummy variables can be specified as shown by equations 5-4 and 5-5.

$$Y = A_0 K^{\alpha} L^{\beta} D_1^{c_1} \ldots D_n^{c_n}$$

5-4. $$\ln Y = \ln A_0 + \alpha \ln K + \beta \ln L + c_1 \ln D_1 + c_n \ln D_n$$

$$Y = A_0 K^{\alpha + c_1 D_1 + \ldots + c_n D_n} L^{\beta}$$

5-5. $$\ln Y = \ln A_0 + \alpha \ln K + c_1 (D_1 \ln K) + \ldots + c_n (D_n \ln K) + \beta \ln L$$

where $D_1 \ldots D_n$ are n dummy variables for technological epochs.

The first specification indicates neutral technological change in the form of a change in efficiency each epoch. The second specification indicates non-neutral technological change in the form of a change in capital intensity and returns to scale. These equations can also be estimated under the restriction that returns to scale are initially equal to one. By using dummy variables, technological change is allowed to take place in a fairly general way and fewer degrees of freedom are lost.

A third approach involves making further simplifying assumptions regarding the nature of technological change. It is often assumed that only changes in efficiency occur. The level of technology can be represented by proxy variable t. Equation 5-6 illustrates this type of function (Hicks neutral technical change). Another alternative is to represent non-neutral technological change in the form of a change in the capital coefficient as shown in equation 5-7.

$$Y = A_0 \quad K^{\alpha} L^{\beta} e^{\lambda t}$$

5-6. $\ln Y = \ln A_0 + \alpha \ln K + \beta \ln L + \lambda t$

$$Y = A_0 \quad K^{\alpha + \lambda t} L^{\beta}$$

5-7. $\ln Y = \ln A_0 + \alpha \ln K + \beta \ln L + \lambda (t \ln K)$

R. Sato and M.J. Beckmann[1] have derived the form of production functions implied by alternative definitions of neutral technical change. A Cobb-Douglas function can be modified to yield Harrod neutral technical change as shown in equation 5-8. The capital-labor ratio

$$Y = A_0 K^{\alpha} (e^{\lambda t} L)^{\beta}$$

5-8. $\ln Y = \ln A_0 + \alpha \ln K + \beta \ln L + \beta \lambda t$

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[1] M. Beckmann and R. Sato, "Neutral Inventions and Production Function", Review of Economic Studies, XXXV, (January, 1968), pp. 57-67.

is dependent on the marginal product of capital and technological change simply augments labor.

If technological change is capital augmenting, Solow neutral technical change may be implied. In this case, the labor-output ratio is a function of the marginal product of labor. This type of technical change is implied by equation 5-9.[1]

$$Y = A_0 \, (e^{\lambda t} K)^{\alpha} L^{\beta}$$

5-9. $$\ln Y = \ln A_0 + \alpha \ln K + \beta \ln L + \alpha \lambda t$$

It is also possible that technological change simply adds an extra bonus to output and that this bonus varies directly with the level of one factor input. Equation 5-10 illustrates product augmenting and capital additive technical change. In this case, the capital-labor ratio is a function of the marginal productivity labor.

$$Y = A_1 e^{\lambda t} K + A_2 K^{\alpha} L^{\beta}$$

$$Y/K = A_1 e^{\lambda t} + A_2 K^{\alpha - 1} L^{\beta}$$

Assuming constant returns to scale in the basic Cobb-Douglas function,

5-10. $$Y/K = A_1 e^{\lambda t} + A_2 (L/K)^{\beta}$$

[1]Hicks neutral, Harrod neutral and Solow neutral technological change cannot be differentiated empirically when a modified Cobb-Douglas function is used. Equations 5-6, 5-8 and 5-9 have the same empirical form, but the coefficient of the proxy variable for technological change is interpreted differently.

An alternative form for this type of production function is

$$5\text{-}11. \quad Y/K = A_1 e^{\lambda t} + A_2(L/K) + A_3(L/K)^2$$

Product augmenting capital additive production functions (equations 5-10 or 5-11) are particularly relevant for Bell Canada where incorporation of technical change may have required the addition of capital. However, these functions must be fitted with a nonlinear program and the assumption of constant returns to scale is implicit.

Technological change may also augment output in proportion to the amount of labor used. This type of relationship would probably not be relevant for technical change in the telephone industry. However, such a function could be estimated using equations 5-12 or 5-13.

$$Y = A_1 e^{\lambda t} L + A_2 K^{\alpha} L^{\beta}$$

Assuming constant returns to scale in the basic Cobb-Douglas function,

$$5\text{-}12. \quad Y/L = A_1 e^{\lambda t} + A_2(K/L)^{\alpha}$$

One alternative form is

$$5\text{-}13. \quad (Y/L) = A_1 e^{\lambda t} + A_2(K/L) + A_3(K/L)^2$$

This section has shown how a Cobb-Douglas production function can be used to measure different types of technological change. In each of the above specifications, a particular type of technological change was assumed and the required modifications in the original Cobb-Douglas equation were made. It should be noted that the original properties which were listed for the Cobb-Douglas function do not apply to each of the modified forms. Other basic production functions can also be modified to represent alternative types of technological change.

E. Investigating Technological Change with a C.E.S. Production Function

1. Fitting a C.E.S. Production Function

Before discussing how a C.E.S. function might be used to investigate technological change, I will outline four estimation methods which have been proposed when it is assumed that no technological change is occurring.

(a) Method One

The C.E.S. function can be represented in logarithmic form as

5-14. $$\log Y = \log \gamma - v/p \log \left[\delta K^{-p} + (1-\delta) L^{-p}\right] + u$$

where u is a random error normally distributed and with zero expected value.

If p and δ were known, this equation could be estimated using ordinary least squares as

$$\log Y = \log \gamma - v/p \log X + u$$

where $x = \left[\delta K^{-p} + (1-\delta) L^{-p}\right]$

Assuming factors are paid their marginal products, the expansion path of a C.E.S. function can be used as a side relation to find the values of p and δ. The expansion path is given by

5-15. $$\frac{r}{w} = \frac{\partial Y/\partial K}{\partial Y/\partial L} = \frac{\delta}{1-\delta} \left(\frac{K}{L}\right)^{-(p+1)}$$

This expansion path can also be written as shown by equations 5-16 or 5-17.

5-16. $$\ln r/w = \ln \frac{\delta}{1-\delta} - (p+1) \ln \frac{K}{L}$$

$$(p+1) \ln \frac{K}{L} = \ln \frac{\delta}{1-\delta} - \ln \frac{r}{w}$$

$$\ln \frac{K}{L} = \frac{1}{1+p} \ln \frac{\delta}{1-\delta} - \frac{1}{1+p} \ln \frac{r}{w}$$

5-17 $$\ln \frac{K}{L} = \sigma \ln \frac{\delta}{1-\delta} - \sigma \ln \frac{r}{w}$$

In the short-run, the input ratio may not be instantaneously adjusted after a change in the factor price ratio. In this case, the input ratio may be a function of some lagged distribution of the input price ratio. If a Koyck lag is assumed, the short-run expansion path of equation 5-16 is

5-18. $$\ln\left(\frac{r}{w}\right) = (1-\lambda) \ln \frac{\delta}{1-\delta} - (p+1)(1-\lambda) \ln\frac{K}{L} + \lambda \ln\left(\frac{r}{w}\right)_{-1}$$

Similarly, the short-run adjustment path of equation 5-17 is

5-19. $$\ln\left(\frac{K}{L}\right) = \sigma (1-\lambda) \ln \frac{\delta}{1-\delta} - \sigma (1-\lambda) \ln \frac{r}{w} + \lambda \ln\left(\frac{K}{L}\right)_{-1}$$

(b) Method Two

A second method of fitting the C.E.S. function involves nonlinear estimation techniques. Most nonlinear algorithms take either of two general approaches.

In the Gauss-Newton approach, a Taylor series expansion of the function is taken around some initial estimates for the parameters. The calculated value of output $(\tilde{Y})$ is a function of the correction vector

$$\left[(\gamma - \gamma_0),\ (\delta - \delta_0),\ (p - p_0),\ \left(\frac{v}{p} - \frac{v_0}{p_0}\right)\right].$$

Elements of the correction vector can be estimated so as to minimize the sum of squares. A new starting point is implied by the estimated correction vector.

$$\text{Min } Z = \sum_{i=1}^{n} (Y - \tilde{Y})^2$$

This process is repeated until successive iterations satisfy some convergence criteria. The Newton method converges rapidly when the Taylor series expansion represents a good approximation to the function and the function approximated has the desired second order properties.

In the Gradient approach, the correction vector is taken to be the direction of steepest descent.

$$Sg = -\left(\frac{\partial Z}{\partial \gamma_0}, \frac{\partial Z}{\partial \delta_0}, \frac{\partial Z}{\partial p_0}, \frac{\partial Z}{\partial v_0}\right)$$

Convergence is often rapid during the first few iterations but usually slows down in later iterations.

There are many different algorithms available based on the above general approach. The program used in this study is based on an algorithm developed by Donald W.

Marquardt[1] which interpolates between the Newton and Gradient approaches. Any nonlinear algorithm can fail if the function is not concave over the entire region. In addition, elongated ridges or relatively flat regions can be a problem. There is no guarantee that any optimum solution is global rather than local. In general, any nonlinear estimate should be checked against results derived with other nonlinear algorithms or regression techniques.

(c) Method Three

A third method which has been proposed by Kmenta is to fit a Taylor series expansion of the C.E.S. function (around p equal to zero). This approximation is given by

$$\text{5-20.} \quad \ln Y = \ln \gamma + v \ln L = (v-1)(1-\delta) \ln \frac{K}{L} - \tfrac{1}{2}p(v-1)\delta\,(1-\delta)\left(\ln \frac{K}{L}\right)^2 + R(p)$$

where R(p) is the remainder and is a function of p. In the case where p is equal to zero, this expansion is equivalent to a Cobb-Douglas function.

There are two problems with this technique. The coefficient of the last term is expected to be very small and, as a result, it is difficult to get a reliable estimate for p. In any case, it has been shown that this particular expansion is a better approximation to a V.E.S.

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[1]Donald W. Marquardt, "An Algorithm for Least-Squares Estimation of Nonlinear Parameters", SIAM Journal, XI, (June, 1963), pp. 431-441.

function than to the C.E.S. function.[1] As a result, this method should not be used to fit a C.E.S. production function.

(d) Method Four

A search procedure has also been proposed as an alternative to the nonlinear procedure. The logarithmic expansion of the C.E.S. function is

$$\text{5-21.} \quad \ln Y = \ln \gamma - v/p \ \ln \left[\delta K^{-p} + (1-\delta)\, L^{-p} \right]$$
$$= \ln \gamma - v/p \ln \hat{X}$$

If the marginal products of capital and labor are to be positive, it is necessary that $0 \leq \delta \leq 1$. In addition, if the implied elasticity of substitution is to be reasonable, p should fall in the range -.5 to 2.0. The procedure is simply to run several ordinary least-square regressions with different values for p and δ used to estimate $\hat{X}$. The regression with the highest coefficient of multiple determination is chosen. Monte Carlo studies by Vittorio Corbo suggest that this method results in fairly small biases in small samples and that the mean square errors are also very small.[2]

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[1]Vittorio Corbo, "More on the Use of Kmenta's approximation", Mimeographed, International Institute of Quantitative Economics, Montreal, (March, 1974).

[2]Vittorio Corbo, "An Iterative Procedure to Calculate Least Squares Estimates for C.E.S. Function: Some Small Sample Properties", Mimeographed, International Institute of Quantitative Economics, Montreal, (March, 1974).

2. Incorporating Technological Change

An investigation of technological change can be performed with a C.E.S. function as well as a Cobb-Douglas function. The nature of technological change can be determined by isolating different technological epochs, fitting a C.E.S. function in each epoch and comparing the parameter estimates. The use of a C.E.S. function provides a more general approach than the use of a Cobb-Douglas, because changes in the elasticity of substitution can be determined. However, the price of this generality is the difficulty encountered in estimation.

It is very unlikely that a C.E.S. function could be fitted to Bell Canada data for different subperiods - only twenty years of data are available. Thus, it is necessary to modify the basic C.E.S. function to allow for the incorporation of technological change directly into the production function. If a time trend were introduced, allowance would be made for a change in efficiency, (a form of neutral technical change). Once again,

$$Y = \gamma_0 e^{\lambda t} \left[\delta K^{-p} + (1-\delta) L^{-p}\right]^{-v/p} e^{u}$$

5-22. $\ln Y = \ln \gamma_0 + \lambda t - v/p \ln \hat{X} + u$

where $\hat{X} = \left[\hat{\delta} K^{-\hat{p}} + (1+\hat{\delta}) L^{-\hat{p}}\right]$

three methods of estimation are possible (use of a side relation, use of a search procedure and use of nonlinear least squares).

As indicated in Chapter II, Bell Canada may have experienced non-neutral technological change. One possibility is to assume non-neutral factor augmenting technical change. P.A. Diamond and D. McFadden have demonstrated that it is not always possible to identify the rate of biased factor augmenting technological change and the elasticity of substitution. They state that

> . . . given the time series of all market phenomena for a single economy which has a neoclassical production function, these same time series could have been generated by an alternate function having an arbitrary elasticity or arbitrary bias at the observed points.[1]

Marc Nerlove has shown that this impossibility theorem must be modified slightly and that the assumption of ". . . exponential factor-augmenting change is sufficient for identification".[2] Other types of non-neutral change which are not factor augmenting can also be assumed.

Unfortunately, a tradeoff exists between the reliability of estimates and the complexity of the equation being estimated. With only twenty years of data, it was impossible to reliably estimate C.E.S. functions incorporating non-neutral technological change. For similar reasons, it was not possible to estimate Variable Elasticity of Substitution (V.E.S.) production functions

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[1]P.A. Diamond and D. McFadden, "Identification of the Elasticity of Substitution and the Bias of Technical Change: An Impossibility Theorem", unpublished, 1965, p. 1.

[2]Marc Nerlove, "Recent Empirical Studies of the C.E.S. and Related Production Functions", in The Theory and Empirical Analysis of Production, pp. 55-122, Edited by M. Brown, (New York: National Bureau of Economic Research, 1967).

with or without the assumed presence of technological change.

F. Investigating Technical Change with Nonhomogeneous Production Functions

A homogeneous production function takes the general form

$$f(\lambda K, \lambda L) = \lambda^{v} f(K, L)$$

where λ is any real constant and v is the degree of homogeneity. Several of the modified Cobb-Douglas functions which have already been suggested are in fact nonhomogeneous functions. Two other types of nonhomogeneous functions will be outlined in this section. These functions were proposed by H.D. Vinod.[1]

The production function shown in equation 5-23 is nonhomogeneous in capital and labor. The equation may be fitted in linear form.[1] Using Bell Canada data, this procedure is not entirely satisfactory because of multicollinearity between the independent variables ln K, ln L

$$Y = A\, K^{a + c \ln L}\, L^{b}$$

5-23. $$\ln Y = \ln A + a \ln K + b \ln L + c \ln K \ln L$$

and ln K ln L. If the parameter c turns out to be insignificant, the function simplifies to a standard Cobb-Douglas function. Although this function is difficult to fit, it does have several desirable properties.

[1] H.D. Vinod, "Nonhomogeneous Production Functions and Applications to Telecommunications", The Bell Journal of Economics and Management Science, III,(Autumn, 1972), pp. 531-543.

The value of the marginal productivity of capital and labor (shown by equations 5-24 and 5-25) will depend on the units chosen for capital and labor. By computing

5-24. $$MP_K = \frac{Y}{K}(a + c \ln L)$$

5-25. $$MP_L = \frac{Y}{L}(b + c \ln K)$$

the elasticity of output with respect to capital (E_K) and labor (E_L), comparisons can be made with regard to the units of measurement. The elasticity substitution is a function of E_K, E_L and c.

5-26. $$E_K = \frac{\partial \ln Y}{\partial \ln K} = a + c \ln L$$

5-27. $$E_L = \frac{\partial \ln Y}{\partial \ln L} = b + c \ln K$$

5-28. $$\sigma = \frac{E_K + E_L}{(E_K+E_L) + 2_c}$$

Both the Cobb-Douglas function and the C.E.S. function had a straight line expansion path. However, the expansion path implied by a nonhomogeneous function will not be a straight line. The scale elasticity (E_K+E_L) is a <u>localized</u> concept which corresponds to returns to scale over a small interval where the expansion path is approximately linear.

One modification of H. Vinod's production function would be to introduce technological change explicitly into the analysis. Equation 5-29 illustrates this specification.

$$Y = A K^{a+c\ln L} L^{b} e^{\lambda t}$$

5-29. $\ln Y = \ln A + a\ln K + b\ln L + c\ln K\ln L + \lambda t$

This would explicitly allow for neutral and non-neutral technical change, but estimation of the parameters of equation 5-29 with Bell Canada data is difficult because of multicollinearity between the four independent variables.

An alternative nonhomogeneous function proposed by H. Vinod is

$$Y = A K^{a} L^{b} e^{c/KL}$$

5-30. $\ln Y = \ln A + a\ln K + b\ln L + c/KL$

The properties of this function have also been derived. Once again, technological change could be specified explicitly in the production function, but multicollinearity makes estimation difficult.

$$Y = A K^{a} L^{b} e^{c/KL} e^{\lambda t}$$

5-31. $\ln Y = \ln A + a \ln K + b \ln L + c/KL + \lambda t$

G. Input Requirement Approach

An input requirement model offers at least two main advantages over a production function model. First, it may be used to incorporate changes in the level of input utilization. This is accomplished by assuming an adjustment process whereby the desired level of each input is approached over time. As the measured level of input falls short of the desired or actual amount of input required to produce a given output, the implication is that utilization levels have increased. Secondly, it may be easier to incorporate disaggregate data into an input requirement model than a production function model.

The easiest way to derive a function with an input as the dependent variable is to simply transform the production function. Employment functions are often fitted in this way. For example, assuming a Cobb-Douglas production function with Hicks neutral technical change and a proportional adjustment process, the requirement for labor is derived below.

$$Y_t = A\, K_t^{\alpha} (L_t^*)^B \; e^{\lambda Et}$$

By transforming the production function

$$L_t = A^{-1/B} \; K_t^{-\alpha/B} \; Y_t^{1/B} \; e^{-\lambda Et/B}$$

where L^* is desired labor input

$$\ln L_t^* = -\frac{1}{B} \ln A - \alpha/B \ln K_t + \frac{1}{B} \ln Y_t - \frac{\lambda}{B} E_t$$

Now if,

$$\frac{L_t}{L_{t-1}} = \gamma \frac{L_{t-1}^*}{L_{t-1}}$$

then

$$\ln L_t = \gamma \ln L_{t-1}^* + (1-\gamma) \ln L_{t-1}$$

and

5-32. $$\ln L_t = -\frac{\gamma}{B} \ln A - \frac{\alpha\gamma}{B} \ln K_t + \frac{\gamma}{B} \ln Y_t - \frac{\lambda\gamma}{B} E_t + (1-\gamma) \ln L_{t-1}$$

This approach assumes that the level of capital, output and technology is given and that the labor input is simply a function of the technical relationships (the production function) and the adjustment process for labor inputs.

E. Kuh[1] fitted employment functions of this type in 1965. He made the additional assumption that no technical change was occurring. The problem with this approach is that the elasticity of labor with respect to output is often less than unity even in the long-run. This would imply that the elasticity of output with respect to labour is greater than one.[2] Although returns to all inputs might be greater than one with a neoclassical production function, if diminishing returns exists for each input the elasticity of output with respect to a particular input must eventually be less than unity as increments are added to that input.

N. J. Ireland and D.J. Smyth[3] have proposed an alternative interpretation of the output coefficient. They point out that the above interpretation assumes a

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[1]E. Kuh, "Cyclical and Secular Labor Productivity in the United States", Review of Economics and Statistics, XLVII, (February, 1965), pp. 1-12.

[2]$$E_{L/Y} = \frac{\partial L}{\partial Y} \cdot \frac{Y}{L} = \frac{1}{\frac{\partial Y}{\partial L}\frac{L}{Y}} = \frac{1}{E_{Y/L}}$$

if $E_{L/Y} = \frac{1}{E_{Y/L}} < 1$

then $E_{Y/L} > 1$

[3]N.J. Ireland and D.J. Smyth, "The Specification of Short-Run Employment Models", Review of Economic Studies, XXXVII, (April, 1970), pp. 28-85.

constant capital utilization rate and that the implied increasing returns to labor is actually biased upward by a simultaneous increase in capital utilization. An alternative interpretation can be made by specifying the utilization rates for both capital and labor in a C.E.S. production function, by assuming a proportional adjustment hypothesis and by assuming that the expansion path of the production function is linear in the short-run. In this case, the derived short-run employment function is shown by equation 5-33. There is no difficulty encountered in interpreting an estimated output coefficient which is less than unity since it does not imply increasing returns to labor alone.

5-33. $\ln L_t = a_0 + a_1 \ln Q_t + a_2 E_3 + a \ln L_{t-1}$

where

$a = \frac{\lambda}{v}$

λ = the proportional adjustment coefficient

v = returns to scale parameter.

Short-run employment functions have been extended in many ways since Kuh's estimates. Excess labour demand models[1] have been used by R.C. Fair. In this approach, an attempt is made to measure the underutilization of labor directly and to include this variable in the

[1]R.C. Fair, The Short-Run Demand Function for Workers and Hours, (Amsterdam: North Holland Publishing Company, 1969).

employment function. P. Dhrymes[1] has used a model based on a C.E.S. production function with constant returns to scale, the marginal condition for labor under cost minimization, a proportional adjustment mechanism for labor input, a specified relationship between actual output and wages and their expected values and a type of embodied technological change. Finally, A. Tinsley[2] has developed short-run employment equations using control theory.

Each of the above models is developed from a partial analysis of the labor input alone. A partial analysis of capital inputs assuming instantaneous adjustment of the labor input is also possible. At this point, I will not attempt to survey the extensive literature regarding investment functions. Since both employment and investment functions are based on a partial equilibrium analysis, neither approach was used in this study.

M. Nerlove[3] has developed an input requirement model in which derived demand equations are developed for

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[1] P. Dhrymes, "A Model of Short-Run Labor Adjustment", in The Brookings Model: Some Further Results, pp. 110-150, Edited by J.S. Duesenberry, (Chicago: Rand McNally and Company, 1965).

[2] A. Tinsley, "A Variable Adjustment Model of Labor Demand", International Economic Review, XII, (October, 1971), pp. 482-510.

[3] M. Nerlove, "Notes on the Production and Derived Demand Equations Included in Macro-Economic Models", International Economic Review, VIII, (June, 1967), pp. 232-42.

all inputs simultaneously. He assumes cost minimizing behaviour and a proportional adjustment process for each input which is independent of the adjustment of other inputs. This is the approach used in this study. M.I. Nadiri and S. Rosen[1] have also developed an input requirements model. They specify capital and labor utilization variables explicitly in the production function. However, utilization data are not available for Bell Canada. The Nadiri-Rosen model also assumes that the adjustment of each input to the desired level is interrelated with the adjustment of all the other inputs. The implication is that the lagged value of each input variable is present in every input requirement equation. Unfortunately, the Nadiri-Rosen interrelated factor demand model could not be reliably estimated with Bell Canada time series data because of the multicollinearity between the input variables and because utilization data were not available.

Input requirement equations derived from a Cobb-Douglas production function with exponential technical change are developed below. There should be little loss of generality in assuming this type of production function since it can be interpreted in terms of Hicks, Harrod and Solow neutrality.

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[1]M.I. Nadiri and S. Rosen, "Interrelated Factor Demand Functions", American Economic Review, LIX, (September, 1969), pp. 457-71 and M.I. Nadiri and S. Rosen, "A Disequilibrium Model of Demand for Factors of Production", American Economic Review, LXIV, (May, 1964), pp. 264-270.

$$Y_t = A K_t^{\alpha} L_t^{\beta} \; e^{\lambda E_t} \; e^{u_t}$$

$$\text{Min } C_t = r_t K_t + w_t L_t - \mu_t \left[Y_t^0 - Y_t \right]$$

$$\frac{\partial C_t}{\partial K_t} = r_t + \mu_t \alpha \frac{Y_t}{K_t} = 0$$

$$\frac{\partial C_t}{\partial L_t} = w_t + \mu_t \beta \frac{Y_t}{K_t} = 0$$

$$\frac{\partial C_t}{\partial \mu_t} = Y_t^0 - Y_t = 0$$

From the marginal conditions with respect to labor and capital inputs

$$\frac{r_t}{w_t} = \frac{\alpha}{\beta} \frac{L_t}{K_t}$$

therefore,

$$K_t = \frac{\alpha}{\beta} \frac{w_t}{r_t} L_t$$

Substituting in the production function

$$Y_t = A \left[\frac{\alpha}{\beta} \frac{w_t}{r_t} L_t \right]^{\alpha} L_t^{\beta} \; e^{\lambda E_t} \; e^{u_t}$$

$$= A \left(\frac{\alpha}{\beta} \right)^{\alpha} \left(\frac{w_t}{r_t} \right)^{\alpha} L_t^{\alpha+\beta} \; e^{\lambda E_t} \; e^{u_t}$$

Therefore, the desired level of labor input is

$$L_t^* = A^{-1/v} \left(\frac{\alpha}{\beta} \right)^{-\alpha/v} \left(\frac{w_t}{r_t} \right)^{-\alpha/v} Y_t^{1/v} \, e^{-\frac{\lambda E_t}{v}} \; e^{-\frac{u_t}{v}}$$

$$\ln L_t^* = \ln k_L - \frac{\alpha}{v} \ln \frac{\alpha}{\beta} - \frac{\alpha}{v} \ln \frac{w_t}{r_t} + \frac{1}{v} \ln Y_t - \frac{\lambda E_t}{v} - \frac{u_t}{v}$$

where $v = \alpha + \beta$

$$k_L = A^{-1/v} \frac{\alpha}{\beta}^{-\alpha/v}$$

If the adjustment mechanism for labor and capital are assumed to be

$$\frac{L_t}{L_{t-1}} = \left(\frac{L^*_{t-1}}{L_{t-1}}\right)^{a_L} e^{\varepsilon_{L,t}} \quad \text{and}$$

$$\frac{K_t}{K_{t-1}} = \left(\frac{K^*_{t-1}}{K_{t-1}}\right)^{a_K} e^{\varepsilon_{K,t}}$$

then

$$\ln L_t = C_L + \frac{a_L\alpha}{v} \ln \frac{r_t}{w_t} + \frac{a_L}{v} \ln Y_t - \frac{a_L}{v} E_t + (1-a_L) \ln L_{t-1} + \left(\varepsilon_{L,t} - \frac{a_L}{v} u_t\right)$$

Similarly,

$$\ln K_t = C_K - a_K \frac{\beta}{v} \ln \frac{r_t}{w_t} + \frac{a_K}{v} \ln Y_t - \frac{a_K}{v} E_t + (1-a_K) \ln K_{t-1} + \left(\varepsilon_{K,t} - \frac{a_K}{v} u_t\right)$$

where C_L and C_K are constant terms.

Following M. Nerlove (1967), it is assumed that the aggregate production function has no error term when capital and labor inputs are stated in terms of the input actually utilized ($u_t = 0$). Providing that the error terms $\varepsilon_{L,t}$ and $\varepsilon_{K,t}$ are normally distributed and are not contemporaneously correlated with the independent variables, ordinary least squares can be used to obtain consistent parameter estimates. However, these estimates will not be the most efficient since they do not take account of structural restrictions on the coefficients.

The aggregate input requirements equations to be estimated are shown by equations 5-33 and 5-34 (A_L and A_K are constant terms).

$$\text{5-33.} \quad \ln L_t = A_L + \frac{a_L}{v} \ln \frac{r_t}{w_t} + \frac{a_L}{v} \ln Y_t - \frac{a_L \lambda}{v} E_t + (1 - a_L) \ln L_{t-1} + \varepsilon_{L,t}$$

$$\text{5-34.} \quad \ln K_t = A_K - \frac{a_K}{v} \ln \frac{r_t}{w_t} + \frac{a_K}{v} \ln Y_y - \frac{a_K \lambda}{v} E_t + (1 - a_K) \ln K_{t-1} + \varepsilon_{K,t}$$

If constant returns to scale (v = 1) are assumed, equations 5-33 and 5-34 can be expressed as

$$\text{5-35.} \quad \ln \frac{L_t}{L_{t-1}} = A_L + a_L \alpha \ln \frac{r_t}{w_t} + a_L \ln \frac{Y_t}{L_{t-1}} - \frac{a_L \lambda}{v} E_t + \varepsilon_{L,t}$$

$$\text{5-36.} \quad \ln \frac{K_t}{K_{t-1}} = A_K - a_K \beta \ln \frac{r_t}{w_t} + a_K \ln \frac{Y_t}{K_{t-1}} - \frac{a_K \lambda}{v} E_t + \varepsilon_{K,t}$$

If the rate of exponential technological change is known ($\lambda = \lambda_0$), equations 5-33 and 5-34 can be expressed as

$$\text{5-37.} \quad \ln L_t = A_L + \frac{a_L \alpha}{v} \ln \frac{r_t}{w_t} + \frac{a_L}{v} (\ln Y_t - \lambda_0 E_t) + (1 - a_L) \ln L_{t-1} + \varepsilon_{L,t}$$

$$5\text{-}38. \quad \ln K_t = A_K - a_K \frac{\beta}{v} \ln \frac{r_t}{w_t} + \frac{a_K}{v} (\ln Y_t - \lambda_0 E_t) + (1 - a_K) \ln K_{t-1} + \varepsilon_{K,t}$$

If the rate of exponential technological change is known ($\lambda = \lambda_0$) and constant returns to scale are assumed, equations 5-33 and 5-34 can be expressed as

$$5\text{-}39. \quad \ln \frac{L_t}{L_{t-1}} = A_L + a_L \alpha \ln \frac{r_t}{w_t} + a_L (\ln Y_t - \lambda_0 E_t - \ln L_{t-1}) + \varepsilon_{L,t}$$

$$5\text{-}40. \quad \ln \frac{K_t}{K_{t-1}} = A_K - a_K \beta \ln \frac{r_t}{w_t} + a_K (\ln Y_t - \lambda_0 E_t - \ln K_{t-1}) + \varepsilon_{K,t}$$

Disaggregate labor requirements functions can also be derived assuming the same type of production function and a proportional adjustment process for each input. The general form of the disaggregate input requirement for input j in period t ($X_{j,t}$) is shown by equation 5-41.

$$5\text{-}41. \quad \ln X_{j,t} = C_j - \frac{a_j}{v} \sum_{i=1}^{n} \alpha_i \ln \frac{p_{j,t}}{p_{i,t}} + \frac{a_j}{v} \ln Y_t - \frac{a_j \lambda}{v} E_t + (1-a_j) \ln X_{j,t-1} + \varepsilon_{j,t}$$

This equation cannot be used for estimation because there is too much multicollinearity between the n relative price variables. However, in Chapter IV it was assumed that Bell Canada faces the same opportunity cost for all types of capital employed. Also, examination of the price variables developed for disaggregate labor inputs reveals that they are very highly correlated over time. I will make the additional assumption that the relative price of different types of labor is constant.[1] These two assumptions permit equation 5-41 to be simplified further.

For the m capital inputs assume $P_{1,t} = P_{2,t} = \ldots = P_{m,t} = r_t$, where r_t is the user cost of aggregate capital input.

For the n-m labor inputs assume $C_{m+1} P_{m+1,t} = C_{m+2} P_{m+2,t} = \ldots = C_n P_{n,t} = w_t$, where $C_{m+1}, \ldots, C_n$ are n-m constants and w_t is the unit cost of aggregate labor input.

If $j \leq m$ (a capital input), then the set of relative price terms can be simplified as

$$- \frac{a_j}{v} \sum_{i=1}^{n} \alpha_i \ln \frac{P_{j,t}}{P_{i,t}}$$

$$= - \frac{a_j}{v} \left(\sum_{i=1}^{m} \alpha_i \ln \frac{r_t}{r_t} + \sum_{i=m+1}^{n} \alpha_i \ln \frac{r_t}{\frac{1}{c_i} w_t} \right)$$

$$= - \frac{a_j}{v} \ln \frac{r_t}{w_t} \sum_{i=m+1}^{n} \alpha_i - \frac{a_j}{v} \sum_{i=m+1}^{n} \alpha_i \ln c_i$$

$$= - \frac{a_j}{v} \left(\sum_{i=m+1}^{n} \alpha_i \right) \ln \frac{r_t}{w_t} + b_j \quad \text{where } b_j \text{ is a constant.}$$

Substituting in equation 5-41, the capital input requirements equation is

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[1]Note that the relative price of capital and labor inputs can still vary over time.

$$5\text{-}42. \quad \ln X_{j,t} = A_j - \frac{a_j}{v}\left(\sum_{i=m+1}^{n} \alpha_i\right) \ln \frac{r_t}{w_t} + \frac{a_j}{v} \ln Y_t - \frac{a_j \lambda}{v} E_t + (1-a_j) \ln X_{j,t-1} + \varepsilon_{j,t}$$

where A_j is a constant and $j \leq m$.

If $j > m$ (a labor input), then the set of relative price terms can be simplified as

$$- \frac{a_j}{v} \sum_{i=1}^{n} \alpha_i \ln \frac{P_{j,t}}{P_{i,t}}$$

$$= - \frac{a_j}{v}\left(\sum_{i=1}^{m} \alpha_i \ln \frac{P_{j,t}}{r_t} + \sum_{i=m+1}^{n} \alpha_i \ln \frac{\frac{1}{c_j} w_t}{\frac{1}{c_i} w_t}\right)$$

$$= - \frac{a_j}{v}\left(\sum_{i=1}^{m} \alpha_i \ln \frac{w_t}{c_j r_t} + \sum_{i=m+1}^{n} \alpha_i \ln \frac{c_i}{c_j}\right)$$

$$= - \frac{a_j}{v}\left(\sum_{i=1}^{m} \alpha_i \ln \frac{r_t}{w_t} + \sum_{i=1}^{m} \alpha_i \ln \frac{1}{c_j} + \sum_{i=m+1}^{n} \alpha_i \ln \frac{c_i}{c_j}\right)$$

$$= + \frac{a_j}{v}\left(\sum_{i=1}^{m} \alpha_i\right) \ln \frac{r_t}{w_t} + b_j. \quad \text{where } b_j \text{ is a constant.}$$

Substituting in equation 5-41, the labor input requirements equation is

$$5\text{-}42. \quad \ln X_{j,t} = A_j + \frac{a_j}{v}\left(\sum_{i=1}^{m} \alpha_i\right) \ln \frac{r_t}{w_t} + \frac{a_j}{v} \ln Y_t - \frac{a_j \lambda}{v} E_t + (1 - a_j) \ln X_{j,t-1} + \varepsilon_{j,t}$$

where A_j is a constant and $j > m$.

Finally, if constant returns or a predetermined value for the technology coefficient is assumed, equations 5-12 and 5-13 may be simplified as in the case of aggregate input requirement equations.

H. Summary

The four major characteristics of any technology are

(a) efficiency
(b) technologically determined economics of scale
(c) capital intensity
(d) elasticity of substitution.

Technological change affecting the first two items is usually classified as neutral, while technological change affecting the last two items is classified as non-neutral.[1]

An aggregate production function defines the set of technologically efficient input and output combinations. A brief survey of alternative types of production functions has been made. The properties of each function implies a given type of technology. As outlined, problems of estimation are a crucial factor in determining which function should be used. If it is impossible to estimate the production function for different subperiods, technological change must be incorporated directly into the functional specification. This necessitates further simplifying assumptions.

If a satisfactory aggregate production function could be estimated, it would be possible to test the Averich-Johnson hypothesis. Over-capitalization would be indicated if the actual capital-labor ratio was greater

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[1]This is a general definition of neutral and non-neutral technical change. As outlined in Section C, several alternative definitions of neutrality have been listed by Sato and Beckmann.

than the optimum ratio (given the level of output and relative factor prices). In addition, the expected level of measured total factor productivity gains could be calculated for expected output levels. It would still be necessary to investigate the cyclical behaviour of total factor productivity. However, the estimation of a production function would be the first step toward the specification of a reasonable productivity goal for an automatic rate adjustment clause. Where possible, aggregate results should be compared with those derived using disaggregate models.

An input requirements model can be developed under the assumption of cost minimization given the production function and the mechanism by which input levels are adjusted to desired levels. Theoretically, this type of model can be used to explain both the long-term trend and the cyclical pattern of productivity. As illustrated, the model can be disaggregated without the introduction of additional explanatory variables in each equation.

Empirical estimates of production function and input requirements models are shown in the next chapter.

Chapter VI

PRODUCTION MODELS FOR BELL CANADA - EMPIRICAL RESULTS

A. Location of Aggregate Data Series and Notation Used

Since no aggregate utilization index is available, it was necessary to specify production models in terms of the capital stock rather than the actual input of capital services. In this study, the current dollar value of undepreciated investment in average total telephone plant was chosen as the best measure of the capital stock. All production functions stated in terms of this net capital stock series were estimated using a net output data series. As a result, the residual of the production function is consistent with net total factor productivity measures which are calculated using net output and net capital stock data.[1] Production functions were also estimated using gross output minus plant retirements and gross capital stock data. For these estimated equations, the residual is consistent with a gross total factor

[1]Alternatively, the production function could have been specified in terms of gross output as a function of net capital stock and labor inputs. To use this type of production function in forecasting net or gross total factor productivity, it would also be necessary to forecast the level of depreciation expense and accumulated depreciation reserves in each year.

productivity measure. Since similar results were obtained in every case, only the results obtained using net output and net capital stock data are presented.

Tables showing all data series are contained in Appendix A and a detailed description and discussion of the data is contained in Chapter IV. Annual data are available for the period 1952 to 1972. All input and output values are stated in millions. Real values are stated in terms of constant 1967 dollars.

The calculated value of gross output minus plant retirements is shown in column three of Table A-13 and the net output series in column three of Table A-15. Labor input is measured in terms of weighted manhours actually worked excluding manhours charged to construction expense. Aggregate and disaggregate series are found in Table A-17. The average gross capital stock series is shown in column three of Table A-18 and the average net capital stock series in column three of Table A-19. Table A-22 shows the real price of aggregate and disaggregate labor inputs. Six different versions of the real user cost of capital are shown in Table A-25. Finally, alternative proxy variables for technological change are shown in Table A-26.

The notation illustrated below will be used throughout the rest of this study.

YN - net output

YG - gross output minus plant retirements

KN - aggregate net capital stock

KG - aggregate gross capital stock

L - aggregate labor input in weighted manhours

L_i - ith labor input in weighted manhours

w - real wage rate of aggregate labor input

w_i - real wage rate of ith labor input

r_i - real user cost of aggregate capital (version i)

D - percentage of calls direct distance dialed

E - percentage of total telephones connected to Electronic Switching System on Number Five Crossbar offices

T - time trend where 1952 = 1, . . ., 1972 = 21

X.Y - variable X multiplied by variable Y

ln X - natural logarithm of variable X

* - t, F or Durban Watson Statistic is significant at 5 per cent significance level.

B. Investigation of Technological Change Using Implied Relationships

R. Sato and M.J. Beckmann[1] have examined the relationship implied by various types of disembodied technical change. In addition to the traditional concepts of Hicks, Harrod and Solow neutrality, several alternative types are classified. Assuming constant returns to scale,

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[1] R. Sato and M.J. Beckmann, "Aggregate Production Functions and Types of Technical Progress: A Statistical Analysis", American Economic Review, XLIX, (March, 1969), pp. 88-101.

exogenously determined factor and output prices and profit maximizing behaviour, it is possible to test the hypothesis that technological change is of a particular type by examining the relative performance of the implied relationships shown in Table 5-1. For example, if technological change is Hicks neutral and the assumptions mentioned above are valid, the labor-capital ratio is by definition uniquely related to the factor price ratio. Either of these variables could be explained as some function of the other variable if technological change were in fact Hicks neutral.

Table 6-1 shows the average absolute percentage error[1] and the Durban Watson statistic obtained when each implied relationship was estimated using net output and net capital stock data over the period 1952 to 1972. Positive autocorrelation is present in every case. The equations were re-estimated using the Hildreth-Lu procedure and the results are shown in Table 6-2. Results obtained using gross output minus retirements and gross capital stock data were very similar.

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[1]Since the dependent variable is not the same in every equation, the variance to be explained is not the same. Comparing the fit of the different equations using the coefficient of multiple determination (the proportion of the total variance which is explained) is misleading in this case. We actually want to compare the residuals of each equation directly. For this purpose, the residual sum of squares, the mean square error, the root mean square error or the average absolute percentage error can be used.

TABLE 6-1

RESULTS OF DIRECT INVESTIGATION OF TECHNOLOGICAL CHANGE
USING ORDINARY LEAST SQUARES ESTIMATION

Type of Technological Change	Functional Form	Test Statistics	User Cost of Capital: Not in Equation	Version[a] 1	3	4	5	6
1. Product Augmenting								
(a) Hicks Neutral	$r_i/w = f\left(\frac{L}{KN}\right)$	APE		3.95	2.83	2.73	2.63	2.80
		DW		.48*	.74*	.73*	.58*	.47*
(b) Labor Additive	$r_i = f\left(\frac{KN}{L}\right)$	APE		3.12	5.23	4.52	2.94	2.42
		DW		.86*	.55*	.60*	.94*	1.06*
(c) Capital Additive	$w = f\left(\frac{L}{KN}\right)$	APE	7.99					
		DW	.14*					
2. Labor Augmenting								
(a) Harrod Neutral	$r_i = f\left(\frac{YN}{KN}\right)$	APE		5.48	9.30	8.33	8.23	7.56
		DW		.34*	.17*	.19*	.14*	.14*
(b) Labor Combining	$w = f\left(\frac{YN}{KN}\right)$	APE	26.77					
		DW	.03*					
3. Capital Augmenting								
(a) Solow Neutral	$w = f\left(\frac{YN}{L}\right)$	APE	3.31					
		DW	.37*					
(b) Capital Combining	$r_i = f\left(\frac{YN}{L}\right)$	APE		3.60	3.54	3.13	2.45	2.23
		DW		.79*	.80*	.87*	1.14*	1.15*
4. Input Decreasing								
(a) Labor Decreasing	$r_i/w = f\left(\frac{YN}{KN}\right)$	APE		4.34	3.65	3.79	3.84	4.00
		DW		.28*	.47*	.40*	.27*	.21*
(b) Capital Decreasing	$w_i/r_i = f\left(\frac{YN}{L}\right)$	APE		3.39	2.87	2.61	2.11	2.10
		DW		.60*	.74*	.74*	.78*	.67*

(See footnotes on following page)

*Significant at 5 per cent significance level.

[a]Version 2 of the User Cost of Capital is not appropriate with net capital stock data.

TABLE 6-2

RESULTS OF DIRECT INVESTIGATION OF TECHNOLOGICAL CHANGE USING HILDRETH-LU ESTIMATION

Type of Technological Change	Functional Form	Test Statistics	User Cost of Capital: Not in Equation	Version[a] 1	3	4	5	6
1. Product Augmenting								
(a) Hicks Neutral	$r_i/w_s = f\left(\frac{L}{KN}\right)$	APE		2.33	2.32	2.33	1.98	1.86
		DW		1.38	1.48	1.72	1.28	1.32
		$\hat{P}$		.8220	.6975	.7750	.7750	.8398
(b) Labor Additive	$r_i = f\left(\frac{KN}{L}\right)$	APE		2.60	3.19	2.80	2.44	1.97
		DW		1.57	1.65	1.85	[illegible].59	1.64
		$\hat{P}$		.6080	.8099	.7939	.5503	.4869
(c) Capital Additive	$w = f\left(\frac{L}{KN}\right)$	APE	3.49					
		DW	.86					
		$\hat{P}$	1.000					
2. Labor Augmenting								
(a) Harrod Neutral	$r_i = f\left(\frac{YN}{KN}\right)$	APE		2.74	3.71	3.23	3.63	3.06
		DW		1.68	1.40	1.66	1.52	1.58
		$\hat{P}$		.8338	.9460	.9364	.9844	.9817
(b) Labor Combining	$w = f\left(\frac{YN}{KN}\right)$	APE	9.12					
		DW	1.11					
		$\hat{P}$	1.000					

TABLE 6-2-Continued

RESULTS OF DIRECT INVESTIGATION OF TECHNOLOGICAL CHANGE USING HILDRETH-LU ESTIMATION

Type of Technological Change	Functional Form	Test Statistics	User Cost of Capital: Not in Equation	Version[a] 1	3	4	5	6
3. Capital Augmenting								
(a) Solow Neutral	$w = f\left(\frac{YN}{L}\right)$	APE	2.23					
		DW	1.54					
		$\hat{P}$	.8722					
(b) Capital Combining	$r_i = f\left(\frac{YN}{L}\right)$	APE		2.57	2.85	2.53	2.34	1.93
		DW		1.57	1.56	1.74	1.56	1.64
		$\hat{P}$		.6445	.6475	.6106	.4336	.4353
4. Input Decreasing								
(a) Labor Decreasing	$r_i/w = f\left(\frac{YN}{KN}\right)$	APE		3.13	2.98	2.92	2.43	2.31
		DW		1.48	1.60	1.75	1.42	1.43
		$\hat{P}$		1.000	1.000	1.000	1.000	1.000
(b) Capital Decreasing	$w_i/r_i = f\left(\frac{YN}{L}\right)$	APE		2.18	2.41	2.32	1.79	1.70
		DW		1.51	1.60	1.76	1.41	1.50
		$\hat{P}$		.7750	.7750	.7750	.6720	.7750

[a]Version 2 of the User Cost of Capital is not appropriate with net capital stock data.

The results given here are based on a simple logarithmic form of the functions shown in Table 5-1. It was found that neither reversing the direction of causality nor introducing a lagged adjustment process significantly altered the relative performance of the different types of technological change tested. As any results in this section are conditional upon the assumptions mentioned above, a more detailed investigation of the functional specifications was not made.

One observation which can be drawn from Table 6-2 is that the choice of the user cost of capital series does effect the size of residuals. For most types of technological change, better fits are obtained with versions 5 or 6. These versions assume

(a) that the debt-equity ratio is optimal,

(b) that the opportunity cost of equity capital can be measured by the average rate of return to 56 United States telephone companies, and

(c) that the opportunity cost of debt can be measured by the marginal cost of debt to Bell Canada (version 5) or by the embedded cost of debt to Bell Canada (version 6).

With data based on version 5 of the user cost of capital, the ranking of the different types of technological change in terms of the average absolute percentage error is as follows:

(a)	Capital Decreasing	1.79
(b)	Hicks Neutral	1.98
(c)	Solow Neutral	2.23
(d)	Capital Combining	2.34
(e)	Labor Decreasing	2.43
(f)	Labor Additive	2.44
(g)	Capital Additive	3.49
(h)	Harrod Neutral	3.63
(i)	Labor Combining	9.12

This ranking indicates two general conclusions. First, given the assumptions made by Sato and Beckmann, Hicks neutral technological change gives as good an approximation to reality as other non-neutral forms. Secondly, non-neutral forms where the rate of technological change is in some way related to the use of capital (Capital Decreasing, Capital Combining or Solow Neutral) give better results than non-neutral forms where technological change is related to the use of labor.

Although these conclusions are dependent on the validity of the Sato-Beckmann assumptions, they do point out that the possibility of neutral technological change exists. Perhaps the major technological innovations related to capital which were described in Chapter II are simply more noticeable than those related to labor. The increase in the observed capital-labor ratio may only be the result of changing factor prices. In any case, production functions implying both Hicks neutral and non-neutral technological change should be specified.

C. Empirical Estimates of Cobb-Douglas Production Functions

1. Equations Estimated without an Explicit Specification of Technological Change

In each estimation, a random normally distributed variable with zero expected value is assumed. The first function estimated was a simple Cobb-Douglas production function with no technological change specified. Results are shown by equation 6-1.

6-1. $$\ln YN = -.53 - .34 \ln L + 1.01 \ln KN$$
$$(-.29) \quad (.59) \quad (12.41)^{*}$$

*Significant at 5 per cent significance level.

$\bar{R}^2$ = .9429

DW = .13*

d.f. = 18

F = 166.25*

Estimation Method - O.L.S.

Equation 6-1 should be rejected on the grounds that the marginal product of labor is negative for all positive values of output and labor input. The equation is also unacceptable on other grounds. Point estimates show decreasing returns to scale (-.34 + 1.01 = .77). However, the returns to scale are not significantly different from one. This is mainly a result of the large confidence interval on the labor coefficient. As indicated by the low t statistic, the labor coefficient is insignificant.

The poor performance of a simple Cobb-Douglas function is not surprising. Our preliminary investigation has revealed the importance of technological change and, in the above estimation, the implicit assumption is that no technological change has occurred. In view of this misspecification, positive autocorrelation is to be expected. Even when equation 6-1 is re-estimated using the Hildreth-Lu procedure to adjust for first order autocorrelation, the estimated labor coefficient is still negative. Similar results were obtained using gross output and gross capital stock data.

Some useful information can be obtained by analysing the residuals of equation 6-1. They are positive until 1957, negative from 1958 to 1966 and positive after 1966. This would indicate that two major shifts may have taken place in the production function. Theoretically, the production function should be fitted for each technological epoch. In this way, any change in the characteristics of production can be picked up. On the basis of residual analysis, the periods 1952 to 1957, 1958 to 1966 and 1967 to 1972 were chosen. Empirical estimates are shown by equations 6-2 to 6-4.

6-2. $\ln YN = .31 - .28 \ln L + .86 \ln KN$
(1.03) (-.85) (5.70)*

$\bar{R}^2 = .9976$

DW = 1.65[1]

d.f. = 3

F = 1060.19*

Estimation Method - O.L.S.
Period - 1952 to 1957

6-3. $\ln YN = 6.40 + 1.01 \ln L + 1.02 \ln KN$
(-6.68)* (4.60)* (28.28)*

$\bar{R}^2 = .9901$

DW = 2.18[1]

d.f. = 6

F = 400.17*

Estimation Method - O.L.S.
Period - 1958 to 1966

[1]Tables not available for this number of degrees of freedom.

6-4. $\ln YN = -7.96 + .44 \ln L + 1.56 \ln KN$

$(-3.48)^* \quad (.50) \quad (7.90)^*$

$\bar{R}^2 = .9842$

DW = 2.74[1]

d.f. = 3

F = 156.65*

Estimation Method - O.L.S.

Period - 1967 to 1972.

This approach has reduced positive autocorrelation and good fits are obtained in each case. In equations fitted using net output and net capital stock data, the elasticity of output with respect to capital input is increasing over time. Total returns to scale also appear to have increased since 1958. This is consistent with the description of technological change given in Chapter II. However, not much confidence can be placed in these conclusions because of the insignificant labor coefficients obtained for the periods 1952 to 1957

[1]Tables not available for this number of degrees of freedom.

and 1967 to 1972. Moreover, the implied marginal product of labor is negative in the first period. Based on these results, it is concluded that the unrestricted Cobb-Douglas function could not be reliably estimated for each epoch.

When analyzing the results of equation 6-1, the assumption of constant returns to scale could not be rejected. As explained in Chapter V, it is possible to specify the Cobb-Douglas function to implicitly make this assumption. When the constant returns Cobb-Douglas function was fitted over the entire period positive autocorrelation was still a problem. Once again, three subperiods were chosen on the basis of residual analysis and the estimated production functions for each period are shown by equations 6-5, 6-6 and 6-7.

$$\text{6-5.} \quad \ln YN_{/L} = \underset{(-3.14)^*}{-.37} + \underset{(11.78)^*}{.50} \ln KN_{/L}$$

$\bar{R}^2$ = .9650

DW = 1.65[1]

d.f. = 4

F = 138.67*

Estimation Method - O.L.S.

Period - 1952 to 1957

[1]Tables not available for this number of degrees of freedom.

6-6. $\ln YN/L = -1.96 + 1.00 \ln KN/L$

$(-7.96)^*$ $(14.14)^*$

$\bar{R}^2 = .9613$

DW = .76[1]

d.f. = 7

F = 199.87*

Estimation Method - O.L.S.

Period - 1958 to 1966

6-7. $\ln YN/L = -4.81 + 1.78 \ln KN/L$

$(-9.56)^*$ $(13.90)^*$

$\bar{R}^2 = .9746$

DW = 2.84[1]

d.f. = 4

F = 193.23*

Estimation Method - O.L.S.

Period - 1967 to 1972.

In the last two subperiods, the implied marginal productivity of labor is not positive. This casts serious doubt on the validity of the implied capital and labor coefficients. The lack of degrees of freedom is a problem. These results cannot be interpreted as proving that technological change has been non-neutral. Another technique must be employed if the Bell Canada production function is to be estimated in the presence of technological change.

[1]Tables not available for this number of degrees of freedom.

2. Equations Estimated with the Explicit Specification of Technological Change

(a) Using Proxy Variable for Technological Change

As discussed in Chapter V, it is possible to modify a production function so that different types of technological change are specified directly. Hicks neutral, Solow neutral and Harrod neutral technological change can all be assumed directly in the specification of a modified Cobb-Douglas function. However, each of these forms gives rise to the same equation to be estimated. Therefore, data alone can not be used to identify the type of technological change.

With this in mind, an equation was specified in the form

$$Y = A_o e^{rt} L^{\alpha} K^{\beta} e^{u}$$

where u is a random error which is assumed to be normally distributed with zero expected value.

In the actual estimation, the logarithmic transformation of this equation was used.

$$\ln Y = \ln A_o + \alpha \ln L + \beta \ln K + rt + u$$

Results of this estimation will now be discussed.

Three proxy variables were specified for technological change. These variables were the percentage of calls which are direct distance dialed (D), the percentage of total telephones connected to Number Five Crossbar and Electronic Switching System offices (E) and a simple time trend (T). The rationale for choosing these variables is explained in Chapter IV. Empirical estimates of a Cobb-Douglas function incorporating technological change are shown by equations 6-8 to 6-10. Good fits were obtained in each of the regressions. The Durbin Watson statistic was in the inconclusive region.

6-8. $\ln YN = -.35 + 1.09 \ln L + .15 \ln KN + .015\ D$

$(-.78)\quad (6.82)^{*}\quad (2.78)^{*}\quad (17.11)^{*}$

$\bar{R}^2 = .9967$

DW = 1.23

d.f. = 17

F = 2005.32*

Estimation Method - O.L.S.

6-9. $\ln YN = 1.02 + .44 \ln L + .32 \ln KN + .026\ E$

$(2.62)^{*}\quad (3.62)^{*}\quad (8.58)^{*}\quad (20.26)^{*}$

$\bar{R}^2$ = .9976

DW = 1.12

d.f. = 17

F = 2768.87*

Estimation Method - O.L.S.

6-10. $\ln YN = 6.02 + .30 \ln L - .40 \ln KN + .116 T$

(16.53)* (3.40)* (-7.69)* (27.94)*

$\bar{R}^2$ = .9987

DW = 1.45

d.f. = 17

F = 5173.04*

Estimation Method - O.L.S.

The inclusion of the technological variable has lowered the capital coefficient in each case - as compared with equation 6-1. This suggests that collinearity may exist between the capital variable and the alternate proxy variables for technological change. In this thesis, Kleins rule of thumb will be used as a test for multicollinearity. Each independent variable should be more highly correlated with the dependent variable than with any other independent variable.[1]

Simple correlation coefficients are shown below.

	D	E	T
ln L	.59	.63	.71
ln KN	.94	.93	.99

[1]L.R. Klein, An Introduction to Econometrics, (Prentice-Hall, 1962), p. 101.

Although E is the least correlated with capital, the simple correlation coefficient between E and the natural logarithm of capital is still large. In spite of this collinearity, it has been argued in Chapter IV that E is the best proxy for technological change. The alternatives are then to delete E (as in equation 6-1) or to retain it (as in equation 6-9).

It has been shown that the mean square error of the estimated capital coefficient can be reduced by the emission of the technology variable only if the true t value of the technology coefficient is less than one. Of course, the true t statistic is not observable. However, C. Toro-Vizcarrando and T.D. Wallace have suggested that the null hypothesis $t_\lambda < 1$ (where λ is the coefficient of the technology variable) be used as a test of whether to drop the additional collinear variable.[1] They print critical values for a noncentral F test.[2] When this test is applied using the error sum of squares in equations 6-1 and 6-9, the alternative of dropping E is rejected at the 5 per cent significance level.

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[1]C. Toro-Vizcarrando and T.D. Wallace, "A Test of the Mean Square Error Criterion for Restrictions in Linear Regression", Journal of American Statistical Association, LXIII, (June, 1968), pp. 558 - 572.

[2]C. Toro-Vizcarrando and T.D. Wallace, "Tables for the Mean Square Error Test for Exact Restrictions in Regression", Journal of American Statistical Association, LXIV, (December, 1969), pp. 1649 - 1663.

M. Feldstein has pointed out that

> Since the null hypothesis $t_\lambda < 1$ is not of interest per se, but only in an instrumental way, the type I and II errors are not directly relevant. A more appropriate guide to the desirability of different conditional omitted variable estimators (corresponding to different critical t_λ values) is the associated loss functions, that is, the mean square errors of the estimates of β as a function of the relevant parameters. [In this case, β would refer to the capital coefficient] . . . the relative loss functions depend on only the true t, the extent of collinearity and the sample size.[1]

Using Monte Carlo experiments, Feldstein has shown that it is better to always retain the additional collinear variable unless "the researcher has a strong prior belief that $t_\lambda < 1$."[2] In view of the importance of technological change as discussed in Chapter II, I would expect it to be a highly significant variable. Once again, it can be argued that the technology proxy variable should be retained even if the only criterion of estimation is the mean square error of the estimated capital coefficient.

Returns to scale implied by equation 6-9 are .76 and this value is significantly different from unity at a

[1]Martin S. Feldstein, "Multicollinearity and the Mean Square Error of Alternate Estimators", Econometrica, XLI, (March, 1973), p. 338.

[2]Ibid., p. 344.

5 per cent level of significance[1], but not significantly different from unity at a 1 per cent level of significance. Equation 6-9 was re-estimated subject to the constraint that returns to scale are constant. Results are shown by equation 6-11. The technology and capital parameters are approximately the same and the labor parameter is only slightly larger.

$$6\text{-}11. \quad \ln YN_{/L} = \underset{(1.61)}{.18} + \underset{(7.54)^*}{.29} \ln KN_{/L} + \underset{(18.46)^*}{.026} E$$

$\bar{R}^2$ = .9964

DW = 1.02*

d.f. = 18

F = 2774.55*

Estimation Method - O.L.S.

Simple correlation coefficients between the relevant variables are shown below.

	E
$\ln KN_{/L}$	.94
$\ln KG_{/L}$	.96

On the basis of slightly less multicollinearity, slightly less autocorrelation and a slightly higher adjusted

[1]The t value for the hypothesis $\alpha + B = 1$ is 2.29 for equation 6-9. The critical t value for 17 degrees of freedom is 2.11 at the 5 per cent significance level and 2.57 at the 1 per cent significance level.

coefficient of multiple determination, equation 6-9 might be chosen over equation 6-11 which is restricted to constant returns to scale.

As pointed out previously, the production function specified in equation 6-9 can be interpreted in terms of Hicks or Solow neutrality (by interpreting the estimated coefficient of the proxy technology variable in a different way). It is also possible to specify non-neutral technological change as an explicit change in the capital parameter. Equation 6-12 shows the Cobb-Douglas function estimated in this modified form.

$$Y = A K^{\alpha + cE} L^{B}$$

$$\ln Y = \ln A + \alpha \ln K + B \ln L + c\,(E^{*}\ln K)$$

6-12. $\ln YN_{/L} = .87 + .37 \ln KN + .41\, L + .0030\, E.LNKN$

$(2.37)^{*}$ $(10.92)^{*}$ $(3.54)^{*}$ $(21.51)^{*}$

$\bar{R}^2 = .9979$

DW = 1.16

d.f. = 17

F = 3106.94*

Estimation Method - O.L.S.

An excellent statistical fit is obtained. Coefficients for capital, labor and technology are significant and the coefficient of multiple determination is high. However, the Durbin Watson statistic is in the inconclusive region and, as shown by the simple correlation matrix, multicollinearity is once again a problem.

	ln KN	ln L	E*LNKN
ln KN	1.00		
ln L	.75	1.00	
E*LNKN	.92	.62	1.00

A choice between the Cobb-Douglas form with technological improvement specified as a gradual change in efficiency or as a gradual change in the capital parameter involves a choice between equation 6-9 and 6-12. Based on the results presented here, neither set of estimates is clearly superior. The problem is that the data do not contain enough information to differentiate between the two types of technological change.

Finally, the results of this section can be compared with those obtained by R. Dobell et al.[1] They fitted a Cobb-Douglas function over the period 1952 to 1967 using gross output, net capital stock, weighted man-hours and the percentage of station-to-station toll calls which were direct distance dialed as a proxy for technological change. Their conclusions for Bell Canada were that:

> (1) An index of technological change . . . plays a crucial role in explaining apparently disparate movements in inputs and outputs . . .

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[1] R. Dobell et al., "Communications in Canada: A Statistical Summary", Telecommission Study 2(b)(i), prepared for Department of Communications, Information Canada, Ottawa, 1971, p. 205.

(2) Use of this index, together with data on deflated values of revenue and plant and wage-weighted labor input measures, enables estimation of a statistically satisfactory aggregate production function of Cobb-Douglas form.

(3) This production function suggests the presence of modest increasing returns to scale over Bell's operation as a whole.

In this study, slightly increasing returns to scale were also obtained using the percentage of total toll calls which were direct distance dialed (equation 6-8). However, these returns were not significantly different from unity at the 5 per cent significance level (t value of null hypothesis $\alpha + B = 1$ is 1.89 as compared with a critical value at the 5 per cent significance level of 2.11). Using E as the proxy variable for technological change, the presence of modestly decreasing returns to scale were indicated (t value of null hypothesis $\alpha + B = 1$ is -2.29 as compared with a critical value at the 5 per cent level of -2.11). In view of these conflicting results, we must conclude that no definite evidence exists which would invalidate the assumption of constant returns to scale at the present scale of operations. This does not rule out the possibility of increasing returns due to the spreading of initial overhead costs at very low output levels.

(b) Using Dummy Variables

It is also possible to explicitly specify technological change using dummy variables. This technique should avoid the loss of degrees of freedom when a production function is fitted to each technological epoch and the introduction of multicollinearity when a proxy variable for technological change is used. As explained in Chapter V, dummy variables can represent either a neutral shift in efficiency or a non-neutral shift in the capital intensity parameter.

In equation 6-13, the dummy variables represent neutral shifts in efficiency. D58 is equal to unity for the years 1958 to 1966 and zero in other years. Similarly, D67 is equal to unity for the years 1967 to 1972 and zero in other years. The labor coefficient is insignificant. Since the implied returns to scale are not significantly different from unity, the equation was re-estimated under this constraint and results are shown by equation 6-14. Since the final dummy variable was not significant, it was deleted in equation 6-15. A good statistical fit was obtained in this equation. All variables are significant, and there is almost no multicollinearity present. The Durbin Watson statistic is in the inconclusive region. However, the implied marginal productivity of labor is zero. This result is questionable.

6-13. $\ln YN = -.90 \ -.21 \ln L + 1.00 \ln KN -.20 \, D58 + .034 \, D67$

$(1.05) \ (-.80) \quad (12.10)^* \quad (-3.08)^* \quad (.35)$

$\bar{R}^2 = .9885$

DW = 1.37

d.f. = 16

F = 431.43

Estimation Method - O.L.S.

6-14. $\ln YN_{/L} = -1.69 + .98 \ln KN_{/L} - .20\ D58 + .031\ D67$

$(-7.64)^{*}\ (12.35)^{*}\ \ (-3.15)^{*}\ \ (.32)$

$\bar{R}^2 = .9860$

DW = 1.29

d.f. = 17

F = 471.61*

Estimation Method - O.L.S.

6-15. $\ln YN_{/L} = -1.75 + 1.00 \ln KN_{/L} - .22\ D58$

$(-19.75)^{*}\ (38.43)^{*}\ \ (-8.89)^{*}$

$\bar{R}^2 = .9867$

DW = 1.30

d.f. = 18

F = 744.56*

Estimation Method - O.L.S.

Equations 6-16, 6-17 and 6-18 show the same set of empirical estimates when the dummy variable enters as a shift in the capital coefficient. On statistical grounds, the estimates are equally good and it is impossible to differentiate between neutral and non-neutral technological change when dummy variables are used. Once again, the implied marginal product of labor is zero in equation 6-18.

6-16. $\ln YN = -.85 - .24 \ln L + 1.01 \ln KN - .027\ D58(\ln KN) + .0034 D67(\ln KN)$

$(-.98)\ (-.91)\ \ (11.19)^{*}\ (-2.88)^{*}\ \ (.26)$

$\bar{R}^2$ = .9884

DW = 1.37

d.f. = 16

F = 428.16*

Estimation Method - O.L.S.

6-17. $\ln YN_{/L} = -1.71 + .98 \ln KN_{/L} - .027\ D58(\ln KN) + .0032\ D67(\ln KN)$
(-7.05)* (11.30)* (2.91)* (.24)

$\bar{R}^2$ = .9857

DW = 1.26

d.f. = 17

F = 463.01*

Estimation Method - O.L.S.

6-18. $\ln YN_{/L} = -1.76 + 1.00 \ln KN_{/L} - .029\ D58\ (\ln KN)$
(-19.68)* (38.16)* (-8.80)*

$\bar{R}^2$ = .9865

DW = 1.28

d.f. = 18

F = 732.81*

Estimation Method - O.L.S.

When dummy variables are used to specify shifts in technology, empirical estimates indicate that returns to scale are constant or slightly diminishing and that it is impossible to differentiate between neutral and non-neutral technological change with the data available. These two conclusions are the same as those reached when a proxy variable for technological change was used. One different result is that the capital coefficient is much higher when dummy variables are used. The reason for this is that the proxy variable for technological change is highly correlated with the capital variable and in this case neither coefficient can be estimated reliably.

D. Empirical Estimates of Constant Elasticity of Substitution (C.E.S.) Production Functions

1. Test for C.E.S. Production Function

As discussed in Chapter V, the Cobb-Douglas production function is a special case of the C.E.S. production function. Before attempting to fit a C.E.S. function, the value of the elasticity of substitution (σ) can be tested under certain assumptions. If exogenously determined factor and output prices, profit maximizing behaviour and constant returns to scale are assumed, a linear relationship between the real wage rate and the output-labor ratio will exist. The value of σ is

$$\ln Y/_L = \alpha + \beta \ln W$$

indicated by the parameter β. This side relation is shown by equation 6-19.

$$6\text{-}19.\quad \ln YN/_L = -.03 + 1.57 \ln W$$
$$(-.65) \quad (32.7)^*$$

$\bar{R}^2$ = .9816

DW = .37*

d.f. = 19

F = 1068.81*

Estimation Method - O.L.S.

These results imply that a Cobb-Douglas function would not be appropriate since the estimated value of σ is 1.57 and is significantly different from unity. However, positive autocorrelation indicates a misspecification. In any case, this approach is applicable only if the assumptions mentioned above are valid. The value of σ should also be tested by directly estimating a C.E.S. production function.

2. Fitting a C.E.S. Production Function Using Side Relations Derived from Cost Minimization

As described in Chapter V, the first method of fitting of C.E.S. production function involves estimating equations derived from the first order conditions for cost minimization. These equations are in the same form if a neutral technological shift in the efficiency parameter is specified in the C.E.S. production function. Table 6-3 shows the estimated side relation with the factor input ratio as the dependent variable while Table 6-4 shows the estimated side relation with the factor price ratio as the dependent variable. Different versions of the user cost of capital are used in each case.

TABLE 6-3

ESTIMATES OF C.E.S. SIDE RELATION USING FACTOR INPUT RATIO AS DEPENDENT VARIABLE[a]

Functional Form	Parameter Estimates a	Parameter Estimates b	Coefficient of Multiple Determination and Durbin Watson Statistic
$\ln KN/L = a + b \ln r_i/W$			
$i = 1$	-1.43 (-1.26)	-1.51 (-4.26)*	$\bar{R}^2$ = .4614 DW = .25*
$i = 3$	-2.50 (-1.46)	-2.00 (-3.44)*	$\bar{R}^2$ = .3520 DW = .29*
$i = 4$	-2.90 (-1.92)	-2.11 (-4.18)*	$\bar{R}^2$ = .4516 DW = .36*
$i = 5$	-3.50 (-2.69)*	-2.45 (-5.35)*	$\bar{R}^2$ = .5803 DW = .35*
$i = 6$	-3.14 (-2.73)*	-2.31 (-5.71)*	$\bar{R}^2$ = .6125 DW = .30*

[a]Estimates are based on the relationship

$$\ln \frac{KN}{L} = \sigma \ln \frac{\delta}{1-\delta} - \sigma \ln \frac{r_i}{W}$$

TABLE 6-4

ESTIMATES OF C.E.S. SIDE RELATION USING FACTOR PRICE RATIO AS DEPENDENT VARIABLE[a]

Functional Form	Parameter Estimates a	Parameter Estimates b	Coefficient of Multiple Determination and Durbin Watson Statistic
$\ln r_i/w = a + b \ln KN/L$			
i = 1	-2.11 (-8.05)*	-.32 (-4.26)*	$\bar{R}^2$ = .4614 DW = .48*
i = 3	-2.29 (-11.97)*	-.19 (-3.44)*	$\bar{R}^2$ = .3520 DW = .74*
i = 4	-2.21 (-11.85)*	-.23 (-4.17)*	$\bar{R}^2$ = .4516 DW = .73
i = 5	-1.97 (-12.47)*	-.25 (-5.35)*	$\bar{R}^2$ = .5803 DW = .58*
i = 6	-1.91 (-11.55)*	-.27 (-5.71)*	$\bar{R}^2$ = .6125 DW = .47*

[a]Estimates are based on the relationship

$$\ln \frac{r_i}{w} = \ln \frac{\delta}{1 - \delta} - (p + 1) \ln \frac{KN}{L}$$

The main observation is that structural coefficients implied by these estimated side relations vary widely depending on the form of the side relation assumed. For example, the implied values for the elasticity of substitution using version five of the cost of capital are shown below.

Table 6-3	=	2.45		
Table 6-4	=	1.00/.25	=	4.00

Although the implied capital intensity parameters all fall within the allowable range ($0 \leq \delta \leq 1.0$), they also vary with the form of the side relation assumed.

Regardless of the form of the side relation used, a relatively poor fit was obtained in terms of the coefficient of multiple determination. Some of the coefficient estimates are insignificant and the presence of positive autocorrelation suggests misspecification of the side relation.

The side relations shown in Tables 6-3 and 6-4 were also fitted assuming a distributed lag adjustment process. Since a lagged dependent variable was present in these equations, the Hildreth-Lu estimation technique was used to test for the presence of autocorrelation.[1] In each case, the estimated coefficient of autocorrelation was not equal to zero. A more serious problem was the multicollinearity introduced by including the lagged dependent variable. The implied values for the elasticity of substitution and the capital intensity parameter were unrealistic.

On the basis of these empirical results, this method of fitting the C.E.S. production function was rejected.

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[1]The Durbin Watson statistic is not an appropriate test for autocorrelation in the disturbance when a lagged endogenous variable is specified. One alternative is to estimate the first order coefficient of autocorrelation using a Hildreth-Lu search technique. Another alternative is to apply an assymptotic test developed by J. Durbin. (J. Durbin, "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressions are Lagged Dependent Variables", Econometrica, XXXVIII, (May, 1970), pp. 410-422.

$$h = a \frac{n}{1-n\,\hat{V}(b_L)}$$

$a = 1-1/2d$

d = Durbin Watson Statistic

n = number of observations

$\hat{V}(b_L)$ = estimated variation of coefficient of lagged dependent variable.

Durbin's test can only be applied when $n\,\hat{V}(b_L) < 1$. The statistic h is distributed as a standard normal variable.

3. Fitting a C.E.S. Production Function Using Nonlinear Regression

The results obtained in fitting various modified forms of the Cobb-Douglas production function suggested that technological change could be specified as Hicks neutral and that the proxy variable E could be used for technical change. A similar C.E.S. function could be specified as

$$Y = \gamma \left[\delta K^{-p} + (1 - \delta) L^{-p}\right]^{-v/p} e^{\lambda E} = \left[\hat{X}\right]^{-v/p} e^{\lambda E}$$

Cobb-Douglas functions were also specified with non-neutral technological change. One method of incorporating non-neutral technological change in the C.E.S. function is to specify a time trend in the capital intensity parameter (δ). However, estimation problems can be encountered in this case if the value of $\hat{X}$ becomes negative for a particular iteration. This form of the C.E.S. function was not estimated.

Estimated coefficients for the Hicks neutral form are shown below. The nonlinear regression algorithm of D.W. Marquardt[1] was used and the coefficient estimates are shown after each set of ten iterations. The residual sum of squares decreases rapidly during the initial iterations but the rate of convergence declines for subsequent

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[1]D.W. Marquardt, "An Algorithm for Least-Squares Estimation of Nonlinear Parameters", SIAM Journal, XI, (June, 1963), pp. 431-441.

iterations. Convergence is finally achieved after 69 iterations (the change in the residual sum of squares is less than .0001 times the value at the previous iteration).

TABLE 6-5

ESTIMATES OF C.E.S. FUNCTION USING NONLINEAR ESTIMATION

Parameter and Residual Sum of Squares	Starting Point	10	20	30	40	50	60	69[a]
γ	1.50	1.25	1.13	1.00	1.57	2.86	3.80	4.81
δ	.60	.60	.61	.62	.66	.66	.65	.61
ρ	2.50	1.27	.94	.71	.36	.26	.20	.10
v	1.10	1.10	1.01	.99	.82	.70	.65	.61
λ	.080	.033	.032	.031	.027	.027	.027	.027
R.S.S.	34,440,000	3,357	2,624	1,805	939	823	802	796

[a]Test Statistics at Final Iteration

$\bar{R}^2$ = .9979

DW = 1.39

Some of the difficulties encountered in nonlinear regression were outlined in Chapter V. However, it is interesting to compare the above results with those obtained using a Cobb-Douglas specification and the same type of technological change as illustrated by equation 6-9.

TABLE 6-6

COMPARISON OF COBB-DOUGLAS ESTIMATES AND NONLINEAR ESTIMATES OF C.E.S. FUNCTION

Parameter Estimate or Test Statistic	Cobb-Douglas	C.E.S
Returns to Scale	.76	.61
Coefficient of Technology Variable	.026	.027
Elasticity of Substitution $(1/1+p)$	1.00	.91
$\bar{R}^2$	.9976	.9979
DW	1.12	1.39

Estimates of returns to scale, the coefficient of the technology variable and the elasticity of substitution are similar. The two functions also perform almost equally well when compared in terms of the Durbin-Watson statistic. Since the dependent variable is different in the two functions (ln YN and YN), a comparison of the residuals and residual sum of squares cannot be made until the residuals from the Cobb-Douglas specification have been recalculated by taking antilogarithms. Also, the goodness of fit cannot be compared using the adjusted coefficients of multiple determination as shown in Table 6-6. However, even when appropriate methods are used for the comparison, there is very little difference in the residual sum of squares of the two functions. The above results suggest that there is little advantage in specifying a C.E.S production function as opposed to the simpler Cobb-Douglas formation in the case of Bell Canada.

4. Fitting a C.E.S. Production Function Using Search Procedure

As described in Chapter V, it is also possible to fit a C.E.S. function using search procedures if Hicks neutral technological change is assumed. The variable ln X must be calculated for initial assumed values p_0 and δ_0 in the range $p_0 \geq -1$ and $0 \leq \delta_0 \leq 1$.

$$Y = \gamma \left[\delta K^{-p} + (1-\delta) L^{-p} \right]^{-v/p} e^{\lambda E} = \gamma X^{-v/p} e^{\lambda E}$$

$$\ln Y = \ln\gamma - {}^{v}/p \ln \hat{X} + \lambda E$$

$$\text{where} \quad \ln \hat{X} = \ln \left[\delta_0 K^{-p_0} + (1-\delta_0) L^{-p_0} \right]$$

For each calculated variable ($\ln\hat{X}$), a C.E.S. production function can be estimated. By comparing the residual sum of squares or the variance of the errors, the C.E.S. function which gives the 'best' fit can be determined.

The variance of errors for each estimated equation is shown in Table 6-7. Over the permissable range for δ and p, there is very little difference in the goodness of fit of different trials. For example, the adjusted coefficient of multiple determination only varies from .9946 to .9982. Using a Cobb-Douglas function ($p = 0$), the $\bar{R}^2$ was .9976. Unfortunately, there is not enough variability in the data to permit differentiation between a Cobb-Douglas and alternate C.E.S. production functions ($p \neq 0$).

TABLE 6-7

ESTIMATES OF C.E.S. FUNCTION USING SEARCH PROCEDURE

Trial Number	Assumed Parameter Values		Error Variance (E.V.)
	δ	p	Net Data
1	0.0	-.75	.001522
2	0.0	-.50	.001523[a]
3	0.0	.50	.001523[a]
4	0.0	2.00	.001522
5	.2	-.75	.00757
6	.2	-.50	.000964
7	.2	.50	.001518
8	.2	2.00	.001523[a]
9	.4	-.75	.000642
10	.4	-.50	.000611
11	.4	.50	.001464
12	.4	2.00	.001522
13	.6	-.75	.000621
14	.6	-.50	.000612
15	.6	.50	.001329
16	.6	2.00	.001523[a]
17	.8	-.75	.000588
18	.8	-.50	.000619
19	.8	.50	.001089
20	.8	2.00	.001523[a]
21	1.0	-.75	.000545[b]
22	1.0	-.50	.000594
23	1.0	.50	.000594
24	1.0	2.00	.000567

[a]Poorest Fit with E.V. = .001523, $\bar{R}^2$ = .9946

[b]Best Fit with E.V. = .000545, $\bar{R}^2$ = .9982

The flatness of the C.E.S. function also accounts for the slow convergence encountered using nonlinear methods. There is little point in making further attempts to find the best C.E.S. function since the difference between the best and the worst function is apt to be minimal.

E. Empirical Estimates of a Variable Elasticity of Substitution (V.E.S.) Production Function

The C.E.S. function can be generalized still further by allowing the elasticity of substitution to vary. Once again, assuming constant returns to scale, exogenously determined factor prices and cost minimizing behaviour, it is possible to test for the presence of a V.E.S. function. Equation 6-20 was estimated for this purpose.

6-20. YN/L = -.56 + 1.15 ln W + .30 ln KN/L

(-4.04)*(10.31)* (3.96)*

$\bar{R}^2$ = .9696

DW = .43*

d.f. = 18

F = 955.25*

Estimation Method - O.L.S.

The elasticity of factor substitution is not significantly different from unity. Since the coefficient of the factor input ratio is significantly different from zero, a V.E.S. function is indicated. However, positive autocorrelation is a problem. Perhaps the assumption of instantaneous adjustment to a change in factor prices is unrealistic. In view of the positive autocorrelation present in equation 6-20, the results of this test for a variable elasticity of substitution were rejected. A V.E.S. production function was not fitted in this study.

F. Empirical Estimates of Nonhomogeneous Production Functions

As discussed in Chapter V, H.D. Vinod has estimated nonhomogeneous production functions using telephone data.[1] He obtained relatively good fits and his equations were also fitted using Bell Canada data. Empirical estimates over the period 1952 to 1972 are shown by equation 6-21.

6-21. $$\ln YN = 79.62 - 20.27 \ln L - 10.90 \ln K + 2.96 \ln K \ln L$$

$$(6.40)^{*} \quad (-6.54)^{*} \quad (6.46)^{*}$$

$\bar{R}^2$ = .9825

DW = .70*

d.f. = 17

F = 376.32*

Estimation Method - O.L.S.

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[1] Vinod's first nonhomogeneous function is

$$Y = AL^{a}K^{b+c \ln L}$$

$$\ln Y = \ln A + a \ln L + b \ln K + c \ln L \ln K$$

where $$E_L = \frac{\partial \ln Y}{\partial \ln L} = a + c \ln K$$

$$E_K = \frac{\partial \ln Y}{\partial \ln L} = b + c \ln L$$

$$\sigma = (E_K + E_L) / (E_K + E_L + 2c)$$

This specification gives a relatively good fit in terms of the coefficient of multiple determination. All coefficients are significant but positive autocorrelation is a major problem.

The main difficulty with the Vinod specification is that technological change is not incorporated directly. Any increase in output that results from technological change over time will be attributed to the increased use of factor inputs. The effects of both neutral and non-neutral technical change will be included in the calculated values for the elasticity of output with respect to capital (E_K) and labor (E_L). As a result, it is impossible to interpret the exact meaning of either the level or the change in E_K and E_L.

Vinod's function was also fitted with a proxy variable for technological change included. The results are shown by equation 6-22.

6-22. $\ln YN = -33.68 + 5.32 \ln KN + 9.48 \ln L - 1.30 \ln KN . \ln L + .035 E$

$(-4.17)^* \quad (4.57)^* \quad (4.50)^* \quad (-4.29)^* \quad (15.33)^*$

$\bar{R}^2 = .9988$

DW = 1.87

d.f. = 16

F = 4208.38*

Estimation Method- O.L.S.

The Durbin Watson statistic lies in the inconclusive range. Also, closer examination reveals that multicollinearity is a major problem. Examination of the correlation matrix shows that the fourth variable is very highly correlated with other variables in the model. The simple correlation coefficients are shown below.

	ln Kn	ln L	lnKNlnL	E	
ln KN	1.00	.8344		.9310	
			D	E	T
ln L	.75	1.00			
lnKNlnL	.99	.83	1.00	.9284	.9798
E	.93	.63	.91	1.00	

Clearly, the Vinod specification cannot be used with Bell Canada data. Since the basic problem is the multicollinearity between lnKN and lnKNlnL, it would be impossible to obtain reliable parameter estimates using the Vinod function even without technological change explicitly specified.

An alternative nonhomogeneous function developed by Vinod was also estimated. Once again, there was too much multicollinearity present to permit reliable estimation.[1]

$$\ln Y = \ln A + a\ln K + b \ln L + c \frac{1}{K.L}$$

The conclusion is that neither of Vinod's specifications can be used with Bell Canada data. In addition to the difficulty encountered in interpreting any results, the equations cannot be estimated because of multicollinearity. Estimation of the Vinod functions is likely to be

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[1]Simple correlation coefficients

	ln KN	ln L
$\frac{1}{KN.L}$	-.95	-.87

difficult with any set of capital and labor data.

G. Empirical Estimates of Production Function Using Disaggregate Data

One of the goals of this study is to compare results obtained at different levels of aggregation. With this in mind, the Cobb-Douglas function, modified to include a proxy variable for technological change, was fitted using disaggregate labor data. Labor inputs were split into two types. The first type included nonmanagement and part-time employees (NMAN), while the second type included all management employees (MAN). Labor inputs were measured in terms of weighted manhours and the disaggregate data is contained in Table A-17. Empirical results are shown by equation 6-23.

6-23. ln YN = 1.58 + .44 LNNMAN-.25 LNMAN+.36 LNKN+.028 E

(4.58)*(3.99)* (-1.18) (8.45)* (16.65)*

$\bar{R}^2$ = .9978

DW = 1.33

d.f = 16

F = 2278.89*

Estimation Method - O.L.S.

The estimated coefficients for management and nonmanagement labor inputs have different signs. Although management labor inputs are not statistically significant in either equation, this does suggest that labor cannot be aggregated by simply adding management and nonmanagement inputs.

Simple correlation coefficients between the variables of equation 6-23 are shown below.

	LNNMAN	LNMAN	LNKN	E
LNNMAN	1.00			
LNMAN	.37	1.00		
LNKN	.34	.97	1.00	
E	.15	.94	.93	1.00
dependent variable YN	.26	.97	.97	.99

Over the period 1952 to 1972, the use of management labor inputs was very highly correlated with the use of capital inputs (.97) and output (.97), while the use of non-management labor inputs was less correlated with the use of capital inputs (.34) and output (.26). Aggregate production models cannot reflect this dissimilarity.

Since all the inputs must be specified as independent variables in a production function, it is very difficult to work with disaggregate data using this approach. In time series, multicollinearity makes the estimation of reliable parameter estimates impossible. This is illustrated by equation 6-23. Further disaggregation would only compound the problem. In the next section, input requirement equations are developed and estimated. Disaggregation is facilitated by the use of this approach.

H. Empirical Estimates of Input Requirement Model

The development and advantages of input requirement models were discussed in Section I of Chapter V. Estimates using aggregate capital and labor data are shown by equations 6-24 to 6-31. These results correspond to equations 5-33 to 5-40 as developed in Chapter V. Since each equation contains a lagged dependent variable, ordinary least squares (O.L.S.) estimates are not consistent if autocorrelation is present. The results shown are based on the Hildreth-Lu (H.L.) estimating procedure. The coefficient of determination (R^2) is unadjusted for the degrees of freedom and is calculated from the residuals.

6-24. $\ln L = 1.10 - .13 \ln \frac{r5}{w} - .11 \ln YN + .003\ E + .78 \ln L_{-1}$

(2.23)* (-1.73) (-.79) (.61) (5.82)*

R^2 = .8830

$\hat{\rho}$ = .0125

d.f = 15

F = 29.18*

Estimation Method - H.L.

6-25. $\ln KN = -1.04 - .03 \ln \frac{r5}{w} + .39 \ln YN - .012\ E + .87 \ln KN_{-1}$

R^2 = .9995

$\hat{\rho}$ = .0040

d.f. = 15

F = 10433.94*

Estimation Method - H.L.

6-26. $\ln \frac{L}{L_{-1}} = .24 - .08 \ln \frac{r5}{w} + .04 \ln \frac{YN}{L_{-1}} - .002\, E$

(-1.08) (-.97) (1.08) (-1.55)

R^2 = .5437

$\hat{\rho}$ = .6291

d.f. = 16

F = .86

Estimation Method - H.L.

6-27. $\ln \frac{KN}{KN_{-1}} = -.17 - .07 \ln \frac{r5}{w} - .06 \ln \frac{YN}{KN_{-1}} - .002\, E$

(-1.92) (-2.27)* (-7.13)* (-3.24)*

R^2 = .9254

$\hat{\rho}$ = .8000

d.f. = 16

F = 31.16*

Estimation Method - H.L.

6-28. $\ln D = 1.15 - .13 \ln \frac{r5}{w} - .09\, (\ln YN - .026\, E) + .74 \ln L_{-1}$

(4.34)* (-1.92) (-1.15) (6.76)*

R^2 = .881

$\hat{\rho}$ = .1797

d.f. = 16

F = 41.29*

Estimation Method - H.L.

6-29. $\ln KN = -2.35 + .10 \ln\frac{r5}{w} + 1.03 (\ln YN - .026 E)$

$(-5.19)^{*} (1.48) \quad (5.77)^{*} \quad (11.28)^{*}$

$R^2 = .9979$

$\hat{P} = .0238$

d.f. = 16

F = 2456.76*

Estimation Method - H.L.

6-30. $\ln\frac{L}{L_{-1}} = -.15 - .04 \ln\frac{r5}{w} + .04 (\ln YN - .026E - \ln L_{-1})$

$(-.73) (-.53) \quad (1.27)$

$R^2 = .5231$

$\hat{P} = .7353$

d.f. = 17

F = .95

Estimation Method - H.L.

6-31. $\ln\frac{KN}{KN_{-1}} = .30 + .01 \ln\frac{r5}{w} + .09 (\ln YN - .026 E - \ln KN_{-1})$

$(6.08)^{*} (.38) \quad (9.05)^{*}$

$R^2 = .9229$

$\hat{P} = .1681$

d.f. = 17

F = 74.45*

Estimation Method - H.L.

Implied structural coefficients are shown by Table 6-8. The unrestricted coefficients as estimated by equations 6-24 and 6-25 are neither reasonable nor consistent. One reason for these unreliable results is that Bell Canada time series data have too much collinearity to permit reliable estimation of this input requirements model. Simple correlation coefficients between the variables in equations 6-24 and 6-25 are shown below. In both equations, only the lagged dependent variable is more highly correlated with the dependent variable than with other independent variables.

	$\ln \frac{r5}{w}$	ln YN	E	$\ln L_{-1}$
$\ln \frac{r5}{w}$	1.00	-.84	-.85	-.48
ln YN	-.84	1.00	.99	.67
E	-.85	.99	1.00	.60
$\ln L_{-1}$	-.48	.67	.60	1.00
Dependent Variable	-.56	.66	.61	.93

	$\ln \frac{r5}{w}$	ln YN	E	$\ln KN_{-1}$
$\ln \frac{r5}{w}$	1.00	-.84	-.85	-.74
ln YN	-.84	1.00	.99	.97
E	-.85	.99	1.00	.95
$\ln KN_{-1}$	-.74	.97	.95	1.00
Dependent Variable	-.74	.97	.94	.999

TABLE 6-8

IMPLIED STRUCTURAL COEFFICIENTS OF ALTERNATIVE AGGREGATE INPUT REQUIREMENT MODELS

Parameter Estimate	Symbol	Equation Number							
		24	25	26	27	28	29	30	31
Coefficient of labor in production function	α	1.18	.25	-2.00	-.17	1.44	.15	1.00	1.11
Coefficient of capital in production function	β	-3.18	.08	3.00	1.17	-4.32	.10	0.00	-.11
Returns to scale	v	-2.00	.33	1.00	1.00	-2.88	.35	1.00	1.00
Coefficient of technological proxy variable in production function	λ	.028	.032	.050	-.033	.026	.026	.026	.026
Proportional adjustment coefficient of labor	a_L	.22	...	.04	...	.26	...	.04	...
Proportional adjustment coefficient of capital	a_K	...	.13	...	-.06	...	.36	...	.09

Unfortunately, attempts to introduce a priori information into the input requirements model did not overcome the problem of multicollinearity. Based on previous results in this chapter, constant returns to scale were assumed in equations 6-26 and 6-27 and the coefficient of the technology proxy variable was assumed to be equal to .026 in equations 6-28 and 6-29. The final two equations incorporate both of these a priori assumptions. Any of the modified forms which explained a significant portion of the variance of the dependent variable also contained collinearity between the independent variables. For example, simple correlation coefficients between the variables in equation 6-28 are shown below.

	$\ln \frac{r5}{w}$	ln YN-.026 E	$\ln L_{-1}$
$\ln \frac{r5}{w}$	1.00	-.79	-.48
ln YN-.026 E	-.79	1.00	.78
$\ln L_{-1}$	-.48	.78	1.00
Dependent Variable	-.56	.75	.93

Although it was impossible to obtain reliable parameter estimates in any of the aggregate input requirement models, predictions of input requirements could still be made providing that the extent and pattern of collinearity were to continue in the future. However, there is little justification for making this assumption.

For similar reasons, it was impossible to obtain reliable estimates of disaggregated input requirement models and results are not presented here. In view of the lack of independence in the time series data, no attempt was made to estimate the input requirement equations simultaneously taking account of restrictions on the parameters or to incorporate an interrelated adjustment process as in the Nadiri-Rosen model.

I. Conclusions

Based on a study of the Bell Canada production process using the production function and input requirement approaches, the following conclusions can be made:

(a) Choice of Aggregate Data Variables

(i) Empirical estimates are relatively unaffected by the choice of gross or net data - providing that capital and output variables are defined consistently.

(ii) Although there was often little difference in the empirical estimates obtained with different versions of the user cost of capital, it was decided on the basis of slightly better empirical results and for theoretical reasons that version 5 would be used in subsequent research. Version 5 is based on the assumption that the debt-equity ratio in each year is optimum, that the opportunity cost of equity is best measured by the average rate of return to 56 United States telephone companies and that the opportunity cost of debt is best measured by the marginal cost of debt actually paid by Bell Canada. The effects of changes in tax rates or tax structure are also incorporated.

(iii) Great difficulty was encountered in defining a proxy variable for technological change. The percentage of telephones connected to either Number Five Crossbar or to Electronic Switching System offices was chosen for use in subsequent research.

(b) Elasticity of Substitution

The C.E.S. and other more complicated forms of the production function either could not be estimated reliably or were consistent with a Cobb-Douglas specification. The elasticity of substitution is defined as unity in a Cobb-Douglas function.

(c) Returns to Scale

The assumption of constant returns to scale could not be rejected at the present scale of operations. However, increasing returns may exist for much lower output levels.

(d) Type of Technological Change

Using 21 years of annual Bell Canada data, it is impossible to differentiate between Hicks neutral technological change and other non-neutral types such as Solow neutral (capital augmenting) or capital additive (product augmenting).

(e) Best Aggregate Production Functions

(i) Using net output, net capital and a proxy variable for technological change, the best production functions obtained are shown by equations 6-9 and 6-12.

6-9. $\ln YN = 1.02 + .32 \ln KN + .44 \ln L + .026 E$

$(2.62)^{*}$ $(8.58)^{*}$ $(3.62)^{*}$ $(20.26)^{*}$

$\bar{R}^2 = .9976$

DW = 1.12

d.f. = 17

F = 2768.87*

Estimation Method - O.L.S.

6-12. $\ln YN = .87 + .37 \ln KN + .41 \ln L + .0030 E.\ln KN$

$(2.37)^{*}$ $(10.92)^{*}$ $(3.54)^{*}$ $(21.51)^{*}$

$\bar{R}^2 = .9979$

DW = 1.16

d.f. = 17

F = 3106.94*

Estimation Method - O.L.S.

(ii) There is some evidence that the capital and technology coefficient in these two production functions may not be reliably estimated because of the collinearity between the capital variable and the proxy variable for technological change. When dummy variables were used to represent technological change, the estimated capital coefficient increased (equations 6-15 and 6-18).

(f) Best Aggregate Input Requirement Model

In spite of the advantages of this approach (permits consideration of both the level and cyclical pattern of productivity), reliable estimates could not be obtained because of the collinearity present in Bell Canada time series data.

(g) Use of Aggregate Data

(i). If possible, management and nonmanagement labor inputs should be considered as separate input variables in the production model.

(ii) Since the use of disaggregate time series data in a production function results in excessive multicollinearity, it was impossible to obtain reliable parameter estimates using a disaggregate production function. Similarly, it was impossible to reliably estimate a disaggregate input requirement model.

(h) Use of Production Models to Predict Short-Term Productivity Gains

(i) In this study, measured inputs do not take into account differences in the level of capacity utilization and this is probably the major determinant of measured short-term productivity oscillations. Allowance for changes in capacity utilization can be implicitly incorporated into an input requirement model, but this type of model could not be reliably estimated using Bell Canada time series data. However, a short-run productivity forecasting model can be developed from the production function. Allowance must be made for short-term deviations from the estimated production function. This type of productivity forecasting model is described in the next chapter.

Chapter VII

SPECIFICATION OF MINIMUM REQUIRED PRODUCTIVITY GAINS IN AN AUTOMATIC REVENUE ADJUSTMENT CLAUSE

A. Short-Run Productivity Forecasting Model

The requirement for and general nature of Automatic Revenue Adjustment Clauses (ARAC) were discussed in Chapter III. One of the problems encountered was the specification of a minimum improvement in productivity which the company must attain before any unit cost increases are passed on as an increase in rates. A Solow type total factor productivity measure[1] was developed using standard accounting measures of input and output. The dollar value of productivity gains calculated using this productivity measure are compatible with other dollar values contained in an income statement. Minimum required productivity gains must eventually be stated in terms of this productivity index.

Unfortunately, standard accounting data series do not provide satisfactory measures of physical inputs and outputs at an aggregate level. More reliable indicators of inputs and outputs (as measured by economists) were

[1]Kendrick and Solow total factor productivity measures are described in Section A of Chapter IV.

described in Chapter IV and a production model was developed in Chapter V and Chapter VI using these alternative data series. Although an input requirements model could not be reliably estimated, it was possible to estimate an aggregate production function of the Cobb-Douglas type. In this section, a productivity forecasting model is developed from the estimated production function. Productivity gains predicted using this formula should be consistent with past performance and will be used as minimum required improvements in productivity. Section B of this chapter describes the calculation of dollar values for these expected productivity gains.

Equation 7-1 is derived by including the error term in the estimated production function shown by equation 6-9. A productivity forecasting model can be developed from this equation as shown below. Similar models could have been derived from alternative production functions.

7-1. $\ln YN_t = 1.02 + .32 \ln KN_t + .44 \ln L_t + .026\, E_t + e_t$

$$\frac{\dot{YN}_t}{YN_t} = \frac{d \ln YN_t}{dt} = .32 \frac{\dot{KN}_t}{KN_t} + .44 \frac{\dot{L}_t}{L_t} + .026\, \dot{E}_t + \dot{e}_t$$

In discrete form, this equation may be represented as

7-2. $Y_t = .32\, k_t + .44\, \ell_t + 2.6\,(E_t - E_{t-1}) + 100\,(e_t - e_{t-1})$

where YN_t is net output and y_t is the percentage change in YN_t

k_t is net capital stock and R_t is the percentage change in KN_t

L_t is labor input (in weighted manhours) and ℓ_t is the percentage change in L_t

E_t is a proxy variable for technological change (the percentage of telephones connected to Number Five Crossbar or Electronic Seitching System offices)

e_t is the error term in the production function.

Now, let the percentage change in total factor input (x_t) and the percentage change in total factor productivity be defined by equations 7-3 and 7-4.[1]

7-3. $x_t = .32\, k_t + .44\, \ell_t$

7-4. $r_t = y_t - x_t$

Equation 7-5 shows the implied expression for the percentage change in productivity.

7-5. $r_t = 2.6\,(E_t - E_{t-1}) + 100\,(e_t - e_{t-1})$

Our problem is to predict r_t when the percentage change in total factor input is unknown. Since the error term of the production function (e_t) is also unknown, equation 7-5 cannot be used directly. However, one alternative is to assume that the size of the error does not vary from year to year ($e_t = e_{t-1}$). In this case, the predicted

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[1] This total factor productivity index is similar to Solow's geometric index. Instead of using the shares of capital and labor, the estimated coefficients from the production function are used as weights in calculating the percentage change in total factor input.

level of desired productivity gains and of desired percentage changes in total factor input are shown by equations 7-6 and 7-7.

7-6. $r_t^* = 2.6\ (E_t - E_{t-1})$

7-7. $x_t^* = y_t - r_t^* = y_t - 2.6\ (E_t - E_{t-1})$

Actually, this predictor of productivity gains picks up little of the year to year variation. In fact, there is little justification for assuming that the error terms of the production function will be equal in subsequent years and some means of forecasting the size of this error term in each year is required.

One approach is to assume a linear adjustment mechanism whereby the change in total factor input adjusts to some desired level (x_t^*).

7-8. $(x_t - x_{t-1}) = a\ (x_t^* - x_{t-1})$

The implication of this assumption is that measured inputs and outputs may show large deviations from the estimated production function relationship in particular years. Since our input data does not take into account changes in the level of utilization, this result is not surprising. Essentially, we are developing a model in which desired input levels are based on the production function but measured input levels are based on the desired level of inputs and on the level of input utilization.

It remains to specify the desired level of total factor input increases (x_t^*). This corresponds to specifying the desired level of productivity gains (r_t^*) when y_t is known. Since the rate of exogenous technological change is generally viewed as proceeding at a fairly uniform pace over short time periods, the major determinant of productivity gains is actually the opportunity which the company has to incorporate these new methods. If output is growing more rapidly in a particular year, it can be argued that this opportunity will be increased. In this study, desired productivity gains were specified as varying proportionately with the percentage increase in output. The desired level of x_t^* is shown by equation 7-9.[1]

$$r_t^* = c\, y_t$$

7-9. $$x_t^* = y_t - r_t^* = y_t - cy_t = (1-c)\, y_t$$

Equation 7-10 shows the final productivity forecasting model and is obtained by substituting equation 7-8 and 7-9 into equation 7-4.

---

[1]Desired productivity gains were also specified as $r_t^* = 2.6\,(E_t - E_{t-1})$. This is the rate of exogenous technological progress as estimated in the production function. However, when the derived productivity forecasting model was estimated, insignificant coefficient estimates and conflicting values for the implied structural coefficients were obtained. Results are not presented here.

$$r_t = y_t - x_t$$

$$= y_t - ax_t^* + (1-a)\, x_{t-1}$$

$$= y_t - a(1-c)\, y_t - (1-a)\, x_{t-1}$$

7-10. $$= (1 - a + ac) y_t - (1-a)\, x_{t-1}$$

The estimated productivity forecasting model is shown by equation 7-11. All data series are described in Chapter IV. A Hildreth-Lu (H.L.) estimating procedure was used so that consistent parameter estimates would be obtained even though a lagged dependent variable is present. Since there is no constant term, the coefficient of determination (R^2) when calculated by the usual formula is not bounded between zero and unity. As an alternative measure of the goodness of fit, the average absolute error (A.A.E.) is listed.

7-11. $$r_t = .93\, y_t - .70\, x_{t-1}$$

(16.56)* (-5.32)*

A.A.E. = .73

$\hat{\rho}$ = .4752

d.f. = 18

Estimation Method = H.L.

Period - 1954 to 1972.

Actual and predicted total factor productivity gains are contained in Table 7-1. The same series are plotted in Figure 7-1. Over the entire period, the average absolute error in the predicted percentage productivity gain was

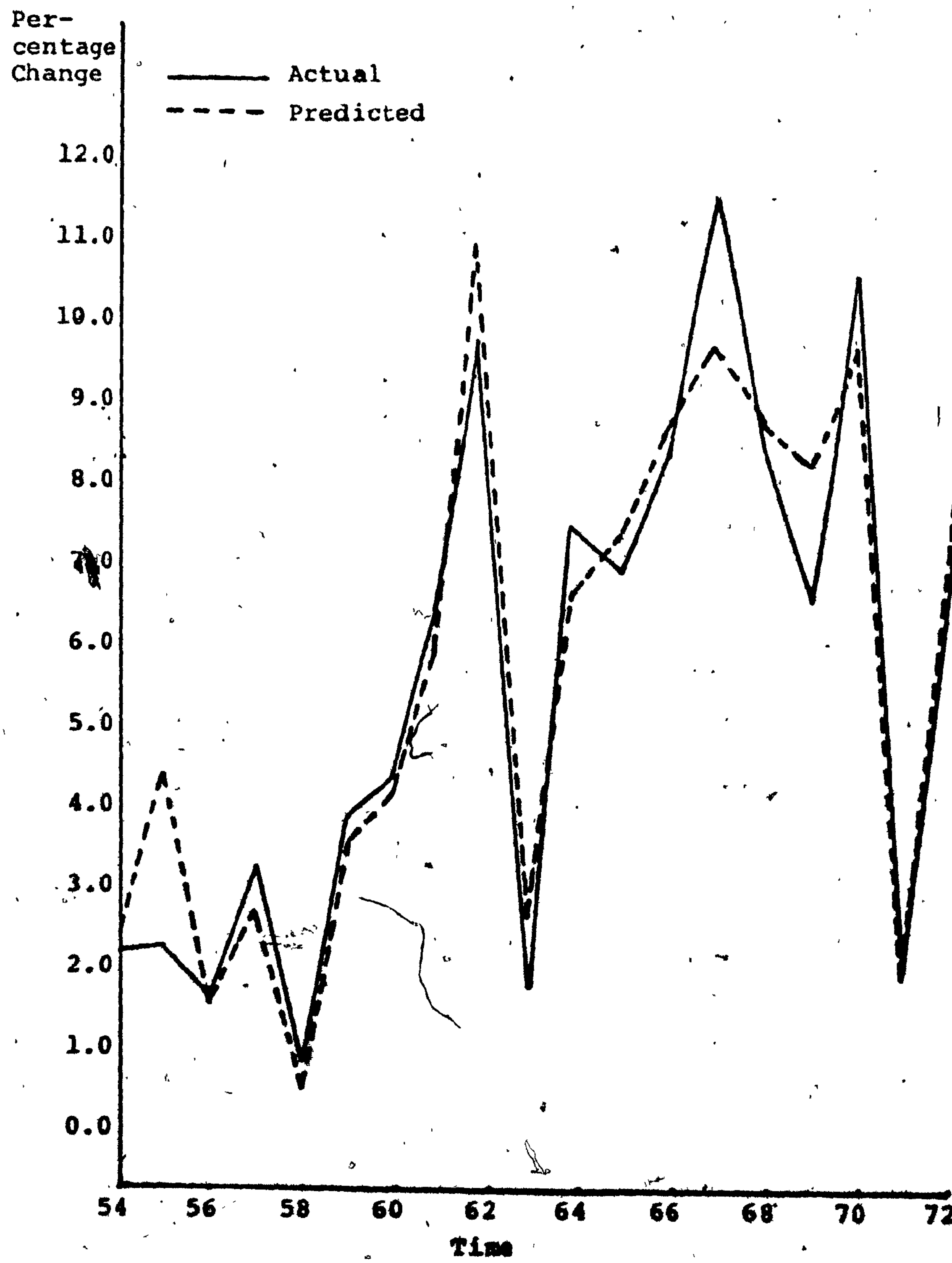
TABLE 7-1

TOTAL FACTOR PRODUCTIVITY GAINS
USING ECONOMIST'S DATA
(Percentage)

Year	Actual	Predicted	Difference
1954	2.136	2.364	-.228
1955	2.130	4.397	-2.267
1956	1.697	1.595	.102
1957	3.181	2.663	.517
1958	.971	.415	.556
1959	3.838	3.523	.315
1960	4.339	4.023	.316
1961	6.276	5.813	.463
1962	9.753	10.859	-1.106
1963	1.172	2.361	-1.190
1964	7.483	6.506	.977
1965	6.867	7.258	-.391
1966	8.238	8.467	-.229
1967	11.545	9.500	2.045
1968	8.357	8.601	-.244
1969	6.497	8.151	-1.654
1970	10.466	9.634	.832
1971	2.091	2.021	.070
1972	7.623	7.950	-.327

FIGURE 7-1

TOTAL FACTOR PRODUCTIVITY GAINS USING ECONOMIST'S DATA



only .73. Predicted productivity gains were high in 1955 by 2.27 per cent and in 1969 by 1.65 per cent. In 1967, the predicted productivity gain was 2.05 per cent below the actual. Errors were much smaller in all other years and special factors of a nonrecurring nature may have affected productivity gains in these years.

Implied values for the structural coefficients are calculated below.[1]

$$-(1-a) = -.70$$
$$a = .30$$
$$1 - a + ac = .93$$
$$1 - .30 + .30c = .93$$
$$c = .23/.30$$
$$c = .77$$

The mean lag implied for the adjustment of percentage changes in total factor input is 2.3 years.[2] In view of the very long lead times required for plant and associated manpower additions, this lag is reasonable. Another implication of the above results is that for every percentage

[1] In this model, the same implied structural coefficients would be obtained by estimating either the reduced form or equations, since the reduced form can be derived by simply rearranging the variables and the error term is not affected.

$$x_t = (a-ac)\, y_t + (1-a)\, x_{t-1}$$
$$r_t = y_t - x_t = (1-a+ac)\, y_t - (1-a)\, x_t$$

[2] The mean lag of a Koyck distribution is $\lambda/_{1-\lambda}$. When $a = .30$ and $\lambda = 1-a$, the mean lag is (1-.30)/.30 or 2.3 years.

point increase in output, productivity gains will increase by .78 per cent after total factor input growth has adjusted completely to the new desired output. This is consistent with the long-term trend of productivity gains and of output growth.[1]

The model was also estimated over different sample periods. Equation 7-12 shows the estimated relationship over the period 1953 to 1969.

$$7\text{-}12. \quad r_t = .92\, y_t - .70\, x_{t-1}$$

(12.74)* (-4.55)*

A.A.E. = .79

$\hat{\rho}$ = .5000

d.f. = 14

Estimation Method = H.L.

Period - 1954 to 1969.

Coefficient estimates are almost the same as in equation 7-11. Given the percentage increase in output, productivity forecasts were made for the years 1970 to 1972. It was assumed that the forecasts would be made on a yearly basis

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[1]In the event of a sustained period of no growth in output, this model implies that there would be no productivity gains. In this case, the productivity forecasting model presented here might not be relevant. Alternatives include making desired productivity gains simply a function of some proxy variable for technological change or of a proxy variable for technological change and the growth of output. However, over the range of output growth rates which have occurred historically, the forecasting model presented here performs well and has the advantage of being simpler and easier to estimate than a more complex version.

and that the actual productivity gain in the previous year would be known. Forecasted and actual values are shown below.[1]

	Actual Productivity Gain (%)	Forecasted Productivity Gain (%)
1970	10.5	9.5
1971	2.1	2.1
1972	7.6	7.9

Although these forecasts are fairly close, it cannot be assumed that forecasts for future years will be equally reliable. Particular events may have a pronounced effect on productivity in a given year and these will not be captured by the model. However, the burden of proof should lie with those arguing that the forecast is not reasonable in a particular year. It will be assumed that equations 7-11 and 7-12 can be used to forecast productivity gains outside the sample period.

B. Dollar Value of Minimum Required Productivity Gains

In the previous section, a model was developed to forecast minimum required productivity gains in terms of input and output data series used by economists. Percentage changes in this productivity index were represented by the notation r_t. Since these predictions should be consistent

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[1]Forecasts were made using the formula

$$r_t = \alpha_1 y_t - \alpha_2 x_{t-1} + \rho e_{t-1}$$

$$= .92\, y_t - .70\, x_{t-1} + .50(r_{t-1} - (.92 y_{t-1} - .70 x_{t-2}))$$

$$= .92\,(y_t - .50 y_{t-1}) - .70(x_{t-1} - .50 x_{t-2}) + .50 r_{t-1}$$

with past performance, they can be taken as minimum required productivity improvements to be incorporated into an Automatic Revenue Adjustment Clause. It remains to convert these productivity requirements from the economist's measure, (r_t) into the equivalent productivity measure defined in terms of standard accounting data. Gains in this productivity measure were calculated in Chapter III and can be represented by the notation ra_t.[1]

Equation 7-13 shows the estimated relationship between r_t and ra_t over the period 1953 to 1972. Although gains in the two productivity measures are highly correlated, the adjusted coefficient of determination is only .7032. Large forecast errors would result if equation 7-13 were used to calculate a predicted level of ra_t given the predicted level of r_t.

7-13. $$ra_t = .20 + .93\, r_t$$
$$(.24) \quad (6.78)^*$$

[1]It is also possible to respecify the productivity forecasting model entirely in terms of accounting data and to derive estimates of ra_t directly. However, since standard accounting data series provide inferior measures of physical inputs and outputs at an aggregate level, it is not surprising that a poor statistical fit is obtained. Over the period 1954 to 1972, the estimated average absolute error is 1.58 per cent (versus .73 per cent from equation 7-11).

$\bar{R}^2$ = .7032

D.W. = 2.55

d.f. = 18

F = 46.02*

Estimation Method - O.L.S.

Period - 1953 to 1972

Fortunately, it can be assumed for our purposes that the automatic rate adjustment is to be calculated at the beginning of each year for the previous year. In this case, the actual values of both r and ra will be known for the previous year and the difference between actual and expected values of r can be used to calculate the expected value of ra. From equation 7-13, a 1.00 per cent change in r corresponds to a .93 per cent change in ra. Combining equations 7-11 and 7-13, expected values of ra can be calculated as

$$7\text{-}14. \quad \hat{ra}_t = ra_t - .93\left[r_t - \hat{r}_t\right]$$

$$= ra_t - .93\left[r_t - (.93(y_t - .48y_{t-1}) - .70(x_{t-1} - .48x_{t-2}) + .48r_{t-1})\right]$$

$$= ra_t - .93r_t + .86y_t - .42y_{t-1} + .65x_{t-1} - .31_{\ t-2} - .46r_{t-1}$$

Expected productivity gains calculated using standard accounting data are contained in Table 7-2. Figure 7-2 plots the actual and expected productivity gains (using standard accounting data). With the exception of 1955, 1967 and 1969, expected productivity gains in terms of accounting data are

TABLE 7-2

TOTAL FACTOR PRODUCTIVITY GAINS
USING STANDARD ACCOUNTING DATA
(Percentage)

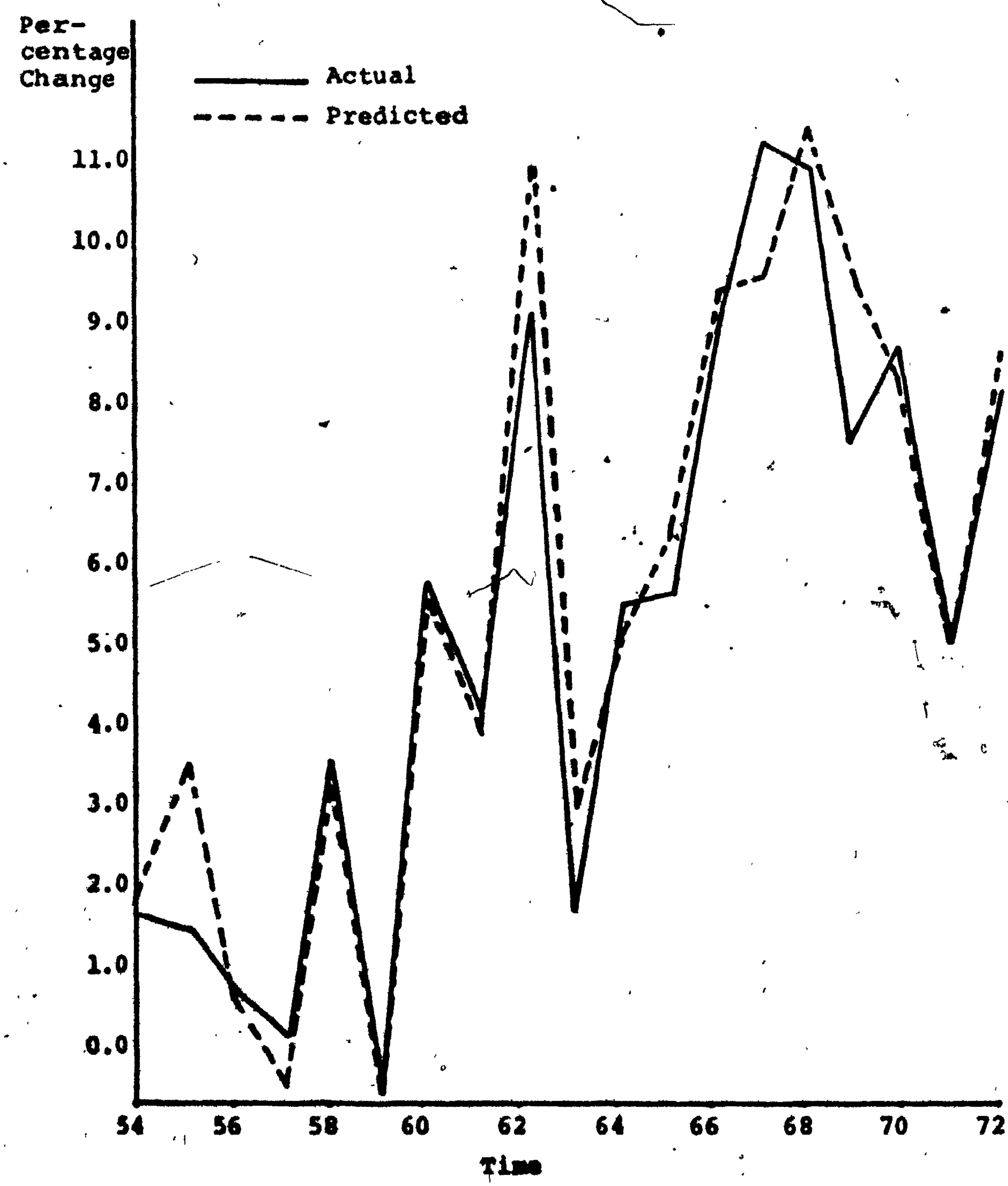
Year	Actual[a] A	Adjustment[b] B	Predicted C = A + B
1954	1.658	-.212	1.870
1955	1.401	-2.108	3.509
1956	.748	.095	.653
1957	.039	.481	-.442
1958	3.535	.517	3.018
1959	-.318	.293	-.611
1960	5.847	.294	5.553
1961	4.111	.431	3.680
1962	9.060	-1.029	10.089
1963	1.797	-1.107	2.904
1964	5.499	.909	4.590
1965	5.663	-.364	6.027
1966	8.974	-.213	9.187
1967	11.181	1.902	9.279
1968	10.939	-.227	11.166
1969	7.664	-1.538	9.202
1970	8.808	.774	8.034
1971	5.120	.065	5.055
1972	8.255	-.304	8.559

[a]This series is calculated in Table 3-7.

[b]The difference between actual and predicted productivity gains as shown in the third column of Table 7-1 is multiplied by .93 in each year to obtain this series.

FIGURE 7-2

TOTAL FACTOR PRODUCTIVITY GAINS USING STANDARD ACCOUNTING DATA



very close to actual levels over the entire sample period. Finally, the dollar value of expected productivity gains can be obtained by multiplying the expected percentage gain times the value of total factor input in the previous period.[1] Dollar values for the minimum required productivity improvement over the period 1955 to 1972 are shown in the second column of Table 8-2.

C. Conclusions

Equation 7-14 can be used to calculate expected productivity gains in terms of standard accounting data ($\hat{ra}_t$). It is based on the following four assumptions.

(a) that the production function can be represented by equation 6-9.

(b) that the adjustment mechanism for gains in total factor input can be represented by equation 7-8.

(c) that the desired level of gains in total factor input can be represented by equation 7-9.

(d) that the relationship between productivity gains measured with standard accounting data and with data defined by an economist can be approximated by equation 7-13.

Dollar values for expected productivity gains are also implied by $\hat{ra}_t$. Over the sample period, estimated values based on equation 7-14 were very close to observed values.

[1]Table 3-7 illustrates this calculation.

This equation will be used in the next chapter to calculate the minimum productivity improvement which is required before any unit cost increases can be passed on as a rate increase.[1] If the company achieves less than this productivity gain, it will be assumed that performance is below the level achieved under similar circumstances in the past. In this case, the company should not be allowed to pass increased unit costs through as a rate increase. Using this approach, the minimum improvement in productivity is not based on the best gain which might be achieved, but only on what was achieved under similar circumstances in the past as determined by equation 7-14.

[1]It is assumed that automatic rate adjustments will be calculated at the beginning of each year for the previous year.

Chapter VIII

CALCULATION AND IMPLEMENTATION OF AUTOMATIC RATE ADJUSTMENTS

A. Maximum Allowed Increase of Output Prices

As outlined in Chapter III, an automatic rate adjustment may be calculated using the following relationship.

$$\begin{array}{c}\text{Dollar}\\ \text{Value of}\\ \text{Rate Adjustment}\end{array} = \begin{array}{c}\text{Dollar Value}\\ \text{of } \underline{\text{Maximum}}\\ \text{Allowed Price}\\ \text{Increase on}\\ \text{Inputs}\end{array} - \begin{array}{c}\text{Dollar Value}\\ \text{of } \underline{\text{Minimum}}\\ \text{Required}\\ \text{Productivity}\\ \text{Gains}\end{array} - \begin{array}{c}\text{Dollar Value}\\ \text{of Rate}\\ \text{Increases}\\ \text{on Other}\\ \text{Income}\end{array}$$

If the company did not allow wages or other input prices to exceed allowed levels and if the required productivity gains were achieved, then the dollar value of rate increases calculated using this formula would leave the rate of return to equity capital unchanged. A full scale rate case would still be required to adjust the allowable rate of return on average total capital and to deal with other regulatory issues such as the relative price of different services.

The main concern of this study has been the specification of an appropriate minimum required productivity objective. A total factor productivity measure should be used since we want to measure the efficiency with which all inputs are employed. Since different opportunities for improvements in productivity exist in each industry and in each company, productivity objectives for Bell Canada which are based on the performance of some other sector are likely to be invalid. A more useful approach is to base the minimum required productivity gain on the performance of Bell Canada in the past when faced by similar conditions. Telecommunications services are provided by a very capital intensive production process and changes in capacity utilization lead to large oscillations in the potential for productivity gains from year to year. As a result, the productivity objective cannot be based on a simple average of productivity gains achieved in the past by Bell Canada. However, a method of specifying the minimum required productivity gain was developed in the previous chapter.

It remains to specify the maximum price increases on input factors which will be allowed. A price index which indicates the maximum allowable price increase must be chosen for each input. In Chapter III, the following general criteria were discussed.

(a) "Subject to the provision that each price indicator accurately represents price changes in that particular input market, indicators should be chosen which are not affected by specific decisions of the company.

(b) Price indexes should be chosen for every input used and allowable expenses for a particular input must not be overly generous when compared with allowable expenses on other inputs.

(c) Reliable data should be available with a minimum of delay for any price index chosen.

These criteria are not completely compatible and the choice of price indexes to indicate allowable expenses will remain a matter of judgment. This topic is not the primary concern of this study and the price indexes shown below were chosen mainly for illustrative purposes.

(a)	Employee Expense	- Bell Canada Index of Employee Expense per Employee
(b)	Depreciation Expense	- Implicit Price Index for Gross Business Fixed Capital Formation
(c)	Other Expense	- Implicit Price Index for Gross National Expenditure
(d)	Income Taxes	- None of increase included as part of allowable expense
(e)	Other Taxes	- Full increase included as allowable expense
(f)	Interest Expense	- McLeod, Young and Weir Index of Rate of Return on 10 Utilities

None of the wage indexes which were examined were highly correlated with the Bell Canada index of employee expense per employee. In view of the importance of price changes on this input, the actual index of Bell Canada employee expense per employee was used to determine allowable [illegible] to grant excessive wage increases and further study should be directed at finding an appropriate price index for employee expense which would not be affected by the results of Bell Canada labor negotiations.

Determining allowable expenses on the book value of depreciation presents a difficult conceptual problem. The actual book value of past vintages will never be affected by price changes in the current year. However, the book value of depreciation is biased downward during an inflationary period since accumulated depreciation reserves measured at book value will not cover the cost of replacing assets as plant is written off. The logical solution is to restate assets and depreciation values in current dollars. Allowable expenses can then be determined by applying an appropriate price index to depreciation expense measured in current dollars. At the present time, a switch to inflationary accounting does not appear likely in the accounting profession. In this study, allowable expenses have been determined by applying the Implicit Price Index for Gross Business Fixed Capital Formation to the book value of depreciation expense. This method at least captures some of the increase in true current dollar depreciation during an inflationary period.[1]

Allowable price increases on inputs in the other expense category are determined by applying the Implicit Price Index for Gross National Expenditure. This is the same price index used in Chapter III for this expense category.

Another conceptual problem is encountered in specifying appropriate price indexes and allowable expenses for income and other taxes. I have simply assumed that any increase in income taxes is meant to be borne by the company and should not be part of allowable expense, while the complete increase in other taxes is considered as part of allowable expenses and may be passed on by the company.

Most long term interest rates are highly correlated over time. The price index chosen here to determine allowable expense is published by McLeod, Young and Weir and represents interest rates on ten utility bonds.

Table 8-1 shows the allowable expense arising from

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[1]During an inflationary period, a switch to inflationary accounting (valuation of assets by restating to current dollar values) would provide a better measure of true depreciation expense. If the allowable rate of return was quoted on the asset base, there would be a further benefit to the company because the absolute value of allowable profits would increase as a result of inflation. However, as with any change in accounting technique, benefits to the company can be eliminated simply by adjusting the allowable rate of return. An Automatic Revenue Adjustment Clause (ARAC) can be instituted either with or without changes in accounting procedures.

TABLE 8-1

MAXIMUM ALLOWED VALUE OF PRICE INCREASE ON INPUTS
(Thousands of Dollars)

Year	Employee Expense A	Depreciation Expense B	Other Expense C	Other Taxes D	Interest Expense E	Total Allowable Expense F = A+B+C+D+E
1954	3,847	-95	549	550	-1,129	3,722
1955	4,300	618	225	1,101	-408	5,836
1956	-320	1,537	1,739	1,003	1,669	5,628
1957	1,967	1,210	1,061	2,021	2,223	8,482
1958	6,763	172	759	1,043	-941	7,796
1959	10,324	594	1,228	1,624	2,272	16,042
1960	9,765	1,012	770	2,166	367	14,080
1961	7,483	237	335	2,170	-1,331	8,894
1962	6,754	1,115	1,003	1,298	0	10,170
1963	5,820	2,526	1,361	1,341	356	11,404
1964	4,838	3,649	1,969	1,620	318	12,394
1965	2,631	5,544	2,809	2,192	933	14,109
1966	6,007	6,115	4,209	4,593	5,023	25,947
1967	11,815	3,311	3,745	5,810	4,180	28,861
1968	18,423	1,115	3,331	3,080	6,513	32,462
1969	19,962	6,809	5,638	5,885	7,115	45,409
1970	24,784	7,326	6,126	798	5,434	44,468
1971	24,858	9,246	4,736	6,747	-8,236	37,351
1972	25,296	15,395	7,446	1,654	-1,299	48,492
Total	195,317	67,436	49,039	46,696	23,059	381,547

each expense category over the period 1954 to 1972.[1] I should point out once again that a subjective judgment is involved in the specification of allowable expenses for each category. The total allowed increase in expenses shown by column F represents only one of several possible combinations.

B. Calculation of Eligible Expense and Percentage Automatic Rate Adjustment

Expenses which are eligible to be passed on as rate increases are calculated by subtracting the minimum required productivity offset and the value of price increases on other income from the maximum allowed increase in expense. Table 8-2 illustrates these calculations for the period 1954 to 1972.[2] Eligible expenses for rate adjustment can also be stated in terms of the equivalent percentage increase in total operating revenue. This series is shown in the first column of Table 8-3.

As outlined previously, automatic rate adjustments are calculated so as to leave the rate of return to equity capital unchanged, providing that the company meets the minimum required productivity objective and does not

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[1]As in Chapter III, the dollar value of price changes are calculated by multiplying the current dollar figure times the change in the price index from the previous year divided by the value of the price index in the current year.

[2]The productivity offsets shown in the second column of Table 8-2 are based on a productivity forecasting model estimated over the period 1955 to 1972. However, as pointed out in Chapter VII, the coefficients of this model were almost unchanged when the model was estimated over different sample periods.

TABLE 8-2

CALCULATION OF AUTOMATIC RATE ADJUSTMENT
(Thousands of Dollars)

Year	Maximum Allowed Value of Price Increase on Inputs[a]	Minimum Required Productivity Offset[b]	Value of Price Increase on Other Income[c]	Eligible Expense for Rate Adjustment
	A	B	C	D = A-B-C
1954	3,722	2,217	61	1,444
1955	5,836	4,518	22	1,296
1956	5,628	940	196	4,492
1957	8,482	-700	148	9,034
1958	7,796	5,158	92	2,546
1959	16,042	-1,110	156	16,996
1960	14,080	11,103	84	2,893
1961	8,894	7,770	33	1,091
1962	10,170	22,300	103	-12,233
1963	11,404	6,891	147	4,366
1964	12,394	11,532	232	630
1965	14,109	16,368	302	-2,561
1966	25,947	26,875	515	-1,443
1967	28,861	29,696	760	-1,595
1968	32,462	39,879	681	-8,098
1969	45,409	35,344	950	9,115
1970	44,468	33,111	1,085	10,272
1971	37,351	23,584	886	12,881
1972	48,492	44,216	1,408	2,868
Total	381,547	319,692	7,861	53,994

(See footnotes on following page.)

[a]This series is calculated in Table 8-1.

[b]This series is calculated by multiplying the predicted productivity gain for each year (Table 7-2) by the value of total factor input in the previous year (Table 3-7). Standard accounting data are used in each case.

[c]This series is calculated in Table 3-6.

TABLE 8-3

COMPARISON OF AUTOMATIC RATE ADJUSTMENTS
AND HISTORICAL RATE CHANGES
(Percentage Change)

Year	Eligible Expense for Rate Adjustment[a]	Historic Rate Change Minus Effect of Change in Rate of Return to Equity Capital[b]	Historic Rate Change[c]
1954	.7	1.2	-.1
1955	.5	1.1	.7
1956	1.6	.8	.3
1957	3.0	1.5	-.1
1958	.8	.7	.7
1959	4.5	3.7	5.4
1960	.7	.4	.5
1961	.3	.1	-.2
1962	-2.6	-2.0	-1.4
1963	.9	1.1	.4
1964	.1	-.8	.0
1965	-.4	-.8	.0
1966	-.2	-.9	-.8
1967	+.2	-.8	-.3
1968	-1.1	-.5	-.2
1969	1.1	1.5	.4
1970	1.1	1.6	2.5
1971	1.3	2.2	2.7
1972	.3	1.1	2.0

[a]This series is calculated by dividing eligible expenses for rate adjustment (Table 8-2) by total operating revenue in each year (Table 3-1).

[b]This series is calculated by subtracting the value of increased compensation per unit of average total equity capital (Table 3-5) from the value of rate increases (Table 3-1). The difference is then divided by total operating revenues (Table 3-1).

[c]Historic rate changes are indicated by the Implicit Price Index for Bell Canada Services (Table A-20).

allow price increases on inputs to exceed allowable levels. Historic rate changes[1] include the effects of changes in the rate of return to equity. Hence, the two series are not directly comparable. If changes in the rate of return to equity are assumed to be predetermined, historic rate changes can be adjusted to exclude the effects of changing rates of return to equity. This adjusted series (second column of Table 8-3) can be compared with rate changes calculated using the automatic rate adjustment formula. The two series are plotted in Figure 8-1.

Over the period 1954 to 1972, automatic rate adjustments as calculated in this chapter, are very highly correlated with the comparable historical rate changes. If the Canadian Transport Commission had used the ARAC described in this chapter to adjust rates on a year to year basis, rate changes would have been very similar to the comparable historical rate changes which actually took place. In addition, periodic rate cases would have been necessary to set an appropriate level for the allowable rate of return on average total capital.[2] However, the frequency of rate cases would have been less and the

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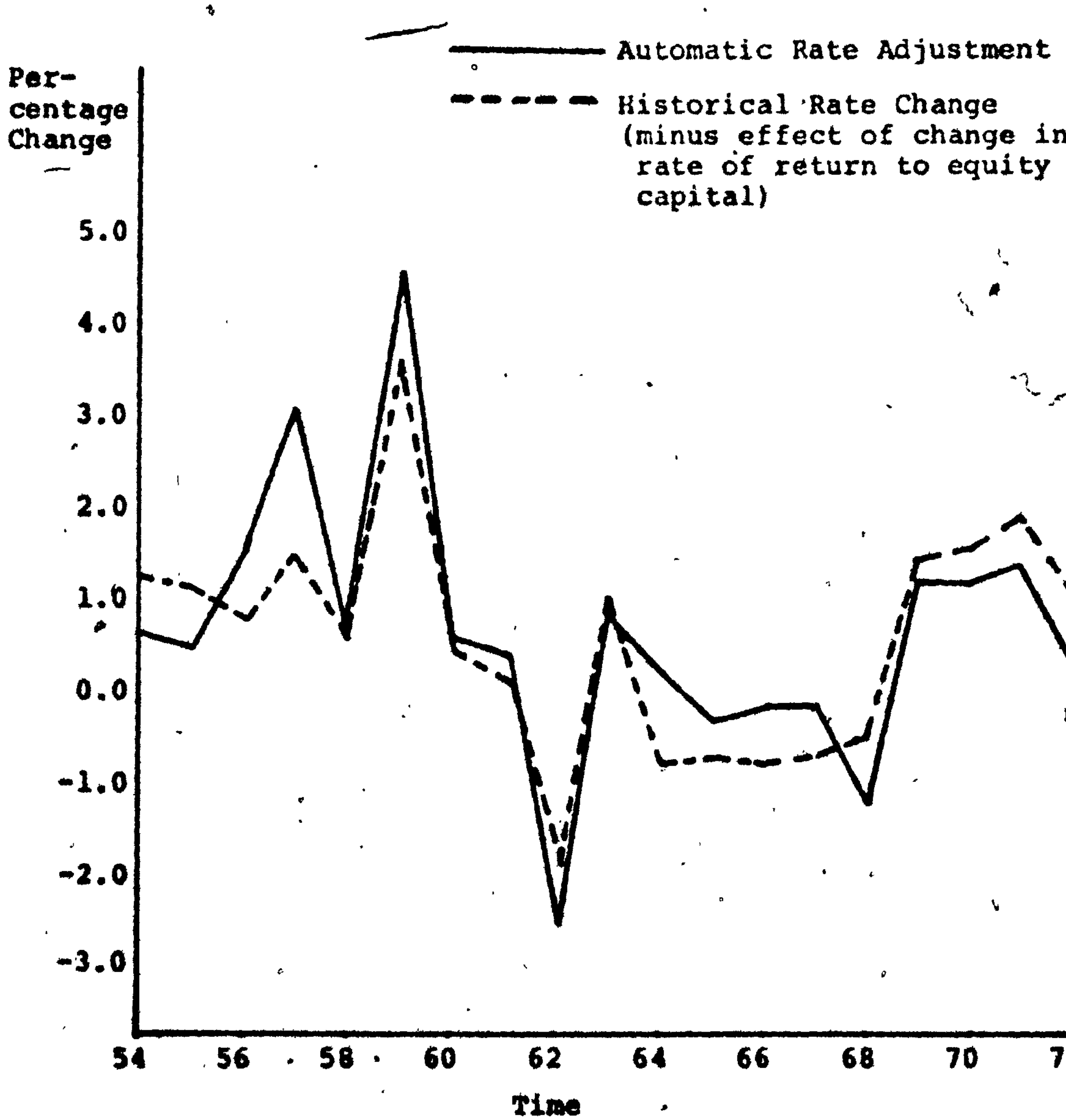
[1] Historic rate changes include the effects of price changes on both regulated and unregulated services. The Implicit Price Index for Bell Services is also determined in part by changes in the mix of services.

[2] Given the debt-equity ratio and the rate of return on debt capital, the allowable rate of return to equity capital is also specified by setting the allowable rate of return on average total capital.

FIGURE 8-1

AUTOMATIC RATE ADJUSTMENTS AND COMPARABLE HISTORIC RATE CHANGES



uncertainty surrounding rate adjustments would have been reduced. As a result, the direct and indirect costs of regulation would have been lower.

C. <u>Implementation of an Automatic Revenue Adjustment Clause</u>

The main concern of this thesis has been to develop a conceptual framework for automatic rate adjustments and a method for specifying the minimum required productivity gain which is required. Agreement must be reached on several issues before an Automatic Revenue Adjustment Clause (ARAC) can be implemented.

Price indexes used to determine allowable expenses in this study were chosen mainly for illustrative purposes. Further study and discussion of each input market is necessary. In particular, it would be desirable if some exogenous price index could be found for employee expense. Indexes used in this study lead to automatic rate adjustments slightly above the comparable historical series from 1964 to 1967. From 1968 to 1972, the situation was reversed. Alternate definitions of allowable expenses could alter this result. Also, implied increases for 1973 should be considered in deciding how allowable expense is to be determined.[1]

Agreement on an appropriate rate of return to total capital and equity capital at the time that the ARAC

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[1]The automatic rate adjustment implied for 1973 is not presented in this study because the most recent input and output data which is publically available covers the period 1952 to 1972.

is initiated represents a second problem. If the company position is that the current rate of return to equity is too low they may not be willing to accept a formula which is based on this rate of return. In Chapter III, it was argued that a range should be established for the allowable rate of return. This would allow the company to be rewarded or punished depending on whether they succeeded in meeting the minimum productivity objective and holding price increases on inputs below allowable levels. Even when the ARAC was implemented, the rate of return could fluctuate within the allowable range and this would increase the incentive for efficient management. However, an appropriate range for the allowable rate of return would have to be agreed upon.

A third problem arises because price changes on unregulated services have not been considered. Theoretically, the calculated automatic rate adjustment applies to price changes on total operating revenues and the dollar value of price changes on unregulated services should be subtracted.

Bell Canada has traditionally maintained high service quality. Quality of service is dependent primarily on long-term investment decisions, but provisions would have to be worked out which ensure that measured productivity objectives are not attained at the cost of a deterioration in the quality of service over time. This tradeoff between service quality and the usual financial performance indicators also exists under the present regulatory environment.

Finally, the timing of rate adjustments would have to be determined. It has been assumed in this study that rate adjustments would be made at the beginning of each year for the previous year. If rate adjustments are desired at the end of each year for the following year, the problem becomes more complicated. A forecast of the income statement and the relevant price indexes would be required. In addition, agreement on some rebate scheme would be necessary.

Initially, I would suggest that the ARAC be implemented on a trial basis. Revisions could be made as experience was gained in the use of the formula. Very small rate adjustments might be left to cumulate until the next year. Especially during this introductory period, both Bell Canada and the Canadian Transport Commission would want to maintain the right to initiate a full scale rate case and bypass the formula adjustment in a particular year.

Chapter IX

SUMMARY AND CONCLUSIONS

Initially, a brief description of the telecommunications industry and of Bell Canada operations was made. The need for some type of automatic mechanism for making rate adjustments in an inflationary period was apparent. This would eliminate the need for continuing rate cases and thereby reduce the direct costs of regulation. Indirect costs arising from uncertainty surrounding future price adjustments and the resulting higher costs of capital would also be reduced.

Several desirable properties for an Automatic Rate Adjustment Clause (ARAC) were discussed. The implementation of an ARAC should not interfere with other regulatory issues such as the relative price of different competitive and noncompetitive services or the extent of vertical integration. Also, there should be no reduction in the incentive for efficient management and no implied bias concerning management resource allocation decisions. Any ARAC which is proposed must be easy to understand, convenient to administer, based on recent cost trends and acceptable politically.

The general form for the ARAC which is proposed in this study can be represented as

$$\text{Dollar Value of Rate Adjustment} = \text{Dollar Value of \underline{Maximum} Allowed Price Increase on Inputs} - \text{Dollar Value of \underline{Minimum} Productivity Gain Required} - \text{Dollar Value of Rate Increases on Other Income}$$

This formula would protect the rate of return to equity capital in the previous period provided that the company met the productivity objective and did not allow price increases on inputs to exceed allowable levels. If the company achieves a higher productivity gain or holds input price increases below the level required by the ARAC, some of the additional profits should remain with shareholders. Similarly, if the company does not meet the performance standards specified in the ARAC, shareholders should suffer. This type of incentive could be achieved if a range was specified for the allowable rate of return. The ARAC would only be fully operative if the rate of return after price adjustment fell within the allowed range.

The main concern of this thesis has been the specification of an appropriate productivity objective. Since different potentials for productivity improvement exist in different companies and different industries, a reasonable productivity objective can only be set by determining the productivity gain that Bell Canada achieved in previous periods under similar circumstances.

In this way, the productivity gain required by the ARAC is at least as high as the gains which have been recorded under the present regulatory environment. A production model is required for Bell Canada if minimum required productivity gains are to be specified in this way.

Standard accounting data as contained in an income statement were used to calculate the dollar value of price changes and productivity gains. Eventually, productivity gains must be specified in terms of this index. However, better measures of physical inputs and outputs can be calculated. A full description of the data used in this study to fit production and productivity models is given in Chapter IV. Most of these data series have been presented by Bell Canada as part of productivity testimony and are publically available for the period 1952 to 1972.

Over this time period, it was impossible to determine if technological change for Bell Canada was Hicks neutral or some other non-neutral form, such as capital augmenting or capital additive. More general types of production functions were estimated, but a modified Cobb-Douglas function produced the best results. Constant elasticity of substitution and nonhomogeneous forms either could not be estimated reliably, could not be interpreted meaningfully or reduced to the simple Cobb-Douglas form. The hypothesis that returns to scale were constant and that the elasticity of substitution was equal to one cannot be rejected based on results obtained in this study. Of course, increasing returns are possible at levels of production lower than were observed during the sample period. Due to collinearity between the capital and technology proxy variable, the relative capital and labor coefficients could not be estimated with precision and estimated production functions were not used to test if Bell Canada employs too much capital.

A production function explains the long-term trend of productivity. However, capacity utilization data were not available and measured inputs do not reflect inputs which are actually utilized. In particular years, fairly large residuals occur in the estimated production function. Although a production function is useful in explaining the long-term trends of measured productivity gains, year to year oscillations are left largely unexplained in a capital intensive industry where labor inputs are also fixed in nature.

An input requirement model implicitly allows for changing utilization levels, but could not be estimated reliably because of collinearity among Bell Canada time series data. Another approach is to assume a linear adjustment process for the increase in total factor input. Given the increase in output, the desired gain in total factor input is implied by the desired productivity gain. Although the rate of change of exogenous technical knowledge may be constant, it was assumed that desired productivity gains are determined by the opportunity to incorporate technological improvements and that this opportunity varies proportionately with the growth of output. A productivity forecasting model based on these assumptions provided a good explanation of productivity gains over the period 1954 to 1972. Implied structural coefficients were also reasonable and varied only slightly when the model was fitted over different sample periods.

A technique was developed to calculate the implied dollar value of productivity forecasts. These dollar values must be consistent with other dollar values shown on an income statement. As stated above, when these dollar values are used to calculate an automatic rate adjustment, the required productivity gains are at least as high as those achieved under the present regulatory system in a similar situation. This calculated productivity offset shows large variations from year to year and illustrates the impossibility of setting a reasonable productivity objective based on a simple average of past productivity gains.

For illustrative purposes, an example was given of the type of maximum allowable input price increases which might be set. Automatic rate adjustments and comparable historic rate changes over the period 1954 to 1972 were calculated. The two series corresponded very closely and the implication is that the Canadian Transport Commission could have used this method of adjusting rates on an annual basis. In addition, periodic rate cases would be required to consider other regulatory problems and to adjust the allowable rate of return.

Agreement must be reached on several issues before an ARAC can be implemented. The exact specification of allowable cost increases on each input and the timing involved require further discussion. However, I believe that a feasible ARAC for Bell Canada could be implemented within the framework discussed in this thesis. The productivity forecasting model itself could be used internally by Bell Canada or by a regulatory body to analyze the consistency of revenue and cost estimates contained in a budget view. In fact, a general approach to the specification of more realistic productivity objectives and price guidelines has been put forward. This approach should be equally applicable to other companies, to other industries and indeed to the entire economy.

APPENDIX A

DATA USED IN CALCULATION OF ECONOMIST'S TOTAL FACTOR PRODUCTIVITY MEASURE AND IN RESEARCH CONCERNING PRODUCTION PROCESS

TABLE A-1

LOCAL SERVICE REVENUE
(Millions)

Year	Current $ Value	Local Service Price Index	1967 $ Value
1952	116.79	92.40	126.40
1953	127.79	93.30	136.97
1954	138.05	93.30	147.96
1955	151.98	93.30	162.90
1956	169.51	93.30	181.68
1957	187.17	93.30	200.61
1958	203.42	93.90	216.63
1959	233.63	100.00	233.63
1960	250.87	100.00	250.87
1961	269.52	100.00	269.52
1962	289.61	100.00	289.61
1963	308.70	100.00	308.70
1964	325.01	100.00	325.01
1965	350.77	100.00	350.77
1966	380.74	100.00	380.74
1967	409.99	100.00	409.99
1968	437.55	100.00	437.55
1969	472.83	100.00	472.83
1970	512.36	100.00	512.36
1971	567.93	103.90	546.61
1972	629.31	106.80	589.24

TABLE A-2

INTRA-BELL TELEPHONE MESSAGE TOLL SERVICE REVENUE
(Millions)

Year	Current $ Value	Intra-Bell Telephone Message Toll Service Price Index	1967 $ Value
1952	47.88	106.05	45.15
1953	51.21	106.05	48.29
1954	54.82	106.05	51.70
1955	61.00	106.05	57.52
1956	67.90	106.05	64.03
1957	72.30	106.05	68.18
1958	75.23	107.26	70.14
1959	85.44	113.31	75.40
1960	89.24	113.31	78.76
1961	94.88	111.81	84.86
1962	104.38	104.32	100.06
1963	108.93	104.32	104.42
1964	117.38	104.32	112.52
1965	130.75	104.32	125.33
1966	137.99	100.72	137.00
1967	152.77	100.00	152.77
1968	162.69	98.78	164.70
1969	185.73	99.22	187.19
1970	220.42	110.93	198.70
1971	231.05	113.41	203.73
1972	255.50	115.79	220.65

TABLE A-3

TRANS-CANADA AND ADJACENT MEMBER TELEPHONE
MESSAGE TOLL SERVICE REVENUE
(Millions)

Year	Current $ Value	Trans-Canada Telephone Message Toll Service Price Index	1967 $ Value
1952	2.30	109.19	2.11
1953	2.66	112.26	2.37
1954	3.01	114.10	2.64
1955	5.53	114.10	4.84
1956	6.53	114.10	5.73
1957	7.40	114.10	6.48
1958	8.54	114.10	7.48
1959	9.93	113.64	8.73
1960	10.68	112.69	9.48
1961	11.59	109.56	10.58
1962	12.80	105.92	12.09
1963	13.92	104.10	13.37
1964	15.31	103.14	14.85
1965	16.74	102.18	16.38
1966	19.69	100.36	19.62
1967	20.10	100.00	22.10
1968	25.27	99.90	25.29
1969	29.20	99.65	29.31
1970	31.85	99.65	31.96
1971	34.92	99.65	35.04
1972	42.42	99.62	42.58

TABLE A-4

CANADA-UNITED STATES AND OVERSEAS TELEPHONE MESSAGE TOLL SERVICE REVENUE (Millions)

Year	Current $ Value	Canada-U.S. & Overseas Telephone Message Toll Service Price Index	1967 $ Value
1952	5.77	94.46	6.11
1953	6.56	94.46	6.95
1954	7.46	94.46	7.89
1955	8.30	94.46	8.79
1956	9.76	93.83	10.40
1957	11.79	91.45	12.89
1958	13.01	91.45	14.22
1959	14.92	91.45	16.31
1960	17.35	100.44	17.27
1961	16.94	102.34	16.55
1962	18.29	102.34	17.87
1963	20.38	102.34	19.91
1964	24.90	102.34	24.33
1965	29.36	102.34	28.69
1966	35.56	102.34	34.75
1967	38.96	100.00	38.96
1968	42.69	100.00	42.69
1969	49.82	100.47	49.58
1970	55.94	100.63	55.59
1971	60.21	100.63	59.83
1972	71.74	100.63	71.29

TABLE A-5

OTHER TOLL SERVICE REVENUE
(Millions)

Year	Current $ Value	Other Toll Service Price Index	1967 $ Value
1952	1.63	97.61	1.67
1953	2.30	100.14	2.29
1954	2.95	101.67	2.90
1955	4.39	101.67	4.32
1956	6.39	101.67	6.29
1957	7.95	101.67	7.82
1958	9.43	101.67	9.28
1959	10.71	101.67	10.54
1960	12.71	101.67	12.50
1961	14.96	101.67	14.71
1962	18.32	101.79	17.99
1963	22.05	101.92	21.64
1964	30.79	101.80	30.25
1965	35.36	101.39	34.88
1966	40.00	100.06	39.98
1967	45.12	100.00	45.12
1968	54.07	99.90	54.12
1969	64.45	101.66	63.40
1970	73.98	101.60	72.81
1971	80.36	104.00	77.25
1972	94.96	104.57	90.81

TABLE A-6

MISCELLANEOUS SERVICE REVENUE - DIRECTORY ADVERTISING
(Millions)

Year	Current $ Value	Directory Advertising Price Index	1967 $ Value
1952	7.21	67.90	10.62
1953	8.05	67.90	11.85
1954	9.34	67.90	13.75
1955	10.72	73.10	14.67
1956	12.32	74.90	16.45
1957	14.79	77.40	19.11
1958	17.65	80.00	22.07
1959	20.45	86.30	23.70
1960	22.50	89.60	25.11
1961	23.49	90.20	26.05
1962	25.05	91.80	27.28
1963	26.05	100.00	26.05
1964	26.51	100.00	26.51
1965	27.41	100.00	27.41
1966	28.41	100.00	28.41
1967	30.21	100.00	30.21
1968	32.53	101.30	32.12
1969	35.56	105.30	33.77
1970	38.66	105.30	36.72
1971	41.58	105.30	39.49
1972	45.71	105.30	43.40

TABLE A-7

MISCELLANEOUS REVENUE - OTHER
(Millions)

Year	Current $ Value	Other Miscellaneous Service Price Index[1]	1967 $ Value
1952	3.17	74.10	4.28
1953	3.78	74.00	5.11
1954	4.26	75.20	5.67
1955	3.54	75.60	4.68
1956	2.22	78.40	2.83
1957	2.49	80.10	3.11
1958	2.67	81.20	3.29
1959	2.89	82.90	3.48
1960	3.09	83.90	3.68
1961	3.95	84.30	4.69
1962	4.48	85.50	5.23
1963	5.20	87.00	5.98
1964	5.11	89.20	5.73
1965	5.37	92.10	5.83
1966	5.81	96.20	6.04
1967	6.42	100.00	6.42
1968	7.00	103.20	6.78
1969	8.55	107.80	7.93
1970	9.56	112.70	8.49
1971	10.45	116.20	9.00
1972	11.93	121.50	9.82

[1] Implicit price index for Gross National Expenditure

TABLE A-8

BELL CANADA OPERATING REVENUES (CURRENT DOLLARS)
(Millions)

Year	Service	Toll Revenues		Miscellaneous		Total
		Telephone Message	Others	Directory Advertising	Other	
1952	116.79	55.96	1.63	7.21	3.17	184.76
1953	127.79	60.43	2.30	8.05	3.78	202.35
1954	138.05	65.29	2.95	9.34	4.26	219.88
1955	151.98	74.82	4.39	10.72	3.54	245.46
1956	169.51	84.19	6.39	12.32	2.22	274.64
1957	187.17	91.49	7.95	14.79	2.49	303.88
1958	203.42	96.77	9.43	17.65	2.67	329.94
1959	233.63	110.28	10.71	20.45	2.89	377.96
1960	250.87	117.27	12.71	22.50	3.09	406.44
1961	269.52	123.41	14.96	23.49	3.95	435.32
1962	289.61	135.47	18.32	25.05	4.48	472.92
1963	308.70	143.23	22.05	26.05	5.20	505.23
1964	325.01	157.60	30.79	26.51	5.11	545.01
1965	350.77	176.84	35.36	27.41	5.37	595.76
1966	380.74	193.24	40.00	28.41	5.81	648.20
1967	409.99	213.83	45.12	30.21	6.42	705.56
1968	437.55	232.68	54.07	32.53	7.00	761.80
1969	472.83	264.75	64.45	35.56	8.55	846.15
1970	512.36	308.20	73.98	38.66	9.56	942.77
1971	567.93	326.17	80.36	41.58	10.45	1,026.49
1972	629.31	369.66	94.96	45.71	11.93	1,151.56

TABLE A-9

BELL CANADA OPERATING REVENUES (1967 DOLLARS)
(Millio[illegible]

Year	Local Service	Toll Revenue: Telephone Message	Toll Revenue: Other	Miscellaneous: Directory Advertising	Miscellaneous: Other	Total
1952	126.40	53.37	1.67	10.62	4.28	196.33
1953	136.97	57.60	2.29	11.85	5.11	213.83
1954	147.96	62.22	2.90	13.75	5.67	232.51
1955	162.90	71.15	4.32	14.67	4.68	257.71
1956	181.68	80.15	6.29	16.45	2.83	287.41
1957	200.61	87.55	7.82	19.11	3.11	318.20
1958	216.63	91.84	9.28	22.07	3.29	343.11
1959	233.63	100.45	10.54	23.70	3.48	371.80
1960	250.87	105.51	12.50	25.11	3.68	397.68
1961	269.52	111.99	14.71	26.05	4.69	426.94
1962	289.61	130.02	17.99	27.28	5.23	470.14
1963	308.70	137.70	21.64	26.05	5.98	500.07
1964	325.01	151.70	30.25	26.51	5.73	539.19
1965	350.77	170.40	34.88	27.41	5.83	589.30
1966	380.74	191.37	39.98	28.41	6.04	646.54
1967	409.99	213.83	45.12	30.21	6.42	705.56
1968	437.55	232.68	54.12	32.12	6.78	763.26
1969	472.83	266.08	63.40	33.77	7.93	844.02
1970	512.30	286.25	72.81	36.72	8.49	916.62
1971	546.61	298.60	77.26	39.49	9.00	970.96
1972	589.24	223.42	90.81	43.40	9.82	1,067.80

TABLE A-10

GROSS OUTPUT (CURRENT DOLLARS)
(Millions)

Year	Total Operating Revenues (A)	Cost of Materials Rent, Services and Supplies (B)	Non-Income Taxes (C)	Gross Output (D=A-B-C)
1952	184.76	28.73	6.60	149.43
1953	202.35	30.77	7.18	164.39
1954	219.88	35.00	7.73	177.15
1955	245.46	40.33	8.84	196.29
1956	274.64	49.01	9.84	215.79
1957	303.88	50.41	11.86	241.62
1958	329.94	56.26	12.90	260.79
1959	377.96	60.38	14.53	303.06
1960	406.44	63.87	16.69	325.88
1961	435.32	66.91	18.86	348.55
1962	472.92	72.66	20.16	380.10
1963	505.23	78.00	21.50	405.72
1964	545.01	80.11	23.12	441.78
1965	585.76	90.21	25.31	480.24
1966	648.20	98.01	29.91	520.29
1967	705.56	98.71	35.72	571.13
1968	761.80	107.29	38.80	615.71
1969	846.15	133.44	44.68	668.03
1970	942.77	138.82	45.48	758.47
1971	1,026.49	160.93	52.38	813.18
1972	1,151.56	185.90	54.19	911.47

TABLE A-11

GROSS OUTPUT (1967 DOLLARS)
(Millions)

Year	Operating Revenues (A)	Cost of Materials Rent, Services and Supplies (B)	Non-Income Taxes (C)	Gross Output (D=A-B-C)
1952	196.33	38.77	8.90	148.66
1953	213.83	41.58	9.71	162.54
1954	232.51	46.55	10.28	175.67
1955	257.71	53.35	11.69	192.68
1956	287.41	62.51	12.55	212.35
1957	318.20	62.94	14.81	240.46
1958	343.11	69.28	15.89	257.93
1959	371.80	72.83	17.52	281.45
1960	397.68	76.13	19.90	301.66
1961	426.94	79.37	22.37	325.20
1962	470.14	84.98	23.58	361.58
1963	500.07	89.66	24.71	385.69
1964	539.19	89.81	25.92	423.46
1965	589.30	97.95	27.48	463.85
1966	646.54	101.88	31.09	513.57
1967	705.56	98.71	35.72	571.13
1968	763.26	103.96	37.59	621.70
1969	844.02	123.78	41.45	678.79
1970	916.62	123.18	40.35	753.09
1971	970.96	138.50	45.08	787.38
1972	1,067.80	153.00	44.60	850.20

TABLE A-12

GROSS OUTPUT MINUS WRITEOFFS (CURRENT DOLLARS)
(Millions)

Year	Gross Output	Writeoffs[1]	Gross Output Minus Writeoffs
1952	149.43	21.25	128.18
1953	164.39	20.51	143.88
1954	177.15	24.46	152.69
1955	196.29	29.32	166.98
1956	215.79	31.82	183.97
1957	241.62	34.05	207.57
1958	260.79	34.28	226.51
1959	303.06	45.74	257.32
1960	325.88	55.94	269.94
1961	349.55	54.75	294.80
1962	380.10	68.05	312.06
1963	405.72	70.06	335.67
1964	441.78	76.20	365.58
1965	480.24	68.46	411.77
1966	520.29	77.31	442.98
1967	571.13	85.41	485.72
1968	615.71	90.52	525.19
1969	668.03	112.64	555.39
1970	758.47	126.08	632.39
1971	813.18	136.02	677.16
1972	911.47	167.43	744.04

[1] 1952-56 data were estimated as 20 per cent of expenditures on new construction in each year.

TABLE A-13

GROSS OUTPUT MINUS WRITEOFFS (1967 DOLLARS)
(Millions)

Year	Gross Output	Writeoffs	Gross Output Minus Writeoffs
1952	148.66	24.60	124.07
1953	162.54	24.19	138.35
1954	175.67	29.15	146.52
1955	192.68	34.98	157.70
1956	212.35	37.39	174.96
1957	240.46	39.78	200.68
1958	257.93	39.81	218.12
1959	281.45	53.06	228.39
1960	300.66	64.60	237.06
1961	325.20	63.45	261.75
1962	361.58	78.03	283.55
1963	385.69	79.52	306.17
1964	423.46	86.69	336.77
1965	463.86	76.58	387.28
1966	513.57	82.50	431.07
1967	571.13	85.41	485.72
1968	621.70	86.29	535.41
1969	678.79	102.49	576.30
1970	753.09	107.03	646.07
1971	787.38	109.60	677.78
1972	870.20	127.61	742.59

TABLE A-14

NET OUTPUT (CURRENT DOLLARS)
(Millions)

Year	Gross Output	Depreciation	Net Output
1952	149.43	29.95	119.49
1953	164.39	32.36	132.04
1954	177.14	35.00	142.15
1955	196.29	38.03	158.26
1956	215.79	43.74	172.05
1957	241.62	55.22	186.40
1958	260.79	62.75	198.03
1959	303.06	72.37	230.69
1960	325.88	79.55	246.33
1961	349.55	86.21	263.34
1962	380.10	94.98	285.13
1963	405.72	106.65	299.08
1964	441.78	115.19	326.59
1965	480.24	127.24	353.00
1966	520.29	145.01	375.28
1967	571.13	165.90	405.23
1968	615.71	187.33	428.38
1969	668.03	214.26	453.78
1970	758.47	242.59	515.88
1971	813.18	270.54	542.64
1972	911.47	320.11	591.36

TABLE A-15

NET OUTPUT (1967 DOLLARS)
(Millions)

Year	Gross Output	Depreciation	Net Output
1952	148.66	34.66	114.01
1953	162.54	38.16	124.38
1954	175.67	41.72	133.96
1955	192.68	45.38	147.29
1956	212.35	51.40	160.95
1957	240.46	64.51	175.95
1958	257.93	72.88	185.05
1959	281.45	83.95	197.49
1960	301.66	91.86	209.80
1961	325.20	99.90	225.30
1962	361.58	108.92	252.66
1963	385.69	121.05	264.64
1964	423.46	131.05	292.41
1965	463.86	142.32	321.53
1966	513.57	154.76	358.81
1967	571.13	165.90	405.23
1968	621.70	178.58	443.12
1969	678.79	194.96	483.83
1970	753.09	205.94	547.16
1971	787.38	218.00	569.39
1972	870.20	243.99	626.21

TABLE A-16

MANHOURS WORKED (EXCLUDING CONSTRUCTION)
(Millions)

Year	Telephone Operators	Plant Craftsmen	Clerical Non-Supervisors	Other Non-Supervisors	Foremen and Supervisors	Executive and Staff	Part-Time and Occasional	Total
1952	18.317	8.304	7.770	4.065	5.503	2.946	1.494	48.399
1953	17.730	8.604	8.139	4.214	5.704	3.080	1.508	48.979
1954	18.967	9.167	9.080	4.478	5.124	3.336	1.625	51.777
1955	19.978	10.613	10.279	4.962	4.725	3.700	1.819	56.076
1956	19.616	11.762	11.658	5.754	5.217	4.175	2.061	60.243
1957	19.788	12.106	12.159	6.462	5.482	4.487	2.095	62.579
1958	18.022	12.493	12.015	6.617	5.337	4.645	2.125	61.254
1959	15.505	12.282	11.165	6.090	5.560	4.608	2.342	57.552
1960	13.938	11.922	10.844	5.739	5.424	4.802	2.385	55.054
1961	12.212	11.543	10.311	5.608	5.181	4.820	2.117	51.792
1962	12.190	11.162	10.496	5.677	4.957	4.986	2.129	51.597
1963	12.797	11.620	10.978	5.817	4.899	5.086	1.992	53.189
1964	12.711	11.960	11.463	5.948	4.609	5.457	1.940	54.088
1965	12.428	12.925	11.544	6.119	4.455	5.947	2.084	55.502
1966	13.139	13.108	12.447	6.662	4.607	6.312	2.034	58.309
1967	12.362	12.902	11.828	6.517	4.908	6.227	1.836	56.580
1968	11.741	12.432	11.370	6.294	4.800	6.143	1.781	54.561
1969	11.846	12.620	11.734	6.422	4.707	6.363	1.843	55.535
1970	11.303	12.829	11.704	6.780	4.867	6.833	1.817	56.133
1971	10.226	12.866	11.642	7.026	5.062	7.309	1.661	55.792
1972	10.076	12.501	11.908	7.366	5.060	7.821	1.642	56.374

TABLE A-17

WEIGHTED MANHOURS WORKED (EXCLUDING CONSTRUCTION)
(Millions)

Year	Telephone Operators	Plant Craftsmen	Clerical Non-Supervisors	Other Non-Supervisors	Foremen and Supervisors	Executive and Staff	Part-Time and Occasional	Total
1952	12.092	8.372	5.959	3.917	7.640	5.482	1.463	44.926
1953	11.783	8.817	6.248	4.094	7.926	5.714	1.475	46.059
1954	12.714	9.350	6.896	4.344	7.180	6.112	1.593	48.188
1955	13.518	10.681	7.751	4.782	6.684	6.697	1.775	51.889
1956	13.218	11.499	8.683	5.492	7.333	7.438	1.999	55.661
1957	13.280	11.668	9.017	6.110	7.721	7.966	2.035	57.798
1958	12.220	12.209	9.016	6.300	7.526	8.252	2.074	57.596
1959	10.709	12.959	8.517	5.938	7.941	8.217	2.248	56.529
1960	9.704	12.340	8.287	5.658	7.782	8.547	2.278	54.597
1961	8.551	12.168	7.935	5.548	7.507	8.690	2.043	52.442
1962	8.451	11.862	8.076	5.601	7.260	9.011	2.019	52.279
1963	8.720	12.313	8.450	5.714	7.179	9.254	1.888	53.518
1964	8.605	12.549	8.825	5.855	6.737	10.022	1.834	54.427
1965	8.400	13.233	8.847	6.006	6.481	10.886	1.946	55.799
1966	8.777	12.948	9.370	6.434	6.650	11.399	1.892	57.470
1967	8.281	12.892	8.962	6.362	7.067	11.286	1.727	56.578
1968	7.928	12.744	8.707	6.221	6.924	11.204	1.761	55.488
1969	8.029	12.031	8.993	6.333	6.760	11.573	1.879	56.598
1970	7.730	13.266	9.023	6.665	6.956	12.340	1.855	57.835
1971	7.067	13.257	8.976	6.878	7.195	13.050	1.701	58.125
1972	6.998	12.929	9.177	7.191	7.171	13.848	1.684	58.998

TABLE A-18

GROSS CAPITAL STOCK[a]
(Millions)

Year	Gross Plant (Current $)	Gross Plant (1967 $)
1952	754.18	872.90
1953	809.98	955.17
1954	884.17	1,053.84
1955	922.47	1,184.33
1956	1,130.76	1,328.74
1957	1,278.60	1,493.70
1958	1,446.18	1,679.66
1959	1,606.65	1,863.87
1960	1,776.99	2,051.95
1961	1,927.42	2,233.39
1962	2,102.05	2,410.61
1963	2,291.39	2,600.90
1964	2,456.32	2,794.45
1965	2,674.94	2,9[illegible]2.11
1966	3,013.03	3,215.62
1967	3,463.23	3,463.23
1968	3,894.68	3,712.76
1969	4,365.71	3,972.44
1970	4,982.20	4,229.37
1971	5,577.05	4,494.00
1972	6,268.57	4,777.87

[a]Includes Average Plant Under Construction

TABLE A-19

NET CAPITAL STOCK[a]
(Millions)

Year	Net Plant (Current $)	Net Plant (1967 $)
1952	531.85	615.56
1953	574.53	677.51
1954	631.12	752.23
1955	717.87	856.65
1956	828.71	973.81
1957	949.44	1,109.16
1958	1,084.84	1,259.98
1959	1,211.67	1,405.65
1960	1,346.37	1,554.70
1961	1,461.42	1,693.41
1962	1,593.45	1,827.35
1963	1,736.91	1,971.52
1964	1,855.30	2,110.69
1965	2,004.02	2,241.63
1966	2,233.98	2,384.18
1967	2,538.86	2,538.86
1968	2,816.47	2,684.91
1969	3,117.85	2,836.99
1970	3,515.29	2,984.12
1971	3,905.63	3,147.16
1972	4,345.66	3,312.24

[a]Includes Average Plant Under Construction

TABLE A-20

IMPLICIT PRICE INDEXES FOR OUTPUT

Year	Local Service	Total Toll Service	Total Miscellaneous Service	Total Bell Canada Service
1952	92.40	104.63	69.68	94.10
1953	93.30	104.73	69.74	94.63
1954	93.30	104.78	70.03	94.57
1955	93.30	104.97	73.70	95.25
1956	93.30	104.79	75.41	95.56
1957	93.30	104.26	77.78	95.50
1958	93.90	105.03	80.16	96.16
1959	100.00	109.02	85.86	101.66
1960	100.00	110.14	88.87	102.20
1961	100.00	109.21	89.30	101.96
1962	100.00	103.90	90.79	100.59
1963	100.00	103.73	97.57	101.03
1964	100.00	103.54	98.08	101.08
1965	100.00	103.37	98.61	101.10
1966	100.00	100.82	99.33	100.25
1967	100.00	100.00	100.00	100.00
1968	100.00	99.27	101.63	99.81
1969	100.00	99.92	105.78	100.25
1970	100.00	106.44	106.69	102.85
1971	103.90	108.16	107.32	105.72
1972	106.80	109.23	108.29	107.84

TABLE A-21

PRICE OF AGGREGATE LABOR INPUT

Year	Employee Expense	Employee Expense Per Weighted Manhour	(Employee Expense Per Weighted Manhour) ÷ Implicit Price Index for Bell Services
1952	75.33	1.677	1.78
1953	83.05	1.803	1.91
1954	90.63	1.881	1.99
1955	101.76	1.961	2.06
1956	111.73	2.007	2.10
1957	121.08	2.095	2.19
1958	127.29	2.210	2.30
1959	130.98	2.317	2.28
1960	134.47	2.463	2.41
1961	136.68	2.606	2.56
1962	142.32	2.722	2.71
1963	150.48	2.812	2.78
1964	157.03	2.885	2.85
1965	166.00	2.975	2.94
1966	181.22	3.153	3.15
1967	192.58	3.404	3.40
1968	204.79	3.691	3.70
1969	226.28	3.998	3.99
1970	255.78	4.422	4.30
1971	282.12	4.853	4.59
1972	314.18	5.326	4.94

TABLE A-22

PRICE INDEXES FOR DISAGGREGATE LABOR INPUTS

Year	Telephone Operators	Plant Craftsmen	Clerical Non-Supervisors	Other Non-Supervisors	Foremen and Supervisors	Executive and Staff	Part-Time and Occasional	Total
1952	2.016	1.913	1.994	1.744	1.734	1.739	1.750	1.782
1953	2.092	1.963	2.069	1.864	1.855	1.859	1.871	1.905
1954	2.180	2.013	2.149	1.947	1.936	1.940	1.953	1.989
1955	2.230	2.048	2.173	2.015	2.004	2.008	2.022	2.059
1956	2.288	2.114	2.235	2.055	2.044	2.048	2.063	2.100
1957	2.440	2.225	2.369	2.147	2.135	2.139	2.154	2.194
1958	2.542	2.307	2.474	2.249	2.237	2.241	2.257	2.298
1959	2.475	2.267	2.420	2.230	2.218	2.223	2.238	2.279
1960	2.542	2.341	2.502	2.358	2.345	2.350	2.367	2.410
1961	2.629	2.415	2.571	2.501	2.487	2.493	2.510	2.556
1962	2.727	2.528	2.670	2.648	2.633	2.639	2.657	2.706
1963	2.817	2.591	2.722	2.724	2.709	2.715	2.734	2.783
1964	2.917	2.682	2.801	2.793	2.778	2.784	2.908	2.854
1965	2.917	2.855	2.920	2.879	2.864	2.870	2.890	2.943
1966	3.085	3.110	3.097	3.077	3.061	3.067	3.088	3.145
1967	3.320	3.350	3.331	3.331	3.313	3.320	3.343	3.404
1968	2.957	3.586	3.537	3.514	3.476	3.483	3.632	3.698
1969	3.817	3.919	3.841	3.778	3.720	3.728	3.916	3.988
1970	4.092	4.208	4.056	3.978	3.967	3.976	4.223	4.299
1971	4.693	4.428	4.246	4.047	4.184	4.192	4.509	4.590
1972	4.999	4.787	4.538	4.328	4.499	4.509	4.851	4.939
Percentage Increase								
1952-62	35	32	34	52	52	52	52	52
1962-72	83	89	70	63	71	71	83	83

TABLE A-23

VARIABLES USED TO CALCULATE USER COST OF CAPITAL

Year	Telephone Plant Price Index (q_t)	Effective Corporate Income Tax Rate (u_t)	Depreciation for Tax Purpose: Depreciation in Current Dollars (v_t)	Depreciation Rate (δ_t)
1952	.8640	.5288	1.087	.0397
1953	.8480	.4881	1.154	.0399
1954	.8390	.4882	1.223	.0396
1955	.8380	.4682	2.006	.0383
1956	.8510	.4683	1.585	.0387
1957	.8560	.4817	1.434	.0432
1958	.8610	.4817	.919	.0434
1959	.8620	.5117	.926	.0450
1960	.8660	.5117	.931	.0448
1961	.8630	.5199	.937	.0447
1962	.8720	.5199	.935	.0452
1963	.8810	.5200	.936	.0465
1964	.8790	.5200	.945	.0469
1965	.8940	.5199	.934	.0476
1966	.9370	.5199	.898	.0481
1967	1.0000	.5199	1.198	.0479
1968	1.0490	.5340	1.120	.0481
1969	1.0990	.5341	1.062	.0491
1970	1.1780	.5341	1.018	.0487
1971	1.2410	.5104	1.126	.0485
1972	1.3120	.4850	1.357	.0511

TABLE A-24

ALTERNATE VERSIONS OF RATE OF RETURN TO CAPITAL

Year	Before Tax Rate of Return on Total Average Net Plant ($r_{B1,t}$)	Before Tax Rate of Return on Total Average Gross Plant ($r_{B2,t}$)	Before Tax Opportunity Cost of Capital -Bell Equity -Marginal Debt ($r_{B3,t}$)	Before Tax Opportunity Cost of Capital -Bell Equity -Embedded Debt ($r_{B4,t}$)	Before Tax Opportunity Cost of Capital -Telephone Equity -Marginal Debt ($r_{B5,t}$)	Before Tax Opportunity Cost of Capital -Telephone Equity -Embedded Debt ($r_{B6,t}$)
1952	.0830	.0701	.1155	.1131	.1183	.1159
1953	.0853	.0751	.1140	.1094	.1261	.1215
1954	.0816	.0702	.1037	.1032	.1205	.1200
1955	.0787	.0657	.0999	.0988	.1283	.1273
1956	.0728	.0639	.0974	.0958	.1260	.1244
1957	.0688	.0676	.0938	.0891	.1309	.1262
1958	.0652	.0686	.0906	.0888	.1254	.1236
1959	.0823	.0786	.1103	.1044	.1387	.1328
1960	.0831	.0762	.12[illegible]6	.1127	.1508	.1389
1961	.0867	.0820	.1115	.1048	.1408	.1341
1962	.0896	.0807	.1138	.1096	.1428	.1386
1963	.0856	.0808	.1084	.1061	.1447	.1424
1964	.0914	.0849	.1130	.1128	.1463	.1462
1965	.0933	.0919	.1183	.1180	.1522	.1519
1966	.0869	.0869	.1204	.1162	.1533	.1491
1967	.0838	.0846	.1395	.1200	.1464	.1401
1968	.0794	.0823	.1323	.1240	.1460	.1378
1969	.0730	.0754	.1266	.1151	.1452	.1336
1970	.0740	.0756	.1407	.1236	.1525	.1354
1971	.0667	.0708	.1322	.1226	.1404	.1308
1972	.0638	.0686	.1332	.1231	.1370	.1269

TABLE A-25

ALTERNATE VERSIONS OF THE USER COST OF CAPITAL[a]

Version Year	$c_{B1,t}$	$c_{B2,t}$	$c_{B3,t}$	$c_{B4,t}$	$c_{B5,t}$	$c_{B6,t}$
1952	.1090	.0972	.1389	.1368	.1414	.1393
1953	.1069	.0977	.1326	.1285	.1435	.1394
1954	.1000	.0900	.1197	.1193	.1346	.1342
1955	.0731	.0616	.0918	.0908	.1167	.1159
1956	.0816	.0737	.1035	.1020	.1289	.1276
1957	.0848	.0838	.1072	.1030	.1404	.1362
1958	.1002	.1033	.1229	.1214	.1541	.1526
1959	.1110	.1078	.1347	.1296	.1588	.1537
1960	.1111	.1053	.1463	.1362	.1685	.1584
1961	.1138	.1097	.1348	.1291	.1596	.1539
1962	.1196	.1119	.1406	.1370	.1657	.1621
1963	.1178	.1137	.1379	.1359	.1696	.1675
1964	.1225	.1168	.1415	.1413	.1705	.1704
1965	.1276	.1264	.1498	.1495	.1797	.1794
1966	.1312	.1312	.1625	.1585	.1932	.1892
1967	.1214	.1222	.1771	.1576	.1840	.1777
1968	.1270	.1301	.1826	.1739	.1971	.1885
1969	.1300	.1327	.1888	.1762	.2092	.1964
1970	.1394	.1413	.2158	.1962	.2293	.2097
1971	.1277	.1325	.2046	.1933	.2142	.2030
1972	.1189	.1247	.2034	.1911	.2081	.1958

[a]All six measures of the user cost of capital were calculated using the formula

$$\frac{c_{Bi,t}}{p_t} = q_t \left[\frac{(1-u_t v_t)}{1-u_t}\right] \delta_t + r_{Bi,t}$$

Data series for q_t, u_t, δ_t and v_t are found in Table A-26 and the six measures of the rate of return on capital ($r_{Bi,t}$) are shown in Table A-25. The implicit price index for Bell Services (p_t) is shown in Table A-20.

TABLE A-26

INDEXES OF TECHNOLOGICAL CHANGE

Year	Percentage of Calls Direct Distance Dialed (D)	Percentage of Telephones in Number 5 Crossbar and Electronic Switching System[a] (E)	Time Trend (T)
1952	.00	.00	1.00
1953	.00	.00	2.00
1954	.00	.00	3.00
1955	.00	.00	4.00
1956	.60	1.24	5.00
1957	1.30	3.35	6.00
1958	5.30	4.77	7.00
1959	9.10	6.03	8.00
1960	15.90	7.67	9.00
1961	22.40	8.81	10.00
1962	26.30	11.18	11.00
1963	31.10	13.81	12.00
1964	37.30	16.83	13.00
1965	43.30	19.34	14.00
1966	47.10	22.16	15.00
1967	50.70	24.88	16.00
1968	56.80	28.11	17.00
1969	62.30	30.61	18.00
1970	67.80	33.55	19.00
1971	72.10	35.71	20.00
1972	76.60	38.65	21.00

[a]Electronic Switching Offices were introduced in 1967. The breakdown of the number of telephones by type of central office from 1967-72 is as follows:

Year	Percentage of Telephones in No. 5 Crossbar Offices	Percentage of Telephones in Electric Switching Offices
1967	24.88	.00
1968	28.06	.05
1969	30.19	.42
1970	32.58	.97
1971	34.28	1.43
1972	36.24	2.41

APPENDIX B

FRINGE BENEFITS INCLUDED IN EMPLOYEE EXPENSE

FRINGE BENEFITS INCLUDED IN RENUMERATION TO LABOR

Insured Benefits

- Life Insurance
- Supplementary Hospital Insurance
- Surgical Medical Insurance

Paid Leave Benefits

- Vacations
- Statutory Holidays
- Sick Leave
- Personal Leave
- Rest Periods
- Retirement Leave

Pension Benefits

- Company Pension
- Canada and Quebec Pension

Payment for Time not Worked

- Grievance and Negotiation

Conditions of Employment

- Food Service and Facilities
- Medical Facilities
- Provision of Autos
- Parking Facilities
- Recreational Facilities
- Club and Association Dues
- Long Service Award

Financial Benefits

- Severance Pay
- Educational Assistance
- Discount Privileges (Concession Telephones)

Pay Supplement

- Workmen's Compensation
- Unemployment Insurance

APPENDIX C

ESTIMATION OF EMPLOYEE EXPENSE PER WEIGHTED MANHOUR IN 1967

ESTIMATION OF EMPLOYEE EXPENSE PER WEIGHTED MANHOUR IN 1967

1. Calculation of Total Weighted Manhours Worked in 1967 by Type of Labor

	Total Manhours	Manhours Excluding Construction	Weighted Manhours Excluding Construction	Total Weighted Manhours
	A	B	C	D=A/BxC
Telephone Operators	12,362	12,362	8,281	8,281
Plant Craftsmen	20,229	12,902	12,892	20,213
Clerical (Non-supervisors)	15,180	11,828	8,962	11,502
Other (Non-supervisors)	7,509	6,517	6,362	7,330
Foremen & Supervisors	6,423	4,908	7,067	9,248
Executive & Staff	9,031	6,227	11,286	16,368
All Management	15,454	11,135	18,353	25,472
Part Time	1,303	1,179	1,229	1,358
All Employees	72,694	56,578	56,578	72,694

2. Calculation of Average Wage per Weighted Manhour in 1967

	Average Wage/ Employee	Average Employees	Total Wage (AxB)	Total Weighted Manhours	Average Wage per Weighted Manhour
	A	B	C=AxB '000'	D '000'	E=C/D
Telephone Operators	3,731	6,946	25,916	8,281	3.130
Plant Craftsmen	6,425	9,935	63,832	20,213	3.158
Clerical	4,287	8,425	36,118	11,502	3.140
Other Non-Management	5,526	4,165	23,016	7,390	3.140
Foremen & Supervisors	8,106	3,563	28,882	9,248	3.123
Executive & Staff	10,051	5,097	51,230	16,230	3.130
All Management			80,112	25,472	3.145
Part Time	2,821	1,517	4,279	1,358	3.151
Total	5,883	39,648	233,249	72,694	3.209

3. Calculation of Employee Expense per Weighted Manhour Excluding Construction in 1967 for all Employees

$$\frac{192,577,000}{56,578,000} = 3.404$$

4. Calculation of Estimated Employee Expense per Weighted Manhour in 1967 (Using Adjustment Factor $\frac{3.404}{3.209} = 1.0608$)

Telephone Operators	3.320
Plant Craftsmen	3.350
Clerical	3.331
Other Non-Management	3.331
Foremen & Supervisors	3.313
Executive and Staff	3.320
All Management	3.336
Part Time	3.343
Total	3.404

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POSTSCRIPT

Since the submission of this thesis, the Canadian Transport Commission (C.T.C.) has proposed a rate adjustment procedure for telecommunications carriers. Submissions have been invited regarding this proposal and public hearings will be held. It is hoped that some type of automatic rate adjustment procedure will be in effect by the end of 1975.

The C.T.C. proposal and the automatic adjustment procedure advanced in my study operate on a similar basis. Rate adjustments are calculated as the value of uncontrollable cost increases minus the value of expected productivity gains. However, the uncontrollable cost increase and the productivity offset are not determined in the same way. Differences between the two proposals are outlined below.

At present, the C.T.C. suggests that uncontrollable labour expenses be calculated using a wage and salary index for the entire economy or a similar index for the actual carrier. The index showing the lowest increase would be chosen. With this method, the national wage increase would become a minimum guideline for company labour negotiations. A more suitable approach would be to calculate a weighted composite index of national wages and salaries for the major job categories of each carrier. I did not develop a new data series for this purpose. Instead, the operation of an automatic adjustment clause was illustrated using the index of actual increases in Bell Canada employee expense per employee. Further study is required in this area.

Since the book value of depreciation represents a biased appraisal of true current dollar depreciation expense, it is not clear how the effect of price increases on capital inputs should be calculated. The C.T.C. proposal is to multiply current investment by the increase in a telephone plant price index. In my calculations, the total book value of depreciation is multiplied by the increase in the Implicit Price Index for Gross Business Fixed Capital Formation. The C.T.C. also includes the effects of changes in actual depreciation rates as part of uncontrollable expenses. I can see no rationale for this approach. Changes in depreciation rates do not result from uncontrollable price increases but rather from a conscious decision to invest in plant with a different expected life.

Uncontrollable increases in interest expenses are not included in the C.T.C. proposal on the grounds that the rate of return on total capital should be determined in a public hearing and should not be subject to change between hearings. My approach was to make the automatic rate adjustment formula operative only when the rate of return on total capital is between established limits and to include uncontrollable interest expense increases in the calculations. Using this method, the allowable range for the rate of return on total capital is set in a public hearing (as the C.T.C. requires). However, only required changes in the return to equity capital are excluded from the formula provided that the rate of return on total capital is within the allowable limits. In addition, the company has a definite incentive to exceed productivity objectives and to keep uncontrollable expense increases below the established limits. I believe that this added incentive for efficient management would offset any possible effect of reduced regulatory lag on management decision making.

Finally, the C.T.C. proposal recognized the theoretical advantages of a total factor productivity measure. However, since few such indexes are available for comparisons, they propose that a 10-year average of labour productivity gains by Canadian manufacturing be used to specify the required productivity offset. In my opinion, the potential for productivity gains is different in each industry and each company. A fair productivity objective can only be determined by examining the performance of the same company in the past under similar conditions. Using this method, required productivity gains would be at least as high as those that have been demanded under the current regulatory process - and it is possible to specify the productivity objective in terms of a total factor productivity measure.

In a capital intensive industry where a large proportion of the labour input is also partially fixed, capacity utilization and the potential for productivity gains vary widely from year to year. In a year when revenue growth is below average, the potential for productivity gains may also be below historic trends. Some method is required to set a reasonable productivity objective for each year. A simple 10-year average of historic gains is not sufficient. Perhaps, the major contribution of my thesis is the development of a reliable short-term productivity forecasting model. Productivity objectives specified using this model should guarantee that required improvements in performance are at least as high as those achieved in the past under similar conditions. The productivity objective also varies from year to year depending on uncontrollable changes in capacity utilization. This modification is necessary if application of an automatic adjustment procedure is to be feasible when sales are not growing at a uniform rate.

As described, there are several modifications in the C.T.C. proposal which I would suggest. However, their proposal definitely represents a step forward in the field of public utility regulation.