COST STRUCTURE CHARACTERISTICS OF THE CANADIAN TELECOMMUNICATIONS CARRIERS:

SOME EMPIRICAL EVIDENCE FROM

BELL CANADA AND ALBERTA GOVERNMENT TELEPHONES (AGT)

by

ANASTASSIOS GENTZOGLANIS

Submitted in Partial Fulfillment

of the

Requirements for the Degree of

Doctor of Philosophy

in the Department

of

Economics

McGill University

Montreal

October 1988

ABSTRACT

This dissertation addresses the issue of cost subadditivity of two Canadian telecommunications carriers, Bell Canada and Alberta Government Telephones (AGT). Multi-output, multi-input models of the production structure of Bell Canada and AGT are estimated under various alternative hypotheses. Subadditivity tests are conducted for both these companies in order to increase understanding of the issues concerning the deregulation of the Canadian telecommunications network and to assist policy makers in their decisions.

The hypothesis that both Bell Canada and AGT are natural monopolies cannot be rejected. Important cost savings are realized from having each of these firms alone in their respective markets producing the total of toll and local calls. Allowing competition in AGT's market would increase costs by approximately 20%, while costs in Bell Canada's market would increase by twice as much. It is found that Bell Canada's cost savings, though still quite important, are significantly reduced after 1983. Apparently, the high adjustment costs that Bell Canada incurs in installing new capital equipment, its organizational restructuring that followed the liberalization of customer premises equipment in 1982 as well as the recent technological changes may explain this turn-about in Bell Canada's cost structure.

We conclude that the 1985 Canadian Radio-Television and Telecommunications Commission's (CRTC) decision not to deregulate Bell Canada's long distance public voice monopoly market (MTS and WATS) was a good one.

RÉSUMÉ

Cette thèse traite de problèmes de sous-additivité des coûts de production de deux entreprises canadiennes des télécommunications, à savoir, Bell Canada et Alberta Government Telephones (AGT). Une fonction des coûts translogarithmique à multiproduits est estimée à la fois pour Bell Canada et AGT. Des tests de sous-additivité des coûts de production desdites entreprises sont effectués dans le but d'éclaircir la question du "monopole naturel" venant ainsi à l'aide des politiciens à la prise de décision concernant la deréglemantation du réseau des télécommunications canadiennes.

L'hypothèse selon laquelle, Bell Canada et AGT sont des monopoles naturels ne peut pas être rejetée. Des économies de coûts importantes peuvent être réalisées si soit Bell Canada soit AGT se trouve toute seule dans son marché respectif produisant la totalité des appels locaux et interurbains. Si on permettait la concurrence dans chacun de deux marchés, les coûts de production augmenteraient de 20% dans le marché desservi par AGT et de 40% dans le marché desservi par Bell Canada. Cependant, pour la période postérieure à 1983, ces économies sont considérablement réduites, du moins pour Bell Canada, quoiqu'elles demeurent quand même assez importantes. Des changements technologiques et/ou la restructuration de l'organisation interne de Bell Canada qui a suivi la liberalization du marché d'équipements des abonnés en 1982 ainsi que les coûts d'ajustement que cette entreprise essuie lorsqu'elle implante son nouvel equipment pourraient être les raisons qui expliquent ce changement de ses coûts de production.

Nous concluons que le conseil de la radiodiffusion et des télécommunications canadiennes (CRTC), a pris, en 1985, la bonne décision d'interdir au groupe Télécommunications CNCP d'entrer dans le marché de monopole des transmission des appels interurbains (MTS et WATS) de Bell Canada.

ACKNOWLEDGEMENTS

There are a number of people who encouraged and supported me throughout my dissertation. First, I would like to express my thanks to Professor Robert Cairns, my principal advisor, who not only gave generously of his time by reading and correcting this dissertation many times but offered a great number of constructive suggestions and perceptive comments.

I have also benefitted greatly from the comments and suggestions of my second advisor, Professor Christopher Green, who always seem to find more in what you did than you thought was there.

There are others who also deserve special mention: Professor David Evans of Fordham University, Professor Sueyoshi Toshiyuki of Ohio State University, Dr Dieter Elixman of the Telecommunications Institute of the Federal Republic of Germany, J. Chung of George Mason University and Jeffrey Bernstein of Carleton University who gave me bits and pieces of advice and provided me with recent and important material.

A number of people from Bell Canada, AGT and Maritime Telegraph & Telephone Company Limited, also provided me with valuable help. First I would like to express my gratitude to Mr. Bernard Lefebvre of Bell Canada who has been of great help in guiding me in the completion of certain calculations at the early stages of my work and in providing me with a huge amount of material. Important material was also provided to me by E. Subissati, G. Staranczak and Dr. F. Dale Orr of Bell Canada. Material with important and valuable comments were provided by Mr. R. Kalvaitis and Mrs. Chantal McCrae of AGT and Mrs. Linda Oliver of MT&T.

I would like to thank as well my colleague and director of the Department of Applied Economics of Laval University, Charles Carrier, for his constant encouragement and his many acts of kindness in making my life at Laval University easier while I was writing the thesis. I am also indebted to my colleague Antonio Lagana who read parts of the dissertation and made valuable comments. Also my colleague P. Yourougou deserves a great deal of thanks.

I also want to express my appreciation to my friend Desirée Rambaran for her excellent editing of this dissertation.

I dedicate this dissertation to my wife, Michelle Larose and to my beloved mother Maria, in grateful appreciation of their kindness, understanding and moral support when I most needed it and to my daughters Maria and Emmanuella who missed me so much but who are too young to understand.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The telecommunications industry has been undergoing and continues to undergo radical changes. Since the hallmark *Carterphone* decision in the late 1960s which permited U.S. business customers to interconnect certified equipment to their telecommunications network, that particular segment of the market (the telecommunications customer premises equipment industry) has been subject to the greatest changes in the structure of competition and technology, both in the U.S. and elsewhere. Since then, a number of countries have pursued a similar policy to that of the U.S., and at present that segment of the industry is subject to more or less open competition internationally.

The idea behind liberalizing the customer premises equipment (CPE) segment of the telecommunications market was that technological changes had divided the until-then unified telecommunications market into various more-or-less independent sub-markets, each of them supporting a different degree of competition.

Technological changes have actually divided the telecommunications market into two broad sub-markets: the transmission and the subscriber equipment market. Previously, both of these markets were under the control of the common carriers. It was the subscriber equipment market that initially came under competitive attack. The liberalization of this market[1] has been advocated on the basis of the argument that manufacturers of the customer-provided equipment did not need the whole market in order to achieve the economies of scale necessary in reducing their unit costs. This market could be shared by a number of manufacturers. Or, stated differently, this market was not considered a natural monopoly any more.

1 For Canada, see *Attachment of Subscriber-Provided Terminal Equipment*, CRTC Telecom Decision 82-14, November 23, 1982.

The liberalization of the telecommunications terminal equipment[2] has been pursued on the almost unanimous[3] belief that this particular market segment of the industry is no longer a natural monopoly. However, no such unanimity exists as far as the deregulation of the telecommunications *transmission market* is concerned.

The telecommunications transmission market has converged[4] with the computing industry due to the digitalization of switching and transmission technology. The advent of microelectronics technology has broken down the traditional separation of voice communications and data communications markets. The digitalization of the voice transmission has had significant impact on the separation of these two markets. No longer able to set demarcations between markets, the previous regulatory regime has been under attack. Pressures have been exercised to liberalize the transmission market as well as the customers' equipment market.

The first shock came in 1959, when the U.S. Federal Communications Commission (FCC), in its *Above 890 Decision*, permitted private entities to

---

2 The customer provided equipment market includes residential and business telephones (including feature telephones), key systems and private automatic branch exchanges (PABXs) and other terminals located in customer's premises. The liberalization of this segment of the market has been advanced without any prior quantitative knowledge concerning its degree of competitive support. Now, as before, behind these (re-) de-regulatory actions lie implicit and often untested assumptions about the functioning of the industry's and firm's behaviour. As will be argued later on, it seems that the same "deregulate and let's see approach" has been followed in the other segments of the market, notably the transmission market (trunk market). It is about time that policy makers base their future policy actions on facts (estimates of econometric studies) rather than on hypotheses.

3 For some reservations concerning the possible problems that will eventually appear in the subscriber equipment market as a result of the deregulatory actions taken in that segment of the market, see E. Sciberras and B.D. Payne, Telecommunications Industry, Longman, 1986. The authors argue that the openess to competition of the subscriber equipment market is quite likely to be destructive in the long run.

4 It can be argued that the telecommunications industry would still have been under the traditional regulatory regime had technology convergence not made possible the disappearance of the traditional market demarcations. It can be argued further that it is the emergence of new technologies that made possible the creation of networks that could by-pass completely the existing monopolies that made deregulation a technological possibilty.

provide point-to-point microwave service to meet their own internal needs. The next major milestone towards competition in transmission markets was the FCC's *Specialized Common Carrier Decision*. It permitted a single carrier, Microwave Communications Inc. (MCI) to provide private line service on a common carriage basis. Competition, it was argued, could be in the public interest by providing new services at lower cost, at least in private line markets. Since then a number of new technologies and a number of gradual regulatory accomodations have made possible the introduction of competition in almost all of AT&T's transmission offerings, including both private line and switched voice services.

A similar pattern of events has been observed in Canada. It was during the 1950s that Canadian National/Canadian Pacific (CNCP) first began to operate its nation-wide microwave network, offering thereby, in direct competition with Bell Canada and the other telephone companies, private line and other data transmission services. During the 1960s and 1970s new rivalry developed between CNCP and Telecom Canada[5], with the introduction of slightly different but better private line and data communication services offered to major business users. In 1979, CNCP succeeded, after a long fight with Bell Canada, to secure access to the latter's network, in return for a fee paid to Bell Canada for allowing CNCP's customers to use directly the telephone infrastructure of both companies. Similarly, in 1983, CNCP applied for permission to connect its system with that of Bell Canada and B.C. Tel in order to supply, in direct competition with them, general public long-distance services (MTS and WATS). In 1985 and after long hearings, the Canadian Radio-Television and Telecommunications Commission (CRTC) denied CNCP's application on the ground that the benefits produced by competition would have been non-significant and unevenly distributed. This interconnection case goes to the heart of the important public policy question of whether the telecommunications system still remains a "natural monopoly"[6].

---

[5] Telecom Canada was created in 1931 as a cooperative comprising ten major Canadian telecommunication carriers in order to provide an integrated cross-Canada long-distance system. Telecom Canada represents almost 88 percent of the telecommunications carriage market in Canada as measured by its total operating revenues. Until 1983, it was known as Trans-Canada Telephone System.

[6] At one time it was considered that a sufficient condition for an industry to be a natural monopoly was the existence of economies of scale. The early

Proponents of deregulation argue that the above-described technological changes have dramatically changed the cost structure of the incumbent monopolies, rendering them ripe for competition (at least some particular segments of their market). Competition is viewed as a means of correcting the alleged inefficiencies created by the application of the traditional pricing principles (mostly from cross-subsidization) and as a means of discouraging heavy telephone users from *by-passing*[7] the network. It is thus argued that both allocative as well productive efficiencies would be increased via the market mechanism. Furthermore, innovation and technical change would be both stimulated and diffusion of new products and techniques would be accelerated[8]. Telephone users' ever-increasing specialized needs for new services would be better served under competition than under regulated monopoly. Customers' choice as well as social welfare would be increased under competition.

The arguments for competition in the telecommunications industry have been adopted by many powerful groups that are lobbying for deregulation of entry into the industry and of pricing of services. Deregulation and therefore competition in the U.S. interexchange market (long-distance) is largely a *fait accompli*. In Canada considerable pressures have been exercised in order that the CRTC could proceed to the deregulation of Bell Canada's and B.C.'s Tel long-distance markets. But an eventual deregulation of the long-distance market gives rise to a number of thorny problems with which policy makers must deal.

---

natural monopoly definitions have been recently challenged and extended by Baumol (1977), Baumol et al (1977, 1982). For the early definitions and the new ones see chapter 3 of this dissertation and references therein.

7 Telecommunications transmission is now possible using microwave, satellite, coaxial and optic fibre cables and other alternative technologies. It is the existence of these technologies that makes it presently possible for a number of voice and data communication users to *bypass* the network facilities of the telephone companies.

8 It is true that competition, under certain circumstances, may stimulate innovative activity, reduce prices to marginal costs and increase social welfare. However, in circumstances where signs of natural monopoly and unsustainability exist competition may not do better than regulated monopoly. Natural monopoly considerations become thus very important in deciding about the desirability of more competition or regulation. This is the reason why we give special attention to the determination of the cost structure of the Canadian telecommunications industry.

The most contentious issue is how to deal with matters of equity and fairness that necessarily come as a result of deregulating the long-distance market. This problem arises because of the pricing principles that have been traditionally applied to the telecommunications industry. Apparently, significant cross-subsidies exist in the present rate structure. It is argued by many that long-distance calls have been over-priced while local calls have been under-priced giving rise to cross-subsidies from business customers to residential customers, from urban to rural and from heavy long-distance telephone users to light telephone users.

Competition will force established carriers to lower long-distance prices so that the latter reflect their costs of production. The alignment of prices to costs will eliminate the "subsidy" originating from the toll market. As a result, local rates will necessarily increase. The increase in local rates will discourage some customers, who may decide to leave the network. Hence, "rate-rebalancing"[9] raises serious public policy concerns about vertical and horizontal equity[10]. In addition to that, the universality of local service -- the goal which the government has pursued up to now -- would be threatened because of the increase in competition in the interexhange (long-distance) market.

It is further argued that if "rate-rebalancing" does not take place large corporate users, by utilizing the new alternative technologies, would by-pass the telephone network. They will attempt to establish a network specific to their needs or they will share one with others. Revenues from these users will then be lost to the established carriers, thereby jeopardizing the viability of the network.

---

9 "Rate-rebalancing" may be defined as the elimination of cross-subsidies from toll to local rates.

10 Equity is linked to the impact of public policies on the distribution of income across different socio-economic groups. Vertical equity is concerned with how a public policy treats persons of different welfare levels. Horizontal equity treats equals equally. Fairness on the other hand is concerned with whether public policies are consistent with widely held social values. See Globerman, S. and Stanbury W.T., "Local Measured Service Pricing or Rate Rebalancing? Efficiency and Distributional Considerations", in Schultz, R. and Barnes, P., (eds), Local Telephone Pricing: Is there A Better Way?, The Centre for the Study of Regulated Industries, McGill University, Montreal, 1984.

It is evident from the above that policy makers must choose between equity[11] and efficiency. However, proponents of competition stress the point according to which equity considerations do not arise. They argue that the present pricing scheme, especially the flat-rate system, is unfair since many customers are charged more than the costs they impose on the system and others are charged less. Rate-rebalancing, achieved as a result of market forces, would increase fairness by yielding prices that would reflect the real costs that customers impose on the system. They propose several methods of improving fairness[12]. As yet, no consensus has been reached on this matter.

In our view, equity and efficiency are not two mutually exclusive objectives. Equity concerns become less acute if we can establish that the cost function of common carriers is subadditive[13]. If subadditivity and nonsustainability characterize the telecommunications industry, efficiency is achieved by not allowing competition. Rate-rebalancing[14], if realized under regulated natural monopoly, would be less onerous than if it were realized under a genuinely competitive market[15]. Consequently, drop offs would necessarily be less numerous. Distributional and therefore equity considerations would become less acute. Obviously, these assertions depend, as was said above, on the question whether the Canadian telecommunications industry is a natural monopoly. Therefore, the empirical examination of the nature of the cost function of the Canadian telecommunications industry is extremely important for the present public policy debate.

---

11 Equity problems arising from the deregulation of the interexhange market are treated in detail in: J. Miller (editor), Telecommunications and Equity: Policy Research Issues, North-Holland, 1986.

12 One of these methods is the introduction of local measured service (LMS). See Schultz, R. and Barnes P., (eds), Local Telephone Pricing: Is there A Better Way?, The Centre for the Study of Regulated Industries, McGill University, Montreal, 1984.

13 The concepts of subadditivity and sustainability are analysed in detail in chapters 2 and 3.

14 Rate-rebalancing is judged to be necessary. This is so because recent technological changes created the possibility of network by-passing by heavy communications users.

15 If the cost function of a firm is subadditive it constitutes a natural monopoly. It is then implied that the existence of a single-supplier is more cost-efficient to society than the existence of a multitude of firms. Since overall costs are lower when a single-firm serves the whole market, the increase in prices would then be less than under competition.

In other words, the present debate in the Canadian telecommunications industry concerns the control of entry. The debate revolves around the question; should Canada continue with the present regulatory regime or should allow entrants (CNCP and others) to compete with Bell Canada and other carriers in the long-distance market? Information on the cost structure of the industry is what policy makers need to make sensible decisions. The most direct way to obtain such information is to estimate the production characteristics (cost function) of the Canadian telecommunications carriers.

This dissertation does not deal with the equity issues of deregulation *per se*. Instead, it focuses on the more specific subject of examining empirically the cost function of both Bell Canada and Alberta Government Telephones (AGT) Company. Its purpose is to provide further insight into the present regulatory dilemma as to whether the Canadian telecommunications industry or parts of it constitute a natural monopoly. If this industry is a natural monopoly the apparently mutually exclusive objectives of equity and efficiency under competition become perfectly compatible under regulated monopoly.

In the U.S., the Justice Department decided to split up AT&T, the world's largest multiproduct firm, on the grounds that natural monopoly does *not* exist in the provision of long-distance calls. However, in Canada the CRTC ruled not to allow competition in the provision of long-distance and local calls, refusing thereby CNCP's 1983 application to provide long distance services in direct competition with the other telephone companies. A plausible question then arises. On what piece of information did the U.S. Justice Department rely in deciding that the AT&T monopoly was not natural? Still further, did the CRTC take the right decision or the wrong one in not allowing the entrance of CNCP into the long-distance market?

The existing empirical evidence concerning the question as to whether the telecommunications industry or part of it still remains a natural monopoly is, at best, inconclusive. In both countries, a number of econometric studies has been undertaken in an attempt to determine whether the telecommunications industry is a natural monopoly. Despite their sophistication, the majority of them provides very little information on the important question of cost subadditivity, the qualitative property of the cost function that determines whether an industry is effectively a natural monoply. This can be explained by the fact that the majority of these studies were undertaken in an era when the new tools (both theoretical and empirical) for determining economies of scale and scope, cost subadditivity and sustainability as have been lately developed by Baumol, Panzar and Willig (1982), were not yet available.

New econometric studies applied to the U.S. telecommunications industry have recently demonstrated that the question of natural monopoly is a debatable issue[16]. At present no Canadian study deals directly with the measurement of cost subadditivity. Previous studies provide some information on economies of scale but they contradict each other (Fuss and Waverman, 1981, Kiss et al, 1983).

It is the dissatisfaction with the present empirical evidence concerning the question of Bell Canada's natural monopoly determination and the absence of any comparative study of Canadian telecommunications carriers that induced us to address this problem. In an attempt to increase understanding of this issue, the dissertation examines the Canadian telecommunications industry from a public policy point of view. Using the information available on costs and prices of inputs and outputs for both Bell Canada and AGT, it examines the production characteristics of both firms and analyzes, on the basis of various alternative hypotheses, the effects of technical change on their production and organizational structure.

Applying various tests, notably the one developed by Evans and Heckman (1983), and on the basis of information provided by its application, we consider the implications of various alternative public policies. It is argued that the empirical evidence flowing from the models suggests that the hypothesis that the cost structure of both Bell Canada and AGT is subadditive cannot be rejected. This, in turn, implies that allowing competition in that industry would affect considerably its present cost level. Indeed, the tests make clear that costs would eventually increase if competition were introduced into this industry. Each company realizes important cost savings in its

---

[16] For the present debate on whether AT&T was a natural monopoly see the recent articles by Charnes, Cooper and Sueyoshi, and Evans and Heckman both in the Management Science, January, 1988. See also "Duality Theory of Data Envelopment Analysis" and "Data Envelopment Analysis Review of AT&T Breakup" both written by T., Sueyoshi (forthcoming).

respective market by having it alone produce the total of local and toll calls as compared to what would be observed if this total output were produced by more than one firm.

These results have been derived by estimating alternative multi-product translogarithmic cost models. We used the most recent data on Bell Canada and AGT to investigate the production characteristics of both firms. A number of points differentiate our study from previous ones. *First*, our behavioural assumptions are different from most of the previous Canadian studies. We assume that both Bell Canada and AGT face exogenously determined prices for their factors of production and for their output levels. Therefore, we can only estimate a system of three equations as opposed to a four-equation system estimated by other researchers on the basis of the assumption that one output (the competitive one) is endogenously determined by Bell Canada.

Second, this is the first *comparative study of* the Canadian telecommunications carriers[17]. Since our objective is to provide further information on the problem of natural monopoly, a two-output, three-input model is estimated for each firm, Bell Canada and AGT, and then for both of them simultaneously on the basis of technological similarities in their production processes.

Third, our model does not use any of the technological indexes used in previous Canadian studies. This is due to the lack of a satisfactory index that could represent adequately the technology used by both companies and the rate of introduction of the new technologies. Thus, we simply use a time-trend as the index of technology.

Fourth, the sample used for both companies contains more information than any previous study, since we used the most recent sample containing 35

---

[17] Actually, there is another comparative study which was undertaken by Bell Canada's researchers. However, their objective was not to measure the cost subadditivity of these two carriers but the productivity gains realized by these firms. A number of other differences exist between their study and ours, as it is mentioned in the text later on. For more details on their study see:F. Kiss and B. J. Lefebvre, "Comparative Analysis and Econometric Forecasting of Factor Inputs and Productivity: Some Empirical Results in Canadian Telecommunications" Paper presented at the Fourth International Symposium on Forecasting, London, England, July 8-11, 1984.

and 18 observations for Bell Canada and AGT, respectively. As a result the inferential ability of our model is greatly increased, rendering our results more reliable (since the degrees of freedom are higher).

Fifth, to our knowledge, this study is the first to measure directly the cost subadditivity of both Bell Canada and AGT. Previous studies attempted to arrive at certain conclusions with respect to the cost subadditivity of Bell Canada using *ad hoc* measures. By contrast, we apply, for the first time, the Evans and Heckman test to Canadian telecommunication carriers.

The remainder of this study is divided into six parts. Chapter 2 is a review of issues currently facing the Canadian telecommunications industry. First the technological changes and the most recent deregulatory accomodations that ensued as a result of them are described. It is argued that the competitive forces introduced first into the CPE market and subsequently into the long-distance market opened up the way for competition into the local exchange market as well (at least in the U.S.)[18].

However, the new competition that arises as a result of AT&T divestiture may erode the financial viability of local exchange service providers and jeopardize government's goal of service universality. This conjecture in conjunction with the information provided by the recent empirical econometric work according to which the pre-divestiture Bell System might have effectivelly been a natural monopoly, suggests that social welfare or economic efficiencies may have been sacrificied because of the introduction of competition into the long-distance U.S. telecommunications market. It is concluded therefore that Canada should not follow the U.S. policy. This conclusion is also confirmed in the rest of the dissertation.

Chapter 3 is a review of the literature of natural monopoly with special emphasis on the economies of scale and scope, sustainability and cost

---

18 This new competition is coming mainly from the recently created "*campuses*", i.e., intermediaries that buy telecommunications services at bulk prices from local and long-distance telecommunications service providers and resell them on a retail basis to unrelated end-users. It seems that the creation of campuses is the result of market failures created by the introduction of competition in the interexchange market, on the one hand, and technological opportunities created by the new technologies, on the other hand.

subadditivity production characteristics of multi-product firms. It is argued that, on the basis of the information provided by our empirical study and recent attempts by competitors to enter only certain segments of the Canadian telecommunications industry, the latter may be nonsustainable. The nonsustainability argument becomes even more important if we take into account the limited size of our Canadian market.

Chapter 4 is a review of the empirical literature dealing with the subject of natural monopoly in telecommunication industries of the U.S. and Canada. The most recent models are reviewed in order to discover whether the existing empirical literature can provide answers to the questions that have been raised in the previous chapters. It is our opinion that the empirical evidence (as it is now formulated) is not conclusive. Further, the empirical literature, at least for Canada, does not provide answers to the present deregulatory problems, that is to say, an answer to the question of whether major telecommunication carriers have a subadditive cost function. Dissatisfied with these shortcomings, we proceed to the estimation of our own model. This is done in chapter 5.

Chapter 5 first presents the conceptual framework as it is applied to the empirical estimation. It presents the various alternative formulations for the one-firm model and two-firm models, and the estimation techniques to be used are discussed . The differences between our model and previous models are highlighted as well. The problems encountered during the empirical estimation are briefly discussed as well .

The empirical estimation of the model is done in chapter 6. We perform various tests in an effort to estimate various production characteristics of the production processes used by Bell Canada and AGT. Special emphasis is placed on the subadditivity tests. It is conclude that the hypotheses that Bell Canada and AGT have subadditive cost structures cannot be rejected. Thus, deregulation might increase costs to society. On the basis of the information obtained from the two-firm model, the hypothesis that Bell Canada and AGT use the same technology is rejected . Consequently, the results of the single-firm models are more suitable for public policy purposes.

Chapter 7 summarizes the main conclusions and identifies areas for future research. It suggests, in the light of the findings of our empirical work, some solutions to the present debate. It is argued that the problems resulted from the appearance of new technologies and the creation of opportunities for by-passers would persist even if market forces are left to determine the prices of the telecommunication services. It is suggested that by-pass would be avoided and the financial viability of the incumbent firms would be safeguarded (efficiency would be achieved) only if the "rate-rebalancing" were realized *under the present market structure*.

This argument is supported by the fact that the empirical results of our study suggest that the network is a natural monopoly while the theoretical considerations of chapter 2 and 3 suggested that it may not be sustainable. The existence of the subadditive cost function guarantees that such a "rate-rebalancing" would be less extensive than the rate-rebalancing that would result under competitive markets. That is, under a regulated monopoly regime, the prices of local calls would not increase as much as they would increase under competitive markets.

Consequently, the financial viability of the network would not be jeopardized and the drop-offs from the system would be less numerous than under competition. This policy would seem to keep both local users and by-passers within the present telecommunications carriers network. The eventual abandonment of the system by some of the users could be avoided by applying policies similar to those envisaged elsewhere (notably in the U.S.). This might be the best policy that takes into account both efficiency and equity criteria. These policy recommendations are treated in more detail in the final chapter.

We may thus summarize by stating that in the absence of any other means to discourage by-pass, rate-rebalancing *under the present market stucture* may be the best way to increase economic efficiency. Market forces and therefore competition may do the job efficiently as well only if no natural monopoly existed in the telecommunications industry. Thus, the debate boils down to the question as to whether the Canadian telecommunications industry is a natural monopoly. It is the answer to this question that will guide policy makers to adopt efficient public policies. The focus of the dissertation will then be on this central issue, i.e., the empirical estimation of the cost function of Bell Canada and AGT.

CHAPTER 2

AN OVERVIEW OF THE CANADIAN TELECOMMUNICATIONS INDUSTRY STRUCTURE AND ITS REGULATORY POLICIES

Any study of the telecommunications regulatory reforms and public policies should begin with a thorough understanding of the industry itself and its institutions.

It has already been said, in chapter 1, that Canada's telecommunications industry structure has significantly changed in the past five years as a result of both technological innovations and regulatory accommodations.

The objective of this chapter is to explain the deregulatory movement in the telecommunications industry by focusing on the underlying forces that have been exercised and have managed to change radically the regulatory policies that have transformed the strucure of this industry, its conduct and its performance. The next section presents the structure of the industry and its institutions.

CANADA'S TELECOMMUNICATIONS INDUSTRY ORGANIZATION AND ITS REGULATORY ENVIRONMENT

A description of Canada's telecommunications industry structure and its regulatory environment at any one point in time would soon be hopelessly out of date. No "snapshot" of the situation would bring to light the dynamic forces currently underlying the telecommunications industry.

This is the reason why the review that follows is mostly concerned with the direction and causes of change and deals only with the most significant recent, and likely, changes. The focal point of the review will be to examine the implications that technological and regulatory changes would have on the carriers' competitiveness.

Previous studies on Canada's telecommunications industry have used the outcome of the U.S. experience with deregulation to support arguments for similar moves in Canada. Such direct "wholesale" applications are not used in the present study.

Nevertheless, some lessons can be learned from the U.S. deregulation experience. To determine what could or could not be applied here, important differences in the industry structure and regulatory environments between the two countries must be addressed. Accordingly, in this chapter some emphasis is placed on comparisons with the U.S.

Table 2-1 provides a cross-section summary of the Canadian telecommunications carriage market, its ownership and its regulatory institutions. As can be seen from this table, 20 telephone companies account for approximately 99 percent of the market. The remaining one percent of the market is accounted for by more than 100 telephone companies. Moreover, the market share distribution of the 20 major carriers is unequal among them. The "Big 3" account for 72.5%.

In the Canadian telecommunications market Bell Canada is by far the most important carrier, as judged by its market operating revenues. British Columbia Telephone (B.C. Tel) is the second largest, with only 1/4 of Bell Canada's operating revenues, while Alberta Government Telephones (AGT) is the third largest, with revenues of only 1/5 of Bell Canada's. The rest of the major carriers (with few exceptions) account for less than 3 percent of the market.

TABLE 2-1

1984, CANADIAN TELECOMMUNICATIONS CARRIAGE MARKET SHARES, OWNERSHIP AND THEIR REGULATORS

Company Name	Total Operating Revenues ($ millions)	Share (%)	Type of Ownership - Principal Shareholder	Regulators
AGT (b)	978.8	9.6	Province of Alberta (100%)	Public Utilities Board of Alberta
Bell Canada (a,b)	$ 5 290.6	51.7	Investor owned (Bell Canada Enterprises - 100%)	Canadian Radio-television and Telecommunications Commission (CRTC)
B C Tel (b)	1 147.8	11.2	Foreign investor owned (through subsidiary of GTE of United States - 51%)	CRTC
CNCP Telecommunications	338.1	3.3	Joint Venture (Government of Canada through CNR and Canadian Pacific - each party 50%)	CRTC
"edmonton telephones"	181.8	1.8	City of Edmonton (100%)	City of Edmonton
Island Tel (b)	30.5	0.3	Investor owned (Maritime Tel & Tel - 36%)	Public Utilities Commission of Prince Edward Island
MTS (b)	2942.3	2.9	Province of Manitoba (100%)	Manitoba Public Utilities Board
Maritime Tel & Tel (b)	282.1	2.8	Investor owned (Bell Canada Enterprises - 36%)	Nova Scotia Board of Public Utilities Commissioners
NBTel (b)	229.6	2.4	Investor owned (Bell Canada Enterprises - 35%)	New Brunswick Board of Public Utilities Commissioners
Newfoundland Telephone (b)	127.0	1.2	Investor owned (Bell Canada Enterprises - 61%)	Newfoundland Board of Public Utilities Commissioners
Northern Tel	25.9	0.3	Investor owned (Bell Canada Enterprises - 98%)	Ontario Telephone Services Commission
Northwest Tel	55.6	0.5	Government of Canada (through Canadian National Railways - 100%)	CRTC
Quebec Telephone	164.1	1.6	Foreign investor owned (through subsidiary of GTE - 55%)	Regie des services publics du Québec
SASK TEL (b)	382.7	3.7	Province of Saskatchewan (100%)	Saskatchewan Public Utilities Review Commission
Télébec Ltée	100.0	1.0	Investor owned (Bell Canada Enterprises - 100%)	Régie des services publics du Québec
Teleglobe Canada	201.6	2.0	Memotec Data Inc. (100%)	CRTC
Telesat Canada (b)	128.0	1.3	Joint Venture (Government of Canada - 50%; approved telecommunications common carriers listed in Schedule I of Telesat Canada Act - 50%)	CRTC
Terra Nova Tel	38.2	0.4	Government of Canada (through Canadian National Railways - 100%)	CRTC
Thunder Bay Telephone	20.3	0.2	City of Thunder Bay (100%)	Ontario Telephone Service Commission
TOTAL	10 231.0	100.0		

a) Telecommunications operations only. b) Members of Telecom Canada.

Source: Revised from, Federal-Provincial Examination of Telecommunications Pricing and the Universal Availability of Affordable Telephone Service, Working Papers, Minister of Supply and Services Canada, October, 1986

Telecom[1] Canada and CNCP Telecommunications (CNCP) are the two national telecommunications carriers. They provide a wide spectrum of services ranging from voice telephony to data and program transmission. CNCP and Telecom together accounted for over 91 percent of the Canadian telecommunications market in 1985. The two differ however in terms of size and services offered.

More specifically, Telecom Canada accounts for almost 90 percent of the market while CNCP Telecommunications accounts for 3.6 %, while the carriers non-affiliated to Telecom Canada account for the remainder. It is also interesting to note that the members of Telecom Canada offer a wider spectrum of facilities and networks for the transmission and switching of both local and long-distance services than CNCP Telecommunications. Their services can be carried on either by the two trans-Canadian microwave relay routes or by co-axial or optical fibre cables, and/or via Telesat Canada's[2] satellite and earth stations.

CNCP, the other national carrier, offers a smaller spectrum of facilities and network. It operates its own national microwave relay system and its own switching centres but it also leases local loops from local telephone companies. CNCP's restricted interconnection to Bell Canada's and B.C. Telephone's local exchange facilities permits its customers to have, through the public telephone network, access to certain CNCP competitive data transmission services and leased circuit services (private lines) but not Message Toll Services (MTS).

---

1 Telecom Canada is an association of the ten major telephone companies listed in table 2-1 plus Telesat Canada - the domestic satellite carrier. Telecom Canada (Trans Canada Telephone System (TCTS), as it was known until 1983) was formed in 1931. Its role was to provide an integrated switching and transmission network across Canada for supplying both voice, data and image communications services. Telecom Canada coordinates the operations of the national telecommunications network, commercializes its products and services across the country and allocates its common revenues accruing from the sale of long-distance services according to a pre-established Revenue Settlement Plan. This is the most important function of the organization. Telecom Canada itself is not regulated by any government or agency.

2 Telesat Canada is the national satellite carrier.

By the same token, B.C. Rail, which operates its own microwave relay system in British Columbia, has been granted limited interconnection to B.C. Telephone network for the provision of private line voice and data transmission on comparable terms and conditions to those applied to CNCP.

Teleglobe Canada carries international traffic by connecting its international gateway switches, trans-oceanic cables and earth stations to the satellites of the International Telecommunications Satellite Organization (INTELSAT). Teleglobe Canada does not deal with Canada-American traffic unless it constitutes an integral part of the trans-oceanic traffic via satellite.

Another aspect of the Canadian telecommunications industry is its ownership structure. As becomes clear from Table 2-1, the Canadian telecommunications industry consists of a mixture of private (domestic or foreign), public and joint venture participants. In 1982, joint ventures accounted for only 4 percent of the market, while public and private ownership accounted for 21 and almost 75 percent of the market, respectively.

It is occasionally argued (McManus, 1973) that the dominance of the private sector in the Canadian telecommunications industry is an indication that the existing Canadian telecommunications system is the result of corporate, not government, decision making. It is argued indeed, that the creation of a national integrated telecommunications system through Telecom Canada was the result of industry's initiative. Consequently, corporate executives and not the government were responsible for planning the development of this system. Indeed, before the creation of Telecom Canada, national long-distance traffic had to go through the United States. McManus (1973, p. 420), argues that, "the telecommunications industry in Canada is the only industry since the fur trade to have voluntarily constructed a link between East and West to the North of Great Lakes without government intervention of some kind".

McManus's argument ignores, however, that the government has played an indirect but significant role in the formation of this industry up to the 1970s[3]. Government, regulators and telephone companies have worked together within a framework of price and rate-of-return regulation[4] to achieve the mutually agreed-upon prespecified objectives of universality of telephone service at just and reasonable rates and at an acceptable level of quality. This indirect intervention of government may be justified on the grounds that corporate management and governments had common objectives and strategies.

Nevertheless, at present, such unanimity and tacit cooperation do not exist. The industry and governments are now divided on the major telecommunications issues as a result of recent technological changes and market demands for new services. New interest groups have been formed as a result of these changes. These groups have diametrically opposed interests. They are lobbying for the government to adopt policies that are of interest to them. The opposing groups, mainly the established carriers and their small customers lobby for the *status quo*. Governments and industry are necessarily divided. This may explain the CRTC's 1985 decision that adopted a two-tier policy (denying on the one hand CNCP's interconnection to Bell Canada's network in providing long-distance calls and liberalizing on the other hand the resale and sharing and the interconnection of private local networks for non-voice services) in an effort to satisfy every interested group[5].

3 Since then government intervention has been more *direct*. In 1975, the federal government transferred to CRTC the jurisdiction over telecommunucations from the Canadian Transport Commission.

4 According to the traditional model of rate-of-return regulation, regulators restrict the revenues of public utilities (natural monopolies) to levels just covering their costs of production. "Price fixing" is thus the heart of this regulatory process. See Kahn, A. E., The Economics of Regulation: Principles and Institutions, Vol. I, New York: Wiley, 1970.

5 Stanbury (1986, p.508) argues that the CRTC's decision was taken in order to "protect the economic positions of the established stakeholders" (he is obviously referring to Bell Canada and B.C. Telephone) at the expense of the possibility to achieve large gains in economic efficiency. It will be shown in Chapter 5 however that the CRTC's decision was the correct one to take, at least for the time being, in the light of the empirical evidence demonstrating that the monopoly of Bell Canada is indeed "natural".

The next important fact of the Canadian Telecommunications industry is its regulatory structure. As can be seen from Table 2-1, the regulatory structure is quite complex in Canada. Each telephone company (except Sask Tel) is regulated either by a federal organization, like the Canadian Radio-Television and Telecommunications Commission (CRTC) or by a provincial government utility board or by a municipal council or provincial Cabinet.

Teleglobe Canada was not subject to any regulation prior to its privatization. Similarly, Telecom Canada is not subject to any regulation while Sasktel was not regulated by a separate agency until after 1982 when Saskatchewan created a regulatory agency, the Public Utilities Review Commission. Approximately 70% of the telecommunications market is regulated by the CRTC while the remaining 30% of the industry is controlled by the provincial governments. There are, however, important differences among provinces. Certain provinces, mainly the prairie provincies, regulate almost all telecommunications within their jurisdiction, while Quebec and Ontario regulate less then 3 percent and 1 percent of the industry respectively. It seems that it is only British Columbia that lacks any degree of jurisdiction over carriers operating within its province.

This organization and complexity of the telecommunications regulatory structure has been identified by Schmidt and Corbin (1985, p. 218) as the "root problem" of the Canadian telecommunications industry. They argue that the delay in both the interconnection of telephone networks and in the introduction of competition in message toll services (MTS), can all be attributed to balkanization and regional differences[6].

Before we examine the current regulatory structure in Canada, it is worth reviewing briefly the main services offered by the Established Common Carriers (ECCs). It will permit us to identify the services that are offered on a competitive basis and on a monopoly basis. It will be

---

6 This may be a factor in explaining this delay. However, we argued above that it is the emergence of powerful groups and their conflicting interests that have divided governments and regulators, rendering them indecisive.

seen that the bone of contention is the question of whether the long-distance calls should be offered on a competitive or monopoly basis.

SERVICES OFFERED BY COMMON CARRIERS

1) Voice Telephony Services

Telecommunication services can be loosely classified (see table 2-2) into two major categories, i.e. voice telephony and message, and data transmission (non-voice telephony). Voice telephony can be further divided into public switched and private line services. Public switched includes both domestic local and long-distance public voice telephone services. Such services are currently provided, on a *monopoly basis*, by all members of Telecom Canada and by other telephone companies. It is worth noting that customer premises equipment (CPE) (telephone sets, inside wiring and PBX) is no longer provided on a monopoly basis, after the CRTC's 1982 terminal attachment decision[7].

As can be seen from Table 2-2, most of the other voice and non-voice services are offered on a duopolistic basis. The telegram services are still offered from coast to coast on a monopoly basis by CNCP and throughout the world via Teleglobe's gateway facilities. The demand for this service is gradually diminishing due to new techniques of transmission.

Private individual or group line services for both voice and data transmission can be easily obtained from the Telecom Canada members, other telephone companies and from CNCP and B.C. Rail (in British Columbia). Telesat Canada - the national satellite carrier - can offer directly via its satellites, private line services to its customers as a result of the CRTC's 1986 decision. Leased circuits can be also obtained from Teleglobe Canada for trans-oceanic communications via its interconnections and its gateway switches with INTELSAT satellites.

---

[7] See *Attachment of Subscriber-Provided Terminal Equipment*, CRTC Telecom Decision 82-14, November 23, 1982. The effects of this decision on industry and customers were analysed by Gentzoglanis, 1981.

TABLE 2-2

OVERVIEW OF TELECOMMUNICATIONS SERVICES AND CARRIERS

Service Category		Carrier Category
1. Voice telephony	Public switched	Telecom and other telephone companies
	Leased circuits (private lines)	Telecom, other telephone companies and CNCP
2. Public message (telegram)		CNCP
3. Switched Teleprinter and other text		CNCP (telex) and Telecom(TWX)
4. Data	Public switched	Telecom and CNCP
	Leased circuits (private lines)	Telecom and CNCP
5. Program Transmission	Audio	Telecom and CNCP
	Video	

Source: Federal-Provincial Examination of Telecommunications Pricing and the Universal Availability of Affordable Telephone Service, Working Papers, Minister of Supply and Services Canada, October, 1986.

2) Message and Data Transmission Services (non-voice telephony)

a) Public Switched Data Services

Data services are provided on a duopoly basis. All members of Telecom Canada, the other telephone companies as well as CNCP are the major suppliers of these services. Teleglobe Canada makes the appropriate arrangements, using its facilities, for connecting domestic customers to the international market. The two major competitive services offered are Infoswitch and Dataroute. The first is offered from coast-to-coast by CNCP, the latter by members of Telecom Canada and other Telephone companies. Both of these services can be connected, via Teleglobe Canada's Globedat international data gateway, to numerous other countries.

So long as technical criteria are met, no major restrictions exist on the use of the public data network. Thus, terminal attachment policies with respect to public data networks have been considered more liberal than for voice. Private data leased circuits are provided by both Telephone Companies and CNCP (B.C. Rail as well).

b) Switched Teleprinter and Text Services

In 1956 CNCP inaugurated its telex service. Six years later, Telecom Canada launched its own switched teleprinter service, namely, its TWX (Teletypewriter Exchange) service. Presently, the telex service is offered by both CNCP and Quebec Telephone and it has a large number of Canadian subscribers. Both services allow access to over one million telex or telex-type installations around the world. CNCP and others (Telecom Canada) provide facsimile communications services which allow for the transmission of graphics over their respective networks. The international connection is provided by Teleglobe's Globefax Facsimile Service. CNCP, Teleglobe and Canada Post operated jointly the Intelpost Service - a graphic (document facsimile) service. A number of new services have been developed lately[8].

---

[8] Among them we mention the telepost, the Interpost, Envoy 100, Envoy Post, Teletext and Infotex. Both CNCP and Canada Post operate

In sum, most of telecommunications services are presently offered on a competitive (duopolistic) basis. The only exception seems to exist in the provision of the local and long distance services. However, as technologies change drastically and the costs of providing these services decline, pressures are being exerted to deregulate the provision of all of these services and to offer them on a competitive basis.

It is thus important to examine the forces of change that led us from the previous situation of monopoly to the present situation of restricted competition. By doing so we open gradually the Pandora's box with the issues of the present regulatory debate. The most important events that changed the structure of the Canadian telecommunications industry are the terminal attachment and procurement policies as well as systems interconnection.

1) TERMINAL ATTACHMENT AND PROCUREMENT POLICIES

It has already been argued that the emergence of rapid technological changes has divided the previously unified telecommunications market into several submarkets.

Indeed, the transmission market has been divided into three submarkets: the local network, the long-distance one and the international market. The equipment market has been divided into the exchange market, on the one hand, and the customer premises equipment (CPE) market on the other hand. Each of these submarkets is examined below.

jointly the telepost (electronic messages) service. The Envoy 100 as well as the Inet 2000 are national information storage retrieval and message transmission service offered by both Telecom Canada and Quebec Telephone. The Envoy Post is a secondary ancillary to Envoy 100 service and it is offered jointly by Telecom Canada and Canada Post.

a) The Customer Premises Equipment Market (CPE)[9]

It was not until the early 1980s that the established common carriers (ECCs) lost their ability to exercise vertical monopoly power and to exploit the subscriber equipment market on a monopoly basis. It was the widespread belief of the time that the established telephone monopolies needed the whole customer equipment market in order to gain the benefits of size necessary for achieving declining unit costs and being therefore the least cost suppliers (natural monopolies).

The major telecommunications common carriers have established their own manufacturing subsidiaries in order to achieve the economies of scale and scope and the economies of technological change[10]. Thus Bell Canada and B.C. Tel both own major equipment suppliers[11]. This vertically integrated structure has long been the dominant feature of the telecommunications industry in Canada and the U.S.

However, the regulatory environment of the terminal attachment market has dramatically changed since the early 1980s[12]. Due to the

---

9 Subscriber equipment includes residential and business telephones, key systems and automatic branch exchanges (PABXs).

10 This vertically integrated industry structure was a unique phenomenon of Canada, the U.S and Sweden. In other parts of the world the service provision and the manufacturing of the subscriber equipment were totally separated. However, after the recent privatizations and deregulations, ECCs are acquiring telecommunications equipment manufacturing firms in an effort to increase their profits and improve their competitiveness. British Telecom for example has aquired the subscriber equipment supplier, Mitel of Canada.

11 The vertically integrated structure between Bell Canada and its affiliate Northern Telecom, has been critically examined during the Restrictive Trade Practices Commission Inqiry. It has been feared that Bell Canada favours its own equipment subsidiary, inhibiting the emergence of competition and perhaps innovative activity. Although this may be of lesser concern in the U.S. after the divestiture of AT&T from its local operating companies, it remains a concern in Canada. (See for example Bell Canada - Review of Revenue Requirements for the Years 1985, 1986 and 1987, CRTC Telecom Decision 86-17, October 14, 1986).

12 As a matter of fact, it was in the late 1950s that the first blow came in AT&T's existing monopoly. The Court of Appeals overturned the Federal Communications Commission's (FCC) decision that the Hush-a-Phone device could not be used with Bell telephones.

impetus of technical and political pressures this market had become more and more open internationally.

It was initially[13] in the U.S. that this market was liberalized. It was argued there that a natural monopoly did not exist in the provision of the CPE market. As a result, competition could be beneficial to the public. Since then a number of countries has followed the same line of policy. Presently, by far, the most open[14] CPE market is that of the U.S.A. and the U.K[15].

Following this liberalization, established suppliers and new entrants (domestic and foreigners) were free to compete openly (in both the U.S. and U.K.) with the previous monopoly of subscriber equipment. Market penetrations of newly established firms are high in both countries. For example, AT&T's market share for US subscriber equipment market fell to below 70 per cent in 1985 from 90% prior to divestiture. Canadian and Japanese firms, through direct investment in the US, have achieved significant market shares. The "success story" of Northern Telecom is attributed to the liberalization of the US subscriber equipment market[16]. In the U.K. a similar trend has been observed. Nevertheless the British Telecom (BT) purchase of Mitel might constrain the inroads of overseas competitors.

---

[13] The first liberalization of this market started in the U.S. in 1980. The FCC however has adopted wiring and other testing and manufacturing standards to permit non-Bell equipment to be directly connected to the network. In 1980 the FCC with its *Computer II* inquiry stipulated that "new CPE", i.e. terminal equipment acquired or manufactured by a carrier after January 1, 1983, could only be sold or leased on an competitive basis.

[14] Open markets are those market structures in which the telephone monopoly extension onto CPE has been substituted for competitive market forces. As a result of this substitution competition has been stimulated in the end-user market place, thereby changing this market structure from monopolistic to competitive. Open markets are not necessarily unregulated. Indeed, complex structures of regulation either still exist or have been set up to oversee the competitive process.

[15] In the U.K., the liberalization of that market and the privatization of British Telecom (BT) was done in 1984/85.

[16] Northern Telecom has 1/3 of the US market for major PBX products.

It has been argued that the complete liberalization of the CPE in both the U.S. and U.K. was due to the fact that there exists a *single* regulatory authority that could enforce its policy nationwide. By contrast, in Canada the liberalization of subscriber equipment market has been only partial. Different rules and prohibitions apply to the regional markets served by provincial regulated monopolies and to the part of the market served by federally regulated monopolies.

Thus, in 1982 the CRTC adopted rules and standards for the subscriber equipment market which were effective only in its own jurisdiction. The progressive liberalization of this market (which was previously dominated by Bell Canada, and B.C. Telephone and their equipment suppliers) has enabled some penetration by small competitors[17]. This penetration remains limited however. Bell Canada still retains 75% of the PBX market and over 85% of key systems. By 1990 its domestic market share is still expected to be 75%. The procurement policies of both Bell Canada and B.C. Tel to buy their telecommunications equipment mainly from their own subsidiaries limits the opportunities for market penetration from new competitors[18].

The regional Canadian subscriber market - the market not dominated by Bell Canada and B.C. Tel - is actually a very closed one because of the procurement policies of provincial authorities. Competitive opportunities are thus limited and vary from province to province. Would-be competitors attempting to enter this market face a welter of different rules and prohibitions. These rules vary from almost no restrictions for Alberta (except Edmonton), to complete prohibitions for

---

[17] For example, Microtel, Mitel and Gandalf which manufacture advanced switching and related products. Canadian Marconi and Spar Aerospace manufacture satellite communications equipment. Canada Wire and Cable and Phillips Cables serve the transmission market while a number of foreign firms, like Alcatel-ITT, Plessey and others manufacture or import and assemble a number of products. For a thorough treatment of this subject see The Supply of Communications Equipment in Canada, DOC, May, 1984.

[18] The telephone companies alone purchased, in 1981, machinery and equipment of $853.3 million of which 91% has been supplied by Canadian manufacturers, mostly by the subsidiaries of the major telecommunications carriers.

New Brunswick and Newfoundland to partial permission to most other provinces. However, these regional markets account for only 20% of the Canadian market.

We can say, following Schmidt and Corbin (1978), that "the nationwide jurisdiction of the FCC has permitted extensive liberalization of telephone company terminal attachment requirements across the country". By contrast, in Canada, "the lack of a regulatory body with authority to give effect to the national dimension in telecommunications" has given rise to a divided regulation, some carriers being regulated by federal, others by provincial agencies. The former has opted for *de jure* open competition in the terminal attachment while the latter have opted for *de jure* closed or limited competition. This divided Canadian regulation seems to be, according to Schmidt and Corbin, the most important hindrance to the formulation of a national telecomunications policy, which they consider so important for promoting international competitiveness.

Because of the existence of two types of regulatory regime in the provision of subscriber equipment, the Canadian CPE markets can be classified as lying between the U.S.A. market and those of most continental European markets (closed markets)[19].

In sum, the liberalization of the CPE market was the result of international political forces stemming chiefly from the U.S. The bandwagon effect was set in motion but in Canada not all provincial governments jumped on it. Once more, the resistance of regional authorities to introduce rapid changes, their belief in the benefits resulting from a monopoly structure and their resistance to accepting changes from above (the federal government) retarded the dispersion of benefits that competition would bring across the country.

Yet, economic as well as technological forces played an important role in the liberalization of the CPE market. It seems that an implicit

---

19 Closed markets are those market structures in which a major carrier extends its monopoly even to the CPE market. Competition is very limited in these markets since the market of domestic suppliers of CPE is indeed very small.

international unanimity existed (which was mostly expressed in the belief) that competition rather than monopoly could better serve the needs of consumers by diffusing technology more rapidly. However, not everybody adopts this argument.

Canada seems to have achieved and maintained a highly advanced telecommunications system and subscriber equipment products despite a monopolistic supplier/distributor industrial structure. Behind Canada's liberalization move, promotion of technical change did not appear to be a very significant factor[20]. The over-riding criterion for such liberalization seemed to be freedom of choice and lower prices for consumers.

However, it seems that the objective in promoting more rapid technical change is no better achieved by one or another market structure. The problem resides in the deficiencies of the mechanisms for the diffusion of new technologies and not in the deficiences of one market structure or another. Competition may be an effective means for permitting the diffusion of technical change in the short run. In the long run it might have some undesirable consequences for firm strategies and behaviour that inhibit innovation and damage international competitiveness.

Apparently, proponents of deregulation challenge the idea that telecommunication services, in their entirety satisfy the conditions of "natural monopoly". They contend that technological changes have reduced unit costs of telecommunication switching and transmission and have expanded the potential for competitive entry into *all* aspects of the industry from manufacturing to service provision. They argue that increased competition would encourage innovation and service diversification.

[20] Canada's monopoly structure has achieved high technical advances if it is judged by international standards. Northern Telecom was responsible for the first world introduction of a variety of digital-technology-subscriber-equipment products and subscriber-equipment-related advanced semiconductor components.

As might be expected the liberalization of one market brings about the liberalization of another. After equipment, it was the turn of the transmission market or the systems interconnection market to be deregulated. However, although the liberalization of the CPE market came about without raising any major concerns about its possible effects on the ECCs cost structure, the attempts to deregulate the transmission market raised significant questions concerning the viability of the ECCs, on the one hand, and the efficiency of the pricing policies used by them, on the other hand. As a result few countries have deregulated completely this segment of the market.

2) SYSTEMS INTERCONNECTION

System or network interconnection goes to the heart of the natural monopoly issue. If the established carriers are indeed natural monopolies the introduction of competition would be to the public detriment. Indeed, should interconnection be freely permitted, new entrants would choose to enter the most lucrative markets, "creamskimming" them and leaving the unprofitable ones to the ECCs. Prices in these markets would necessarily increase while service might be reduced in other segments of the market. Society would not have retained the most efficient market structure. These arguments have been advanced on many occasions by the ECCs in both Canada and the U.S.

In the U.S. the FCC with its *Above 890 Decision* authorized, in 1959, private entities to establish and operate point-to-point microwave systems to meet their own internal needs, provided that they met designated technical standards. Microwave transmission for private lines for large business users was then allowed for the first time. In 1969, the FCC with its *Specialized Common Carrier Decision*, approved provision by Microwave Communications Inc (MCI) of microwave link between Chicago and St. Louis. In the mid-1970s MCI expanded its offerings from primarily private line data services to voice transmission (its Execunet service). Moreover, in 1977, according to the *Execunet I* decision, MCI was able to provide its Execunet services in open competition with AT&T's interstate MTS and WATS services. Thus, private microwave systems have been allowed to "bypass"[21] the public switched network since the late 1950s. A number of new firms, such as specialized terrestrial and satellite or other common carriers (OCCs)[22] and resale[23] carriers entered the industry.

In 1978, under the Court's *Execunent II* order, competition was facilitated still further. Under this order AT&T was obliged to provide service interconnections to MCI, so that its customers could access AT&T's vast customer population.

Of course, the 1980s brought even more substantial changes. On January 1, 1984 the Bell System's[24] monopoly ended with the implementation of the *Modified Final Judgement* (MFJ). According to the latter, AT&T had to divest its operating companies (BOCs) which were permitted to offer local monopoly services and long-distance ones within their operating jurisdictions called Local Access and Transport Areas (LATAS). The divested BOCs were reorganized in seven Regional Holding Companies (RHCs). Although they were allowed to sell new terminal equipment they were prohibited from manufacturing the telephone equipment. The AT&T retained its long-distance operations and terminal equipment.

---

21 *Bypass* has never been formally defined. However, it can be broadly defined to mean the use of communications facilities or services such as video, voice, or data that circumvent the telephone exchanges of the public switched network. Bypass can be either "economic" or "uneconomic". *Economic bypass*, as it is defined by the New York Telephone Company, "occurs when bypass costs are less than ECCs costs for local switched carrier access". "*Uneconomic bypass* occurs when a bypass supplier can provide selected customers access at a higher cost than the ECCs but at a lower price because regulation causes the ECCs' access charges to be held at an artificial level above the costs".

22 Some of the firms that were called OCCs are, MCI, GTE-Sprint, USTS and WU.

23 Resellers realize profits by buying a bulked priced service, such as WATS, and then reselling it in smaller "packages" at lower rates than the basic or undiscounted ones.

24 The Bell System included AT&T's Long Lines operations and its affiliated Bell Operating Companies (BOCs). The Bell System dominated, by far, the Independent telephone companies, in terms of assets, revenues, earnings and access lines.

The implementation of the MFJ has changed dramatically the structure of the telecommunications industry in the U.S.A. According to this decision the local exhange companies were designated as *bottleneck*[25] *monopolies* (natural monopolies) and gateways to the telephone end users. On the other hand, the interexchange (long-distance) segment of the market was designated as competitive. Interexchange carriers must compete for the existing long-distance market. In order that this competition be viable, the RHCs (the local echange service providers) were required to provide connection on an equal basis between their facilities and those of the interexchange carriers. The third segment of the market which comprise CPE and the supply of information service[26], were designated as naturally competitive.

Today, as a result of all these decisions, competition exists for virtually all of AT&T's transmission offerings, including private line, switched voice services, resale and sharing by users or new vendors of MTS and WATS markets.

Central to AT&T's pre-divestiture opposition to the competitive inroads were the arguments that entry would result in "creamskimming" and in diversion of revenues needed to support basic services. These arguments were repeatedly rejected by the FCC and the Courts, which found that it was in the public's interest to allow competition in the provision of all telephone services but the local ones.

In Canada, a parallel situation has emerged but on a smaller scale. It was during the 1950s that CNCP started operating its own

---

[25] Judge Harold Greene defines bottleneck monopolies as the "local companies with their ownership of the local switching systems and thus the pathways which the interexchange and information providers must use if they wish to reach the ultimate consumers" (Judge Harold Greene, *United States vs AT&T*, *Opinion*, Washington, DC, 13 January, 1986, p.8).

[26] Information services were defined in the MFJ as "the offering of a capability for generating , acquiring, storing, transforming, processing, retrieving, utilizing or making available information which may be conveyed via telecommunications.." (Ibid, Section IV(J)).

coast-to-coast microwave network for the provision of specialized voice and data services. However, due to systems interconnection prohibition, CNCP customers were obliged to have two local distribution lines into their premises. In August 1979, CNCP was granted connection to Bell Canada's and in 1981 to B.C. Telephone's networks in return for a compensation to the owners of the network (Bell Canada and B.C. Tel). Such interconnection permitted CNCP's customers to use its network directly for line voice and data services through the customers ordinary telephones.

CNCP Telecommunications has recently demonstrated an interest in the provision of long-distance calls (MTS and WATS). It applied to CRTC for permission to connect its system with that of Bell Canada and B.C. Tel in order to compete with them in the long-distance public voice telephone market (MTS and WATS).

To be sure, the introduction of competition into the long-distance segment of the market has been possible due to the way technological change has progressed in the transmission segment of the market[27]. Indeed, important cost-reducing technologies have made possible the provision of long-distance calls on a by-pass or on a competitive basis[28]. It is important, however, to note that new technologies have not had the same impact on the provision of local calls. Thus, although the costs of subscriber loops and other nontraffic-sensitive investments associated with access to the network have fallen, their reduction is not as significant as in the traffic-sensitive portion of the market

---

27 Early transmission of telephone calls involved the use of crude open wire. This was eventually replaced by insulated copper wire pairs that connected subscribers to central offices. Multipair cables and then multiplex equipment was further developed to transmit multiple signals over the same channel. Coaxial cables, microwave radio systems, satellites, cellular radio and fibre optics eventually replaced all old transmission technologies.

28 The costs for providing long-distance calls and other traffic-sensitive services have been declined significantly due to the combination of various relative cheap technologies, such as satellites, fibre optics, microwave and greater multiplexing technologies. The cost of a satellite has fallen from $2 million each in 1965 to about $5,000 in 1986, while that of fibre optic cable from $10 per metre to $.60 per metre in 1985 and to $.01 by 1990.

(long-distance). Since establishing a local network is still expensive, new firms wanting to enter the interexchange (long-distance) segment of the market require interconnection to the public network.

Important economic questions concerning the efficiency of the present market and tariff structure, on the one hand, and distributional and equity considerations, on the other hand, arise as a result of permitting interconnection. The economic issues arising from technological changes as well as from entry deregulation of the long-distance market are examined next.

THE ISSUES IN THE PRESENT REGULATORY DEBATE

The present regulatory issue, in Canada, centres around the question of which market structure (competition or regulated monopoly) is more appropriate in providing the long-distance services (MTS, WATS).

With regard to the distribution of domestic local services, the natural monopoly character of the ECCs is usually admitted, at least so far as wire service is concerned. As far as the switching and transmission of long-distance calls is concerned, critics of the telecommunications monopoly challenge the economies of scale and scope argument. Critics argue that recent developments in technology have undermined the traditional rationale for the monopoly provision of long-distance services. Accordingly, regulated or publicly-owned monopoly may not be the most appropriate market structure for realizing the full potential of technical advance.

It has been further argued that the rapid growth in demand for advanced communications services (related primarily to data, text and image transmission) is mostly for highly diversified and specialized services with wide variations between users in the options sought. Regulated or publicly-owned monopolies, so the argument goes, have enormous difficulties in entirely satisfying diversified demands through universally available public networks, no matter how sophisticated the latter may be. Proponents of deregulation argue then that competition may be the appropriate market structure for filling up the present gap.

Similar arguments have been advanced in the U.S. as well and they ultimately led to the divestiture of AT&T from its operating companies. It is thus appropriate, at this stage, to examine, briefly, the U.S. experience with deregulation in the long-distance market and see whether such an experience is valuable for Canada as well.

The U.S. experience

As was mentioned above, the MFJ as well as other FCC decisions permitted the proliferation of interexchange carriers. Each carrier specializes in the provision of certain services. Moreover, carriers under LATAS are not allowed to offer a full range of outputs. Such a specialization in the provision of telecommunication services has created a discrepancy between what end users need and what the specialized carriers offer (de Fontenay et al, 1987). Dissatisfied customers demand one-stop-shopping and end-to-end communications. Astute entrants, realizing that a gap exists in the market, have procceeded in the formation of what Alain de Fontenay et al (1987) call the *campuses*. That is to say, the manager of the campus acts as an agent of a group of unrelated end-users (the campus) and the various interexchange and LATA carriers[29].

[29] Campuses compete directly and indirectly with both interexchange and bottleneck monopoly carriers. As intermediaries i.e., as retailers in the provision of a *gamut* of telecommunications services, the campuses compete directly with the local exchange service providers by gradually taking over the traditional functions of the pre-divestiture telephone companies. The campuses are thus *local* competitors. They act as direct *internal campus bypassers*. Competition comes from *external campus bypass* as well. The campuses may choose to connect its members (unrelated end-users) to the outside world without using the local exchange network at all. The necessity to create campuses stems from the recognition that existing technologies still permit the realization of *economies of scope* (supply complementarities). Indeed, transmission, switching, and terminal facilities have been designed and are still designed to accommodate many kinds of digitilized information. Voice and nonvoice, graphic, numerical as well as video communication services, all make joint and common use of both local and interexchange facilities. *Efficiencies in production* are thus favouring the creation of centralized all-embracing-telecommunications-service provision. Joint service offering is also dictated by *demand interrelationships* that exist in the provision of services that may be viewed as technically separable. These interdependencies in demand

Important policy implications arise from this new emerging competitive structure in the U.S. telecommunications industry. Some of these implications have been lately analyzed by de Fontenay et al (1987). They argue that competition arising from the campuses may erode the financial viability of local exchange service providers since end-users (who highly utilize the telecommunication services) will have an interest in forming campuses, bypassing[30] the local network. Campuses will be formed in the most lucrative and densest routes, leaving local networks with the thin and sparsely populated markets. The goal of universally available service at affordable prices would be sacrificed in the name of competition[31].

Phillips (1985), in discussing the potential effects of divestiture on the U.S. telecommunications industry structure and

---

permit a single-company or a campus to internalize them. *Transaction costs* for customers are minimized when interrelated services are offered by a single-all-embracing-telecommunications-service provider (the campus). These demand complementarities were important sources of private and social efficiencies in the pre-divestiture U.S. telecommunications structure. Thus, economies of scope, demand interrelationships as well as the possibility of realizing economies of scale are currently driving the post-divestiture specialized carriers to seek reintegration and to form the campuses.

30 In the U.S. there is already a great number of bypass systems installed such as the Las Vegas Starnet private microwave links between hotels and the Greater Pittsburgh WESDIN multitech network. Others are on the way to be constructed. UCLA's new private telephone system is expected to be one of the world's largest private networks. Olympia and York and United Telecommunications, Inc., have announced that they will jointly offer services that circumvent the local telephone company. IBM, CBS Inc., and Sears Roebuck and Co. have announced the formation of a joint venture to provide two-way information and transactional services such as videotex electronically.

31 De Fontenay et al, 1987, Faulhaber, 1987, and others, argue that this outcome is the result of regulatory constraints that do not permit LATAS to compete with campuses on an equal footing, and that such a problem will eventually disappear by completely deregulating the local exchange as well. The complete deregulation argument is associated with the notion of contestability. If a market is contestable none of the established firms or any other player enjoys market power and therefore the prices that will emerge will be socially optimal.(See next chapter for details). De Fontenay et al, 1987, Faulhaber, 1987 and others, argue that the local network is indeed contestable and therefore ripe for competition. No regulatory restrictions on either incumbents or entrants are thus necessary.

performance, reaches the same conclusion as the one reached by de Fontenay et al. He argues that the instability created from the segmentation of the U.S. telecommunications market structure, after divestiture, would lead to the creation of campuses. Phillips predicted that the sacrifice of supply complementarities (economies of scope) and demand complementarities, resulting from the divestiture of AT&T, would create forces for a gradual reappearence of contracting integration (campuses) and even the emergence of ownership integration of the U.S. telecommunications system. The regrouping of services under the hand of one supplier (the campus manager), would be a substitute for the old U.S. Bell System. He notes, however, that such an integration would proceed faster in the enhanced service[32] areas than it would in ordinary voice telephone service. As a result, ordinary plain old telephone service (POTS) would deteriorate in importance to the companies and in quality to its users, while high-valued new services would be offered in an efficient nation-wide network. Universality of service might be sacrificed. In addition, economic efficiencies would have been sacrificed as well if it is judged by the latest U.S. empirical evidence which suggests that the pre-divestiture Bell System might have effectively been a natural monopoly.[33]

Since Canada has not yet gone as far as the U.S. with its deregulatory policy, it may be preferable to safeguard the existing market structure and allow only gradually limited competition in some specific segments of the market, as is needed. One wonders whether it is desirable to go all the way and to deregulate completely the Canadian telecommunications industry, as in the U.S., and then to try to come back to the original situation. In addition, as is discussed in the next chapter, the unregulated natural monopoly telecommunications

---

32 The CRTC defines basic and enhanced services as it follows: "A basic service is one that is limited to the offering of transmission capacity for the movement of information" while "an enhanced service is any offering over the telecommunications network which is more than a basic service." (CRTC, Decision 84-18).

33 See A. Charnes, W.W. Cooper and T. Sueyoshi, 1988 and details in chapter 4 of this dissertation.

industry may not be sustainable[34], if we take into account the limited size of the Canadian market[35]. However, before we judge the appropriateness of entry deregulation of the Canadian telecommunications industry it is advisable to review, briefly, the debate in Canada.

The debate in Canada

The deregulation of the long-distance market is even more complex in Canada than it was in the United States. This is true if we consider that distributional and equity considerations are probably much more important for the policy makers in Canada than in the United States. It is thus germane to associate the question of which market structure is the most appropriate one to efficiently satisfy the ever-increasing specialized needs of customers, to the question of *rate- rebalancing*[36]. Rate-rebalancing issues become complex when they are interwined with the social goal of universal service at affordable prices, set forth by governments and regulators as well.

The problem arises because a high degree of cross-subsidization seems to exist in the present telecommunications pricing system[37]. Cross-subsidies are the product of present pricing practices employed by telephone companies and approved by regulators for the purpose of realizing the goals of universal service at affordable prices[38].

---

34 A monopoly is not sustainable if no price exists which would deter economically inefficient entry by competitors. (See next chapter for details).

35 This may be true even if we allow for the increase in demand for the old and new services.

36 Rate-rebalancing can be defined as an increase in local tariffs and a decrease in long-distance tariffs.

37 At present, there is no agreement about the nature of this cross-subsidization. See, R.D. Denious "The Subsidy Myth", Telecommunications Policy, 1986, p.259. The cross-subsidization argument is widely used by the ECCs. If cross-subsidies are present, established carriers, in order to meet competition, would reduce tariffs on long-distance calls while they would increase tariffs in their monopoly market (local calls market). The pre-entry overall rate of return would, thereby, be maintained.

38 Historically, the pricing of telecommunication services has been based on a "value-of-service" concept, in which services are priced

According to these pricing practicies the company's total costs are only recovered in the aggregate. The price of an individual service may not necessarily cover its costs of provision. Whether individual prices cover costs is immaterial, as long as a company's total costs are covered in the aggregate and all services are offered on a monopoly basis. As a result of this pricing policy wide cross-subsidies from long distance to local services, from urban to rural areas and from business to residential customers have occurred.

Some figures (tables 2-3 and 2-4) provided by Bell Canada and Sask Tel (although contested) illustrate the disproportion that exists between local and long distance revenues and costs and therefore the magnitude of cross-subsidization. The over-pricing of long distance calls and the under-pricing of local calls in respect to their costs of production, generate the imbalance in revenues that is unequally distributed among industries[39].

Table 2-5 illustrates that a number of industries, namely, the service-oriented ones, make heavy use of long-distance telecommunications services. Table 2-6 shows toll revenues as a percentage of total operating revenues for Telecom Canada members. As can be seen from these tables the telephone companies dependent heavily on the revenues derived from a number of business-toll subscribers rendering them vulnerable should the business-toll subscribers decide to leave the network.

---

according to their value to a defined group of customers, rather than on the strict "cost-of-service" approach. The company-wide rate averaging principle has also been applied, in which services with similar features are priced the same throughout a telephone company's operating territory, irrespective of costs. The application of such a pricing schemes has given rise to 1) flat rate pricing for local service; 2) class-wide rate averaging; 3) contributions from toll revenues toward the recovery of access costs. These traditional pricing practices have, recently, been attacked as causing distortions in resource allocation.

[39] Canadian businesses, the group that uses the long distance services most, spent approximately $4 billion on telephone and telegraph in 1981. That is about 0.7% of their total input costs for goods and services.

TABLE 2-3

BELL CANADA'S ESTIMATED REVENUES AND COSTS BY SERVICE CATEGORY, 1983

Category (1)	Revenues (2)	Costs (3) ($ Millions)	(2)-(3)	(3)+(2)
Local service (non-competitive)	1 389	2 630	(1.241)	1.89
Toll service (non-competitive)	1 988	626	1 362	0.32
Competitive network	386	317	69	0.82
Competitive terminal	878	834	44	0.95
Common	99	333	(234)	-
Total company	4 740	4 740		

Source: Response to Interrogatory, Bell (CRTC), May 22, 1984 - 22IC - as found in Steven Globerman, "Economic Factors in Telecommunications Policy and Regulation", in Stanbury, (ed.), Telecommunications Policy and Regulation, IRPP, Montreal, 1986.

TABLE 2-4

NET REVENUE AND EXPENSES BY LINES OF SERVICE FOR THE YEAR 1982 - SASK TEL

Category (1)	Revenues (2)	Costs (3) ($ Millions)	(2)-(3)	(3)+(2)
Local	52.3	102.9	(50.6)	1.97
Toll	179.4	54.8	124.6	0.31
Optional	25.9	24.0	1.9	0.93
Unregulated	35.3	26.8	8.5	0.76
Common	2.8	79.4	(76.6)	
Total	295.7	287.9		

Source: Steven Globerman, "Economic Factors in Telecommunications Policy and Regulation", in Stanbury, (ed.), Telecommunications Policy and Regulation, IRPP, Montreal, 1986.

TABLE 2-5

INDUSTRY SECTORS WITH HIGHEST PERCENTAGE EXPENDITURES ON TELEPHONE AND TELEGRAPH SERVICES, 1981

Industry Sector	Annual expenditure on telephone & telegraph ($ millions)	Telephone and Telegraph as % of all purchased inputs
Radio and TV Broadcasting	87	5.2
Health Services	209	3.0
Banks and Credit Unions	201	2.8
Rwy Transport	148	2.7
Misc. Services to Business	191	2.4
Advertising Services	18	2.3
Wholesale Trade	461	2.1
Other Fin. Ins. & Real Es.	555	2.0
Construction - Other	7	2.0
Insurance	81	1.7

Source: Federal-Provincial Examination of Telecommunications Pricing and the Universal Availability of Affordable Telephone Service, Minister of Supply and Services Canada, Report, October, 1986

TABLE 2-6

TOLL REVENUES (INTERPROVINCIAL AND INTRAPROVINCIAL) AS A PERCENTAGE OF TOTAL OPERATING REVENUES OF TELECOM CANADA MEMBERS, 1982.

	%
SASK TEL	65.0
AGT	64.0
MTS	59.2
Newfoundland Telephone	58.9
Maritime Tel & Tel	56.5
NBTel	55.8
B.C. Tel	55.0
Island Tel	54.0
Bell Canada	49.5

Source : R. SCHULTZ and A. ALEXANDROFF, Economic Regulation and the Federal System, University of Toronto Press, Minister of Supply and Services Canada, 1985.

Indeed, as new low-cost technologies become available and widely known, high use business customers will eventually atempt to establisha network specific to their needs in order to provide by-pass services. The by-passing of the existing telephone network would jeopardize the long term financial viability of telephone companies. Residential customers will face an increase in their rates and they, or at least a part of them, will be adversely affected forcing the poorest to abandon the network[40]. Universality, the most important social goal of the government, may be jeopardized.

Critics (Kahn, 1984, Wenders, 1987) argue that the traditional regulatory and rate-setting practices create considerable *allocative inefficiencies* and therefore a reduction in social welfare. Economic efficiency can be increased, so the argument goes, only if the telecommunication services are priced at their marginal cost[41]. They support the view that structural deregulation and therefore the introduction of competitive forces would necessarily align prices to costs, thereby eliminating cross-subsidization and promoting efficient markets for local and long-distance telephone service and telecommunications equipment[42].

They further argue that rate-rebalancing will discourage customers from bypassing both the long-distance and local exchange portions of the

---

40 Estimates by Peat Marwick reveal that 20,000 to 25,000 subscribers will drop off the network in the combined territory covered by Bell Canada and B.C. Tel., if rates increase by 66.5% in Ontario and Quebec and by 56.8% in B.C. Bell Canada itself has estimated this number to be 160,000.

41 Some argue for the introduction of Ramsey-Boiteux pricing schemes. Ramsey-Boiteux pricing is a type of value-of-service pricing. Under certain conditions each price is inversely related to the elasticity of demand. Ramsey-Boiteux pricing has the additional merit of assuring sustainability of natural monopoly. For details, see discussion in the next chapter.

42 However, Breslaw and Smith (1982), using Bell Canada data, and examining the effects of historical prices on social welfare have concluded that the latter has approximated optimality, even though the prices have been consistent neither with Ramsey-Boiteux nor with competitive market prices (marginal cost).

network. Allocative efficiency gains can thus be realized by avoiding uneconomic bypass.

It is true that competitive forces can drive prices to marginal costs of production increasing thereby social welfare *only* if markets are perfectly competitive or perfectly contestable. However, we believe that the telecommunications market is neither perfectly competitive nor perfectly contestable. On the contrary, natural monopoly considerations as well as unsustainability may better characterize this industry. Natural monopoly and unsustainability favour entry and price regulation. A segment of a market may be better served by a competitor who is specializing in the production of one output only but the presence of competitors would increase the costs of telecommunication services to all consumers.

As far as the uneconomic bypass argument is concerned, in our view, it cannot be avoided even if competitive forces were allowed into the telecommunications industry[43]. As was mentioned above, the U.S. experience with structural deregulation, divestiture and rate-rebalancing has demonstrated that uneconomic bypass is still possible by the formation of campuses. Paradoxically the levy of high access charges, instead of safeguarding the local exchange network from competition, threatens its financial viability and with it the universality of service. The presence of economies of scale and scope inherent in the present technology in conjunction with the threat of uneconomic by-pass drives various U.S. carriers towards a reintegration and a more unified structure (campus).

The financial viability of the Canadian telecommunication carriers would be assured and uneconomic by-pass would be avoided if rate-rebalancing occurred *under the present market structure*. Social welfare would be increased since the increase in local rates under the present monopolistic industry structure would be lower than under competition.

---

[43] Uneconomic bypass cannot be avoided either even *if* the cost structure of the telecommunications industry fulfills the requirements of natural monopoly. A "rate-rebalancing" would be necessary in order to avoid uneconomic by-pass.

This "orderly" rate-rebalancing[44] outcome is dictated from the natural monopoly character of the Canadian telecommunications industry[45]. It can then be concluded that technological changes do not necessarily call for entry deregulation of the telecommunications industry, as long as they do not radically erode the subadditivity[46] of the cost structure of natural monopolies. All that is required is an adjustment of regulation to the changing environment.

Thus, the recent changes in technology within the telecommunications industry, the convergence of telecommunications and computer technologies, and increased competition in Canada and elsewhere raise questions concerning the *pricing* arrangements only that have been adopted in the telecommunications industry but *not the structure* of the industry itself. However, it can be said that as new technologies become more widely available and cheaper, bypass will become the most critical variable to determine the policy debate on pricing issues as well as on the appropriate market structure (monopoly or competition) in providing the traditional monopoly services[47].

The CRTC's policy, up to now, is characterized by an absence of deregulatory fervor. Indeed, the CRTC in its 1985 decision, after

---

[44] Taking into account what has been said concerning the Canadian telecommunications cost structure this "orderly" rate-rebalancing can only be realized by the industry's regulators and not by market forces.

[45] The cost structure of Bell Canada and AGT is estimated in Chapter 6. We conclude there that the hypothesis that the cost structure of both these companies is subadditive cannot be rejected.

[46] A cost function is subadditive if centralized production is cheaper than separate production. A subadditive cost function gives rise to a natural monopoly. For details, see the next chapter.

[47] In areas where bypass neither seems to threaten the viability of the public switched network nor to erode its subadditive cost structure, competition is permitted. Thus, following the example of FCC some years ago, the CRTC, by its 1985 decision, decided to deregulate the market for sharing and reselling. Moreover, the CRTC, by its 1985 decision, permitted interconnection of the private local networks for non-voice services to the public switched voice or data network. It also permitted B.C. Rail to interconnect its facilities to B.C. Tel network in order to allow the former to offer private line voice and data services.

taking into account the equity and risk considerations that would result from entry deregulation, opted for the *status quo*. Bell Canada and B.C. Tel maintained their monopoly for the provision of long-distance services while CNCP was not allowed interconnection. By the same token, the CRTC has recently (August 1988) reiterated its policy by prohibiting Call-Net Telecommunications to compete with Bell Canada in the provision of MTS and WATS services[48]. Thus, the policy followed by the CRTC in the past few years may be judged as the most appropriate one in the light of the analysis presented above and the one that will be presented in the following chapters[49].

CONCLUSIONS

By and large, the Canadian telecommunications market is presently characterized by a limited "unleashing" of competitive or market forces. A duopoly or an oligopoly characterizes most segments of this market (private lines, data transmission). The segments where services are still provided on a monopoly basis are local and long-distance services and the market for telegrams. The most liberalized market, although not everywhere in Canada, is the CPE market.

The recent deregulation movement is the result of a wide variety of political, economic, social, technical and industrial factors. Obviously, a regulatory structure evolves as a result of factors internal or external to the industry, always fashioned so as to attain pre-established criteria and objectives. Economic and technological changes can bring changes in the objectives and the latter can bring about changes in the regulatory structure. The elaboration of a final policy should be based whenever possible, on both quantitative knowledge as well as on theoretical considerations.

---

[48] See *Resale to Provide Enhanced Services*, CRTC Telecom Decision 88-11, August 16, 1988.

[49] It is our opinion, however, that the CRTC's policy has been driven mostly by social and political considerations and not by the strict economic ones we reveal here.

It becomes clear from the above that policy makers, before contemplating a deregulation of the Canadian telecommunications industry have to allow for natural monopoly arguments. The scope for competition actually depends on the extent of natural monopoly. Indeed, when economies of scale and scope are large and present in many services the scope of competition is limited, but when technological changes and increases in demand for specialized services render economies of scale and scope less important, the scope for competition is broadened. It is, these factors that determine the efficient structure of the industry.

Thus, the whole debate in the telecommunications industry boils down to the determination of the nature of its cost structure. An empirical test of the industry's cost structure is presented in chapter 6, while a review of the empirical studies is presented in chapter 4. In the next chapter, we lay down the theory that will permit us to make the empirical tests. In addition it summarizes the arguments for and against the introduction of competition into the Canadian telecommunications industry.

CHAPTER 3

POLICY FORMULATION FOR THE CANADIAN TELECOMMUNICATIONS INDUSTRY: THEORETICAL PERSPECTIVES

The telecommunications industry has long been considered to belong to the class of industries whose technological structure satisfies the conditions of natural monopoly. Consensus concerning the definition as to what constituted a natural monopoly as well as the policy implications flowing from this definition were the main characteristics of the older industrial organization literature. It was the existence of strong economies of scale, as measured by scale elasticity, that defined the most efficient industry configuration and to a certain extent the degree of regulation.

This traditional theory has recently been challenged and significantly extended by Baumol, Panzar and Willig, (1982). According to Baumol et al such new concepts as economies of scope, cost subadditivity, and sustainability, as well as a refinement in the definition of some old ones such as economies of scale, should be used to define natural monopoly and to implement the appropriate public policy. Their approach has had considerable influence[1] among economists and the latter started implementing the new theory in a number of industries including telecommunications.

This chapter reviews this new theory and some other industrial organization theories that have influenced policy formulation for the telecommunications industry. The review will permit us to identify the virtues and potential weaknesses of the new and older theories, and to judge the "appropriateness" of the policies that have been implemented in the telecommunications industry.

---

1 See chapter 4 of this dissertation.

THE EARLY NATURAL MONOPOLY THEORIES AND REGULATION

Historically, in Canada, the U.S.A. and elsewhere[2] telecommunications service provision as well as subscriber equipment distribution was the responsibility of one major operator. The telecommunications service providers and equipment distributors established subscriber equipment manufacturing subsidiaries for serving their needs. This monopolistic, vertically integrated industrial structure described the telecommunications industry well in most countries until the late 1970s. Such an industry structure was believed to confer all the benefits of the least cost supplier, namely, economies of scale, economies of scope and economies of technological change[3].

Society could avail itself of these alleged benefits only if regulation of the supply of telecommunication services could be imposed as a substitute for competition. As a matter of fact, competition was judged to be unsuitable for this type of industry. The unsuitability-of-competition argument in defining the necessary conditions for a natural monopoly was advanced by Richard T. Ely a long time ago. Ely[4] et al (1927, p.188) recognized that in circumstances where economies of scale were great, competition was unsuitable. It was argued that in such circumstances monopoly may be the least cost source of supply while competition may be self-destructive, resource-wasteful and thus inefficient.

This "unworkability-of-competition" argument was further elaborated by several economists. Kaysen and Turner (1959, p. 191) defined natural monopoly as a situation that arises as a result of:

---

2 The vertically integrated industry structure was a unique phenomenon of Canada, the U.S.A. and Sweden only. (See footnote 10 of chapter 2).

3 In some European countries, especially in West Germany, arguments have been occasionally advanced that economies of scope may exist in the provision of both telecommunication services and equipment manufacture. In North America such an argument has been explicitly stated in the findings of the Restrictive Trade Practices Commission and in a paper by R. E. Olley (1987).

4 Ely, R.D. et al, Outlines of Economics, Fourth Revised Edition, The Macmillan Company, New York, 1927 (Copyright, 1893).

> "A relationship between the size of the market and the size of the most efficent firm such that one firm of efficient size can produce all or more than the market can take....and can continually expand its capacity at less cost than that of a new firm entering the business. In this situation, competition may exist for a time but only until bankruptcy or merger leaves the field to one firm; in a meaningful sense competition here is *self-destructive*"(emphasis added).

In such circumstances, a single supplier may better serve consumer needs than a large number of firms. Entry and new competition result in loss in economic welfare.

Kahn (1971, p. 119) describes natural monopoly essentially in the same manner as Kaysen and Turner. He argues that:

> "..the critical and all embracing characteristic of natural monopoly is an inherent tendency to decreasing unit costs over the entire extent of the market. This is so only when the economies achievable by a larger output are internal to the individual firm if, that is to say, it is only as more output is concentrated in a single supplier that unit cost will decline".

Thus, it seems that, for many economists, the overriding criterion for defining natural monopolies was the existence of pervasive economies of scale (the supply characteristics).

Notwithstanding that, some economists stressed, and related the monopoly outcome to, the conditions of market demand. Kahn (ibid, p.173) pointed out that where demand is highly volatile and the number of customers large, natural monopolies emerge as a necessity of making large investments to meet customers' peak-load demand. He argues:

> "An additional source of ... potential economies of scale is found not on the supply but on the demand side... Variability in demand ...., other things being equal, ..makes it more efficient to supply many customers and regions than few; that is to say, it gives rise to economies of scale when the dimension along which output is measured is not the quantites taken by some given number of customers but the number and diversity of customers and markets served...In consequence, the firm that covers the entire market is likely to have ... lower average cost, than two or more separate firms, each supplying some portion of the total market".

In such circumstances, competition is not only more costly but it may also be unworkable, self-destructive and destabilizing to an industry. This failure of competition to exercise a healthy regulating influence on the market, induced many economists to suggest *direct regulation* of industries with declining costs (natural monopolies)[5].

The evolution of the telecommunications industry structure, until the end of the 1970s in certain countries, can thus be explained by the acceptance of the above-mentioned definitions as to what constitutes a natural monopoly.

The telecommunications industry was assumed to meet the criteria for natural monopolies. The belief that cost and production conditions in the telecommunications industry conferred major or limitless economies of scale, led government authorities to establish a *de jure* monopoly in Canada and elsewhwere. *Conduct regulation* was then established by the regulatory commissions in constraining the *de jure* monopoly from abusing its market power. Such market structure, price and rate-of-return regulation served the Canadian telecommunications customers quite well until well into the 1970s.

Nationally, social objectives such as "universality" and "equality of service" are reflected in high telephone penetration rates[6]. Such high penetration rates can probably be attributed to the pricing principles that have been applied by the regulatory commissions and the companies themselves. Indeed, the rates of individual services were not necessarily designed to recover related costs. That is, the pricing

---

5 For example Henry Carter Adams argued in 1887: "...where the law of increasing returns works with any degree of intensity, the principal of free competition is powerless to exercise a healthy regulating influence... The control of the state over industries should be coextensive with the application of the law of increasing returns in industries...Such business are by nature monopolies". See Henry Carter Adams *Relation of the State to Industrial Action*, in Dorfman, J., *Two Essays by Henry Carter Adams*, New York: Augustus M. Kelly, 1969.

6 At present, 98.5% of Canadian households possess a telephone and 39% possesses more than one.

policy applied has been one that permitted the recovery of the telephone companies' total costs in the aggregate[7].

In fact the application of these rate making principles was judged to be incompatible with a competitive market structure. Regulation was used as the tool for achieving government's policy goals[8]. However, it is presently alleged (Wenders, 1987, Kahn, 1974) that the attainment of these goals by regulation and the application of the above-mentioned pricing principles neglected important changes in technologies and costs of the common carriers.

Wenders (1987) argus that changes in technology in recent years have reduced unit costs of telecommunications switching and transmission and have increased pressures for competition in all segments of the industry. He raises questions concerning the appropriate structure of the industry as well as the pricing principles that have been adopted. Under these increasing pressures, the regulatory commissions have been obliged to make changes in the traditional way of regulating. Regulation now must be applied not only to the monopoly's conduct but to

---

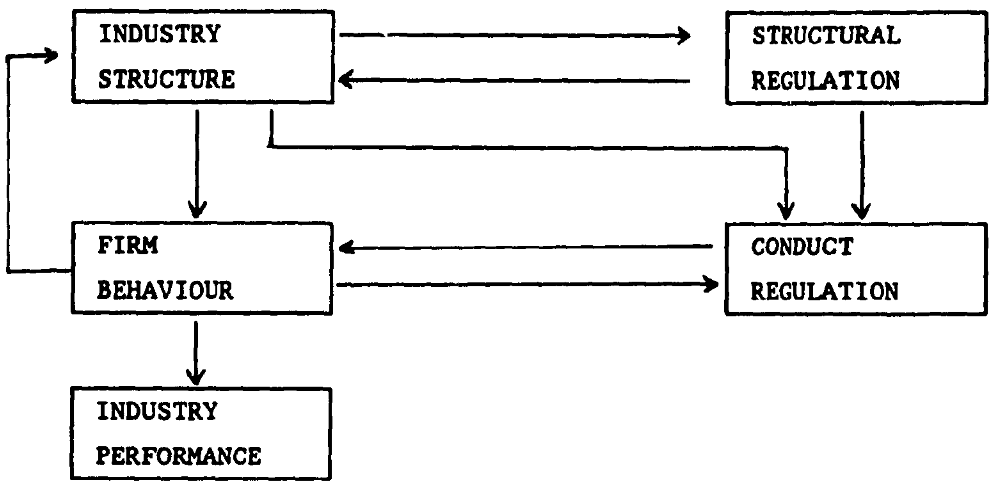
7 This practice has been described as the principle of company-wide rate averaging and value-of-service pricing. According to the first principle, rates for services with similar features are the same throughout a telephone company's operating territory, regardless of the type of location, terrain, technology employed etc. According to the second principle, prices differ according to the importance of the service (price-elasticity) to each customer class of users (business and residential for example), not to the costs of supplying them.

8 The goals of universality and equality of service were and still remain the priority of policy makers in government. This becomes clear from the following statement of the former-minister of communications Marcel Masse: "First and foremost, we must develop a policy which preserves universal access to the telecommunications system at affordable prices. Canadian telephone service to individuals and households is among the very best in the world. No policy, no matter what its industrial or economic benefits, can be considered acceptable if it lowers the current level of service, which is so essential to so many Canadian citizens. Similarly, no policy can be considered acceptable if it means that this essential service will not continue to be universally affordable". (Marcel Masse, Address to Electrical and Electronic Manufacturers Association Meeting, Montebello, Quebec, June 20, 1985, p. 4).

its *structure* as well[9]. Market structure is a *variable* that can be determined by both the conduct of the firms and the *structural regulation*. Figure 3-1 illustrates the regulation of the Canadian telecommunications industry using the traditional Industrial Organization paradigm.

Figure 3-1

Structural and Conduct Regulation of the Canadian Telecommunications Industry



The appropriate definition of natural monopoly on the one hand and the appropriate market structure (monopoly or competition) that would best serve the public interest in the new telecommunications environment on the other hand are once again at the forefront of the debate. Before we present the new theory of natural monopoly, it is useful to present briefly the main arguments against government regulation of public

9 It is true that structural regulation (franchise monopoly) has been applied since a long time ago to the telecommunications industry. However, in the past, almost everybody had accepted the validity of the argument that the industry was a natural monopoly. By contrast, recently, many challenge the validity of this argument. Whenever the government or the regulator believes that this industry still constitutes a natural monopoly structural regulation is reinforced.

utilities, as they have been expressed by the Chicago school of economic thought.

PREDECESSORS OF THE CONTESTABILITY THEORY: THE CHICAGO SCHOOL

The traditional natural monopoly theory and regulation has been severely criticized by the Chicago school. As early as in the 1960s advocates of less regulation advanced the argument that rate-of-return regulation could impose costs to society that could be greater than the alleged benefits. George Stigler and Clair Friedland (1962), in a study attempting to measure the effects of regulation on the performance of electric utilities, found that regulation of electric utilities had no significant effect on either prices or profitability. Such a result could be explained either by the inability of regulators to confine the operations of electric utilities to pre-specified levels of cost, output and price, or by the existence of substitute products. The latter could constrain the exercise of monopolies' market power in a more efficient way than regulators can do. In both circumstances, regulation is redundant. Stigler and Friedland thus advocated complete deregulation.

Milton Friedman (1962, pp. 128-9) went one step further. While he accepted the arguments of Stigler and Friedland, he further argued that other factors such as dynamic changes can undermine monopoly power. If competition is permitted, the benefits to consumers can accumulate more rapidly, "skillfully and cheaply". He argues that it is not even necessary to have actual competitors in the market. Indeed, *he contends that total deregulation without competitors is as efficient as actual competition* (in the structural sense, i.e., a large number of competitiors). Effective competition can always be exercised from alternative, *substituable products or services* as well as from *dynamic changes*. Prices will thus be lower without regulation than with regulation.

This type of argument is reinforced if we take into consideration the fact that in some instances the regulatory agencies may fall under the control of regulated firms (capture theory of regulation)[10]. In such circumstances regulation is at best ineffective and may be harmful. Total deregulation would make the market more competitive and promote consumer welfare, even without the existence of alternative competing suppliers.

By the same token, Posner (1969, p. 636) argues that public utility regulation has negative effects on social and economic welfare. Moreover, he doubts that any change in the way that regulators apply regulation could advance the public welfare. He suggests that monopoly firms presently subject to public utility regulation should be completely deregulated. With respect to telecommunications, he states that:

> "...Communications is a contemporary example of an industry undergoing rapid technological changes that apparently opening up a host of new competitive opportunities. In general, the tempo of change in the economy seems to be increasing. The most pernicious feature of regulation would appear to be precisely its impact on change - its tendancy to retard the growth of competition that would erode the power of regulated monopolist. To embrace regulation because an industry is today a natural monopoly and seems likely to remain so is to gamble dangerously with the future. To impose regulation on the basis of a prophecy that the industry will remain monopolistic forever may be to make the prophecy self-fulfilling".

Thus, according to Posner and other Chicago economists, complete deregulation could render markets workably competitive either because of changes in technology or growth in consumer demand[11]. Deregulation, even if it does not alter radically the market structure (in the structural sense), may have a beneficial effect on market peformance. Thus, according to Posner, the focal point of policy makers should be

---

10 The capture theory of regulation was developed much earlier. See Bernstein, M.H., Regulating Business by Independent Commission, Princeton University Press, Princeton, 1955.

11 According to Sharkey (1984) growing market demand in telecommunications and rapid technological changes may render a natural monopoly unsustainable. In such circumstances, government regulation may be needed in order to protect the natural monopoly from inefficient entry. This policy recommendation is obviously in contrast to the one advanced by Posner and other Chicago economists. For more details see below.

market performance, not competition *per se*. Competition is not a goal but it must be used as a means to achieve a goal. If the least cost provision of goods and services is one of the goals of policy makers, competition or the *threat* of it can discipline suppliers.

Demsetz (1968), writing in another context, suggested an alternative mechanism for restraining monopoly's market power while at the same time safeguarding all the benefits to consumers. Franchise bidding is suggested as an alternative and more efficient means of "regulation". According to Demsetz's argument, whenever technological conditions determine that a single supplier can serve the entire market more cheaply than a multiplicity of firms (natural monopoly), society can avail itself of the advantages of the least cost supplier if this firm must compete for the right to be a monopolist. This competition *for* the market, as opposed *to within* the market (the latter is impossible since technology dictates a single producer as the least cost one), can provide a check on the exercise of monopoly power. Regulation of the natural monopoly service is thus not needed[12]. Although Demsetz's view of franchise bidding as a contest for the market requires the existence of a governmental or franchise authority, contestability theory requires none. Demsetz's theory can thus be considered a precursor of the recent theory of contestable markets.

In sum, the Chicago School argues for a complete deregulation of the telecommunications industry. It is argued that deregulation will have salutary effects on market performance, even if telecommunications industry structure does not change to a substantial extent (in the structural sense). Whether deregulation will increase the number of

[12] Williamson (1976) however, has severely criticized Demsetz's franchise bidding mechanism. He argues that the latter is not a perfect substitute for goverment regulation. There are circumstances (the reader is referred to the original article for the description of them) where franchise bidding may still require some type of government regulation, and may introduce new economic distortions unique to the franchise bidding process. Williamson recognizes however, that there are circumstances where franchise bidding may be a desirable alternative to public utility regulation. Using the present terminology when markets are contestable franchise bidding may be superior to public utility regulation. However, if markets are contestable no governmental or franchise authority is required.

firms in the industry, thereby altering the market structure, depends on barriers to entry facing new firms. This is the subject matter of contestability theory. Before we discuss some of the properties of this theory as they are applied to the telecommunications industry, it is necessary to present in some detail the new theory of natural monopoly as has been recently developed by Baumol, Bailey, Panzar, Willig, Faulhaber, Sharkey and others.

THE NEW THEORY OF NATURAL MONOPOLY AND REGULATION

The traditional theory of natural monopoly has been greatly revised and extended by a number of economists, most of them associated with the Bell Laboratories of the United States. By 1977 a number of pathbreaking articles by Baumol, Bailey, Panzar, Willig and Faulhaber had appeared and had transformed the landscape of the traditional theory of natural monopoly. By 1982, Baumol, Panzar and Willig (BPW) had incorporated and interwoven these ideas in a new broader framework named contestability theory.

Although the analytical framework of the theory of contestable markets is quite different from the one developed by the Chicago School, it can be argued that the former constitutes, in many respects, an offspring of the latter[13]. Indeed, both schools of thought down-play the role of barriers to entry and both claim the existence of a natural mechanism that assures the emergence of the most cost efficient market structures. The latter point is best illustrated by Baumol (1982). In presenting contestability theory he argues that:

> "...while the industry structures which emerge in reality are not always those which minimize costs, they will constitute reasonable approximations to the efficient structures. If this is not so it is difficult to account for the similarities in the patterns of industry structure that one observes in different countries....Market pressures must surely make any very inefficient market structure vulnerable to entry, to displacement of incumbents by foreign competition, or to undermining in other ways" (Baumol, 1982, p. 8).

---

[13] Although there are many differences between these schools of thought, our purpose is not to identify them here.

In the next section we attempt to present the theory of what can be called technological determinism of the efficient market structure, (the concept of subadditivity) and the mechanism employed in achieving that structure (the concept of contestability theory).

TECHNOLOGICAL DETERMINISM OF MARKET STRUCTURES: COST SUBADDITIVITY

According to Baumol et al [1982], for a given vector of market demands the nature of the available productive techniques determines the industry's optimal configuration (natural monopoly, duopoly or oligopoly).

One of the novel characteristics of their theory is the endogenous determination of the industry's structure. In contestable markets (which will be defined below) the optimal (the least-cost) industry configuration (market structure) is determined endogenously and simultaneously with its output vector and the firm's pricing behaviour (conduct). To arrive at this outcome, some redefinitions of the traditional market structures and reconsiderations of their internal functioning is required.

Baumol et al. start y redefining the industry structure for which most confusion exists i.e. the concept of natural monopoly. According to them the existence of subadditivity of costs is the defining characteristic of natural monopoly. *Cost subaditivity* is said to exist when a single firm produces a set of outputs $Q = (Q_1, Q_2, \ldots . Q_n)$ at lower cost than two or more firms (A, B, m) can, each one producing part of the total $[(Q_{1A}, Q_{2A}, \ldots, Q_{nA}), (Q_{1B}, Q_{2B}, \ldots, Q_{nB}), \text{etc}]$. That is to say, when:

$$C(Q_1, Q_2, \ldots, Q_n) < C(Q_{1A}, Q_{2A}, \ldots, Q_{nA}) + C(Q_{1B}, Q_{2B}, \ldots, Q_{nB}) + \ldots + C(Q_{1m}, Q_{2m}, \ldots, Q_{nm})$$

If the optimal number of firms that minimizes the above cost function is one, i.e. m=1, the industry is a natural monopoly. The cost function is said to be strictly subadditive if the above inequality holds. The existence of two or more firms in the industry will necessarily increase social costs and reduce economic welfare.

In the single-product case, a sufficient condition for subadditivity is the existence of economies of scale[14]. For a given level of production (Q) there exist global economies of scale if

$C(\lambda Q) < \lambda C(Q)$ for $\lambda > 1$

Dividing both sides by λQ, we have

$$\frac{C(\lambda Q)}{\lambda Q} < \frac{C(Q)}{Q},$$

and it can be seen that the average cost is a declining function of output, and the cost function is subadditive. Thus, in the single-product case the concept of cost subadditivity is not much different from the traditional concept of declining average costs used for defining the existence of a natural monopoly.

For a firm producing Q to be a natural monopoly, the industry must have subadditive costs over the *entire* range of outputs. That is to say, subadditiviy is not a local concept but a global one (Baumol et al. p. 171). This implies that data dealing with the costs of producing *all* levels (small, medium and large) of output are needed in order to determine whether an industry is a natural monopoly and therefore whether its cost function is subadditive. A cost function is *globally subadditive* if it is subadditive at all levels of output. The single-firm industry structure resulting from it is called a *global natural monopoly*. *A local natural monopoly* results from a locally subadditive

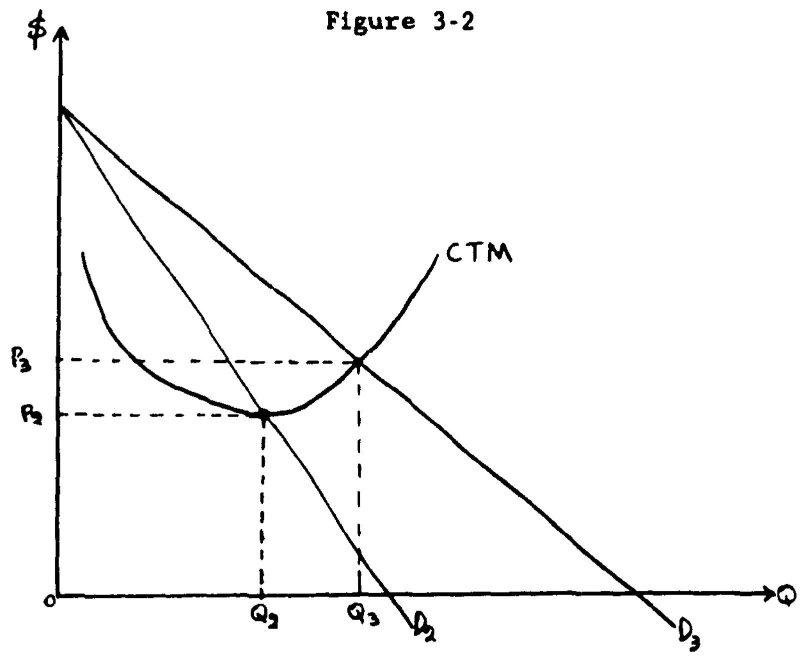
---

[14] The existence of economies of scale is a sufficient condition for subadditivity but not a necessary one. A cost function can be subadditive even if increasing average cost is exhibited for a fraction of the outputs. It is thus possible to have a subadditive cost function exhibiting both economies and diseconomies of scale. (See Sharkey, 1982).

cost function, i.e. a cost function that is subadditive at a *particular* level of output[15].

Thus, information on costs at scales of operation outside the range of currently available information is necessary for making the subadditivity test[16]. Nevertheless, in multi-product firms, cost subadditivity is reflected in both economies of scale and *economies of scope* i.e. economies of joint production. In this case however, economies of scale become a much more complicated concept than in single-output production. The economies of scale concept in a multi-output production is best illustrated by a diagram.

Figure 3-2



In the output space the ray (OR) emanating from the origin depicts the proportions at which the production of two outputs (Q_1,Q_2) takes place. If these proportions are fixed, we can define the behaviour of the average cost as well as its minimum point along this ray. Ray

15 See Evans, ed. 1983, chapter 6.

16 Subadditivity tests requiring less information have been developed by Evans and Heckman (1983). For more details see Chapter 5 of this dissertation and references therein.

average costs (RAC) may be either declining or increasing[17]. If they decline global economies of scale are present along the ray.

Declining ray average costs do not necessarily reflect the cost behaviour of *specific* outputs. It is, however, interesting to know the cost behaviour of specific products. In that case Baumol et al develop the concept of *average incremental cost* (the additional cost incurred by adding a particular product to the product set). If small increases in a particular output give rise to declining average incremental costs, *product specific economies of scale* are said to exist.

However, the presence of product-specific economies of scale alone is not adequate for cost subadditivity, since it reflects only partially the effect of the output *mix* on the firm's costs. The behaviour of costs is also influenced by changing the firm's *scope* of production. A more comprehensive measure of the effect of changes in the *composition* of output on the firm's cost is thus required. The concept of economies of scope provides us with such a measure. *Economies of scope* are the economies "imparted not by the size of output of any one product of the firm but by the sheer number of different items it produces simultaneously" [Baumol, 1979].

Economies or diseconomies of scope reflect the cost savings or disavings that result from multiproduct vs. specialized firm operations. For the two product case, Q_1, Q_2 economies of scope exist if:

$$C(Q_1, Q_2) < C(Q_1, 0) + C(0, Q_2)$$

---

17 Formally, ray average cost (RAC) can be defined as:

$$RAC\ (\lambda Q_0) = \frac{C(\lambda Q_0)}{\lambda}$$

where Q_0 is a given output vector used as unit of measurement arbitrarily set equal to one ($\Sigma Q_{0i} = 1$) and λ is a scalar ($\lambda > 0$). RAC is declining when RAC (λQ_0) is a declining function of λ.

Thus economies of scope exist when specialized production is more expensive than multi-product single-firm production.

Global economies of scope exist when such economies are present at all levels of output. Global product-specific economies of scale in conjuction wirh global economies of scope imply global natural monopoly[18]. Thus, an industry's cost structure is subadditive and the monopoly firm is "natural" when the two above-mentioned conditions are present.

In sum, the concept of natural monopoly in a multi-product setting is much more complex than that of the single-product firm. Not only the scale of operations affects the costs but so does the product mix (the scope of operations) as well. Thus cost behaviour is a function of economies of scope, overall economies of scale and product-specific economies of scale at different levels of output. The balance of all these factors will determine the shape of the cost function and therefore its additivity. These cost characteristics will determine the industry's optimal configuration.

If the industry's minimum cost of supplying the vector Q of outputs is attained when a single firm exists in the market a natural monopoly emerges. If a greater, but still small, number of firms is needed to attain the minimum cost, a natural oligopoly will emerge. If by contrast, this number is large the market is naturally competitive. Thus, the industry's cost characteristics along with market demand will determine the optimal market configuration in supplying the output vector Q at least cost.

However, nothing guarantees that such an optimal industry configuration will automatically be adopted by the market. In order for an industry's least-cost configuration to emerge the market *must be contestable*. Only then will incumbents be forced to behave optimally

[18] This is a sufficient but not a necessary condition for natural monopoly.

when adopting prices which can be maintained in the face of potential entry (sustainable prices).

Baumol, Panzar and Willig [1982] argue that sustainable prices may be adopted by incumbents only in circumstances where the *threat of entry or potential of competition* is *credible*. Potential competition refers to the possibility of rapid entry by vigilant would-be competitors, if the incumbent ever decides to exercise its monopoly power and raise its price significantly above its marginal cost. We emphasize that in such a situation actual entry is not required to discipline incumbents. The threat of entry is sufficient for constraining incumbents' monopoly power. The threat of entry may be credible in those markets where entry is absolutely free and exit is completely costless. When there are no sunk costs[19] or regulatory constraints the threat of entry becomes credible (Baumol et al, 1982). Markets with such characteristics are defined to be *perfectly contestable*. The crucial feature of the contestable market is its vulnerability to what Baumol calls "hit-and-run" entry. For hit-and-run entry to have its desirable welfare effects, at least three assumptions must be met.

First, the same market demand is assumed to be confronted by both incumbents and potential entrants. Moreover, it is assumed that potential entrants have access to and utilize the same technology as incumbents (there is no innovation).

Second, there must not be any barriers, legal or technological (economies of scale are not considered to be barriers), to either entry or exit.

Third, the reaction of incumbents to changing market conditions must involve a considerable lag, although consumers and potential

---

19 Sunk costs are the costs associated with irreversible investment i.e. expenditures dedicated to a particular use or market that have no value in an alternative use.

entrants may react with a shorter lag to market opportunities (differences in prices)[20].

If the above conditions characterize a market, the threat of entry is as effective as actual competition. Potential entry or competition *for* the market will discipline incumbents' pricing behaviour, forcing them to fix prices no higher than their marginal cost of production. In perfectly contestable markets, it is the possibility of "hit-and-run" entry that *forces* incumbents to adopt pricing policies that both deter entry and minimize industry's costs. This is so because entry is attracted whenever a positive profit or inefficient production (unnecessary costs) is present in the industry. Incumbents by adopting optimal prices in the market (first-best where $p = MC$ or second best, Ramsey-Boiteux prices, depending on the technology) realize a normal rate of return on their investment rendering, thereby, the industry's configuration *sustainable*. Thus, in perfectly contestable markets efficiency is maximized since competition drives prices toward marginal cost. No cross-subsidies, flat-rates or any other inefficient pricing schemes can emerge in these markets.

Equally, in single-output monopoly contestable markets, the incumbent monopolist will adopt a price equal to its average cost ($MC \leq p = AC$). This Ramsey-Boiteux or *stationary limit* price (Baumol, 1977) improves social welfare[21] compared to the welfare attained when prices are imposed by the regulator. Deregulation can thus be applied in order to eliminate the inefficiencies resulting from cross-subsidization and flat-rate pricing schemes.

However, public utilities such as telecommunications hardly satisfy the conditions of contestable markets. The telecommunications industry is characterized by high fixed costs many of which are sunk and nontransferable to other uses, posing thereby significant barriers to

---

20 These three crucial assumptions of contestability theory (as well as other ones) have been severely criticized by Shepherd (1984) and others.

21 As it is shown below, Ramsey-Boiteux pricing has the additional merit of assuring sustainability of natural monopoly under a wide range of conditions.

entry and exit. This industry, or at least segments of it, for example the residential local exchange network, is not contestable[22]. In some circumstances the industry may also not be sustainable. That is to say, even if they were contestable markets, it is possible that firms would not be able to find entry-deterring prices in order to ward off socially undesirable entry. Put differently, there are circumstances where sustainable prices do not exist. Government intervention via regulation may then be warranted.

It is thus important to analyse the problems that arise 1) from the non-existence of sustainable prices in the telecommunications industry and 2) the scope of regulation in unsustainable natural monopoly industry configurations.

UNSUSTAINABILITY AND GOVERNMENT REGULATION

An industry's configuration is said to be sustainable if no new firm would decide to enter that industry[23]. A natural monopoly (one

---

22 This is at least the argument formulated by Willig (1978). He states: "...It seems intutively clear that the market for, say, traditional local access to residential subscribers is as yet not contestable, certainly with respect to the twisted-pair technology. In order to challenge the existing OC [local telephone operating company] in an area served by a given central office, an entrant would have to irreversibly invest in costly central office facilities and in a substantial number of local loops. Once the investments were put into place, and a low price offerred, the OC would have [an] incentive to compete in price so as to maintain its customer base. Then the entrant would find its facilities underutilized and its price well below the hypothesized original higher price that preceded its entry. Of course, when assessing the profitability of entry, a rational entrepreneur would anticipate these eventualities and would not respond with irreversible investment to a high price charged by the incumbent OC". See Robert D. Willig, "Market Structure and Government Intervention in Access Markets", in Gerald Faulhaber and Alan Baughcum, eds., *Telecommunications Access and Public Policy: Proceedings of the Workshop on Local Access*, Ablex Publishing Corporation, Norwood, New Jersey, 1984.

23 Formally, an industry's configuration is defined to be sustainable when $p^eQ^e \leq C\ (Q^e)$ for all $p^e \leq p$ and $Q^e \leq Q\ (p^e)$, i.e., when entry is unprofitable (where p^e stands for the price of entrants). This will occur when the firms composing the industry produce all the quantity that the market demands at the least possible industry cost. Consequently, each cost-minimizing firm will fix a price that

with a globally subbaditive cost function), assures its sustainability when the chosen set of prices and outputs permit the monopolist to satisfy its budget constraint (the revenues created are enough to cover its total costs), while it wards off competitive entry. In other words, the set of prices that is feasible (does not generate losses) to the incumbent monopolist but infeasible (generate losses) to any entrant may be deemed as sustainable. Potential entrants, by offering some or all of the monopolist's products and by charging the same or lower than the incumbent monopolist's price, would suffer losses.

The problems arising from the non-existence of sustainable prices appear to be of great complexity in industry configurations that are dominated by natural monopolies. This is so because under natural monopoly the post-entry cost of producing a given combination of outputs is greater than it is before entry. If the incumbent monopolist is vulnerable to profitable entry a case can be made for structural regulation of the unsustainable natural monopolist. If entry is not protected the most efficient industry configuration would be sacrificed. This is so since competitive entry will raise costs of production to society[24].

The subject matter of sustainability theory is the optimal pricing of an incumbent facing actual or potential entry. It is thus necessary to specify incumbent's behaviour when facing entry.

Potential entrants contemplating market entry must make certain assumptions concerning an incumbent's anticipated behaviour. According to Panzar and Willig (1977), potential entrants expect incumbents to act in a way which is consistent with the Bertrand-Nash hypothesis. That is to say, it is assumed that incumbent's prices will not change in response to actual or threatened entry, at least in the very short-

reflects its level of efficiency i.e. the lowest possible price. The latter must not be so low to threaten the firm's financial viability nor so high to attract new costless entry.

24 Obviously, competitive entry into monopolistic industry configurations that do not have subadditive cost structure does not pose any problems from a social point of view.

run[25]. Such pricing behaviour permits would-be competitors to enter the market, whenever entry is possible, undercut the incumbent's price, and realize a positive profit, at least temporarily. Even if the incumbent firm reduces its price below the new entrants' price after a time, the new competitors can readily exit the market since no sunk investment costs are present. The sustainable industry configuration that may emerge by applying Panzar and Willig's "price game" is called *price-sustainability*, since it is based on the Bertrand-Nash assumption of price rigidity[26].

The possibility that a natural monopoly may not be able to find a set of prices that would deter entry was first analysed by Faulhaber (1975). Indeed, Faulhaber showed that, in the single product case, no price-sustainable equilibrium exists when the demand curve intersects the incumbent's monopolist average cost curve (AC) beyond its minimum point, but within the natural monopoly region. The vulnerability of a natural monopolist to competitive entry when the monopolist operates in the rising portion of its AC curve is illustrated by the diagram below.

Let Q_3 be the quantity demanded for the telecommunication services. The natural monopolist satisfies the total market demand D_3 and fixes the price P_3. Since the natural monopoly operates in the rising portion of its AC curve, it is not sustainable. This is so because a competitor could enter the market, produce a level of output equal to Q_2 that corresponds to the minimum average cost, leaving only

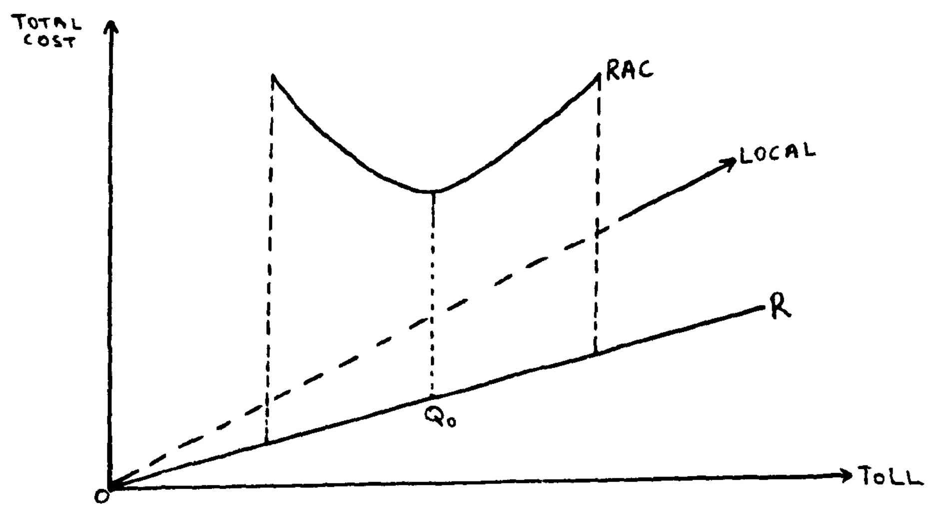
---

25 Although this assumption seems unrealistic in non-regulated monopolies, it describes more accurately the behaviour of regulated monopolies such as the telecommunications industry. In such industries the prices chosen are the ones decreed by the regulatory agency and they change only gradually and after a considerable time lag. If a natural monopoly is proven to be sustainable under such restrictive assumptions, it can be concluded that, in the absence of these assumptions, no firm will ever decide to enter the industry unless it posseses superior technology or the prices that have been chosen by the incumbent monopolist happen to be the wrong ones.

26 However, it may be possible that new entrants form more pessimistic assumptions concerning the incumbent's reactions if potential entry occurs. They may assume that the incumbent keeps its *quantity constant*, in case of entry, instead of price. The sustainable industry configuration that may emerge by applying the Cournot-Nash assumption ("quantity game") is called *quantity sustainability*.

one-third of the market to the established natural monopoly. If the established natural monopoly is bound by regulation to the price P_3 (the price game

Figure 3-3



assumption), its costs of production will be higher than its revenues and it will lose money. It will be driven out of business. The natural monopoly is thus not sustainable. The socially optimal industry configuration would have been sacrificed and society would have been worse off if we allowed competitive entry. Therefore the preservation of the most efficient industry structure would be warranted by adopting structural regulation, regulation that prevents entry[27].

[27] The nonsustainability argument for goverment intervention has been challenged by Brock and Sheinkman (1983). They have demonstrated that if a more "realistic" assumption is made (that monopolist and entrants play a quantity game), an equilibrium situation will arise and the necessity for government intervention will be dispelled as a result. Thus, when the Bertrand-Nash assumption of price rigidity is replaced by the Counot-Nash assumption of quantity invariability the previous situation of price-unsustainability becomes quantity sustainable.

In the multi-product case, the possibility of the existence of non-zero cross-elasticities of demand render the task of determining sustainable prices even more complicated. Unfortunately, as yet, little is known about the necessary or sufficient conditions under which a natural monopoly can be made sustainable. Panzar and Willig (1977), however, have demonstrated that a sustainable price vector always exists if costs satisfy weak cost complementarity and demands are independent. By contrast, the non-existence of sustainable prices is more likely when there is strong demand substitutability among the products of the incumbent monopolist, weak cost complementarities in their production and strong product-specific scale economies[28]. Baumol (1979) and Baumol et al (1977, 1982) have shown that if overall economies of scale as well as trans-ray convexity characterizes the production structure of the incumbent monopolist, the latter by adopting *Ramsey-Boiteux prices* assures its sustainability[29]. Thus, under open entry conditions the weak invisible hand induces the natural monopoly to adopt the Ramsey-Boiteux optimal prices.

Since the Ramsey-Boiteux sustainable prices minimize the allocative distortions caused by the break-even constraint under increasing returns to scale, second-best optimality is achieved. However, customers with inelastic market demand contribute much more to fixed and non-separable costs than those with elastic market demands.

---

[28] The conditions under which a natural monopoly, especially in the multi-product case, is sustainable are still imperfectly understood. A number of articles has appeared attempting to identify these conditions. See for example, Mirman et al, 1983, 1984, 1985 and Spulber, 1984, 1987. Baumol (1977) and Baumol et al (1977) have established, however, that under quite general conditions Ramsey (inverse elasticity) pricing assures sustainability.

[29] In the case of single-output production the natural monopoly is sustainable for every output Q if the latter realizes economies of scale at all outputs and if its AC of production is lower than the AC of potential entrants for every output which is less than the incumbent monopolist's output (Sharkey, 1984, p. 88). In such circumstances the necessary condition for sustainability (equilibrium), is that the monopolist price be equal to its average cost ($MC \leq p = AC$). By adopting these Ramsey-Boiteux prices (*stationary limit prices)*, the monopoly assures its sustainability (Baumol, 1979).

As applied to the telecommunications industry, Ramsey-Boiteux pricing implies a high price for local services and a lower price for long-distance services. Such a pricing policy, although very attractive from an economic-efficiency point of view[30], presents enormous difficulties of implementation both methodological and political. Implementing Ramsey-Boiteux pricing may be equivalent to the sacrificing of the government's universal policy goal of telecommunication services. Since the abandonment of service universality is very unlikely in Canada[31], the adoption of Ramsey-Boiteux pricing policy is highly improbable. If the price structure required for improving economic efficiency (Ramsey-Boiteux prices) is prohibited to the incumbent natural monopoly, as a part of the regulatory mandates and entry into the industry is permitted, sustainability may then be impossible (Baumol et al, 1982, p. 358). In public policy terms, if there is no stable price equilibrium in the face of free entry and exit, structural (entry) regulation may be required. If there does not exist a set of stable prices the incumbent natural monopoly is indeed vulnerable to entry. Should it be structurally deregulated, society's optimal industry configuration would be sacrificed. Thus, unsustainable natural monopolies should be structurally regulated.

The unsustainability argument makes clear that competitive entry into nonsustainable markets is inefficient. This outcome occurs because entrants are not obliged to serve the entire market demand[32]. The nonsustainability argument gives an elegant explanation of why, in the past, regulators have prohibited competitive entry into naturally monopolistic industries. The main reasons for regulation, as the argument of nonsustainability makes clear, were and still are in some

---

30 Ramsey-Boiteux prices permit the incumbent natural monopolist to cover its costs and to realize a fair rate of return on its investment by causing minimal distortion in demands. From an economic-efficiency point of view society's resources are used optimaly maximizing thereby its welfare. This is the weak invisible hand theorem for monopoly. (Baumol et al, 1977).

31 See footnote 7 of this chapter.

32 It should be noted that the sustainability literature employs the assumption that the entrant is not obliged to serve the entire market demand while the incumbent monopolist does.

countries, the preoccupations with wasteful duplication of the network, loss of revenues from cream-skimming activities and higher total costs to consumers. It is only when an industry's configuration is sustainable in addition to being contestable that social welfare will be maximized without entry and price regulation. That is to say, contestability alone is not sufficient to ensure an outcome that is in the public interest. However, if a market is contestable and the optimal industry configuration is sustainable no new firm will decide to enter the market[33]. If competitive entry is observed in contestable markets (particularly in some segments of them), and if the industry is in fact a natural monopoly, such entry may be construed as evidence of non-sustainabilty. In such circumstances the efficient market structure is threatened by inefficient (cream-skimming) entry. Price and entry regulation may then be necessary. Thus, whenever sustainable prices do not exist or it is impossible to implement them, the industry's configuration is in disequilibrium. Social welfare would be reduced if no protection, in the form of structural (entry-prohibiting) regulation, were offered to the incumbent natural monopolist.

We must admit, however, that the non-existence (or existence) of price sustainability by itself is not a sufficient condition for (or against) government regulation. For example, an industry's configuration may be price sustainable but these prices may not be adopted by the incumbents[34].

Nevertheless, Sharkey (1984, p. 89-90) has shown that in industries with growing market demand and economies of scale as well as in industries with continuous technological advancements (both characteristics are present in the telecommunications industry) unsustainability is a likely possibility. He concludes that "in a dynamic market a natural monopoly with sunk costs may be inherently

[33] Of course, it is possible that the potential entrant possees a more cost efficient technology than the incumbent, or that the incumbent happens to choose either by mistake or regulatory decree a set of nonsustainable prices that may icite the competitor to enter the natural monopoly industry.

[34] In such circumstances such behaviour will attract entrants and erode the natural monopoly's efficient cost structure.

unsustainable" (p. 149). This is precisely the conclusion at which Baumol et al (1982) arrive as well. They assert (p. 361-2) that "unsustainability is the rule in growing markets where capacity construction costs are sunk and subject to increasing returns to scale". In such circumstances competition is not viable and therefore structural regulation may be seen as a more effective means of promoting efficiency in the market. We can thus argue that the nonsustainability argument is a more likely possibility in the telecommunications industry than in other less dynamic ones. A strong case for structural regulation may then be made.

All in all, competitive entry may occur even in industries dominated by a single-firm natural monopoly. The latter may in some circumstances be unsustainable. As yet, no empirical method is available for detecting the existence of unsustainability. However, the econometric estimation of the monopoly's cost function -- as it is done in chapter 6 in this dissertation -- confirms the existence of a natural monopoly in the Canadian telecommunications industry. Therefore, society would maximize its social welfare by having its monopoly firm producing the industry's total output. Important economies of scope may be sacrificed by letting rivals entering the market, while conduct regulation is still preserved for the incumbent monopolist.

Structural regulation seems quite attractive from a social point of view. As a matter of fact it has been widely applied in the telecommunications industry in both Canada and in the United States. It palliates the problems caused by the existence of heavy sunk costs and unsustainability. However, lately other policy options have been envisaged in the United States that would permit an increase in a market's degree of contestability . It is thus worth considering them briefly. As will be seen below, some authors consider that these solutions are appropriate for the Canadian telecommunications industry as well.

A policy option[35] that has been advanced in the U.S. is the separation of sunk costs from the incumbent dominant firm. Such a separation may reduce the need for regulation. However, such a policy does not obviate the need for government regulation altogether. The latter is still needed in order to assure equal access to sunk facilities by all participants. As Bailey puts it, "by detaching sunk costs from the serving firm, much of the need for traditional economic regulation of the service industry disappears, even if the industry is still a natural monopoly. Instead, government intervention can often be limited to ensuring fairness of access to the sunk facility". (Bailey, 1981, p. 179).

This is precisely the solution that has been adopted in the United States in the separation of AT&T from its Bell Operating Companies (BOCs). After divestiture in 1982 the BOCs were obliged to permit AT&T and other competing long distance carriers to have access to their facilities on an equal basis, provided an access charge[36,37]. As a

[35] Obviously, this is not the only one. For example, Willig (1982), suggested that potential entrants may be able to avoid vulnerable irreversible investments by dealing with large customers, or a geographically concentrated group of customers, on a contract basis. Such entrants would only commit their investments after contractual agreements had been reached that assured them enough continuing business to cover their necessary sunk investment costs. Portions of the local access market that are amenable to business relationships of this kind may indeed approach contestability. Bailey (1981, p. 182) on the other hand argues that the contestability of the telecommunications market can be improved by adopting policies that promote technical changes that replace technologies that have large sunk costs with others that require less investment and higher mobility. This would include LANS (Local Area Networks), teleports, fibre optics, satellites, cellular radio, etc. Indeed, she states, "other rules must be devised to handle sunk-cost problems. These may include encouraging technical changes that replace technologies involving large sunk costs with technologies that offer more opportunity for mobility or shared use".

[36] To the extent that the telecommunications industry is a natural monopoly, these policy recommendations may be erroneous and might have the opposite effects (reduction of social welfare) as has been argued above.

[37] In Canada such an approach has not been adopted. The CRTC has denied CNCP Telecommunications demand for access to Bell Canada's network in order to provide long distance calls on a competitive basis. (See Telecom Decision 85-19 and Stanbury, 1986, in Stanbury ed., 1986).

result of this policy, the emphasis of the debate has shifted from the concept of sustainability to the concept of contestability. In effect, the debate[38] at present in the United States centres around the question of whether the telecommunications industry, the local exchange system, is or can become contestable (de Fontenay et al, 1987). De Fontenay et al., (1987) have gone so far as to argue that "an enforceable equalization in the regulatory treatment between the local exchange service provider and its competitors could result in a contestable market". The advocated enforcable regulatory treatment may be interpreted in the present context as complete deregulation (structural as well as conduct deregulation) (Faulhaber, 1987).

Indeed, Faulhaber (1987) in his latest book writes: "the last two decades have demonstrated that the regulation of the [US] telecommunications industry has been a failure, and yet we continue to look to the regulators to solve the problems of the industry. The lesson should be crystal clear: regulation will not solve these problems; regulation *is* the problem" (emphasis in the original).

It is argued that by deregulating the telecommunications industry completely, efficiency would be increased by bringing prices closer to costs (Kahn, 1984). "Regulation, both retards and distorts" trends towards new products and declining costs (Faulhaber, 1987). Market contestability would increase, so the argument goes, the greater the

---

Also, as recently as in May 1987, the CRTC (Decision 87-5) directed Bell Canada and CNCP to cease providing Call-Net Telecommunications the underlying services and facilities used to offer its Selective Call Forwarding (SCF) and Call Detail Account Recording) equiped services because they are considered to be basic long distance services and not enhanced services. Thus, the CRTC, has reiterated, once again, its conviction that resale of telecommunication services that directly compete with public long distance telephone service is prohibited. This is so because, according to the CRTC, competition would "reduce the capability of telephone companies to maintain and extend local service at affordable rates [as well as] would not contribute to the maintenance of universally available basic telephone service" (Ottawa, CRTC, news release, 16 August, 1988).

38 As it is argued below there is presently a revival of interest and a debate concerning the question whether the telecommunications industry in the U.S. (the pre-divestiture Bell System) was a natural monopoly.

freedom of entry to and exit from the market *and* the greater the freedom of pricing. Unless both arrive together the beneficial welfare effects of contestable markets would not be realized. In other terms, *structural* (entry) *deregulation* must be accompanied by *conduct* (price) *deregulation*.

Permitting free entry and exit in the telecommunications industry without liberating at the same time the incumbent from the obligation to submit any rate readjustment to the regulatory commission, would not necessarily maximize the total of consumers' and producers' surpluses (de Fontenay et al, 1987). Moreover, unless both applied at the same time, problems such as cream-skimming, cross-subsidization, predatory pricing, inefficient entry, etc. may occur (Baumol et al, 1982, p. 481). It is argued that comprehensive deregulation is the *sine qua non* for consumers being able to avail themselves of the advantages that true contestability provides, even if competition (in a structural sense) is never realized. Indeed, to quote Faulhaber, Congress must envisage "immediate deregulation". The latter will provide the necessary means that will allow the emergence of a true market-place competition that will replace the present patchwork that characterizes the U.S. telecommunications industry.

Opponents (Shepherd, 1983, Trebing, 1987) of this policy (the *structuralist school*) argue that comprehensive deregulation may not be beneficial to the public. This is so since the fully-deregulated telecommunications *dominant monopoly*[39] may apply a predatory pricing policy. Predation is possible since the partial monopoly can easily extend its market power derived from its monopoly market (in Canada, from the local and long-distance calls) into its competitive markets

---

[39] The dominant carrier argument, also called *asymmetric competition* by Sharkey (1984) is not the same as the dominant firm model found in the industrial organization literature, but it is essentially the same as the *infant industry* argument found in the international trade literature. See Subissati, 1986, and the discussion therein as this argument is applied to the Canadian telecommunications industry. We can say that the dominant firm market model shifts the focus of deregulatory policy away from market performance at the industry level (a characteristic of the contestability theory) and toward the conduct of the dominant firm facing competitive entry.

(private lines, PBXs etc.) threatening thereby the viability of competitors.

Proponents of the contestability theory argue that such a behaviour by a dominant firm must not be construed as predatory *per se*, but instead as a response to its unsustainability. Indeed, if economies of scale for individual substitute products are relatively strong while economies of scope are relatively weak, a dominant firm's financial viability may be threatened by specialized single-output producers. This occurs in spite of the fact that a multi-product single firm's production is socially more cost efficient (compared to the multi-firm specialized production) [Baumol, 1977, and Baumol et al, 1982, pp. 474-475].

Such a sustainability problem arises in situations where the government undertakes structural deregulation but not conduct deregulation (Baumol et al, 1982, p. 482). If government eliminates conduct regulation as well, the dominant firm will be able to cope with this sustainability problem by continually adjusting its pricing behaviour i.e. by adopting responsive limit pricing. However, we have shown above that a naturally monopolistic industry configuration may not be able to find a set of prices that deters entry, especially if such an industry structure is contestable.

Moreover, proponents of the dominant firm argument contend that contestability theory demands a lot from the regulatory agencies. How can they be sure that such dominant strategic action is a response to the unsustainability problem and not a deliberate use to thwart actual or potential competition (predatory)? Furthermore, how important and how frequent is the sustainability problem? How likely is it that a dominant firm will encounter such a pricing dilemma? Regulators cannot disregard a dominant firm's strategic behaviour in the name of unsustainability. Long established incumbents and new entrants cannot be treated equally, as the contestability theory argues, at least in the short and medium run (at the initial stages of deregulation).

The contestability arguments for complete deregulation as they apply to the Canadian telecommunications industry have not been adopted in Canada. However, it has been argued (Subissati, 1986) that if the CRTC ever decides to deregulate Bell Canada, the public interest would be better served by espousing the arguments of the contestability theory and by rejecting the dominant firm arguments (the structural school). Indeed, in concluding his analysis Subissati states: "*positive* policy initiatives designed to promote contestabilty in all telecommunications markets by reducing barriers to entry and by promoting the development of competicing technologies are more likely to serve the public interest than *negative* policy initiatives designed to prevent predation or handicap the dominant firm. Public policies that focus on the fair treatment of competitors may be unfair to consumers" (ibid, p. 69).

In Canada, however, we have not gone as far as in the U.S. with respect to the deregulation of the telecommunications industry. At present, one wonders whether both the contestability as well as the dominant firm arguments can be applied to the Canadian telecommunications industry. For Canada, what seems to be important now is the determination of the degree of subadditivity of its telecommunications industry cost function and of the industry's sustainability. The desirability of competition, actual or potential, is a function of the degree of the industry's subadditivity. The public interest would be better served if the public policies that are adopted are based on a comprehensive knowledge of the industry's cost function. The determination of the Canadian telecommunications industry cost function is thus important in the present regulatory debate.

Moreover, as was argued above, it is possible that the incumbent monopolist be unsustainable in the face of open competitive entry even if its cost function is subadditive. In the United States, Pool (1984, p. 114) argues that the creation of LATAs with boundaries which go far beyond the local exhange reflects the realization that the bottleneck monopoly was not sustainable, contrary to the original view expressed by the Department of Justice. Non-sustainabilty may be more serious in Canada than in the U.S. if we take into account the limited size of both the Canadian market and the incumbent natural monopolist. Moreover, "there is no guarantee that making markets 'more competitive' will generally enhance welfare, particularly if non-price rivalry is intensified". (Schmalensee, 1988).

In sum, subadditivity as well as sustainability of the telecommunications industry seem to be the most important policy questions facing the regulatory authorities in Canada. Theoretically, the possibility of nonsustainability raises serious concerns in case of entry deregulation of the Canadian telecommunications industry. Unfortunately, no empirical method is available for detecting the existence of unsustainability. However, we possess the necessary tools to investigate empirically whether the cost structure of the Canadian telecommunications industry is subadditive. In the next chapter we review the empirical studies carried out in both Canada and the U.S. in order to test for the subadditivity of the cost function of Bell Canada and AT&T. In chapter 5 we present our own model for Bell Canada and AGT. This model is estimated and its results are presented in chapter 6. Lastly, chapter 7 summarizes the main conclusions of this dissertation.

CHAPTER 4

COST SUBADDITIVITY IN THE CANADIAN TELECOMMUNICATIONS INDUSTRY: EMPIRICAL EVIDENCE[1]

A great number of econometric studies has been carried out in both the U.S.A. and Canada in order to test whether the telecommunications industry is a natural monopoly. The early studies have mostly focused on economies of scale tests to verify the existence of natural monopoly. Unfortunately, these tests are not the most appropriate ones in verifying the existence of cost subadditivity. Therefore, they will not preoccupy us here. Since the appearance of Baumol's, Panzar's, Willig's, Bailey's and others' seminal papers on multi-product monopolies, a large number of studies has been carried out, in an attempt to shed more light on the cost subadditivity of industries. At the same time the emphasis has shifted from the estimation of production functions to the estimation of cost functions. The estimation of the translog (transcendental logarithmic) cost function, was and still is[2] at the forefront of the empirical work, at least in the telecommunications industry. The proliferation of the empirical studies in that industry may be explained by the sweeping changes the industry has undergone, since the *Carterphone* decision in 1968.

Unfortunately, despite the large number of empirical studies, policy makers in government and business had to make decisions based, to a great extent, on their intuition[3], rather than on the information

---

1 This chapter owes much to Kiss, F. and B. Lefebvre, March, 1987, "Econometric Models of Telecommunications Firms: A Survey", *Revue Economique*, 2, pp. 1-53.

2 It seems that the translog cost function has started falling out of favour for a number of reasons. First, there is limited evidence that this function tends to overestimate scale economies (Gallant, 1981). Second, it may approximate the true cost function locally but not globally and probably in an inaccurate way (Guilkey and Lovell, 1980). In spite of these weaknesses we do use this function for our empirical estimation. For reasons why see next chapter.

3 This argument *may* not be correct. Policy decisions taken in telecommunications industries and other industries as well are the

provided by empirical studies. This can be explained largely by the weaknesses of most empirical studies and the problems inherent in them.

Indeed, the lack of a solid theoretical framework capable of dealing with real-world multi-product industries seemed to be the most limiting factor in every formulation of the empirical studies. Moreover, due to the complexity of the investigated phenomena, especially the empirical treatment of technological change and the jointness of multiproduct technologies of telecommunications firms, a number of writers approached the above phenomena in a different manner. As a result a plethora of highly divergent estimates has emerged. Due to this, policy makers had some difficulties in assessing them.

This chapter attempts to provide a thorough review of the major empirical studies, in an effort to make the assessement much easier and to provide policy makers with a global perspective on the findings of the empirical studies. The major differences and similarities as well as their interrelation are highlighted. Such a survey will enable us to identify the most important contributions and possible weaknesses of these studies while at the same time helping us in the formulation of our own model, a task that is undertaken in the next chapter.

It is important to note at the outset that the econometric estimates of the telecommunications *production functions* are not included in this survey because of their limited relevance to the present debate. Moreover, not all econometric models dealing with the estimation of the *cost function* of Canadian and American telecommunication firms are included either[4]. Only the most prominent models are presented. These are the models that provide information on both product-specific economies of scale and economies of scope; i.e., they offer the information needed in judging the industry's cost subadditivity. These are the empirical studies that test for the

---

result of a battle among various interests groups. Large institutional users may have been more adept in persuading government to deregulate the telecommunications industry in their own interest.

4 For a more exhaustive survey of the econometric cost functions studies, applied to the telecommunications industry, see, Kiss, F. and B. Lefebvre, March, 1987.

existence of natural monopoly in the telecommunications industry, consistent with the new theory of multiproduct monopoly, as presented in chapter 3.

For purposes of comparison and for the demonstration of the evolution of the econometric studies, a few single-output models, for the American and Canadian telecommunications firms, are also presented. Before delving into these studies, it is appropriate to present, briefly, the economic properties of the estimated cost functions. Since the present survey focuses only on those studies that use the translog cost function in their empirical estimation, it is judged advisable to present this function's main properties. This is done below.

FLEXIBLE FUNCTIONAL FORMS: TRANSLOG COST FUNCTIONS

The translog cost function (TL) has a wide appeal among researchers since it can provide information on at least three important economic characteristics of the production process: 1) factor substitution possibilities; 2) output expansion effects (scale effects); and 3) the rate and bias of technological change.

In regulated industries, such as the telecommunications industry, the second characteristic has received most attention. This is so because the scale effects (and the cost complementarity effects) are closely related to the question of natural monopoly. In a more dynamic context, the estimation of the rate of technical change is obviously an important input to the natural monopoly issue.

Although production functions can provide the information needed for making decisions on the issue of natural monopoly, the cost functions are judged more appropriate for this particular purpose[5]. The most widely used cost function in the telecommunications industry is the translog cost function.

The translog cost function is quadratic in logarithms and is one of the family of second-order Taylor-series approximations to an

[5] Explanations for this argument are given in the next chapter.

arbitrary cost function $[C = f(Q_1,\ldots,Q_m; P_1,\ldots,P_n; T)]$. The translog approximation of the cost function takes the form:

$$\ln C = \alpha_0 + \sum_{i=1}^{m} \alpha_i \ln Q_i + \sum_{j=1}^{n} \alpha_j \ln P_j + \epsilon_T \ln T + \frac{1}{2} \epsilon_{TT} (\ln T)^2$$

$$+ \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{n} \alpha_{im} \ln Q_i \ln Q_m + \frac{1}{2} \sum_{j=1}^{n} \sum_{n=1}^{n} \gamma_{jn} \ln P_j \, 1P_n$$

$$+ \sum_{i=1}^{m} \sum_{j=1}^{n} \delta_{ij} \ln (Q_i) \ln(P_j) + \sum_{i=1}^{m} \rho_{iT} \ln(T) \ln(Q_i)$$

$$+ \sum_{j=1}^{n} \mu_{jT} \ln (P_j) \ln(T) \qquad (1)$$

where $Q_1,\ldots,Q_m$ are the output variables, $P_1,\ldots,P_n$ represent the prices of factors of production and T is an index of technological change.

Unfortunately, this translog cost function cannot provide us with information concerning economies of scope since, in order to be able to carry out such a test, some output must assume a value of zero. But this cost function cannot accomodate a zero as one of its arguments since it would involve a logarithm of zero[6]. It is for this reason that some researchers have decided to employ the generalized translogarithmic cost function (GTL). The latter is obtained by substituting the Box-Cox tranformation for the natural logarithms of $Q_1,\ldots,Q_n$ and/or T in the translog form. The *Box-Cox transformation* for output Q_k is written as

6 It is for this reason that these cost functions have been mostly applied to the single-output industries. To apply them to the multi-product industries, analysts sometimes form an aggregate measure of the diverse outputs produced by the industry and treat it as a single-product industry. It will be seen in a latter section that this cannot be done for the telecommunications industry.

$$Q^* = \frac{Q_i^{\lambda_i} - 1}{\lambda_i}$$

while the transformation for the technology variable is done in a similar way. This generalized translogarithmic cost function is also called hybrid translog cost function (Fuss and Waverman, 1981). Evans and Heckman (1983) have applied the Box-Cox transformation to *all* of the explanatory varibies and they call their function a *Box-Tidwell* function.[7] The translog cost function is a special case of the generalized translog cost function, since the latter reduces to the former as the values of the λ_i, approach zero. By estimating the most flexible cost function, i.e. the GTL we can test which equation is more consistent with the data. It is thus important to test (if the data permit) various functicnal specifications before a particular functional specification is imposed on the data.

The translog cost function is constrained to be *linearly homogeneous* of degree one in factor prices, since a proportionate increase of all factor prices will cause a proportionate increase in total costs, *ceteris paribus* (outputs and technology remain unchanged).

It was argued above that the number of parameters to be estimated from the translog cost function increases very quickly as the number of its arguments increase. The number of observations being limited in the telecommunications industry, the risk of multicollinearity is high and the reliability of the estimates thus obtained is reduced. More degrees of freedom can be obtained and the multicollinearity problem reduced by applying Shephard's lemma. Thus, firm's behaviour is the additional source of information needed.

It is customary to assume that the firm's objective is to minimize cost (minimize input levels in order to produce exogenously determined

7 As it will be seen in a later section, these cost functions are not without problems either.

volumes of outputs)[8]. Then, from the production theory, we can apply Shephard's lemma and construct the cost share equations (S_j) for each input j as

$$S_j = \frac{P_j X_j}{C} = \alpha_j + \sum_{j=1}^{m} \gamma_{ij} \ln P_j + \sum_{k=1}^{n} \delta_{ij} \ln Q_i + \mu_{jT} \ln T \quad (i=1,..,m) \quad (2)$$

As it is seen, the parameters of the above formula, constitute a subset of those of equation (1) and therefore the cost share equations (S_j) increase the degrees of freedom available, and consequently the statistical precision[9]. Equations (1) and (2) can thus be estimated simultaneously.

Christensen and Greene (1976), suggested an estimation of the simultaneous equations system (consisting of the translog cost function, the cost share equations and/or the revenue share equations) by using Zellner's seemingly unrelated equations technique (SUR method). The majority of the studies reviewed in this chapter use Zellner's iterative technique (ITSUR)[10]. The non-singularity of the variance-covariance matrix is preserved by deleting one of the cost share equations. The

---

8 This asumption is perhaps the most serious disadvantage of the translog cost function. Such an assumption has only limited applicability to the telecommunications industry and to other regulated industries as well. In such industries, regulated prices (if regulation is effective) do not provide the same discipline as market prices in assuring cost minimizing behaviour.

9 Additional information can be generated, increasing further the degrees of freedom, by using the profit maximizing assumption. The firm's profit maximizing equilibrium condition, MC = MR, yields "revenue share" equations for every output i, which can be written as:

$$R_i = \frac{P_i\ Q_i}{C} = \frac{Q_i\ (\alpha_i + \sum_{i=1}^{m} \beta_{im} \ln Q_i + \sum_{j=1}^{n} \delta_{ij} \ln P_j)}{1 + (1 / \epsilon_i)} \quad (i = 1,..,m) \ (5)$$

Thus, the revenue share equations is the ratio of revenue from output i to the total cost of production. When functions (1), (2), and (5) are estimated simultaneously, the number of degrees of freedom and consequently the precision of the estimates, increases.

10 For a brief explication of the Zellner technique see next chapter.

deleted equation does not affect the maximum likelihood parameter estimates. Maximum likelihood estimates (ML) reduce to the iterative Zellner method when the variance-covariance matrix converges. Indeed, multiple regression analysis can be viewed as a special case of maximun likelihood analysis. Besides Zellner's techniques, others such as full information maximum likelihood (FIML), three-stage least squares (3SLS), two-stage least squares (2SLS), and other methods have been used by various authors.

Either Divisia or Tornqvist index numbers were used for both volumes of outputs and prices of factor inputs. In almost all studies a normalization operation has been performed[11]. Such normalization is done either on the *expansion point* (the point around which the Taylor series expansion takes place) or on the sample mean of the variable.

In most of the studies surveyed, econometricians have used a proxy for technological change as an independent variable. In some, the technological change variables enter in a simple way. Most of the studies (mainly the AT&T studies) assume that technological change has resulted in a proportional shift of the cost curve over time. Such a simple representation of the technology makes the least demand on the degrees of freedom. In some other studies, technological change takes some more restricted forms, such as output-augmenting or factor-augmenting.

The estimation of the translog cost functions provide important information on at least the following three classes of economic characteristics: 1) substitutability of factors of production; 2) scale and scope effects, and 3) technical change biases. The information they convey and the way they are measured in the context of the translog cost function is described below[12]:

---

[11] Only one study from those reviewed does not use any normalization. (See Breslaw and Smith, 1980).

[12] A more detailed analysis of each class of economic characteristics of the production process and an application of them to the translog cost function is provided in the next chapter.

1) Measures of Substitutability of Factors of Production

Two important types of summary statistic, the *own-price elasticity* (ϵ_{ii}) and the *cross-price elasticities* (ϵ_{ij}) of demand for factors of production, describe the economic behaviour of factor inputs.

The cross-price elasticities provide information on the substitutability of the factors of production. If ϵ_{ij} is positive, the factors of production are complementary, and when it is negative they are substitutable. If the cross-price elasticity is zero, they are neither.

For production processes involving three or more factors of production, Uzawa has derived the Allen partial elasticities of substitution (σ_{ij}), taking the factors two by two. If two factors of production are substitutable, an increase in the price of one will bring about an increase in the quantity used of the other. The σ_{ij} will thus have a positive value. If σ_{ij} has a negative value, the two inputs are complementary. Although $\sigma_{ij} = \sigma_{ji}$, the cross-price elasticities (ϵ_{ij}) are not necessarily symmetric.

2) Measures of Scale and Scope effects

Without doubt, the most important production characteristic for policy purposes is the behaviour of costs as both scale and product mix of the telecommunications firms vary. The statistics obtained from these observations, determine whether a telecommunications firm (Bell Canada for example) is a natural monopoly. The most important statistics obtained from the observation of the relationship that exists in the production process between inputs and outputs are; 1) the *output elasticities of cost* i.e., the cost elasticities with respect to outputs (ϵ_{CQk}), and 2) the *output elasticities of inputs* i.e., the input elasticities with respect to outputs (ϵ_{iQk}).

The former are used for the derivation of the latter and also for the derivation of the scale elasticity. The *scale elasticity* (ϵ) is the summary statistic informing us of the *degree of overall economies of scale*[13].

In the production process, input proportions may change not only because of changes in the price of inputs but also because of changes in quantities of particular outputs. Evidence of this relationship of input proportions and output changes is provided by the *output elasticities of inputs* i.e., the input elasticities with respect to outputs (ϵ_{iQk}).

The production structure is said to be *homothetic* with respect to output k if the proportions of the factors of production utilized in the production process are independent of changes in output k, i.e., when ϵ_{iQk} are equal for all inputs. If this last property holds for all of the outputs the production structure is *homothetic* and consequently, changes in the mix of factors of production are caused by changes in relative input prices and/or technology.

3) Measures of Technical Change

The economic characteristics of technological changes are another category of economic properties that the estimation of the translog cost function provides. Technological changes may result in reductions of costs of production, or they may be input-biased (capital-using, labour-saving, etc). A number of summary statistics provides us with this information. The *technology elasticity of cost* (ϵ_{CT}), i.e., the cost elasticity with respect to technological change, informs us about cost savings resulting from technical change.

---

13 Overall economies of scale are said to exist when a proportionate increase in all outputs results from a less-than-proportionate increase in inputs. The inverse of the sum of the output elasticities of cost is the measure of scale elasticity, i.e.,

$$\epsilon = \left(\sum_{k=1}^{n} \epsilon_{CQk} \right)^{-1}$$

If $\epsilon > 1$, global increasing returns to scale characterize the production process. If on the other hand, $\epsilon < 1$, the production structure exhibits global decreasing returns to scale, and constant global returns to scale, if $\epsilon = 1$.

If $\epsilon_{CT} < 0$, technological changes are cost saving. As was mentioned above, the measurement of technical change is a very difficult task for any researcher. Various authors have used various ways to include the technological change variables in the translog cost equation, giving rise to non-comparable technology elasticities.

The input biases of technological changes are measured by the *technology elasticities of inputs*. If $\epsilon_{iT} > 0$ technological change is input saving. If it is positive, it is input using and if it equals zero, it is input neutral.

When input prices remain constant over time, any reduction in costs of production may be due either to changes in technology or to changes in the scale of production. The rate of change of this cost efficiency can be calculated relatively easily from time series data. What is more difficult is the decomposition of these cost efficiencies into scale and technical change effects. Some researchers have devised methods of separating these two effects. The evidence derived from productivity studies on technical change effects will be presented while we are revising the empirical cost studies.

This survey will focus mostly on the three above-mentioned production characteristics, namely, factor substitution possibilities, scale and scope effects, and the rate and bias of technical change.

THE SINGLE-OUTPUT MODELS

The single-output models cannot inform us of the existence of economies of scope since they deal, by definition, with only one output. However, they can provide us with information concerning the existence of overall economies of scale that can be generated by a variety of factors that affect the process of production, namely, output-specific economies of scale and economies resulting from the joint production of various interrelated products.

Three econometric single-output models for Bell Canada and two for AT&T will be discussed at this section. They were the first attempts to deal with the complex problems of economies of scale and technological change in telecommunications.

A) SINGLE-OUTPUT MODELS: BELL CANADA

1) Denny, Fuss and Everson (1979)

The study by Denny et al. and the study of Smith and Corbo that will be discussed next were probably the first to attempt to apply the new concepts of industrial organization to Canadian telecommunications. They estimated single output translog cost function for Bell Canada in an attempt to test for the existence of economies of scale within the entire Bell Canada telecommunications system. Although the models resemble each other in many respects, the most significant differences are the specification of technical change and the variable representing the price of capital. Denny et al.'s proxy variable representing Bell Canada's technological change is represented by the percentages of telephones with access to direct distance dialing (DDD) facilities.

Denny et al. report the estimated *factor input characteristics* only at the expansion point of the function. Table 4-1 reproduces the parameter estimates of their model while table 4-1A reports important characteristics of the production process used by Bell Canada.

The price-elasticity of demand for capital, labour and materials is very low (inelastic). Capital and labour and labour and material are substitutable factors of production, while capital and material are neither substitutes nor complements.

The estimates of the *input-output* relationships are quite interesting. *Substantial economies of scale are* indicated, with a scale elasticity of e = 1.58, estimated at the expansion point. However, they note that a misspecification either of output or of technology has produced highly trended annual scale elasticities and therefore the latter are not reported. The homotheticity hypothesis is rejected outright. As far as *technological change* is concerned they have found that it has mostly been capital using and labour and material saving.

Technological progress has shifted the cost function downward, but none of the first- and second- order technology parameters is significantly different from zero. The elasticity of cost with respect to technological change (the technology elasticity of cost) is reported to be -0.124 and is statistically significant at the sample mean.

2) Smith and Corbo (1979)

Smith and Corbo worked along the same line as Denny et al. However, they estimated, in addition to a single output translog cost function, a two-output translog production and cost model[14]. Bell Canada's productivity study provided most of the data, while some other, mostly publicly available sources, provided the information necessary for completing the study. The period covered extended from 1952 to 1976.

The more interesting aspects of their results are presented in Table 4-1 and 4-1A. The most significant difference between the results of this study and the others is found in the estimates of the *factor input characteristics*. Although their estimates of price-elasticity of demand are low (inelastic) as in the other studies, they are the highest of all the surveyed models. Capital's own-price elasticity is around -0.5 and it remains stable over time. Labour's own-price elasticity is - -0.7 to -0.8 during the 1950's but at the end of the period it becomes unity. There is almost no difference between the price elasticity of capital and that of material.

The characteristics of the substitution of factors of production are very similar to those of other models. Again capital and material are neutral, while capital and labour and labour and material are substitutes. Nonhomotheticity is the main characteristic of the *input-output relationship*. Declines in the capital-labour ratio have been attributed to output expansion (a surprising result). Economies of scale (the scale elasticity is 1.22.) are present for the whole period of the study. However, economies of scale are not reported for the years 1956 and 1957. Moreover, technical changes have been capital-using, labour-

---

14 The two-output translog cost model is presented latter on.

TABLE 4-1

A COMPARISON OF BASIC FEATURES OF SINGLE-OUTPUT, THREE-INPUT COST FUNCTIONS OF BELL CANADA

Studies	SMITH AND CORBO	DENNY ET AL	KISS ET AL			KISS AND LEFEBVRE	
Year	1979	1979		1981-1983		1984	1984
Functional Form	TL	TL	FULL GTL	HOMOTHE-TIC GTL	HOMOTHE-TIC GTL AUTO	SINGLE FIRM TL	TWO-FIRM TL
Data Set	1952-76	1952-76		1952-78		1956-81	1956-81
Tech Change	Time Trend	DDD,MSE Q-aug-menting	Q-,I-aug menting		K-aug. Time trend		
Behavioral Assumption	Cost Min	Constr Profit Max		Cost Min	Cost Min		
Estimation Method	ITSUR	IT3SLS		ITSUR	ITSUR		
Cap	.466	.396	.510	.510	.509	.542	.542
Lab	.342	.425	.317	.317	.319	.297	.296
Output	.946	.695	.579	.577	.574	.576	.600
Tech	-.951	.079	-.194	-.178	-.189	-.588	-.650
Cap^2	.023	.159	.224	.226	.216	.241	.214
Cap-Lab	.054	-.063	-.137	-.138	-.106	-.163	-.129
Cap-Output	-.092	.032	--	--	--	--	-.022
Cap-Tech	.372	.171	.213	.213	.195	.347	.373
Lab^2	-.081	.022	.082	.108	.070	.130	.122
Lab-Output	.098	.022	.013	--	--	--	.010
Lab-Tech	.330	-.152	-.204	-.201	-.184	-.302	-.325
$Output^2$	.961	-.219	.067	.097	.105	.141	.300
Output-Tech	-2.246	-.154	-.529	-.582	-.734	-.734	-1.153
$Tech^2$	3.234	.079	-.755	-.738	-.773	1.430	2.566

saving and material-neutral. They had as an effect to shift downward total production costs, over time.

3) Kiss et al. (1981, 1983) and Kiss and Lefebvre (1984)

Kiss et al., searching for an "appropriate" representation of Bell Canada's production technology, applied various tests and restrictions on the single output generalised translog cost function, and they end up by accepting a *homothetic generalized translog cost function* (GTL) with a Box-Cox transformation of the technology variable and a logarithmic transformation of the output. The period tested was 1952 to 1978, using improved data, although the technological change variable used was the time-trend proxy variable used in the model of Smith and Corbo (1979).

Table 4-1 reports the parameter estimates resulting from the estimation of the full GTL function, the homothetic GTL function and the homothetic GTL adjusted for first order autocorrelation. The results are very similar to those reported by Denny et al. (1979).

Indeed, as far as the *factor input characteristics* are concerned, it can be said that factor demand is price inelastic and that capital and labour and material and labour are substitutable, while capital and material are neutral (see table 4-1A).

The second category of production properties is quite interesting. In particular, the scale elasticity is estimated to be equal to 1.75 at the expansion point. The hypothesis of constant returns to scale is rejected as well as the homogeneity hypothesis. Economies of scale are estimated to be important for the whole study period, with the exception of the first few years of the sample.

The *technology elasticity of cost* indicates that technological changes have been labour-saving, capital-using and material-neutral. Technological changes displaced downwards the total cost function only moderately.

TABLE 4-1A

A COMPARISON OF BASIC ECONOMIC CHARACTERISTICS OF COST FUNCTIONS OF BELL CANADA

OWN- AND CROSS- PRICE ELASTICITIES OF FACTOR DEMAND, ECONOMIES OF SCALE

AND TECHNICAL CHANGE EFFECTS

SINGLE-OUTPUT MODELS											
BELL CANADA STUDIES											
STUDIES	Smith and Corbo	Denny et al.	Kiss et al.	Kiss and Lefebvre	Kiss and Lefebvre		Smith and Corbo	Denny et al.	Kiss et al.	Kiss and Lefebvre (s.firm)	Kiss and Lefebvre (two firm)
YEARS	1979	1979	1981	1984	1979		1981	1979	1981	1984	1984
OWN- PRICE ELAST. K L M	-0.5 -0.1 -0.6	-0.2 -0.6 -0.5	-0.05 -0.3 -0.5	-0.01 -0.3 -0.6	-0.06 -0.3 -0.3	Homothe-ticity	NO	NO	YES	YES	NO
CROSS- PRICE ELAST. K-L K-M L-M	S N S	S C S	S N S	S N S	S N S	Scale Elasti-city	1.22	1.58	1.75	1.73	1.67
Technology bias						K L M	U S N	U S S	U S N	U,S S S	U,S S S
	NOTE: S: Substitutes; C: Complements; N: Neutral						NOTE: U: Using; S: Saving; N: Neutral				

The Kiss and Lefebvre (1984) model, although different in many respects from the Kiss et al. model, gives essentially the same results. The main differences were in the measurement of the variables, the specification of the model and the data sample. (A broader sample was utilized covering the period from 1956 to 1981). They constructed a two-firm model (Bell Canada and Alberta Government Telephones) and used cross-sectional data, in an attempt to analyse the productivity differences between the two firms.

Their results indicate an inelastic price demand for the three inputs of production, while the scale elasticity indicates a high degree of economies of scale. Technological changes have induced downward shifts of the total cost function, although they became less significant at the end of the sample period.

In sum, the results obtained from the empirical studies, utilizing a single output multi-input cost function (various forms of the translog cost function), indicate that the cost structure of Bell Canada was characterized by strong economies of scale during the whole sample period. Technological change was capital-using, labour-saving and material-neutral. Technological changes have caused downward shifts of the cost function, although these shifts were less important at the end of the sample period. It is interesting to compare these results to the results obtained from the American studies done for AT&T.

B) SINGLE-OUTPUT STUDIES: AT&T

1) Nadiri and Schankerman (1979, 1981)

Many attempts have been made to estimate the economic properties of AT&T's production structure. Nadiri and Schankerman were probably the first ones to use a flexible functional form for performing such tests. They estimated two models, one single-output, three-input model, and another single-output, four-input model. (In addition to the capital, labour and material inputs, they included the stock of the Bell System's R&D input.) The period covered was from 1947 to 1976. Technological changes were represented by an exponential time trend. The following conclusions can be drawn from their study.

TABLE 4-2

A COMPARISON OF BASIC FEATURES OF SINGLE-OUTPUT, FOUR-INPUT COST FUNCTIONS OF AT&T

Studies	Nadiri AND Schankerman			Christensen et al			
Year	1981			1981-1983			
Functional Form	TL		1/3 TL	1/11- TL	1/12 TL		
Data Set	1947-76			1947-79			
Tech Change	Time Trend			Bell System R&D			
Behavioral Assumption	Cost Min.				Cost Min		
Estimation Method	ITSUR			2-Stage ITSUR			
Cap	.430		.496	.521	.528		
Lab	.426		.397	.367	.362		
Output	.565		.619	.575	.604		
Tech	-.012		.065	.034	-.067		
Cap^2	.114		.057	.278	.269		
Cap-Lab	-.082		-.004	-.255	-.232		
Cap-Output	.009		--	--	.082		
Cap-Tech	.050		.142	.047	--		
Lab^2	-.14		.031	.216	.242		
Lab-Output	.006		--	--	-.098		
Lab-Tech	-.051		--	-.145	-.047		
$Output^2$	--		--	-.0268	--		
$Tech^2$	0.005		--	.316	.663		

TABLE 4-2A

A COMPARISON OF BASIC ECONOMIC CHARACTERISTICS OF COST FUNCTIONS OF AT & T:

OWN- AND CROSS- PRICE ELASTICITIES OF FACTOR DEMAND, ECONOMIES OF SCALE

AND TECHNICAL CHANGE EFFECTS

SINGLE-OUTPUT MODELS: AT & T STUDIES					
STUDIES	Nadiri and Schanker-man	Chris-tensen et al.		Nadiri and Schanker-man	Chris-tensen et al.
YEARS	1979	1981		1979	1981
OWN- K PRICE L ELAST. M	-0.3 -0.5 -1.1	-4.5 -6.7 -5.7	Homothe-ticity	YES	YES,NO
CROSS- K-L PRICE K-M ELAST. L-M	S S S	S C,S S	Scale Elasti-city	2.12	1.5-1.9
Factor Substitution			K L M	U S S	U S S
	NOTE: S: Substitutes; C: Complements			NOTE: U: Using; S: Saving	

First, the *factor input characteristics*, as they are reported in Table 4-2A, show that price inelasticity characterizes both capital and labour, while the materials price elasticity is almost unitary. All pairs of factors of production are substitutable, except research and labour which are complementary.

Economies of scale are the other important characteristic of the two models. The three-factor model gives a scale elasticity of 1.75, and four-factor, 2.12. Although the annual scale elasticity estimates are not reported, calculations performed by Kiss and Lefebvre (1977), indicate a "pronounced trend of the degree of economies of scale over time". Homotheticity is rejected in the four-factor model, while it is accepted in the three-input model.

Technological change has been capital-using, labour-saving and material-neutral, for the two estimated models. However, an estimation problem was present concerning the technological change characteristics. The four-input model reports positive first- and second-order-neutral technology parameters, "suggesting that accelerating total cost increases resulted from technological improvements during the sample period". This problem may be attributed to the combined use of both time and price-of-R&D-stock variables for technology. Nadiri and Schankerman decompose the productivity gains, reporting that during the entire sample period, improvements in technology have contributed to the improvement of annual total productivity by an average increase of approximately 1.2 per cent.

2) Christensen, Cummings and Schoech (1981)

Christensen et al. estimated a great number of alternative specifications of flexible functional forms (a total of fifty cost functions). Their sample period covered the years from 1947 to 1979, and their data were mostly obtained from AT&T's productivity study. A number of alternative variables were used as representatives of the level of technology. Annual R&D expenditures, one belonging to the Bell System and the other being the sum of the R&D expenditures of the Bell System and Western Electric, as well as the percentage of direct-dialed long distance calls and the percentage of telephones connected to modern switching facilities were the variables used to capture the changes of the technology over time.

Since their main objective was to study the scale economies of AT&T, they report thoroughly on scale elasticities. They found that significant economies of scale were present throughout the period under investigation. The scale elasticities range, depending on the model, from 1.52 to 2.28. Adjustments for autocorrelation gives higher scale elasticity estimates at the expansion point. However, such estimates seem to be insensitive to the various forms and proxies assumed for technological change. Changes in the utilization of factors of production, as well as the explicit inclusion of variously defined quasi-fixed inputs, leave unaffected the estimated scale elasticities.

Technological changes are found to be capital-using, labour-saving and material-neutral. The negative first-order technology parameters indicate downward shifts of the total cost function over time. The results are destabilized when second-order terms in output and technology are taken into account. The authors conclude then that the inclusion of the second-order terms, may be "a too general specification" for successful estimation.

From their attempt to estimate multi-output translog cost functions, they conclude that the poor behaviour of these models suggests that there is a trade-off between the generality of a model and the quality of its estimates.

In sum, it can be argued that the empirical estimates of single-output multi-input models for AT&T are consistent with those of Bell Canada. Researchers in both countries have found strong economies of scale for both AT&T and Bell Canada, suggesting that both firms utilized the same or similar technologies that gave rise to economic similarities in their production processes.

Although these studies provide us with valuable information concerning the presence of economies of scale, they are not very valuable from a public policy perspective. This is so because, in the present policy debate, we need to know not only whether the costs of the telecommunications industry decline as output increases, but (and this is probably more interesting and relevant to the debate) which one of the services contributes to the reduction of costs and whether the provision of all the services by one firm contributes to significant realization of economies of scope. That is to say, although we need information on the simultaneous presence of product-specific economies of scale and economies of scope, the single-output models only provide us with information concerning the presence of overall economies of scale. It is thus necessary to review some of the multi-output models. We start by presenting the two-output models and then in the next section we present the three-output models.

TESTS FOR COST SUBADDITIVITY: TWO OUTPUT-MODELS

As was shown in the previous chapter, the subadditivity of production costs is the most appropriate test for judging whether a multi-output monopoly is "natural". The simultaneous existence of product-specific economies of scale and economies of scope is a sufficient condition for cost subadditivity. The two-output models, by disaggregating the total telecommunications output into two separate categories (local and long-distance services), offer an opportunity for judging the subadditivity of their costs. Two models dealing with Bell Canada's and AT&T's cost structure are presented below.

A) TWO-OUTPUT STUDIES: BELL CANADA

1) Smith and Corbo (1979)

Smith and Corbo estimated a two-output translog model for Bell Canada, classifying its output as "competitive services" (toll, other than message and miscellaneous) and "monopoly services" (local and message toll). The competitive output was assumed to be endogenously determined while the monopoly output was assumed exogenously determined. Their parameter estimates, resulting from the estimation of a two-output translog cost function, one revenue-share equation and two cost-share equations, are presented in Table 4-3.

TABLE 4-3

A COMPARISON OF BASIC FEATURES OF TWO-OUTPUT, THREE-INPUT COST FUNCTIONS OF BELL CANADA

Studies	SMITH and CORBO		KISS et al				
Year	1979			1981			
Functional Form	TL		Full GTL	TL	Best GTL		
Data Set	1952-76			1952-78			
Tech Change	Time Trend			Q and Factor aug.			
Behavioral Assumption	Cost Profit Max				Cost Min		
Estimation Method	ITSUR			ITSUR			
Cap	.481		.510	.511	.512		
Lab	.328		.318	.319	.319		
Local	.866		.633	.463	.503		
Toll	.031		.063	.101	.114		
Tech	-.775		-.204	-.151	-.175		
Cap^2	.079		.0214	.236	.220		
Cap-Lab	-.0021		-.0109	-.162	-.147		
Cap-Local	-.151		-.02	.111	.082		
Cap-Toll	.040		-.02	-.074	-.039		
Cap-Tech	.322		.216	.263	.220		
Lab^2	-.068		.0216	.263	.220		
Lab-Local	.131		.009	-.166	-.098		
Lab-Toll	-.037		.002	.109	.061		
Lab-Tech	-.026		-.178	-.230	-.164		
Local^2	.601		.306	3.185	--		
Local-Toll	-.023		-.016	-.617	--		
Local-Tech	--		-.329	-1.639	-1.136		
Toll^2	.018		.003	.971	--		
Toll-Tech	.033		-.328	.160	--		
Tech^2	0.989		1.127	2.391	1.669		

TABLE 4-3A

A COMPARISON OF BASIC ECONOMIC CHARACTERISTICS OF COST FUNCTIONS OF BELL CANADA: OWN- AND CROSS- PRICE ELASTICITIES OF FACTOR DEMAND, ECONOMIES OF SCALE, ECONOMIES OF SCOPE, SUBADDITIVITY, AND TECHNNOCOGICAL CHANGE EFFECTS

TWO-OUTPUT MODELS: BELL CANADA STUDIES						
STUDIES		Smith and Corbo	Kiss et al.		Smith and Corbo	Kiss et al.
YEARS		1979	1981		1979	1981
OWN- PRICE ELAST.	K L M	-0.3 -0.9 -0.6	-0.1 -0.5 -1.0	Homothe- ticity	NO	NO
CROSS- PRICE ELAST.	K-L K-M L-M	S S S	S C,S S	Scale Elasti- city	1.20	1.62
Cost Complemen- tarity				LOC-MTS LOC-OTS MTS-OTS	YES,NO	O
				COTS SUBADDI- TIVITY	SUB	SUB
Technology bias				K L M	U S S	U S S
		NOTE: S: Substitutes; C: Complements			NOTE: U: Using; S: Saving O: Neither Yes: Economies; No: Diseconomies; SUB: Subadditivity	

We observe that their results are very similar to those obtained from the estimation of the single output model. As far as *factor input characteristics* are concerned, we ascertain that demand for the inputs of production is price inelastic (see table 4-3A). The only difference lies in the substitutability of the capital and material factors of production. In the single output model these two factors were neutral, while in the two output model they are strongly complementary.

The *input-output relationship* that indicates whether there is homotheticity of the cost function reveals that the growth of the local and message toll services have strongly increased the labour-capital, and labour-materials ratios. On the other hand, the growth of competitive services has induced an increase in the capital-labour and capital-material ratios, though to a lesser degree. Economies of scale are present for every year of the sample period, but they are low. The scale elasticity at the expansion point (1967), is estimated to be 1.20. Local economies of scope are shown to be present for a considerable part of the observation period covered by the data used in the study. In particular, they show that declines in the marginal costs of providing monopoly services were the result of the increase in the volume of competitive output. Global economies of scope are not indicated.

As far as *technological change* is concerned, the Smith and Corbo study demonstrates that it has been labour- and material- saving and capital-using. Quite substantial cost savings are attributed to the downward shifts of the cost function induced by these technological changes.

2) Kiss et al. (1981)

Kiss et al. classify Bell Canada's services into two categories, "local", including miscellaneous services, and "toll" services that include message toll and private line services as well as other toll services. These two services are subject to a Box-Cox transformation, while the other variables are translogarithmically transformed. They proceed to the estimation of their model by restricting to zero four parameters of the following variables: local squared, toll squared, local-toll interaction, and toll-technology interaction.

Their results are not different from those obtained by Corbo and Smith (1979), at least as far as the *factor input characteristics* are concerned. The price elasticities of demand for the three factors of production remain stable throughout the sample period. Demand for capital is very price inelastic, though that for labour is moderately inelastic. That for materials is approximately unitary. Substitutability is observed between labour and capital and labour and material, though capital and material are almost neutral. Input ratios are influenced by changes in output growth; i.e., the homotheticity hypothesis is rejected. The labour-capital and the labour-material ratios are reduced due to the local output growth while these ratios are increased due to the toll output growth. None of the growth of the two outputs had any effect on the capital-material ratio. These *output elasticities of inputs* are shown in Table 3. In agreement with the other studies, *technological changes* were estimated to be capital-using and labour- and material- saving. Technological changes have induced moderate downward shifts of the total cost function.

In agreement with Corbo and Smith, Kiss et al. found strong economies of scale in the production process of Bell Canada for most of the years under investigation. Most of the 1950's were characterized by constant returns to scale, while the 1960's and 1970's were characterized by increasing returns to scale, with a scale elasticity ranging from 1.22 to 1.72. These overall economies of scale have mostly originated from the economies of scale realized in the production of local output. The scale elasticity of local output-specific economies of scale is 1.56 at the expansion point, while the degree of overall economies of scale at the same expansion point (1967) is 1.62. Thus the contribution of toll product-specific economies of scale to the overall economies of scale is not significant. The production of toll output thus exhibits moderate (or non-existent at all) scale economies. (They have been estimated by Kiss et al (1981) to be 1.09). *Economies of scope* have been much more important. They have estimated that a separation of Bell Canada's monopoly into two independent firms, one providing the local output and the other the toll output, would have increased Bell Canada's costs by more than 9% at the expansion point. Costs would have been even higher for the other years of the sample period.

Although the above mentioned results are very interesting indeed, a warning to the reader is appropriate at this point. The results of the Kiss et al study are highly dependent on the restrictions imposed on the output interaction terms. Such restrictions limit the application of tests for investigating local cost complementarities in the production process. Furthermore, as reported by the authors, the results concerning the output-specific economies of scale and economies of scope are obtained only after encountering substantial difficulties.[15] They conclude that even if we use flexible functional forms, serious problems are still encountered in the estimation process. Further improvements either in the statistical methods or in the data used may ameliorate the estimation problems encountered.[16]

B) TWO-OUTPUT STUDIES: AT&T

1) Evans and Heckman (1981, 1983, 1988)

The most complete and sophisticated models for AT&T are probably the ones presented by Evans and Heckman. They estimate eight different models; one uses the translog cost function, another corresponds to the Fuss and Waverman model ("hybrid" or generalized cost function) and the third one is what they call the Box-Tidwell model. A Box-Cox transformation is applied to all explanatory variables for the Box-Tidwell model, while for the TL and GTL models, such a transformation is applied only to the output variables, while a logarithmic transformation is applied to the factor prices. These three models are then estimated

15 Some of the difficulties encountered are: 1) A number of annual estimates of economies of scope are not realistic; 2) The output-specific economies of scale statistics are mildly trended; 3) The estimated economies of scope and toll specific economies of scale are statistically insignificantly different from zero and one respectively.

16 Problems associated with data or the statistical techniques are discussed below.

with and without adjustment for autocorrelation. Then, they proceed to the estimation of two more models, one restricted for neutral technical change and another restricted for non-output augmenting technological change. In all these models a technological change variable which contains lagged Bell System R&D expenditures is used (table 4-4).

After a careful examination of all the above estimated models, Evans and Heckman conclude that the translog model adjusted for serial correlation and with the unrestricted form of technological changes, is the best representation of AT&T's production process.

Their results are quite different from those reported in other studies (see table 4-4A). At the expansion point (1961), the own price elasticity of demand for the three factors of production have the expected negative signs. In contrast to the other studies, however, the demand for labour is very insensitive to its price changes. The demand for capital is perfectly inelastic, while that for materials is moderately insensitive. The cross-price elasticities of the three factors of production show a substitutability among them.

Evans and Heckman tested for homotheticity and they accepted that the translog model adjusted for serial correlation is homothetic, while for the unadjusted model the homotheticity hypothesis is rejected at the 5% level and it is accepted at the 1% level. Homotheticity is rejected for the remaining models.

Economies of scale characterize all the production processes. The adjusted translog model produces the lowest scale elasticity estimates (1.39), while for the non-adjusted model the scale elasticity is much higher (1.57).

The most unusual finding relates to their *technological changes*. Evans and Heckman find that technological changes have no input bias. For the adjusted translog model the hypothesis of neutral technological change cannot be rejected.

TABLE 4-4

A COMPARISON OF BASIC FEATURES OF TWO-OUTPUT, THREE-INPUT COST FUNCTIONS OF AT&T

Studies	Evans and Heckman						Charnes	Kiss and Lefebvre
Year	1983-1988						1985-88	1985
	Unadjusted			Adjusted			Adjusted	Best
Functional Form	TL	Modif. TL	Box-Tidwell	TL	Modif. TL	Box-Tidwell	TL	GTL
Data Set	1947-77						1947-77	1947-79
Tech Change	Distributed Lag of R&D by AT&T (R&D DL)						R&D DL	R&D DL
Behavioral Assumptions	Cost Minimization						Min of $\Sigma d_t = \Sigma(C_t obs - C_t est)$	Cost Min
Estimation Method	2-Stage ITSUR						Goal Prog/ Constr.	
Capital	.536	.537	.537	.536	.538	.535	.450	.544
Labour	.354	.354	.354	.354	.353	.354	.449	.347
Local	.294	.368	.206	.206	.237	.282	.799	.454
Toll	.420	.345	.462	.504	.422	.401	-.80	.270
Tech	-.161	-.120	-.193	-.201	-.120	-.146	-.016	-.101
Cap^2	-.197	-.193	.190	.223	.220	.216	.141	.196
Cap-Lab	-.163	-.161	-.158	-.183	-.181	-.179	-.087	-.167
Cap-Local	.354	-1.93	.399	-.343	-3.24	.335	-.135	.548
Cap-Toll	-.221	5.75	-.263	-.180	9.98	-.170	-.938	-.368
Cap-Tech	.106	.107	.119	.081	--	.074	-1.10	.111
Lab^2	.176	.173	.171	.174	.174	.162	.113	-.184
Lab-Local	-.352	-4.17	-.390	-.362	-7.54	-.355	.141	-.515
Lab-Toll	.209	.177	.224	.161	.218	.161	-1.13	.323
Lab-Tech	-.108	-.109	-.120	-.052	--	-.054	1.28	-.101
$Local^2$	-10.55	-.462	-13.06	-16.64	-.284	-13.6	4.54	--
Local-Toll	7.76	.367	10.23	12.16	.390	9.41	-5.20	--
Local-Tech	-.967	--	-1.92	-1.55	--	-.640	3.10	.192
$Toll^2$	-5.28	-.432	-7.90	-8.96	.278	-6.49	5.65	--
Toll-Tech	.358	--	1.51	1.43	--	.591	-3.12	-.325
$Tech^2$	.412	-.361	-.126	-.180	-.397	-.007	.822	--

TABLE 4-4A

A COMPARISON OF BASIC ECONOMIC CHARACTERISTICS OF COST FUNCTIONS OF AT & T: OWN- AND CROSS- PRICE ELASTICITIES OF FACTOR DEMAND, ECONOMIES OF SCALE, ECONOMIES OF SCOPE, SUBADDITIVITY, AND TECHNOLOGICAL CHANGE EFFECTS

TWO-OUTPUT MODELS: AT & T STUDIES							
STUDIES	Evans and Heckeman	Charnes et al.	Kiss and Lefebvre		Evans and Heckeman	Charnes et al.	Kiss and Lefebvre
YEARS	1983	1985	1985		1983	1985	1981
OWN- K PRICE L ELAST. M	-0.05 -0.2 -0.6	-0.2 -0.3 -0.1	-0.1 -0.1 -0.5	Homothe-ticity	NO	NO	NO
CROSS- K-L PRICE K-M ELAST. L-M	S S S	S C S	S S S	Scale Elasti-city	1.39	1.39	1.38
Cost Complemen-tarity				LOC-MTS LOC-OTS TS-OTS	-- NO --	-- YES --	-- 0 --
				COTS SUBADDI-TIVITY	SUPER	SUB	SUB
Technology bias				K L M	N S N	S S U	U S S
	NOTE: S: Substitutes; C: Complements				NOTE: Using; S: Saving; N: Neutral		

The most significant contribution of Evans and Heckman lies in the development of a local subadditivity test which can be easily applied within the confines of the data sample.[17] Applying their local subadditivity test by assuming that AT&T's actual output is divided between two competing firms of various sizes, they find that the unadjusted translog cost function is subadditive, while the adjusted and the unadjusted Box-Tidwell translog cost function is *superadditive*, for most of the reported two-firm combinations. *Thus they reject the hypothesis of local subadditivity*, arguing that AT&T's production structure is actually superadditive since they observe the superadditivity property for all the years between 1958 and 1977. In summarizing their findings, they state: "We found that the Bell System *did not have a natural monopoly* over any of the output configurations which were realized between 1958 and 1977. *Two firms were always able to produce these output configurations more cheaply than a single firm.*" (Evans, ed., 1983, p. 272, emphasis added).

Their findings, however, have been severely criticized by other authors.[18] Kiss and Lefebvre (1987) argue that the Evans and Heckman two-output model produces "empirically valuable estimates of the economic properties of the production process of AT&T *at the expansion point* of their cost functions, but the estimates that refer to observations *away from the expansion point* (especially those which contain the poorly estimated second order output terms) do not seem to have any empirical value (p.341, emphasis in the original)".

Kiss and Lefebvre attribute this inconsistency of the empirical estimates to the utilization by Evans and Heckman of a uniform Box-Cox transformation to all non-logarithmic variables. (Such a uniform Box-Cox transformation hypothesis is rejected by Kiss and Lefebvre). If the translog cost function is rejected and the GTL function is accepted, considerable improvements are observed in the second-order parameter

[17] This test will be described in the next chapter.

[18] See for example, Sueyoshi T. and P. Anselmo, 1984, and Charnes et al., 1988.

estimates. More importantly, both Hicks-neutral technological change and the occasional superadditivity observed by Evans and Heckman disappear.

Another critique of the Evans and Heckman model was advanced by Charnes et al (1985, 1988). They specified a two-output adjusted translog cost function, and they estimated it on the Evans and Heckman data sample. Their model is based on the methods of goal programming/constrained regression. In their model the objective of the firm is to minimize the difference between observed and estimated costs of production[19], subject to an appropriate constraint.

Their results are not directly comparable to those obtained from the other studies since the statistical techniques employed are completely different. Nevertheless, their scale elasticity is the same as the one obtained by Evans and Heckman, i.e., 1.39 at the expansion point (1961). However, as is reported by Kiss and Lefebvre, the estimates of overall economies of scale are counter-intuitive, in the sense that a negative toll output elasticity of cost is reported, on the one hand, and on the other hand, the annual scale elasticity estimates are unrealistically highly trended.

Charnes et al's tests on cost subadditivity indicate a subadditive cost function. The costs of having two separate firms providing AT&T's 1961 output would be 15 to 73 per cent higher. This high degree of subadditivity is also observed for other years between 1958 and 1977. Such a result is consistent with that reported by Kiss and Lefebvre (1986). They estimate a full GTL model and a translog model, and arrive at the conclusion that a high degree of subadditivity characterizes the production process of AT&T, in the range of 16 and 26 per cent at the expansion point (1961) for the full GTL model.

---

[19] Their main hypothesis is that the assumption of technical efficiency as is employed by most of the empirical researchers is not appropriate, since actual production always involves waste in the use of scarce resources. The estimation of a cost surface *across* the sampled points of cost observations is thus inappropriate. Instead, an estimation of the cost surface *below* the observed cost point is more appropriate.

THREE-OUTPUT COST FUNCTIONS FOR BELL CANADA

In an effort to increase the available evidence of cost subadditivity and to provide more "appropriate " information on the present telecommunications policy debate, researchers carried their efforts a step further by constructing three-output cost functions. These models have only been constructed in Canada, for investigating the production process of Bell Canada, and there are no equivalent studies for AT&T. In what follows, a brief summary and a critical evaluation of the main studies is provided.

1) Denny et al. (1979)

Denny et al. disaggregate toll output into two sub-categories, the first containing message toll service and the second, other toll services including WATS. The third output, local service, is assumed to be exogenous, while the two toll services are assumed to be endogenously determined by Bell Canada. Bell Canada's objective is assumed to be profit maximization. Proxy variables, one representing the percentage of telephones connected to modern switching equipment (MSE), and the other accounting for the percentage of telephones with access to direct distance dialing facilities (DDD), are assumed to capture the technological changes introduced during their sample period. It is further assumed that these technological changes were of the output-augmenting variety. Denny et al. estimated this three-output translog cost function simultaneously with two cost share and two revenue share equations. Table 4-5 reports the results of their study.

Their results are in agreement with those reported by the previous studies, at least as far as the economic behaviour of factor inputs is concerned. The own-price elasticities for the three factors of production are negative, as is expected *a priori*. They are very low, indicating that their demands are price inelastic. Only capital's price elasticity is positive, but by pre-constraining the capital-squared term, they force it to be negative and low. The cross-elasticities of the three inputs indicate that labour and capital, and labour and

TABLE 4-5

A COMPARISON OF BASIC CHARACTERISTICS OF THREE-OUTPUT, THREE-INPUT COST FUNCTIONS OF BELL CANADA

Studies	FUSS and WAVERMAN	DENNY et al	KISS et al	BRESLAW and SMITH
Year	1981	1979	1981	1981
Functional Form	GTL	TL	GTL	TL
Data Set	1952-77	1952-76	1952-78	1952-78
Tech Change	Q-aug. DDD,MSE	Q-aug. DDD,MSE		Index of switching
Behavioral Assumptions	Constr. Profit Max	Constr. Profit Max	Cost Min	Constr. Profit Max
Estimation Method	IT3SLS	IT3SLS		FIML
Cap	.475	.418	.510	.410
Lab	.352	.404	.317	.390
Local	.942	.513	.659	-.780
MTS	.094	.063	.092	.391
OTS	.025	.009	-.049	.198
Tech	--	--	-.173	1.659
Cap^2	.249	.189	.225	--
Cap-Lab	-.122	-1.102	-.099	--
Cap-MTS	-.059	-.022	-.008	-.20
Cap-OTS	-.025	.029	-.04	-.028
Cap-Tech	--	--	-.167	-.109
Lab^2	.0074	.059	.60	--
Lab-Local	-.260	-.038	-.073	--
Lab-MTS	.0487	.028	.010	.020
Lab-OTS	.031	-.02	.007	-.028
Lab-Tech	--	--	-.0108	-.109
$Local^2$	-.492	-.145	2.043	.378
Local-MTS	.010	-.104	-.155	-.138
Local-OTS	.019	-.042	-.205	-.027
Local-Tech	--	--	-1.798	-.277
MTS^2	-.036	.030	.033	.902
MTS-OTS	-.023	.016	.106	-.006
MTS-Tech	--	--	-.711	.045
OTS^2	-.002	.013	.024	.034
OTS-Tech	--	--	.076	-.007
$Tech^2$	--	--	3.277	--
λ-Local	-1.076	-.327	--	--
λ-MTS	-1.592	-1.676	--	--
λ-OTS	-2.396	3.742	--	--

TABLE 4-5A

A COMPARISON OF BASIC ECONOMIC CHARACTERISTICS OF COST FUNCTIONS OF BELL CANADA: OWN- AND CROSS- PRICE ELASTICITIES OF FACTOR DEMAND, ECONOMIES OS SCALE, ECONOMIES OF SCOPE, SUBADDITIVITY, AND TECHNOLOGICAL CHANGE EFFECTS

THREE-OUTPUT MODELS: BELL CANADA STUDIES									
STUDIES	Denny et al.	Kiss et al.	Breslaw and Smith	Fuss and Waverman		Denny et al.	Kiss et al.	Breslaw and Smith	Fuss and Waverman
YEARS	1979	1981	1980	1981		1979	1981	1980	1981
OWN- PRICE ELAST. K L M	-0.1 -0.5 -0.6	-0.05 -0.5 -0.3	-0.6 -0.6 -0.8	0[1] -2.4 -0.4	Homothe-ticity	NO	NO	NO	NO
CROSS- PRICE ELAST. K-L K-M L-M	S N S	S C S	S[1] S[1] S[1]	S C S	Scale Elasti-city	1.47	1.43	1.29	0.94[1]
Economies of scope					LOC MTS OTS	-- -- --	-- -- --	-- -- --	NO NO 0
Cost Complemen-tarity					LOC-MTS LOC-OTS MTS-OTS	YES YES NO	YES YES NO	YES YES YES	NO NO YES
					COTS SUBADDI-TIVITY	SUB	--	SUB	SUP/SUB
Technology bias					K L M	U,S S S	U S S	U S N	--- --- ---
	NOTE:	S: Substitutes; C: Complements; N: Neutral 1: Constrained				NOTE:	U: Using; S: Saving; N: Neutral SUB: Subadditivity; SUP: Superadditivity		

material are substitutes, while capital and material are neutral (see table 4-5A).

As far as the homotheticity of the cost structure is concerned, it seems that the factor proportions, especially those of capital and material, are quite insensitive to changes in the three outputs, while the proportions of labour and capital and labour and material are only affected in a small way by changes in the volume of the three outputs.

Economies of scale are found to be an important characteristic of the production process of Bell Canada. The scale elasticity is calculated to equal 1.46, at the expansion point. *Strong overall economies of scale are thus indicated.* However, Denny et al. report that the cost elasticity with respect to local output is strongly trended, causing an upward trend in the annual scale elasticities. Economies of scope or output-specific economies of scale are not reported in their study. This is probably due to the fact that the translog specification of their cost function does not allow for such investigations. However, Kiss et al. (1983), using the estimates reported by Denny et al., calculate local cost complementarities and they find that significant cost complementarities exist between local and toll services. They further conclude that the provision of message and other toll services do not offer cost benefits to Bell Canada.

Denny et al. also found that technical changes caused moderate cost reductions for the sample period. Furthermore, the technology elasticities of inputs indicated that the access to direct distance dialing facilities resulted in considerable labour savings (almost 24%), and moderate material savings (9%), while it increased the utilization of capital by 12%. Contrary to the other studies, Denny et al. found that the modern switches have reduced the utilization of all three inputs, by about the same proportions (17%).

2) Breslaw and Smith (1981)

The model estimated by Breslaw and Smith is not directly comparable to the other three-output models, since their variables are not normalized around their sample mean or any other variable (see table 4-5). However, their elasticity estimates are comparable, since they are not affected by the normalization of the variables. Their model is also different as far as the technological change specification is concerned. They do not restrict the technological change variables to be output-augmenting as Denny et al. do. Nevertheless, the Breslaw and Smith model is similar to the one developed by Denny et al. in a number of respects. They estimate the same translog cost function and two cost-share and two revenue-share equations using the same technique. The assumed behaviour of firm and the output classification are the same.

Table 4-5A summarizes the main findings of their study. The demand for the factors of production is price inelastic. Their substitution is unitary due to the restrictions imposed on the second order factor price parameters. The production structure is not homothetic. Considerable economies of scale characterize the production process of Bell Canada (with an average of 1.60). Local cost complementarity characterizes most of the years of the sample period. More specifically, statistically significant cost complementarities between message toll and local services characterize the production process but such cost complementarities tend to be statistically non-significant between private line output and message toll and local services. *Cost subadditivity characterizes the production process of Bell Canada.* Technological changes have been capital-using and labour-saving and have resulted in considerable cost savings.

3) Fuss and Waverman (1978-1981)

The most interesting and advanced study undertaken to date for the Canadian telecommunications industry is that of Fuss and Waverman. The Fuss and Waverman study is a generalization of the study done by Denny et al. in 1979. Fuss and Waverman explicitly introduce a "hybrid" or a generalized translog cost function (GTL), and they apply a Box-Cox transformation on the three output variables, while the prices of the factors of production are logarithmically transformed. Local output is assumed to be exogenously determined and the two long-distance services are assumed to be endogeously determined. Technological changes are assumed to be output-augmenting as by Denny et al.

Examining the economic behaviour of factor inputs they find, as in other studies, that the demand for labour and material is price inelastic, although moderately so. The demand for capital is constrained to be perfectly price inelastic. Substitutability between labour and capital and labour and material is indicated, while capital and material are complements.

Fuss and Waverman offer interesting and unusual results concerning the characteristics of, and the relationship between the inputs and outputs of, the production process. First of all, they report that the production process is characterized by nonhomotheticity and *constant returns to scale*. Their scale elasticity estimate is 0.94 at the cost function's expansion point. Such an outcome is attributed to the cancelling out effects of the two opposing forces. *First*, they find that strong economies of scale characterize the production of the two toll services, (2.58 for message toll[20] and 2.24 for other toll services) while the production of the local services is characterized by constant returns to scale. *Second*, although they find economies of scale to be very important, Fuss and Waverman find that strong diseconomies of scope characterize the production of two of the three outputs. They estimate that it would have cost 31% less if Bell Canada's local services had been produced separately from its toll services by an independent firm. These costs savings would be a bit lower but still quite important (20%) if the message toll services had been produced separately from local and other toll services. Diseconomies of scope are less important for other toll services (about 2%). Bell Canada's cost function is thus described as *approximately additive* by Fuss and Waverman.

---

20 This estimate is reported by Kiss and Lefebvre and not by Fuss and Waverman. The economies of scale estimate are for the expansion point.

The Fuss and Waverman model has been severely criticized as being quite vulnerable to possible changes in the restrictions imposed upon it. For one, Kiss and Lefebvre (1987) relax the assumption made by Fuss and Waverman concerning the equality of the Box-Cox parameters of the three output variables. The results change dramatically. The constant-returns-to-scale hypothesis is rejected and instead the hypothesis of increasing returns to scale is accepted. The scale elasticity at the expansion point is quite high, 1.93. Kiss and Lefebvre apply the Evans-Heckman test to the Fuss and Waverman model and they find a high degree of cost subadditivity. According to their estimates, having a single supplier costs 30% less than various two-supplier combinations. But Kiss and Lefebvre reject the three-output model on the basis that it is "too general" to permit a useful estimation of the economic properties of the production processes of Canadian telecommunications.

SUMMARY AND MAIN CONCLUSIONS FROM THE EMPIRICAL EVIDENCE AND SOME POLICY RECOMMENDATIONS

It is important to note that the usefulness of the empirical studies summarized above is not limited to the information they provide concerning economies of scale, scope and cost subadditivity in general. Other aspects such as the economic behaviour of factor inputs and the economic properties related to changes in technology are equally important. It is thus important to make a comparison and evaluation of all these studies on the basis of the global information they provide and not solely on the information on economies of scale and scope. A brief summary, an evaluation and a comparison of all these models follows.

1) Comparing Input and Output Parameters

Comparing the *first order* parameters obtained from the models surveyed, we can ascertain that the estimates are quite robust. There is very little variation in the first-order factor-price parameters. Their variation for Bell Canada is a bit higher than that for AT&T. The range of variation of the labour parameters is between 0.30 and 0.45, those of capital, between 0.40 and 0.54, and of materials, between 0.10 and 0.19.

By the same token, the estimates of the first order output-parameters are quite robust as well. The variation of the total output parameters lies between 0.52 and 0.75. The variation of the local output parameters is much more disparate varying between 0.21 and 0.66. The toll output parameters range between 0.27 for AT&T and 0.11 for Bell Canada. The three-output models of Bell Canada report the message toll parameters and the other toll parameters to be 0.1 and 0.03, respectively.

The first-order *technology parameters* for Bell Canada are less easily comparable since different measures of technology are employed by various authors in order to evaluate the effects of technological changes on Bell Canada's production process.

On the contrary, for AT&T they are comparable since the same measures of technology have been used by all researchers. They range between -0.02 and -0.19. The *second order parameters*, on the other hand, are quite variable. This is true for the majority of the input-output interaction terms, on the one hand, and the squared-output, output interaction and squared-technology terms, on the other hand. In order to eliminate such a variability some researchers constrain them to zero from the beginning.

The models surveyed provide us with interesting information concerning the *factor input characteristics*. Demand is price inelastic for all three factors of production in most of the models surveyed. In all models, the demand for capital is much more inelastic than that of labour or materials. There appears to be substitutability between labour and the other two factors of production and an indeterminate relationship between capital and materials.

2) Technological Changes Characteristics

Many studies have been carried out in order to measure Bell Canada's and AT&T's productivity growth and technical change effects on employment and other factors of production. The impressive growth in total factor productivity in telecommunication firms is evidence of rapid technological change. Technical progress has as an effect the shift of the production function so that the same amount of inputs can produce more output. Nevertheless, the same effect is produced when increasing returns to scale characterize the production process. It was thus necessary to decompose the total factor productivity (TFP) growth between economies of scale effects and technical change or efficiency effects.

For AT&T, Nadiri and Schankerman develop a decomposition method, and they argue that 1.2 per cent of total factor productivity growth can be attributed to technical change improvements. For Kiss and Lefebvre, technological changes contribute to the increase of TFP by only 0.6%, meaning that economies of scale effects are more important than changes in technology to the increase in TFP.

For Bell Canada, the technological change effects on the increase of TFP are in the range of 0.6% to 0.8% per annum, as reported by Denny et al. (1979), Kiss (1983) and Kiss and Lefebvre (1985). For Kiss et al.'s (1981, 1983) two-output model, 1.3% of TFP improvement is attributed to changes in technology.

These small effects of technical change on telecommunications TFP are debatable. They may be explained, however, by the fact that the surveyed models estimate "*static* cost functions in which the technology elasticity of total cost reflects the *immediate* (within one observation) cost *shift*." (Kiss and Lefebvre, 1987; emphasis in the original). More dynamic models may be able to give us more precise information on the rate of change of technical progress and its rate of introduction. The analysis of such models is beyond our objectives, however[21].

3) The input-output relationship

It has already been argued that the majority of the studies surveyed have been carried out as an attempt to offer policy guidance to policy makers in industry and government. Such guidance can be obtained

---

21 For dynamic models applied to the Canadian telecommunications industry see, Bernstein, 1987, 1988a, 1988b.

from the evidence on economies of scale, scope and cost subadditivity that the econometric studies offer. The provision of adequate and valuable information on the nature and composition as well as on the degree of internal economies exhibited by the technologies of telecommunications firms is the *sine qua non* for taking such important decisions as the introduction of competition in this vital sector of the economy. Unfortunately, as a group, the studies surveyed shed little light on these issues. The empirical evidence, as was shown above, is confused and contradictory in many respects.

Overall economies of scale are reported by almost all models surveyed. They range between 1.20 and 1.90 at the expansion point. The only model that does not reject the constant-returns-to-scale hypothesis is the one by Fuss and Waverman. (The scale elasticity in their study is 0.94 at the expansion point). However, as Kiss and Lefebvre demonstrate, this outcome may be due to the equal Box-Cox output transformation. If this assumption is relaxed, significant economies of scale (1.90) result.

Many models employ a single aggregate output. These models obviously cannot provide information on *output-specific economies of scale and scope*. If we exclude all of them, a very limited number of models can be retained indeed. The only models that provide information on these subjects are the Kiss et al (1983) truncated two-output generalized translog cost model of Bell Canada, and that of Fuss and Waverman (1981). But they offer contradictory evidence in many respects.

Kiss et al estimate that the degree of local output-specific economies of scale is equal to 1.56, while that of toll output is 1.09. Fuss and Waverman, on the other hand, report approximately constant returns to scale in the the production of local services, while the production of message and other toll services is characterized by very high economies of scale. Kiss et al. report that economies of scope between local and toll services do exist. This result contradicts the one obtained by Fuss and Waverman, namely, that the production of local and toll services is characterized by high degrees of diseconomies of scope. The same production characteristic holds for message toll and the other two output categories. Moreover, Fuss and Waverman report neither economies nor diseconomies of scope in the production of private line services (non-message toll) and other services. The presence or absence of economies of scope can also be verified by the output interaction parameters. There are cost complementarities if the production process has negative output-interaction parameters.

Thus, although most of the models surveyed do not comment on cost subadditivity, information on economies of scope can be obtained. Most of the two- and three- output models for Bell Canada report complementarities between local and the two categories of toll service. For example, in the study of Smith and Corbo it is mentioned that increases in the volume of competitive services lower the marginal cost of local and message toll services (regulated services). Fuss and Waverman, however, argue that message and other toll services offer significant cost advantages if they are jointly produced. The joint production of local services and other toll services offer non-significant cost disadvantages.

For AT&T, the model of Charnes et al, although it does not report on the subject, has negative output interaction parameters which suggest that cost complementarity is present in the production process of AT&T. In contrast, the positive output interaction parameters reported by Evans and Heckman indicate that the production of local and toll services by AT&T imposes a cost disadvantage.

The most important single piece of information for the present policy debate is the knowledge of the cost subadditivity of the cost function. However, cost subadditivity is reported by only three models surveyed. Once again the information they provide is contradictory. However, it seems that this contradiction arises because of the use of some assumptions such as the one of the equal Box-Cox transformation of all the outputs parameters. If this assumption is abandoned, cost subadditivity characterizes the production processes of Bell Canada and AT&T.

Kiss and Lefebvre, in their review article, calculate rough-and-ready cost subadditivity tests for most of the remaining models as well. They conclude that cost subadditivity is indicated in a robust way in the models surveyed. The single-supplier cost advantages, as they are reported in the three original studies,[22] do not change or they change only slightly after Kiss and Lefebvre recalculate them using data which contain improvements in the measurement of the variables. Fuss and Waverman's finding of no substantial cost subadditivity[23] and Evans and Heckman's finding of mix of statistically significant and non-significant sub- and super-additivities are reconciled with the findings of the previous models if the assumption of equal Box-Cox transformation parameters for outputs is abandoned.

In sum, policy makers wishing to take decisions on telecommunications in the light of the evidence of the empirical studies presented above will, inevitably, face a real dilemma. On the one hand, the majority of the studies reviewed report the existence of significant overall economies of scale. But they cannot be used for purposes of taking policy decisions since, as Baumol et al. have demonstrated, cost subadditivity is the criterion for natural monopoly where there are two or more products. The two studies reporting on cost subadditivity show that Bell Canada's cost structure is, at best, simply additive.

Nevertheless, it was shown above that these results are very sensitive to conditions pre-imposed on the generalized translog cost function. When one changes the conditions, the results change dramatically. This non-robustness of the estimates, even of the most advanced studies, is a very serious problem for use of econometric results in policy making.

In the next chapter we present the conceptual framework as it will be applied to the empirical estimation of this dissertation. Then, in

---

[22] The three original studies that report cost subadditivity tests are: Evans and Heckman (1983), Charnes et al. (1985), and Kiss and Lefebvre (1985).

[23] Actually, it yields statistically insignificant estimates of both subadditivity and superadditivity.

chapter 6 we will attempt to estimate the translog cost function using a longer time series and the technique employed by Evans and Heckman in order to offer more precise estimates of the production characteristics of Bell Canada and Alberta Government Telephones (AGT). To the best of our knowledge, this study is the first one to offer a comparison of the cost characteristics between two Canadian Telecommunication carriers. Therefore, it can shed more light on the public policy debate, and may even assist policy makers in their decision making.

CHAPTER 5

THE EMPIRICAL MODEL

As the previous chapter makes clear, econometric evidence on the nature of costs for multi-product telecommunications firms has begun to accumulate and policy makers must evaluate its importance for regulatory design.

In this chapter the focus will be on the implementation of subadditivity tests in order to verify whether Bell Canada and AGT are natural monopolies. The role of our model is to investigating the robustness of the conclusions of previous studies.

In any empirical analysis, concerns normally include specification of the model (including selection of variables as well as choice of functional form), properly defining and collecting relevant data, and choosing techniques to be used in estimation. Each of these is discussed below.

CONCEPTUAL FRAMEWORK, DATA, VARIABLES AND SUBADDITIVITY TESTS

CONCEPTUAL FRAMEWORK

As was mentioned in Chapter 3, Bell Canada produces a variety of services using factors of production grouped under the headings of capital (K), labour (L) and materials (M). For purposes of the empirical investigation its outputs can also be grouped into local and long-distance service outputs. Its cost function can thus be written as:

$$C = f(Q_1, Q_2, P_1, P_2, P_3, T) \tag{5-1}$$

where Q_1 is local service output, Q_2 is long-distance service output, P_1 is the capital rental rate, P_2 is the wage rate, P_3 is the price for materials, and T is an index of technological change.

Although Bell Canada's and AGT's production processes are more realistically described by a three-output model, estimation of such a model imposes a great demand on the data and consequently significant problems of multicollinearity[1] arise. This is the reason why we estimate a single-output model for AGT[2] and a two-output model for both Bell Canada and AGT. The combination of local telephone service, directory advertising, and miscellaneous service is called *local service* while the aggregate of interprovincial and intraprovincial long distance service is called *long distance service*. In the one output model both *local* and *long distance* are combined into an aggregate output.

Baumol et al (1982) discuss several properties that the functional form of a multi-product cost function should possess. *First*, it should be a 'proper' cost function-- "one consistent with minimization of the outlay on inputs, at constant input prices, subject to the technological feasibility of the outputs' production with the aid of the input quantities used". A proper cost function must be non-negative and non-decreasing, concave and linearly homogeneous in the input prices. *Second*, for an analysis of a multi-product industry, the cost function should yield a reasonable (i.e., positive) cost figure for output vectors that involve zero outputs of some goods and positive outputs of others. *Third*, the cost function should be consistent with both economies and diseconomies of scope. *Fourth*, as a matter of empirical practicability, the cost function should not require the estimation of the values of an excessive number of parameters. *Finally*, the functional form should impose no restrictions on the values of the first and second partial derivatives.

The function that satisfies most of Baumol et al's desiderata is, without doubt, the multi-product translog cost function (TL). Since its early introduction by Christensen, Jorgenson, and Lau, in 1973, it has been greatly used and expounded in many empirical studies.

It is claimed that the multi-product translog cost function provides a useful second-order Taylor series approximation to any twice differentiable

---

1 It has already been noted that, in the translog cost function the number of parameters to be estimated increases very quickly with the introduction of additional variables.

2 The problem of multicollinearity is much more severe with the estimation of the cost function of AGT than of Bell Canada since the number of observations for the former are only about a half of the latter. Thus, the number of degrees of freedom is more limited for AGT than for Bell Canada.

cost function. Furthermore, it is claimed to be the most suitable cost function for testing various hypotheses concerning the alternative characteristics of the production processes. This is so, since it imposes fewer restrictions on the characteristics of the production structure than any other commonly used functional specification.

These are important reasons supporting the decision to estimate a cost rather than a production function. However, some additional reasons deserve to be mentioned.

First, the present debate in the Canadian telecommunications industry concerns the control of entry (continuation of the present regulatory regime or allowing CNCP and others to compete with Bell Canada and other carriers in the long-distance market). Information on the cost structure of the industry is what policy makers need in making sensible decisions. The most direct way to obtain the needed information is to estimate the cost function and not the production function.

Second, the possibility of bias is reduced by utilizing the cost function rather than the production function, since factor prices (the arguments of the cost function) are more likely to be exogenous than factor inputs.

Third, when output disaggregation is required, a cost function specification is much easier than a production function specification.

Fourth, the degree of multicollinearity is reduced (and therefore the results are more reliable) when cost functions are used, since the degrees of freedom available from the data can be increased by applying Shephard's lemma[3]. The system of factor demand functions generated by the application of Shephard's lemma, in conjunction with the cost function, increases the number of observations without increasing the number of parameters.

These are the principal reasons that motivated us to estimate a cost rather than a production function. Moreover, two additional reasons should be noted. *First*, by estimating a cost function we are in line with the

[3] Shephard's lemma is explained below.

theoretical literature presented in Chapter Three. *Second*, by estimating a cost function we are making our approach comparable to the previous studies presented in chapter 4 (dealing with the production characteristics of the telecommunications industry).

In sum, although the production function is capable of providing us with the necessary information to make decisions on the issues of natural monopoly, the cost function, for the reasons mentioned above, is judged more appropriate for this particular purpose. Thus, the estimation of the translog cost function is placed at the centre of the estimation procedure in the present study.

The translog approximation to (5-1) is:

$$\begin{aligned}\ln C = \alpha_0 &+ \sum_{i=1}^{2}\alpha_i \ln Q_i + \sum_{j=1}^{3}\alpha_j \ln P_j + \epsilon_T \ln T \\ &+ \frac{1}{2}\sum_{i=1}^{2}\sum_{m=1}^{2}\beta_{im} \ln Q_i \ln Q_m + \frac{1}{2}\sum_{j=1}^{3}\sum_{n=1}^{3}\gamma_{jn} \ln P_j \ln P_n \\ &+ \frac{1}{2}\epsilon_{TT} (\ln T)^2 + \sum_{i=1}^{2}\sum_{j=1}^{3}\delta_{ij} \ln(Q_i) \ln(P_j) + \sum_{i=1}^{2}\rho_{iT} \ln(Q_i) \ln(T) \\ &+ \sum_{j=1}^{3}\mu_{jT} \ln(P_j) \ln(T) \qquad (5\text{-}2)\end{aligned}$$

Where $i,m = Q_1, Q_2$ and $j,n = K, L, M$; Q_i stands for output, viz. Q_1 for local and Q_2 for toll output; P_j refers to the prices of factors of production, viz. capital (K), labour (L), and materials (M). T is an index of technical change, and C is the minimized total cost. The translog cost function is assumed twice differentiable, so that its Hessian with respect to the input prices is symmetric. This implies, accepting the validity of Young's theorem, the following *symmetry* restriction,

$$\frac{\partial^2 C}{\partial P_j P_n} = \frac{\partial^2 C}{\partial P_n P_j}$$

which further implies that $\gamma_{jn} = \gamma_{nj}$ for $j \neq n$ $(j,n = K,L,M)$.

i.e. the second order derivatives of cost with respect to the prices of the factors of production are independent of the order of differentiation. In addition the following symmetry conditions must hold:

$$\beta_{im} = \beta_{mi} \qquad \text{for } i \neq m \qquad (i,m = Q_1,Q_2)$$

The cost-share functions are derived by applying *Shephard's lemma* as

$$S_j = X_j = \frac{\partial C}{\partial P_j}\,\frac{P_j}{C} = \frac{\partial \ln C}{\partial \ln P_j} = \alpha_j + \sum_{j=1}^{3}\gamma_{nj}\ \ln P_j + \sum_{i=1}^{2}\delta_{ij}\ \ln Q_i + \mu_{jt}\ \ln T$$

$$\text{where} \qquad 0 < S_j < 1 \qquad \text{and} \qquad \sum_{j}^{3} S_j = 1 \qquad (5\text{-}3)$$

It is to be noted that the same parameters are common to all three cost share equations (equations 5-3) which are a subset of the parameters appearing in the translog cost function. The equality of these parameters is the *sine qua non* condition for the system of equations to be consistent with cost-minimizing behaviour. A test can be explicitly applied for verifying whether such an equality holds in practice. If this is indeed the case the estimated parameters of the system of equations are unbiased. Bias may be present when the equality constraint is not satisfied.[4]

Any meaningful cost function should be homogeneous of degree one in input prices. This is a reasonable assumption since a simultaneous increase

---

[4] While in principle the estimated parameters of the translog cost function must be equal to the corresponding parameters of the cost share equations, in practice this condition is rarely met. For such and other inconsistencies between theory and practice surrounding the neoclassical production theory see: Elie Appelbaum "Testing Neoclassical Production Theory", Journal of Econometrics, 7, (1978), pp.87-102.

in all input prices, by say 10%, will result in an equivalent (10%) increase in total costs. In the translog cost function this requires that:

$$\sum_{j=1}^{3}\alpha_j = 1, \qquad \sum_{n=1}^{3}\gamma_{jn} = 0, \qquad \sum_{j=1}^{3}\delta_{ij} = 0, \qquad \sum_{j=1}^{3}\mu_{jt} = 0 \tag{5-4}$$

The same set of restrictions on parameters follows from the *adding-up* requirement (5-3) of the cost shares.

The translog cost function (5-2) has a general form since restrictions such as homotheticity and Hicks neutrality are not imposed *a priori*. Such restrictions as well as the cost-minimizing behaviour can be statistically tested.

Several other hypotheses concerning the structure of technology can also be tested with this general translog cost function. *Separability* of the cost function in both output and input prices is one such hypothesis. If the functional separability of the cost function cannot be rejected, it implies that an aggregate measure of output Q exists, where Q is the sum of local and toll telephone services, i.e., $Q = f(Q_1,Q_2)$. The separable cost function can thus be written as $C = F\ [f(Q_1,Q_2),\ P_j,\ T] = F\ (Q,\ P_j,\ T)$. This implies the following set of restrictions at the expansion point of the translog cost function[5] (5-2)

$$\delta_{jQ1}\ \alpha_{Q2} = \delta_{jQ2}\ \alpha_{Q1}, \qquad\qquad j = K,\ L,\ M$$

Acceptance of the above restrictions, implies that Bell Canada's or AGT's local and toll outputs can be aggregated into one output. It is then possible to estimate a single-output cost function and use the scale-elasticity estimate in order to test for the existence of natural monopoly. As will be seen later on, this cannot be done in the telecommunications industry.

---

5 See Denny, M. and C. Pinto, "An Aggregate Model with Multiproduct Technologies", in Fuss M. and D. MacFadden, Production Economics: A Dual Approach to Theory and Applications, Amsterdam, North-Holland), 1978.

Another important hypothesis that can be tested using the translog cost function is the *nonjointness* hypothesis. Nonjointness is important because of the information provided on the existence or nonexistence of economies of scope. If the marginal cost of production of output is independent of the production of output (Q_2) the production structure is characterized by nonjointness. In other words, nonjointness in production requires that the marginal cost of production of (Q_1) should be independent of the level of production of (Q_2)[6]. The absence of synergies in production guarantees such an independence in the production processes. That is, if the nonjointness hypothesis is accepted, it implies that neither economies nor diseconomies of scope exist from the joint production of the two outputs. If this is so, the costs of producing the outputs separately will equal the cost of producing them jointly, i.e.,

$$C = F\ (Q_1,\ Q_2,\ P_j,\ T) = C_{Q1}\ (Q_1,\ P_j,\ T) + C_{Q2}\ (Q_2,\ P_j,\ T)$$

The cost function is nonjoint when the following condition holds at the expansion point of the function[7]: $\beta_{12} = -\ \alpha_{Q1}\alpha_{Q2}$

Another important characteristic to be tested, is the *homotheticity* hypothesis. If the parameters relating inputs to outputs are null ($\delta_{ij} = 0$) the production process is said to be homothetic. This means that the

6 This can be expressed mathematically as

$$\frac{\partial(MC_1)}{\partial Q_2} = \frac{\partial^2 C}{\partial Q_1 \partial Q_2} = 0$$

It may be shown that when the above condition holds, we obtain the relation

$$\frac{\partial^2 \ln C}{\partial \ln Q_1 \partial \ln Q_2} = -\left(\frac{\partial \ln C}{\partial \ln Q_1}\right)\cdot\left(\frac{\partial \ln C}{\partial \ln Q_2}\right)$$

which reduces to $\beta_{Q1Q2} = -\alpha_{Q1}\alpha_{Q2}$ at the expansion point of the function.Acceptance of such a restriction implies that the cost function exhibits neither economies nor diseconomies of scope.

7 Fuss, M. and MacFadden, 1978, Ibid.

proportions of the factors of production used do not vary with the levels of output or alternatively that changes in scale of operations or in output level do not affect the cost shares. If they do, then the cause may be changes in the relative input prices or changes in technology. Homogeneous cost functions are by definition homothetic and their cost elasticity among outputs is constant[8]. If the restriction $\delta_{ij} = 0$ is accepted then the cost function is homothetic, i.e.,

$$C = F(Q, P, T) = A(Q) \cdot g(P,T)$$

Lastly, it is worth testing the effects of technology on the production structure of Bell Canada and AGT. If the primal production function is characterized by *Hicks-neutral technical change*, that is if technical change increases the efficiency of all factor inputs equally, the dual cost function can be written as

$$C\ (Q,P,T) = A(T) \cdot f(Q,P).$$

For this to be true the following set of restrictions must be satisfied for the translog cost function;

$$\rho_{it} = 0, \quad \text{and} \quad \mu_{jt} = 0.$$

If the primal production function is characterized by *nonfactor-augmenting technological change* the dual cost function can be written as

$$C\ (Q,P,T) = A(T) \cdot f[g(Q,T),P]$$

and the translog parameter restrictions must be $\mu_{jt} = 0$.

Finally if the primal production function is characterized by *nonoutput-augmenting technical change* the dual cost function can be written as

8 The elasticity of cost with respect to output is constant if $\beta_{im} = 0$.

$$C\,(Q,P,T) = A(T) \cdot f[Q,h(P,T)]$$

and the translog parameter restrictions must be $\rho_{it} = 0$.

All the above hypotheses will be tested in the present study. By far the most important ones, for our purposes, are the separability and the nonjointness hypotheses.

However, information on overall economies of scale and on the elasticities of cost with respect to each output is also essential. The formulae that will be used to calculate these elasticities are given below[9].

The derivative of the logarithm of cost with respect to the ith service (output) represents ith *output elasticity of cost* (cost elasticity with respect to output i) and it is given by

$$\epsilon_{CQi} = \frac{\partial C}{\partial Q_i}\frac{Q_i}{C} = C_{Qi}(Q_i/C) = \frac{\partial \ln C}{\partial \ln Q_i} = \alpha_i + \sum_m \beta_{im}\ln Q_m + \sum_j \delta_{ij}\ln P_j + \rho_{iT}\ln T \quad (5\text{-}5)$$

These output elasticities of cost are useful in measuring the *partial and overall scale economies*. These scale economies measure the relative changes in outputs when the firm's expenditures change while input prices remain constant. These are reciprocals of the output elasticities of cost. The partial scale economy of one output when other outputs and prices of the inputs remain constant may be measured as

---

9 We simply reproduce them here since these formulae are well established in the literature and they can be easily found in many empirical works. See for example, Fuss and Waverman (1981), Kiss et al. (1983), Kiss and Lefebvre (1987) and references therein.

$$\epsilon_{Q1} = (\frac{C}{Q_1})/(\frac{\partial C}{\partial Q_1}) = 1/(\frac{\partial \ln C}{\partial \ln Q_1}) = 1/\epsilon_{CQ1} = (\epsilon_{CQ1})^{-1}$$

Consequently, the *overall scale economies* are obtained as

$$\epsilon = \Sigma_i(\epsilon_{CQi})^{-1} \qquad (5\text{-}6)$$

When for any given proportionate increase in each output simultaneously, the total costs increase by a lower proportion than the outputs the computed value of the scale elasticity ϵ is greater than one and increasing returns to scale are said to exist in the multiproduct situation.

The translog cost function allows for technical change effects. The rate of technical change may be represented as a time related shift in the cost function so that

$$\epsilon_{CT} = \epsilon_T + \epsilon_{TT} + \sum_{i=1}^{2}\rho_{iT} \ln(Q_i) + \sum_{j=1}^{3}\mu_{jT} \ln(P_j) \qquad (5\text{-}7)$$

If the *technology elasticity of cost* (ϵ_{CT}) or the cost elasticity with respect to technical change (equation 5-7) is negative, it implies that technological changes are cost saving.

It is customary to investigate the empirical nature of derived demands for factors of production by employing various techniques for estimating the Allen-Uzawa (1962) *partial elasticities of factor substitution* (AES). Binswanger (1974) has derived both the AES (σ_{jj}, σ_{jn}) and the (own- ϵ_{jj} and cross- ϵ_{jn}) price elasticities of demand for factor inputs in the translog cost function framework as

$$\sigma_{jj} = \frac{\gamma_{jj} + S_j^2 - S_j}{S_j^2} \tag{5-8}$$

$$\sigma_{jn} = \frac{\gamma_{jn} + S_n S_j}{S_j S_n} \tag{5-9}$$

$$\epsilon_{jn} = \frac{\partial \ln X_j}{\partial \ln P_n} = \frac{\gamma_{jn} + S_j S_n}{S_j} = S_n \sigma_{jn} \tag{5-10}$$

$$\epsilon_{jj} = \frac{\partial \ln X_j}{\partial \ln P_j} = \frac{\gamma_{jj} + S_j^2 - S_j}{S_j} = S_j \sigma_{jj} \tag{5-11}$$

where S_j's are the cost shares. A change in the value of the cost shares may vary the AES and hence the price elasticites. Therefore these elasticites are not constrained to be constant.

The own-price elasticities (ϵ_{jj}) tell us whether the demand for factors of production is elastic or inelastic. The cross-price elasticities (ϵ_{jn}), on the other hand, indicate the substitutability that may exist among factors of production. If ϵ_{jn} is negative, complementarity exists between the factors of production. If ϵ_{jn} is positive, the factors of production are substitutes, while if ϵ_{jn} is zero, the factor inputs are neutral. The same conclusions can be drawn using instead the Allen-Uzawa elasticities of substitution (AES). It is to be noted however, that although $\sigma_{nj} = \sigma_{jn}$, the cross-price elasticities ϵ_{jn} are not necessarily symmetric[10]. Both the own-price elasticities as well as the AES will be used to carry out our calculations. Before a description is given of the data and variables used to carry out this study, we will present the major structural characteristics of Bell Canada and AGT.

[10] See Fuss and Waverman (1981), Kiss et al. (1983), Kiss and Lefebvre (1987).

BASIC CHARACTERISTICS OF BELL CANADA AND AGT

It was mentioned in chapter 2 that Bell Canada is, by far, the largest telecommunications company in Canada. It is privately-owned with more shareholders than any firm in Canada. It serves the most populated markets in Canada, i.e., the provinces of Ontario and Quebec, as well as the Northwest Territories. It is federally regulated by the CRTC.

AGT is the third largest telecommunications firm in Canada. It is mainly concentrated in the province of Alberta except Edmonton which is served by "Edmonton Telephones". It is a crown corporation, regulated by the Alberta Public Utilities Board. Its size is 1/5 of Bell Canada's.

Both firms offer a wide range of services, such as local and long-distance calls, private line services, mobile communications, data transmission etc. It is the provision of local and long-distance services that is done on a monopoly basis. Some degree of competition is present in the provision of all other services.

Although both companies offer a similar gamut of services, important differences exist in the structure of their services (see table 5-1). For example, the share of local services to total revenue was 33% in AGT and 57% in Bell Canada in 1968, and 30% and 48%, respectively, in 1981. Furthermore, although this share seems to have been maintained at about the same level for AGT (30.3% in 1987), for Bell Canada it has been declining. As far as the share of long-distance revenue in total revenue is concerned, it increased from 62% in 1968 to 66% in 1981 for AGT and has maintained that level since then (in 1987, it was 65.4%). The corresponding figure for Bell Canada was 37% in 1968 and 48% in 1981. Thus, AGT has a larger proportion of long-distance services than Bell Canada.

As is reported by Kiss and Lefebvre (1984), AGT's revenues and outputs have grown faster than those of Bell Canada. The growth rate of total revenue for AGT was 16.7% between 1968 and 1981, while the corresponding growth rate for Bell Canada was 12.38%. The difference in the output growth rate was even more pronounced. The output growth rate for AGT was 14.9% while for Bell Canada it was 8.2%, for the same period (see table 5-2). It is interesting to note that for the same time period the production of local service accelerated

Table 5-1: Selected Statistics

ITEM	1968			1981			1981/1968	
	AGT	BELL	B/A	AGT	BELL	B/A	AGT	BELL
Total revenue ($000) (1)	87,278	746,087	8.5	743,030	3,732,571	5.0	8.5	5.0
Capital expenditures ($000) (2)	58,000	338,629	5.8	480,014	1,401,500	2.9	8.3	4.1
Net capital ($000) (1)	912,621	6,116,405	6.7	2,168,144	11,244,448	5.2	2.4	1.8
Telephones (000) (2) (3)	650 (4)	5,451	8.4	1,832 (4)	9,609	5.2	2.8	1.7
Long distance calls (000) (2)	35,106	243,080	6.9	198,930	747,900	3.8	5.7	3.1
Employees (2) (3)	6,090	37,489	6.2	13,429	57,868	4.3	2.2	1.5
Expensed hours worked (000) (1)	7,915	54,561	6.9	17,461	81,074	4.6	2.2	1.5

Source: Kiss, F. and B. Lefebvre, "Comparative Analysis and Econometric Forecasting of Factor Inputs and Productivity: Some Empirical Results in Canadian Telecommunications", Paper Presented at the Fourth International Symposium on Forecasting, July 8-11, 1984.

Table 5-2: Annual Growth Rates in Output (percent)

YEAR	LOCAL			LONG DISTANCE			OTHER			TOTAL OUTPUT		
	AGT	BELL	A-B	AGT	BELL	A-B	AGT	BELL	A-B	AGT	BELL	A-B
1969	10.80	7.45	3.35	15.19	13.88	1.31	-3.19	7.73	-10.92	12.90	9.92	2.98
1970	9.19	6.74	2.45	12.72	8.53	4.19	14.58	8.24	6.34	11.67	7.53	4.14
1971	9.29	6.43	2.86	10.77	4.43	6.34	7.14	7.03	.11	10.14	5.66	4.48
1972	11.18	7.46	3.72	16.52	12.08	4.44	3.61	9.80	-6.19	14.30	9.52	4.78
1973	9.03	7.58	1.45	15.47	15.01	.46	9.32	-18.37	27.69	13.29	10.02	3.27
1974	14.30	8.26	6.04	20.99	12.79	8.20	11.85	12.47	-.62	18.71	10.33	8.38
1975	15.20	7.78	7.42	18.99	12.97	6.02	-.85	18.86	-19.71	17.17	10.37	6.80
1976	13.92	6.00	7.92	7.90	8.50	-.60	8.45	18.59	-10.14	9.60	7.47	2.13
1977	11.28	5.09	6.19	11.60	8.25	3.35	10.28	12.53	-2.25	11.45	6.74	4.71
1978	12.65	4.21	8.44	17.35	11.25	6.10	14.72	29.22	-14.50	15.81	8.26	7.55
1979	15.11	3.21	11.90	18.59	8.27	10.32	10.04	10.48	-.44	17.21	5.84	11.37
1980	17.20	4.93	12.27	19.04	10.37	8.67	19.15	13.63	5.52	18.50	7.85	10.65
1981	16.09	3.42	12.67	12.46	10.66	1.80	18.13	11.37	6.76	13.77	7.21	6.56
69-81:	12.71	6.04	6.67	15.20	10.54	4.66	9.48	10.89	-1.41	14.19	8.20	5.99

Source: Kiss, F. and B. Lefebvre, "Comparative Analysis and Econometric Forecasting of Factor Inputs and Productivity: Some Empirical Results in Canadian Telecommunications", Paper Presented at the Fourth International Symposium on Forecasting, July 8-11, 1984.

for AGT while it decelerated for Bell Canada. Long-distance output showed no discernible trend.

The information provided above concerning the output growth rates of both companies is useful when combined with the empirical findings of economies of scale and scope reported in the next chapter.

Another important aspect of interest for our purposes[11] is the rate of introduction of new technologies. Although this variable seems to be the most interesting one for our model, unfortunately no public information exists on this variable. Kiss and Lefebvre (1984) provide limited information with respect to switching technology. They report indices of the number of telephones connected to various types of central office. These include crossbar, analogue and digital electronic equipped central offices. They conclude that AGT introduced new technologies at a faster rate than Bell Canada. Furthermore, AGT introduced the new technologies much earlier than Bell Canada (see table 5-3). However, there exists a cyclical movement in the pace of introduction of new technologies for both companies. Apparently, as output grows, new technologies are introduced, but with a lag.

It is important to note as well that a major organizational change took place in 1982 at Bell Canada. In June 1982, Bell Canada announced its intention to restructure the Bell group companies. After public hearings the CRTC allowed Bell Canada to proceed with the reorganization of its corporate structure. The reorganization became effective at the end of April, 1983.

As can be seen from Chart 1, before the restucturing Bell Canada was both an operating and a holding company with interests in many other affiliates. After the reorganization, Bell Canada became a wholly owned subsidiary of the newly created unregulated holding company, Bell Canada Enterprises Inc. (BCE). With the restructuring, Bell Canada functions mainly as an operating telecommunications company. This reorganization of Bell Canada coincides with the liberalization of the customer premises equipment (CPE) market. It will be argued below that the reorganization of Bell Canada

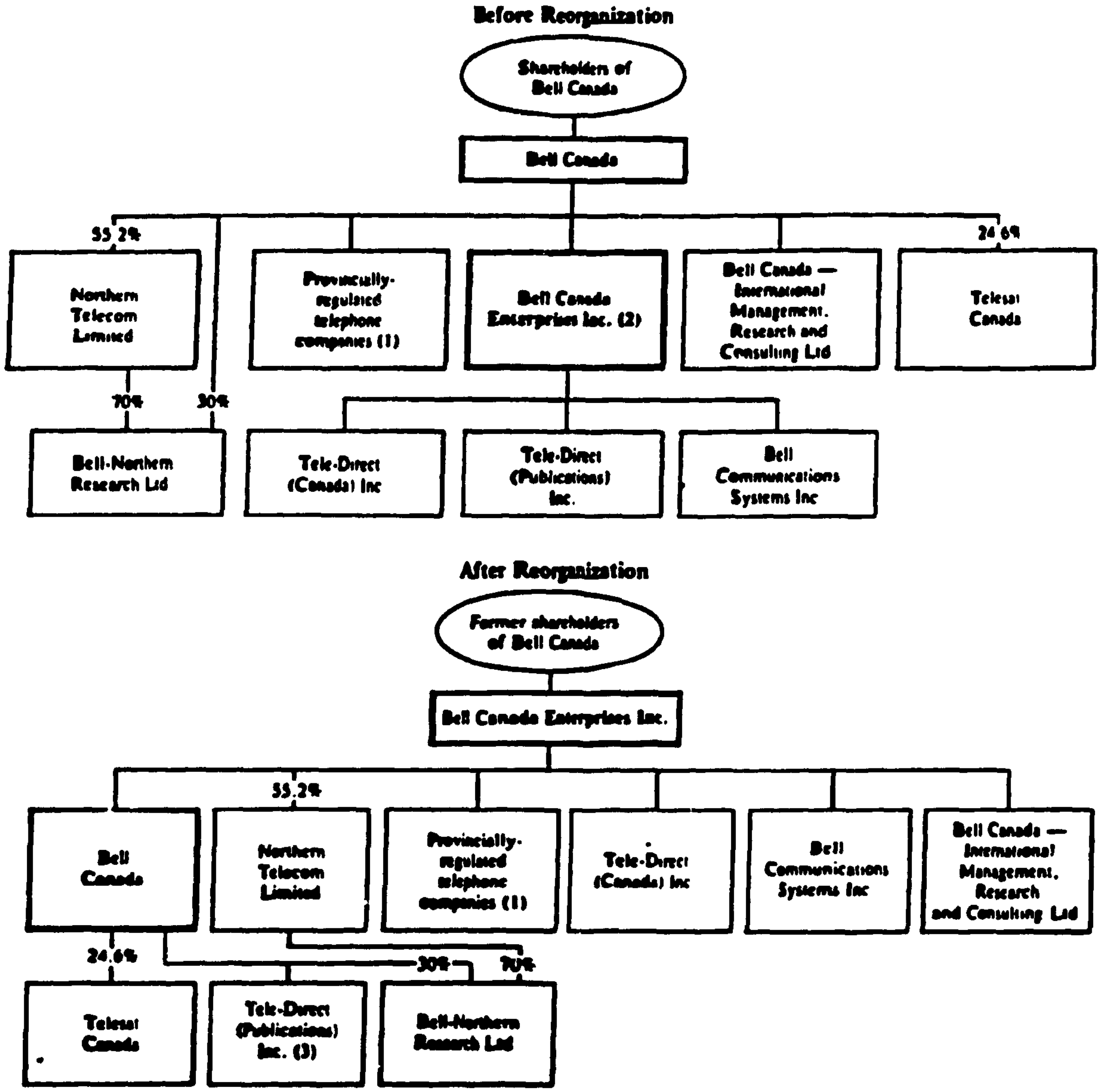
[11] It may explain the turn-about that we observe in the cost structure of Bell Canada since 1982. See next chapter for details

Table 5-3: Percentage of Telephones by Central Office

YEAR	CROSSBAR		ANALOG ELECTRONIC		DIGITAL ELECTRONIC	
	AGT	BELL	AGT	BELL	AGT	BELL
1968	18.0	28.1	-	0.0	-	-
1969	18.9	30.2	-	0.4	-	-
1970	22.9	32.6	-	1.0	-	-
1971	23.5	34.3	-	1.4	-	-
1972	24.8	36.2	5.1	2.4	-	-
1973	25.1	38.0	7.8	3.6	-	-
1974	26.4	39.5	9.0	6.2	-	-
1975	25.1	40.2	15.3	8.5	-	-
1976	24.7	40.8	21.4	11.4	-	-
1977	23.4	41.0	33.6	13.9	-	-
1978	22.3	41.2	41.3	15.9	-	0.0
1979	22.5	41.6	46.7	18.1	1.3	0.1
1980	23.9	41.5	47.3	18.8	2.5	0.3
1981	21.5	41.2	48.3	19.1	12.0	3.1

Source: Kiss, F. and B. Lefebvre, "Comparative Analysis and Econometric Forecasting of Factor Inputs and Productivity: Some Empirical Results in Canadian Telecommunications", Paper Presented at the Fourth International Symposium on Forecasting, July 8-11, 1984.

**CHART 1.: BELL CANADA GROUP CORPORATE STRUCTURE
BEFORE AND AFTER REORGANIZATION**



(1) Newfoundland Telephone Company Limited, 63.5% owned. Northern Telephone Limited, 99.1% owned. The Capital Telephone Company Limited, 100% owned. Télébec Ltée, 100% owned. Maritime Telegraph and Telephone Company, Limited, 35.4% owned. The New Brunswick Telephone Company, Limited, 35.8% owned.

(2) Formerly named Tele-Direct Ltd. Tele-Direct Ltd., formerly a wholly-owned subsidiary of The Capital Telephone Company Limited, became a direct, wholly-owned subsidiary of Bell Canada on June 11, 1982. Tele-Direct Ltd. was renamed Bell Canada Enterprises Inc. on June 22, 1982 and a new company was created named Tele-Direct (Canada) Inc. to carry on printing, publishing and related businesses.

(3) It is intended that as soon as practicable after the Reorganization this corporation will be transferred by BCE to Bell Canada. The description reflects this eventual transfer.

Source: Canadian Telecommunications: An Overview of the Canadian Telecommunications Carriage industry, Doc, 1983.

may be one of the factors explaining the turn-about that we have observed in its cost structure since 1983.

THE DATA AND VARIABLES

In order to estimate the model, we require data on total costs, the quantity of outputs (local and toll), and the prices and cost shares of the three factors of production: capital, labour and other inputs. The major source of data for Bell Canada is Bell Canada's Input and Output Volume and Price Indices Tables that were kindly made available to us by Bell Canada for the years 1952 to 1986. This is the first study for which these data have been made available. (Previous studies used data for the period 1952 to 1978). The data also differ from the ones used in previous studies in that the method of computing them is slightly different due to change in accounting methods used by Bell Canada in measuring its inputs and outputs.

The output measures used in this econometric estimation are constant dollar measures of: 1) local and 2) toll outputs. These volume indexes are calculated using the Tornqvist aggregation formula and they are direct volume indexes. Due to changes in accounting procedures that were implemented by Bell Canada in 1980, a reclassification of output categories has resulted as compared to those identified by Kiss (1983). These new volume indexes also reflect the changes brought about by the creation of Tele-Direct Publications in July 1971 on the one hand, and periodic revisions and updates on the other hand.

The input measures are divided by Bell Canada into three categories: capital, labour and other inputs (previously called material input). Using Tornqvist price indexes, the input price indexes are implicitly (indirectly) calculated by dividing cost by its respective volume index.

Data for AGT are obtained from the evidence of Olley's, "Study of AGT Total Factor Productivity", Volume VII, January 19, 1987 which were kindly made available to us initially by B. Lefebvre of Bell Canada and subsequently by R. Kalvaitis of AGT. Disregarding some of the differences especially with the measurement of capital, the AGT data are quite comparable to those of Bell

Canada. Using Tornqvist's index number formula, Olley[12] aggregates a great number of outputs into three distinct categories: local, toll and miscellaneous as well as into a single index of total output.

The inputs are classified into three distinct categories as well: capital, labour and materials. AGT, being a public enterprise, is somewhat insulated from capital market forces. For this reason its total annual cost of capital is represented by the residual return to capital. (The residual return on capital is the total operating revenue after subtracting costs of labour and material inputs). By contrast, Bell Canada uses the user or rental cost of capital approach. The volume of physical capital is represented by the constant dollar value of net telecommunications plant in service, while the aggregate price index of total capital is derived implicitly as the ratio of the index of total capital cost to the Tornqvist volume index of total capital. The method used for constructing the other input indices is similarly comparable to the one used by Bell Canada.

TESTS FOR NATURAL MONOPOLY

The purpose of this study is to test for the existence of natural monopoly in the technology of two Canadian telecommunication firms, i.e,. Bell Canada and AGT.

As was mentioned in Chapter 3, global information concerning the cost function is required in order to test for the existence of a natural monopoly. Unfortunately, such global information about cost of production and market demand is rarely, if ever, available. Baumol, Panzar and Willig (1982) have derived the necessary and sufficient conditions for the existence of a local natural monopoly that require somewhat less information. They suggest the performance of a two-tier test (Baumol et al, p. 172). The first-tier consists of testing for the necessary condition i.e., for the existence of economies of scope. The existence of economies of scope is the necessary condition for cost subadditivity (ibid, p. 174); if economies of scope do not

---

[12] As a matter of fact, AGT's data for the period 1968 to 1981 were measured by Olley and Le (<u>Total Factor Productivity of Canadian Telecommunication Carriers, 1984</u>), while Olley extended them up to 1986 (Study of Alberta Government Telephones Total Factor Productivity, 1987).

exist, separate production is more expensive than a joint production. The second-tier test consists of testing for the sufficient conditions for cost subadditivity. The simultaneous satisfaction of both product-specific economies of scale and economies of scope suffices for proving that the cost function is subadditive and therefore that the monopoly is natural. This is so because a separate production of outputs will result in a sacrifice of both economies of scale resulting from volume production and economies of scope resulting from synergies of joint production.

Testing for the sufficient condition of natural monopoly we require information about the cost of separate production of each output. Unfortunately, reliable data for separate production are seldom available. Consequently, Baumol, Panzar and Willig's test is seldom applicable in practice. This is one of the major drawbacks of their test.

In the case of data availability, Baumol, Panzar and Willig suggest the following test for natural monopoly. Test first for the necessary conditions for natural monopoly. If the test fails, the subadditivity of the cost structure is decisively rejected. Then test for the sufficient conditions. If the sufficient conditions are satisfied, the subadditivity of the cost structure is decisively accepted. On the other hand, if the sufficient conditions are rejected while the necessary condition is accepted the test is inconclusive. This (the inconclusiveness of the test) is another drawback to the solution to the problem of natural monopoly, as advanced by Baumol, Panzar and Willig.

Faced with the above-mentioned problems in testing for the existence of subadditive cost structures, Evans and Heckman (1983) decided to construct a subadditivity test that is less stringent, as far as data information requirements are concerned. Their test, which is based on the definition of of the subadditive cost function, relies on the idea of dividing the observed yearly volume outputs of the incumbent monopoly (AT&T) into a number of assumed competitors, each of which produces various combinations of outputs but none of which is permitted to produce less than the minimum of the sample's output. The condition that each assumed competitor produces at least the minimum of the sample's output, guarantees that the test is performed *within the confines of the data sample*. An important condition for performing this test is to assume that both incumbent monopoly and the assumed competitors utilize the *same technology*[13]. The results would, obviously, change if we assume that different technologies are indeed used by incumbents and competitors alike. Nevertheless, for making our results comparable to other studies and for facilitating the calculations, the Evans-Heckman hypothesis of common technology utilization by all firms is maintained here.

Their subadditivity test for a two-firm, two-output case is constructed in the following way[14].

Let $Q_t^* = (Q_{1t}^*, Q_{2t}^*)$ be the output vector realized in a given year t for each of the two products Q_1 and Q_2. Let the smallest output vector observed in the sample be $Q_m = (Q_{1m}, Q_{2m}) = (\min Q_{1t}^*, \min Q_{2t}^*)$

Firm A's production is equal to $Q_{At} = (\phi Q_{1t} + Q_{1m},\ \omega Q_{2t} + Q_{2m})$

Firm B's production is equal to $Q_{Bt} = [(1-\phi)Q_{1t} + Q_{1m},\ (1-\omega)Q_{2t} + Q_{2m}]$

The parameters (ϕ,ω) satisfy the following conditions: $0 \le \phi \le 1$ and $0 \le \omega \le 1$. An extrapolation of the cost function to unobservable output configurations is avoided by restricting the ranges of ϕ and ω to actually observed values of both Q_1 and Q_2 by means of the following expressions:

---

13 This asumption (the symmetry asumption) together with the constraints (5-12, 5-13) imposed by Evans and Heckman (in order to make their test operational), have been severely criticised by Sueyoshi and Anselmo (AER, 1986). They argue that the symmetry condition as well as the constraints (5-12, 5-13) limit dramatically the "admissible region" in which subadditivity is supposed to be measured to a more "restricted region" so that the observed output configurations lie outside the real admissible region. Sueyoshi and Anselmo argue that the conclusions drawn from the application of the subadditivity test must be questioned since the number of accepted entries in the restricted region is quite limited. However, in spite the criticism, it seems that the test proposed by Evans and Heckman is an improvement compared to what Baumol et al had offered as an alternative.

14 For their original contribution see Evans and Heckman 1983, p.267 and American Economic Review, 1984.

$$R_L \leq \frac{\phi Q_{1t} + Q_{1m}}{\omega Q_{2t} + Q_{2m}} \leq R_U \tag{5-12}$$

$$R_L \leq \frac{(1-\phi)Q_{1t} + Q_{1m}}{(1-\omega)Q_{2t} + Q_{2m}} \leq R_U \tag{5-13}$$

where $R_L = \min(Q_{1t}/Q_{2t})$ and $R_U = \max(Q_{1t}/Q_{2t})$ where the min and max are taken over all years t (1952-1986 for Bell Canada and 1968-1985 for AGT).

The global production of both firms A and B may be indicated by

$$Q_{1t} + 2Q_{1m} = Q^*_{1t}$$

$$Q_{2t} + 2Q_{2m} = Q^*_{2t}$$

so that

$$Q_{1t} = Q^*_{1t} - 2Q_{1m}$$

$$Q_{2t} = Q^*_{2t} - 2Q_{2m}$$

It is clear from the above conditions that this allocation is feasible only in the region $Q^*_{1t} > 2Q_{1m}$. Only output levels satisfying this constraint are included in the test. The degree of subadditivity can thus be easily measured by using the following formula:

$$\text{Sub}_t(\phi,\omega) = \frac{C(Q^*_t) - C_{At}(\phi,\omega) - C_{Bt}(\phi,\omega)}{C(Q^*_t)} \tag{5-14}$$

where $C(Q^*_t) = C(Q^*_{1t}, Q^*_{2t})$ is year t's observed total cost of one of the firms which produces two outputs, Q^*_{1t} and Q^*_{2t}, in that same year t. Each firm's cost in producing outputs in the proportions indicated by ϕ and ω are indicated by the following cost functions:

$$C_{At}(\phi,\omega) = C_{At}(\phi Q_{1t} + Q_{1m}, \omega Q_{2t} + Q_{2m}) \tag{5-15}$$

$$C_{Bt}(\phi,\omega) = C_{Bt}[(1-\phi)Q_{1t} + Q_{1m}, (1-\omega)Q_{2t} + Q_{2m}] \tag{5-16}$$

Subadditivity and therefore the most efficient industry configuration is determined by the sign of the $Sub_t(\phi,\omega)$ term. If $Sub_t(\phi,\omega) < 0$ over all of the possible region, at least local subadditivity of the industry is confirmed. The monopoly configuration is thus more efficient than the industry configuration given by (ϕ,ω) region. This is of course a local, not global test of subadditivity. However, if local subadditivity fails to be found, it is implied that global subadditivity fails to be achieved as well. If on the other hand the $Sub_t(\phi,\omega) > 0$, local superadditivity of the cost function is confirmed. Multi-firm production is the most efficient industry configuration. Lastly, when $Sub_t(\phi,\omega) = 0$, the cost function is simply locally additive. Breaking up the incumbent monopoly may not confer benefits to society.

IMPLEMENTATION OF THE EMPIRICAL ANALYSIS

The availability of data on annual input and output prices and volumes of production for both Bell Canada and AGT were important considerations in the decision to analyse the economic properties of the production characteristics of these two firms.

At first a translog cost model for each firm is developed (separately) and the economic properties of each firm's production process are studied and compared to each other. Efficiency in the estimated parameters may be further increased by constructing a two-firm model capable of providing with information on the cost characteristics of the two firms.

The estimation of each single-firm translog cost function needs the following specification. The translog cost function (5-2) together with the cost share equations (5-3) are simultaneously estimated as a multivariate regression system. The inclusion of cost share equations in the estimation procedure increases the degrees of freedom without adding any unrestricted regression coefficients, resulting thereby in more efficient parameter estimates[15]. The efficiency of estimation can be further increased by imposing known restrictions (the ones mentioned in equation 5-4, for example) on the coefficients in the equations.

The estimation method employed for the above system of equations is that proposed by Zellner (1962). The following specification concerning the disturbance terms is required for applying Zellner's technique. Additive disturbances are specified for each of the cost share equations and the original translog cost function. Such additive disturbance terms may reflect random errors in optimization. The disturbance term of the original translog cost function is not present in the cost share equations since the latter are obtained by differentiation of the translog cost function. These additive errors are assumed to have zero expected values and finite variances for each of the four equations of the model given in equations (5-2) and (5-3). Since the sum of the cost share equations is unity the corresponding disturbances sum to zero. The variance-covariance matrix required to implement Zellner's method is thus singular, and thereby renders unoperational Zellner's procedure. Operationality (non-singularity) is restored by deleting one of the cost share equations from the system.

Following the majority of empirical studies the material cost share equation is deleted here. However, without applying some specialized statistical technique, the estimates obtained will depend on which equation is deleted. Invariability of the estimates to which equation is dropped, is preserved under maximum likelihood estimation (Barten 1969). Using the iterative seemingly unrelated regression estimation method (ITSUR) until convergence is achieved, results in maximum likelihood estimates (Dhrymes (1970) and Kmenta and Gilbert (1968)). Thus if one uses Zellner's iterative seemingly unrelated regression method (ITSUR), any cost share equation can be deleted.

The Zellner technique for estimating a system of seemingly unrelated equations consists, briefly, of the following steps: 1) a consistent estimate

---

[15] See Christensen and Greene "Economies of Scale in U.S. Electric Power Generation" Journal of Political Economy, 1976, p.662

S_1 of the cross-equation covariance matrix Σ is first formed, then 2) the joint-generalized-least-squares estimate of the vector of parameters β is calculated by using S_1 instead of Σ. The iterative method (ITSUR) is a bit more complicated. From the residuals of the second step above, a new estimate S_2 of Σ is formed. Now using S_2 instead of S_1 a new estimate of the parameter vector β is formed. This procedure continues until estimates of β and Σ converge. Both techniques can be used for linear or nonlinear estimation of the parameters of the system of equations[16]. The non-linear ITSUR method is used here in order to estimate the parameters of the translog cost function of Bell Canada and AGT.

Since the iterative Zellner procedure permits us to obtain maximum likelihood estimates, testing hypotheses can be carried out by employing the likelihood ratio test. Denoting by $|\hat{\Omega}_R|$ the determinant of the restricted estimates of the disturbance covariance matrix and by $|\hat{\Omega}_U|$ the unrestricted one, the likelihood ratio can be written as:

$$\lambda = [\frac{|\hat{\Omega}_R|}{|\hat{\Omega}_U|}]^{-T/2}$$

where T refers to the number of observations. The hypotheses are tested using the fact that $-2\ln\lambda$ has a chi-squared distribution with degrees of freedom equal to the number of independent restrictions being imposed (Goldfeld and Quandt (1972), pp.72-74)).

In estimating our model, we first used the linear ITSUR method and then the non-linear one with the normalization as described below. We normalized both cost and input prices by the price of materials (or other inputs in the case of Bell Canada). This gave us the following set of equations for each firm:

---

[16] See for example, Amemiya, T. Advanced Econometrics, Harvard University Press, Boston, 1985.

$$\ln C/P_o = \alpha_0 + \sum_{i=1}^{2}\alpha_i \ln Q_i + \sum_{j=i}^{3}\alpha_j \ln P_j/P_o + \epsilon_T \ln T$$

$$+ \frac{1}{2}\sum_{i=1}^{2}\sum_{m=1}^{2}\beta_{im} \ln Q_i \ln Q_m + \frac{1}{2}\sum_{j=1}^{3}\sum_{n=1}^{3}\gamma_{jn} \ln P_j/P_o \ln P_n/P_o$$

$$+ \frac{1}{2}\epsilon_{TT} (\ln T)^2 + \sum_{i=1}^{2}\sum_{j=1}^{3}\delta_{ij} \ln(Q_i) \ln(P_j/P_o) + \sum_{i=1}^{2}\rho_{iT} \ln(Q_i) \ln(T)$$

$$+ \sum_{j=1}^{3}\mu_{jT} \ln(P_j/P_o) \ln(T) \tag{5-17}$$

where $i,m = Q_1, Q_2$ and $j,n = K, L, M$

$$S_j = X_j = \frac{\partial C}{\partial P_j}\frac{P_j}{C} = \frac{\partial \ln C}{\partial \ln P_j} = \alpha_j + \sum_{j=1}^{3}\gamma_{nj} \ln P_j + \sum_{i=1}^{2}\delta_{ij} \ln Q_i + \mu_{jt} \ln T \tag{5-18}$$

Our attempts were not successful with either method. Changing normalization (dividing by the sample mean of the material variable or by the 1980 value of the same variable) proved to be fruitless. If no normalization is performed, the results obtained are statistically and economically rea onable. We decided then to estimate the above system of equations using the non-linear ITSUR method and without normalization.

Our model differs from other models in the following points. *First*, the behavioural assumptions are different. It assumes that both Bell Canada and AGT face exogenously determined prices for their factors of production and for their output levels[17]. In most other Canadian studies, it is assumed that the

[17] The exogeneity hypothesis of both input and output prices may be explained as follows. The prices for local and toll services of both Bell Canada and AGT are regulated by their respective regulatory commissions. The regulated companies are thus obliged to meet the entire demand at the regulated prices. These prices are determined therefore exogenously. The assumption that Bell Canada and AGT face exogenously determined input prices is harder to justify *a priori*. Both companies face powerful trade unions and the wage

level of one of the outputs (the competitive one) offered by Bell Canada is endogenously determined ((Smith and Corbo (1978), Fuss and Waverman (1981)). Due to the endogeneity assumption these researchers were able to use a revenue share equation, in addition to the translog (5-17) and cost share equations (5-18) above. They estimated, therefore, a four-equation system. By contrast, following Evans and Heckman, we estimate a three-equation system.

Second, the index of technology used here is completely different from the one used in the other studies. Previous studies have used such diverse technology indices as the percentage of telephones connected to direct distance dialing facilities or the percentage of telephones connected to modern switching facilities, etc. Unfortunately, we do not possess such a measure of technological change. Therefore, we used a time trend as technological index. This is the index that imposes the least demand on the data, as far as degrees of freedom are concerned. However, using a time trend as an index of technological change makes our results less comparable with previous studies. Our attempts to incorporate previous indices of technological change into our model, as well as the utilization of a dummy variable as a proxy of technical changes, proved unsuccessful.

Third, our study covers a longer time period than any previous study. Our sample for Bell Canada covers the period from 1952 to 1986 and for AGT the period runs from 1968 to 1985. Previous studies of Bell Canada used a sample of 27 observations only. No study, of this type, has been done for AGT[18]. By increasing the number of observations, the number of degrees of freedom is increased as well and therefore the inference ability of our model. More reliable results can then be established. Policy recommendations may then have more validity.

Fourth, our model is not normalized. This in fact makes our results less comparable to previous ones.

---

rates are determined by negotiations. Moreover, the other inputs, capital and materials are purchased from their affiliates (at least for Bell Canada) over which some control may be exercised on the part of the parent companies. However, our tests reject the hypothesis that output and input prices are endogenously determined.

18 Kiss and Lefebvre (1984) have carried out a study for AGT but their objective was to measure and compare productivity performance.

On the basis of information obtained from the estimation of a single-firm model, we attempted to estimate a two-firm model. A dummy variable has been introduced in order to account for the production differences that may exist between Bell Canada and AGT. We specified the following model.

$$\ln (C/P_o) = (\alpha_0 + \alpha_0 D) + \sum_{i=1}^{2} (\alpha_i + \alpha_i D) \ln Q_i + \sum_{j=1}^{3} (\alpha_j + \alpha_j D) \ln (P_j/P_o)$$

$$+ \epsilon_T \ln T + \frac{1}{2} \epsilon_{TT} (\ln T)^2 + \frac{1}{2} \sum_{i=1}^{2} \sum_{m=1}^{2} (\beta_{im} + \beta_{im} D) \ln Q_i \ln Q_m$$

$$+ \frac{1}{2} \sum_{j=1}^{3} \sum_{n=1}^{3} (\gamma_{jn} + \gamma_{jn} D) \ln (P_j/P_o) \ln (P_n/P_o)$$

$$+ \sum_{i=1}^{2} \sum_{j=1}^{3} (\delta_{ij} + \delta_{ij} D) \ln(Q_i) \ln(P_j/P_o) + \sum_{i=1}^{2} (\rho_{iT} + \rho_{iT} D) \ln(Q_i) \ln(T)$$

$$+ \sum_{j=1}^{3} (\mu_{jT} + \mu_{jT} D) \ln(P_j/P_o) \ln(T) \qquad (5\text{-}19)$$

where $i,m = Q_1, Q_2$ and $j,n = K, L, M$ and the dummy variable $D = \begin{cases} 1 & \text{for AGT} \\ 0 & \text{for Bell Canada} \end{cases}$

The cost share equations are:

$$S_j = X_j = \frac{\partial C}{\partial P_j} \frac{P_j}{C} = \frac{\partial \ln C}{\partial \ln P_j} =$$

$$= (\alpha_j + \alpha_j D_n) \ln(P_j/P_o) + \sum_{j=1}^{3} (\gamma_{nj} + \gamma_{jnn} D_n) \ln(P_j/P_o) +$$

$$+ \sum_{i=1}^{2} (\delta_{ij} + \delta_{ijn} D_n) \ln Q_i + (\mu_{jt} + \mu_{jTn} D_n) \ln(T) \qquad (5\text{-}20)$$

This model differs from the one used by Kiss and Lefebvre in the following ways. *First*, we use a longer data sample for both companies. *Second*, we use two outputs instead of one (inclunding AGT). *Third*, we use a different index of technology. They used confidential technology indices, while we use a time trend as an index of technology. *Fourth*, the number of parameters estimated here is greater than the one estimated by Kiss and Lefebvre. We can therefore have more complete and more accurate information on the production characteristics of AGT.

In sum, this model is the first to make comparisons of the production characteristics of two Canadian telecommunication firms. It applies for the first time the Evans and Heckman subadditivity test in order to examine the characteristics of the production processes used by Bell Canada and AGT. However, the estimation of the above-specified one-firm and two-firm models, using linear and non-linear ITSUR techniques, produced many problems. If not normalized the models performed much better. We opted therefore for non-normalization. Having specified the empirical models, we can now proceed to their estimation and testing of hypotheses. The main results are presented in the next chapter.

CHAPTER 6

ESTIMATING ECONOMETRIC MODELS FOR BELL CANADA AND AGT

INTRODUCTION

The conceptual framework of the previous chapter is used here in order to study the production characteristics of Bell Canada and AGT. We proceed by estimating the single-firm model for Bell Canada first and then for AGT. The single-firm model of Bell Canada is a two-output (local and toll), three-input production model, while that of AGT is a single-output, three-input model. However, we do estimate a two-output, three-input model for AGT as well.

Important conclusions can be drawn from these estimations. Our calculations indicate the existence of economies of scale and scope in the production processes of these two companies. The hypothesis of cost subadditivity cannot be rejected for either firm.

On the basis of the hypothesis that technological similarities exist in the production processes of Bell Canada and AGT we proceed to the estimation of a two-firm model[1]. This model is a two-output three-input model. On the basis of the results obtained we reject the hypothesis that the two firms employ similar technologies. Thus, the results of the single-firm model should be used for public policy purposes. Both the results and policy conclusions are presented below.

SINGLE-FIRM MODEL: ESTIMATING BELL CANADA'S TWO-OUTPUT, THREE-INPUT COST FUNCTION: TESTS OF HYPOTHESES AND FINAL SPECIFICATION OF THE ESTIMATED COST STRUCTURE

The single-firm cost functions were first estimated for Bell Canada and then for AGT. After numerous and laborious attempts, the system of the translog cost function (5-17) and the two cost share equations (5-18) produced

---

[1] The two-firm model is employed in order to increase the efficiency of our parameter estimates. The two-firm model is estimated on the assumption that technological similarities exist in the production processes of both Bell Canada and AGT.

the estimates that are presented in Table (6-1) below. The implied estimates (the first- and second- order material coefficients and the interaction coefficients of material with the other factors of production) were obtained from the parameter relationships of the linear homogeneity restrictions. This set of parameters is referred to as the final specification and is used for further analysis.

As can be seen from Table 6-1, the model indicates a fairly good fit as the R^2 of both the cost function and the two share equations makes clear. Moreover, the Durbin-Watson statistic, being around the value of two (2), does not cause the null hypothesis of no autocorrelation to be rejected.

Regarding the sign and size of the estimated parameters we observe that most of them have the "correct" (from the economic point of view) sign and a "reasonable" magnitude. The technology parameter is negative and statistically different from zero indicating that cost savings have been realized by Bell Canada during the whole sample period. The first-order output parameters have the "correct sign" as well, while their magnitude is "reasonable" indicating significant overall economies of scale. They are equal to 1.54 ((1 / (0.359 + 0.290) - 1.54)) at the expansion point of the function (1980).

The most important parameter for our purposes is the second-order cross-interaction output parameter. It is the parameter that determines whether the cost function is or is not locally subadditive. Therefore, no particular sign is expected *a priori* for this parameter. If it is positive, it would be highly surprising to find a subadditive cost function. On the other hand, if it is negative a subadditive cost function would be expected. From Table 6-1 we observe that the local-toll interaction parameter has a negative sign, indicating cost savings for Bell Canada as a result of producing jointly both local and toll calls[2]. (The meaning of the other parameters is discussed later on).

In attempting to estimate this system of equations a number of problems was encountered. It is worth mentioning some of them.

---

2 The subadditivity test performed later on in this chapter confirms this statement.

TABLE 6-1

Parameter estimates for Bell Canada's Two-Output Cost Function (1952-86) (t-statistics in parentheses)			
Parameter	Estimates[3]	Parameter	Estimates
Intercept	24.560 (3.78)	Local-Local	6.089 (3.06)
Capital	0.040 (3.53)	Toll-Toll	1.900 (2.58)
Labour	0.732 (9.56)	Local-Toll	-3.410 (-3.26)
Material	0.288	Cap-Local	0.018 (0.38)
Local	0.359 (2.96)	Cap-Toll	-0.140 (-4.75)
Toll	0.290 (3.53)	Lab-Local	0.00019 (0.01)
Technology	-0.167 (2.29)	Lab-Toll	0.103 (5.67)
Cap-Cap	0.172 (19.52)	Mat-Local	-0.0189
Lab-Lab	0.066 (2.38)	Mat-Toll	-0.001
Cap-Lab	-0.124 (-9.24)	Local-Tech	-1.982 (-2.25)
Mat-Mat	-0.010	Toll-Tech	2.029 (2.17)
Cap-Mat	0.296	Lab-Tech	-0.269 (-8.87)
Lab-Mat	0.190	Cap-Tech	-0.0289 (7.46)
Tech-Tech	0.460 (2.38)	Mat-Tech	-0.020
ρ_c	0.546 (3.18)	$\rho_{sk} - \rho_{s1}$	0.596 (40.08)
	R^2		Durbin-Watson
Cost function	0.9995		2.350
Capital Share	0.9915		2.228
Labor Share	0.9937		2.371

First, a problem that was encountered in this studv was the absence of any index adequately representing the level of technology. In several U.S. studies the index of technology used was a lagged measure of R&D expenditures. Unfortunately, such a measure was not available for Bell Canada. The measure

3 For the estimates concerned with the material input, t-statistics are not indicated since the parameters have been obtained as implied estimates through the linear homogeneity constraints.

of technological change used in this study is simply a time trend[4]. Alternative measures of technological change such as the one used by Fuss and Waverman (output-augmenting technological change) and a dummy or binary variable which took the value of one from 1974 onwards and a value of zero in prior years were used in an attempt to improve our estimates. Generally, these specifications gave substantially less satisfactory results than was originally expected. Some of the estimates had the "wrong" signs, giving as a result positive own-price elasticities of demand for factor inputs and higher generalised variances than the ones resulting from the estimates reported in Table (6-1) above.

The estimates are critically affected not only by changing the technology index specification, but also by allowing for corrections for serial autocorrelation. The results presented in Table (6-1) above have been derived on the assumption that the disturbance terms are generated by a first-order autoregressive scheme such as the one given below.

$$u_{it} = v_{it} + \rho_i u_{i,t-1}, \qquad (6\text{-}1)$$

where $i = C,K,L,M$, t denotes time and the v_{it} are multinormally distributed with

$Ev_{it} = 0 \qquad i = C,K,L,M$

$Ev_{it}v_{jt} = \sigma_{ij} \qquad i,j = C,K,L,M$

$Ev_{it}v_{js} = 0 \qquad i,j = C,K,L,M \qquad t \neq s$

and the disturbances u_{it} are assumed to be temporally uncorrelated, contemporaneously correlated, and multinormally distributed with

$Eu_{it} = 0 \qquad i = C,K,L,M$

$Eu_{it}\, u_{jt} = \sigma_{ij} \qquad i,j = C,K,L,M$

$Eu_{it}\, u_{js} = 0 \qquad i,j = C,K,L,M \qquad t \neq s$

Thus, under (6-1), the disturbances are temporally uncorrelated across equations (i.e the disturbances of different time periods and of different

---

4 We also used the U.S. index of technological change but this specification performed poorly for the Canadian data.

equations are free from autocorrelation), temporally correlated within equations, and contemporaneously correlated across equations (i.e. the disturbances in different equations but corresponding to the same time period are correlated). Unless we correct for serial autocorrelation, the parameter estimates are dramatically affected, as can be easily seen from Table 6-2 below.

TABLE 6-2

Parameter Estimates for Bell Canada's Two-Output Cost Function (1952-86) (t-statistics in parentheses) Not Corrected for Serial Correlation			
Parameter	Estimates	Parameter	Estimates
Intercept	-1.023 (-1.19)	$Tech^2$	-0.096 (-2.55)
Capital	-0.832 (-6.67)	Cap^2	6.503 (5.77)
Labour	1.49 (16.36)	Lab^2	1.197 (1.11)
Cap-Lab	-4.355 (-4.82)	Cap-Local	0.217 (3.15)
Local	(1.589) (1.83)	Cap-Local	-1.845 (-0.92)
Toll	-0.039 (0.12)	Cap-toll	0.051 (0.93)
$Local^2$	-1.170 (-2.41)	Loc-Tech	0.862 (4.24)
$Toll^2$	0.234 (2.11)	Toll-Tech	-0.545 (-4.36)
Local-Toll	0.325 (0.83)	Lab-Tech	0.017 (0.17)
Lab-Local	-0.112 (1.89)	Cap-Tech	-0.011 (-0.82)
Lab-Toll	-0.086 (-2.34)	Tech	1.268 (-4.14)
	R^2		Durbin-Watson
Cost Function	0.9983		0.665
Capital Share	0.9425		0.926
Labour Share	0.9652		0.936

Apart from the fact that many parameters are not significantly different from zero, the local-toll interaction parameter has a positive sign, leading us to conlude that joint production of local and toll calls by Bell Canada does not bring about cost savings, but on the contrary diseconomies of scope exist. Thus, if we were to draw conclusions from this table, we would arrive at ones diametrically opposite to those based on specifications that correct for serial correlation (in Table 6-1 above). This is not surprising, however, since on the one hand the available data, being in form of index numbers, are highly trended and on the other hand the length of the time series on costs is very limited (35 observations only).

It is thus necessary to correct for serial correlation and to impose the symmetry and homogeneity assumptions on the model, in order to be able to estimate our parameters (21 in total). The number of parameters amounts to 32 if such restrictions are not imposed. The few degrees of freedom remaining limit the inferential ability of the model. It is thus important to use the prior information provided by production theory if we want our results to be informative. The results reported in Table 6-1 above are based on imposing both the symmetry and homogeneity (of degree one in prices) restrictions as they are implied by production theory, as well as on correcting for serial correlation.

If such restrictions are not imposed, the results can change dramatically as is illustrated in Table (6-3) below where neither the symmetry and homogeneity restrictions nor corrections for serial autocorrelation were imposed. It can be seen, once again, that the local-toll interaction parameter is positive, indicating that joint production brings about an increase in the cost of production of Bell Canada. Furthermore, the magnitude of most of the estimated parameters is not reasonable, while most of them are not statistically significant from zero.

TABLE 6-3

Parameter estimates for Bell Canada's Two-Output Cost Function (1952-86)
(t-statistics in parentheses)
Symmetry and Homogeneity assumptions are not imposed

Parameter	Estimates	Parameter	Estimates
Intercept	0.187 (4.66)	$Tech^2$	0.024 (3.52)
Capital	4.487 (1.22)	Cap^2	-1.061 (-2.25)
Labour	-4.487 (-1.43)	Lab^2	-0.624 (-1.161)
Cap-Lab	20.497 (1.34)	Cap-Local	-1.845 (-0.92)
Local	(-0.357) (-2.62)	Cap-Local	-1.845 (-0.92)
Toll	-0.093 (-1.40)	Cap-toll	2.461 (2.01)
$Local^2$	0.064 (0.71)	Loc-Tech	-0.056 (-6.00)
$Toll^2$	-0.093 (-1.40)	Toll-Tech	0.00075 (1.67)
Local-Toll	0.195 (1.61)	Lab-Tech	0.064 (0.10)
Lab-Local	4.149 (1.89)	Cap-Tech	-0.753 (-1.65)
Lab-Toll	-2.918 (-2.23)	Tech	0.210 (5.11)

It is thus important to bear in mind that the statistical inference of the model and therefore the policy conclusions drawn from it are conditional on the specific assumptions of symmetry and homogeneity and the appropriate corrections for serial correlation. These words of caution are extemely important since estimates such as those reported in Table (6-1) are supposed to be informative to both managers and policy makers in aiding them to make such important decisions as corporate strategies and/or determining the appropriate degree of competition in highly important industries such as telecommunications.

It is probably this limited applicability of the highly sophisticated econometric models that prevented them, in the past, from being used by policy makers for policy purposes. Nevertheless, since the unconditional data (data and parameters obtained without imposing prior information and restrictions) are less informative than the conditional one, constrained estimates may reveal some evidence on the natural monopoly issue and the nature of technology used by these industries.

SUBSTITUTABILITY OF FACTORS OF PRODUCTION

The Allen-Uzawa elasticities of substitution (AES) and price elasticities of demand as formulated in (5-8 to 5-11) were compared in order to measure factor substitution possibilities. Several important findings emerge from the results reported in Table (6-4) below.

TABLE 6-4

Own- and Cross- Price Elasticities and Allen Partial Elasticities of Substitution (Evaluated at the Mean Observations)[5]

	Labour	Capital	Materials
Labour	-0.389	-0.0103	2.75
Capital	-0.0103	-0.079	5.25
Materials	2.75	5.25	-0.128

First, the own-price elasticities of demand for the three factors of production, capital, labour and materials, were negative as required by production theory, and indicated inelastic demand for factor inputs by Bell Canada. The own-price elasticity of demand is lower for capital than for the

5 As was mentioned in chapter 5, the Allen-Uzawa partial elasticities of factor substitution ($\sigma_{ij} = \sigma_{ji}$) are symmetric, while the cross-price elasticities ϵ_{ij} are not necessarily so.

other factors, indicating that demand for capital is more price-inelastic. The demand for labour is the most price elastic as indicated by its own-price elasticity. The AES indicate that labour and capital are complements, while labour and material as well as capital and material are substitutes. Greater substitutability is being exhibited between capital and material and less one between capital and labour.

BIASED IMPACTS OF TECHNICAL CHANGE AND NONHOMOTHETICITY

The input-output relationships as presented in Table (6-1) indicate that the interaction parameters between labour and local output and capital and local output are both small and insignificantly different from zero, while the interaction parameters between both inputs and toll output are both highly significant. These interaction parameters indicate the way in which growth in both outputs have caused input mix to vary. Calculating the input elasticities with respect to outputs, we observe that these elasticities are not equal for all inputs, suggesting that the input mix is not independent of the growth of both outputs, and therefore the production structure cannot be homothetic. Indeed, such a hypothesis is rejected by applying likelihood ratio tests, as is indicated in Table 6-5 below.

Table 6-6 indicates the output and technology elasticities of costs and the output elasticities of inputs. It reveals that increases in the volumes of outputs led to less than proportionate increases in inputs in the data sample. The only exception seems to be the elasticity of toll output with respect to capital which has a negative sign, indicating that capital is a regressive[6] factor of production with respect to toll output. This is highly improbable. The elasticity of local output with respect to the labour input is unusally high, a fact that may be attributed to the small coefficient used to calculate it.

Table 6-5 also reports tests of various alternative hypotheses concerning the production structure and technological change of Bell Canada. As can be seen from this table, on the basis of the likelihood ratio test we also reject the nonjointness hypothesis. Rejection of this hypothesis

---

6 It implies that Bell Canada uses less capital as the number of toll calls increases.

indicates that the production structure of Bell Canada may exhibit either economies or diseconomies of scope. Furthermore, the separability hypothesis is also rejected. This implies that it is not possible to form an aggregate output for Bell Canada and estimate a single-output cost function and calculate the scale-economy estimate in order to test for the existence of a natural monopoly. A more disaggregated output, such as used here, may be more appropriate for performing the natural monopoly test.

As far as technological change is concerned, our tests as reported in Table 6-5 below indicate that the neutral technical change hypothesis is decisively rejected. Since we also reject the hypotheses that technical change is nonfactor- and nonoutput- augmenting, it implies that technological change has been both factor- and output- augmenting.

TABLE 6-5

Tests of Alternative Hypotheses Concerning Various Characteristics of the Structure of Production and Technological Change for Bell Canada			
Hypothesis	Likelihood Ratio Statistics for	Number of Restrictions	Critical Values of χ^2 at 0.05 and 0.01
Homotheticity	29.59	4	9.49 13.28
Homogeneity	26.33	7	14.10 18.50
Separability	9.54	2	5.99 9.21
Nonjointness	24.26	1	3.84 6.63
Unitary Elasticities of Substitution	33.19	3	7.81 11.34
Neutral Technical Change	30.99	4	9.49 13.28
Nonfactor Augmenting Technical Change	29.86	2	5.99 9.21
Nonoutput Augmenting Techinical Change	27.26	2	5.99 9.21

The production process of Bell Canada exhibits a high degree of overall economies of scale as is indicated by its scale elasticity of 1.56 at the expansion point of the function (19°0).

As far as technological change is concerned, the statistically significant first-order technology parameter indicates rather substantial cost savings as a result of technical progress. The second order technology parameter is positive but not statistically significant from zero. Calculating the output and technology elasticities of cost (see table 6-6) and the output elasticities of inputs at the mean of the sample, we draw the following interesting conclusions.

First, cost savings are indicated from the coefficient of cost elasticity with respect to technological change (-3.357). It is to be noted, however, that the technology elasticity of cost depends rather crucially on the nature of the technology index used. Previous studies have not made use of the technology index used here. Thus the technology elasticity of this study cannot be compared to that of other studies.

Second, technological changes are shown to be capital- as well as labour- and material- saving (see Table 6-6 below). This result is contrasted to the results of other studies which have shown that technological changes were capital-using and labour- and material- saving. The following table summarizes the major findings concerning the output elasticities of inputs and the technology elasticity of cost.

TABLE 6-6

Output and Technology Elasticities of Costs and Output Elasticities of Inputs (Evaluated at Mean Observations): Case Study Bell Canada

	Local	Toll	Tech
Cost	0.839	0.064	-3.357
Labour	8.246	0.437	-4.080
Capital	0.931	-0.520	-2.15
Materials	0.70	0.0566	-0.205

EVIDENCE ON NATURAL MONOPOLY FOR BELL CANADA

One of the objectives of this thesis is to reach conclusions that may help policy makers in industry and government to have better knowledge of the characteristics of the production technology used by Bell Canada and AGT. Such information, if reliable, may be used for public policy purposes. The "Evans and Heckman" test on cost subadditivity (see chapter 5) is one measure that permits us to localize the output combinations in order to determine whether or not Bell Canada is a natural monopoly.

We have applied this test for Bell Canada and for the years 1961 to 1986[7]. Table 6-7 reports the calculated sub(ϕ,ω) for our base year 1980 only, and for the combinations of (ϕ,ω) corresponding to

$$\phi = 0,\ .1,\ .2,\ .3,\ldots\ldots\ldots\ldots,.8,\ .9,\ 1.0$$
$$\omega = 0,\ .1,\ .2,\ .3,\ldots\ldots\ldots\ldots,.8,\ .9,\ 1.0$$

and excluding the values that do not satisfy the inequalities given by (5-12) and (5-13), in the previous chapter.

TABLE 6-7

Percentage of Gain or Loss From Multi-Firm VS. Single-Firm Production: Case Study Bell Canada (Year 1980)

ϕ =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
ω =												
0.0	-63											0.0
0.1	-66	-75										0.1
0.2	-69	-77	-85									0.2
0.3	-72	-79	-85	-92								0.3
0.4	-75	-80	-86	-91	-96							0.4
0.5			-86	-90	-94	-98						0.5
0.6				-89	-91	-94	-96					0.6
0.7						-90	-91	-92				0.7
0.8						-86	-86	-85	-85			0.8
0.9							-80	-79	-77	-75		0.9
1.0										-66	-63	1.0
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

As can be seen from Table (6-7) above, all signs are negative indicating that single firm production is always cheaper than multifirm production. Important savings (some of them quite substantial) thus appear to result from having only one firm produce the output configuration of the 1980 year. In other words, the negative signs indicate the percentage losses via increased

---

[7] 1961 is the first feasible year for the subadditivity test since both local and toll output doubled by this year. For more details on the test, see the original article of Evans and Heckman as well as chapter 5 of this thesis.

costs that will occur as a result of breaking Bell Canada down into two separate entities, each one producing the mixture of local and toll outputs the way it is indicated by the pairs of rim values.

As Evans and Heckman note, however, this is a test of local subadditivity and not a global one. Acceptance of local subadditivity does not necessarily imply global subadditivity. Nevertheless, the results of this test as it is applied to Bell Canada indicate that single-firm production is very likely cheaper than multifirm production. This result is also confirmed in Table 6-8 below which reports the maximum per cent loss from having more than one firm produce the whole of both local and toll calls for the entire period of our test.

TABLE 6-8

Maximum Per cent Loss from Multifirm vs. Single-Firm Production: Case Study: Bell Canada

Year	% of Loss	Year	% of Loss
1961	-31	1974	-58
1962	-34	1975	-55
1963	-37	1976	-50
1964	-39	1977	-49
1965	-40	1978	-54
1966	-45	1979	-55
1967	-47	1980	-63
1968	-50	1981	-64
1969	-52	1982	-73
1970	-53	1983	-42
1971	-49	1984	-35
1972	-48	1985	-23
1973	-53	1986	-22

The negative sign of all values in the above table further suggests that single-firm production is more cost efficient than a multi-firm one. Observing the table carefully we can discern, however, that considerable losses would have been incurred by breaking up Bell Canada up to 1982. Since 1983 these losses appear to have become less important. It is interesting to find the reasons which may explain the turn-about that seems to have occurred in the cost structure of Bell Canada since the early 1980s.

A number of factors may be advanced for explaining Bell Canada's cost structure turn-about. However, few of them seem to be plausible but highly conjectural. First, the introduction of competitive forces into the customer premises equipment market that occurred during the early 1980s[8] might be a factor explaining this turn-about[9]. This argument implicitly accepts that economies of scope may exist between network and terminal equipment services. Although there is no North-American empirical study that examines the possibility of cost complementarities between network and terminal equipment services, such a possibility has been suggested to exist in the West German telecommunications industry. Indeed, it is argued there, at least in the KMW German report, that economies of scope would be sacrificied and the Deutsche Bundespost monopoly might become unsustainable if competition were allowed into its terminal equipment market[10].

In addition, Bell Canada's organizational restructuring, the result of increased competition, may be a factor in explaining its cost structure turn-about. Indeed, in April 1983, Bell Canada reorganized its corporate structure and became a wholly owned subsidiary of the then newly created unregulated holding company, Bell Canada Enterprises Inc. (BCE). With this restructuring, Bell Canada functions mainly as an operating telecommunications company (see chart 1, chapter 5)[11].

Second, the turn-about of Bell Canada's cost structure coincides with the company's plan to digitalize its network at a very rapid rate. Kiss and

---

8 It was mentioned in chapter 2 that the CRTC liberalized the attachment of network-addressing terminal equipment, such as telephones and PBXs, on an interim basis for Bell Canada on August 5, 1980. On November 23, 1982, the CRTC issued its decision (Telecom Decision CRTC 82-14) in which it concluded that the liberalization of the terminal attachments should be continued.

9 The intensification of competition from local and foreign competitors for customers telecommunications eqipment and increased pressures for reducing the prices of long-distance calls may have decreased Bell Canada's revenues, suggesting thereby that this firm, though a natural monopoly (as the previous tables make clear), may not be sustainable.

10 See Snow, M., p. 18, 1988.

11 This argument suggests that economies of scope may have been sacrified as a result of Bell Canada's reorganizational restructuring. However, we are not sure whether Bell Canada was, indeed, realizing economies of scope from its previous organizational structure.

Lefebvre (1984), indicate that a serious attempt to digitalize Bell Canada's network started as late as 1981. For that year 3.1% of Bell Canada's telephones were connected to central offices using digital electronic swithching technology, while a year before this percentage was only 0.3%. By contrast, AGT started digitalizing its network in 1979 and at a rate much faster than Bell Canada. By 1981, the percentage of telephones by central office using digital electronic equipment was already 12% for AGT, while three years earlier (1979) it was 1.3%.

Bernstein (1988), writing in another context, has estimated a short-run cost function for Bell Canada. He has found that significant adjustment costs are incurred by Bell Canada in installing new capital into its production process. Indeed, he estimated that for $1.00 of marginal capital costs Bell Canada must incur an additional cost of $0.30 to install the new capital into its production process. Since, as was mentioned above, the year 1981 marks the beginning of the introduction of digital electronic equipment at a very rapid rate, the adjustment costs brought about by this digitalization may explain the apparent erosion of Bell Canada's cost structure.

In sum, our empirical model suggests that the production structure of Bell Canada may be locally subadditive for every year of the sample. Important cost savings would result from having only one firm producing the total of both local and toll outputs. However, these cost savings seem to decrease quite substantially since 1983. Our model fails to take into account the structural changes that have occurred and have managed to change radically the market structure as well as the internal organization of the Canadian telecommunications industry. As a result our model fails to explain the turn-about that apparently occurred in the cost structure of Bell Canada around the 1980s. This seems to be its most serious weakness. Considerable efforts must be made in order to find out what happened in Bell Canada's cost structure during that period. The reasons advanced above are only suggestive.

So far, we have examined the production characteristics of Bell Canada. Now we can go on and examine AGT's cost structure characteristics. In the first section we estimate a one-output three-input translog cost function. Then we do the same thing for a two-output, three-input cost function.

Finally, the subadditivity test for AGT is performed as well in order to determine whether its production structure is in effect a natural monopoly.

SINGLE-FIRM MODEL: ESTIMATING AGT'S ONE-OUTPUT, THREE-INPUT COST FUNCTION

Using annual data for the period 1968 to 1985 and imposing the assumptions of symmetry and homogeneity in input prices, we estimate the translog cost function for AGT as specified in equation (5-17) of the previous chapter. Attempts to estimate all the parameters of the function proved unsuccessful. Several parameters were insignificant and some had the "wrong" signs. In all alternative specifications, certain parameters showed a certain stability, while some others changed signs frequently and, further, they were all insignificant. The parameter that was performing poorly was the second order technology parameter. Applying likelihood ratio tests, the hypothesis that this parameter was equal to zero could not be rejected. Imposing such a restriction improved considerably the performance of the model. Table 6-9 indicates the results of the final specification of the translog cost function for AGT.

TABLE 6-9

Parameter Estimates for AGT's One-Output Cost Function (1968-85) (t-statistics in Parentheses)			
Parameter	Estimates	Parameter	Estimates
Intercept	11.039 (1.75)	Cap-Cap	0.218 (5.78)
Output	0.583 (0.44)	Cap-Lab	-0.168 (-4.28)
Capital	0.675 (9.47)	Lab-Lab	-0.015 (-0.29)
Labour	0.307 (5.86)	Cap-Output	-0.163 (-3.31)
Tech	-0.783 (-1.19)	Lab-Output	-0.0028 (-0.06)
Lab-Tech	0.014 (0.17)	Cap-Tech	0.233 (3.12)
Output^2	-0.087 (-0.30)		
ρ_c	0.721 (7.27)	$\rho_{SK} - \rho_{S1}$	0.653 (21.01)
	R^2		Durbin-Watson
Cost Function	0.9958		1.071
Cap Share	0.8031		2.253
Lab Share	0.7604		2.153

Note: The variables in the regression were not normalized

As can be seen from table 6-9, the first-order technology parameter is not significant. This parameter remained insignificant in all estimated cost functions. This may be an indication that technological changes may not have a considerable instantaneous influence in diminishing costs and improving productivity, but their effects may be spread over a longer time period.

SUBSTITUTABILITY OF FACTOR INPUTS

The own- and cross- price elasticities of demand for factor inputs for AGT calculated at the mean observations are presented in Table 6-10 below. We observe from the table that the own-price elasticities of demand for the three inputs of production are all negative, as is expected *a priori* from production theory.

TABLE 6-10

Own- and Cross- Price Elasticities of Substitution (Evaluated at the Mean Observations): Case Study: AGT			
	Labour	Capital	Materials
Labour	-0.714	-0.0240	0.646
Capital	-0.0165	-0.0657	0.212
Materials	1.154	0.0821	-0.711

Greater inelasticity is exhibited by the capital input while the labour and the material inputs are more elastic, exhibiting approximately an equal elasticity. The cross-price elasticities of demand for the factor inputs demonstrate that capital and labour are complementary factors of production while labour and materials are substitutes. This finding contrasts with the one found in the Kiss and Lefebvre's study (1984) in which they demonstrate that complementarity was exhibited only by labour and material inputs while the other inputs were substitutes for each other.

TESTING VARIOUS ALTERNATIVE HYPOTHESES CONCERNING AGT'S PRODUCTION AND TECHNOLOGICAL CHANGE CHARACTERISTICS

The fact that the number of parameters estimated is greater than that of the study by Kiss and Lefebvre permits us to perform certain tests and calculations concerning the nature of production and technological change used by AGT.

Our calculations reveal that technological changes have been capital- as well as labour- using (capital being the factor with the highest elasticity, indicating that it is used much more intensively compared to labour) and material- saving. These estimates as well as the estimates of the technology elasticities of cost (cost elasticities with respect to technological changes), evaluated at their mean observations are all presented in Table 6-11 below.

As can be seen from table 6-11 the technology elasticity of cost has a positive sign, leading us to conclude that technological changes as they are applied by AGT have not resulted in cost savings. This finding is surprising. If this is true, and if cost savings are indeed realized, then they may result from both output expansion (economies of scale) and from synergies from the joint production of local and toll outputs. It would be interesting to examine the impact of technical change and scale effects on factor proportions and productivity gains but this subject goes beyond the objectives of this study which are to examine whether the cost structure of Bell Canada and AGT are subadditive. In answering this question a two-output model for AGT is estimated in the following section.

TABLE 6-11

Output and Technology Elasticities of Costs and Output Elasticities of Inputs (Evaluated at Mean Observations): Case Study AGT

	Output	Technology	
Cost	N.A	0.286	
Labour	N.A	0.377	
Capital	N.A	1.369	

Note: N.A. means not applicable in this case

SINGLE-FIRM MODEL: ESTIMATING AGT'S TWO-OUTPUT, THREE-INPUT COST FUNCTION

The availability of a greater sample size permitted us to implement and estimate a translog cost function for AGT using two outputs and three inputs. To our knowledge, this is the first estimation of the two-output, three-input model for AGT.

Estimating a model with so many (21) parameters and so few observations poses a great number of difficulties. Serious problems of multicollinearity and lack of sufficient degrees of freedom prevented us from obtaining information on all parameters. To improve the inferential ability of our model, we had to impose a number of restrictions in addition to the symmetry and homogeneity retrictions imposed from the beginning. On the basis of likelihood ratio tests we could not reject the hypothesis that the second order technology term and the interaction of technology with both input and output terms were different from zero. By imposing these additional restrictions we reduce the number of parameters to be estimated to fourteen. If we allow for correction for serial autocorrelation and we further assume that the first order autorregressive parameters are equal for both share equations the number of parameters to be estimated increases to sixteen. Their values are shown in Table 6-12 below.

TABLE 6-12

Parameter Estimates for AGT: Two-Output, Three-input Cost Function (1968-85) (t-statistics in Parentheses) Corrected for Serial Correlation			
Parameter	Estimates	Parameter	Estimates
Intercept	4.774 (3.23)	Tech	-0.095 (-1.30)
Local	0.513 (3.23)	Cap^2	0.273 (10.55)
Toll	0.430 (2.28)	$Labour^2$	-0.040 (-1.10)
Cap	0.627 (30.03)	Cap-Lab	-0.117 (-3.96)
Lab	0.329 (14.82)	Lab-Tech	0.0010 (0.13)
$Local^2$	3.619 (5.27)	Cap-Tech	-0.035 (-4.34)
$Toll^2$	2.234 (3.94)	ρ_C	0.645 (-3.54)
Local-Toll	-2.070 (9.12)	$\rho_{SK}=\rho_{SL}$	0.399 (3.60)
	R^2		Durbin-Watson
Cost Function	0.8293		1.462
Capital Share	0.7593		1.661
Labor Share	0.7424		1.785

Note: The variables in the regression were not normalized.

Observing the parameters of Table 6-12 above we discern that most of them are statistically significant. The technology parameter has a negative sign indicating that the introduction of technological changes over time has caused cost savings --some of them quite substantial. However, the technology parameter is not statistically different from zero, a fact that reduces the validity of the above conclusion. It is important to note, however, that this problem plagued all the alternative models estimated for AGT.

Another important conclusion that can be drawn from the above table is that the production structure of AGT exhibits a moderate degree of overall economies of scale, as indicated by the inverse of the sum of both local and toll outputs (1.06) at the expansion point of the function (1980). The second-order output interaction parameters are both positive and statistically different from zero, while the second-order cross-output interaction parameter (local-toll) is negative and statistically different from zero. Its negative sign indicates that cost savings (economies of scope) are realized as a result of producing together both local and toll services. This will also be reflected in the subadditivity test that we perform in the next section.

Comparing this coefficient to the corresponding one of Bell Canada we observe that the magnitude of the latter is higher (in absolute terms) than that of the former. We can thus conclude, tentatively, that Bell Canada realizes more important cost savings from the joint production of both services than does AGT. The subadditivity test and the tables presented below confirm this conclusion. We can now perform the subadditivity test.

SUBADDITIVITY TESTS FOR THE PRODUCTION STRUCTURE OF AGT

Although we could not estimate all the parameters of the translog cost function of AGT due to the limited number of observations available, it is possible to apply the subadditivity test as was presented in the section above for Bell Canada by using only the values of the estimated parameters. The results of this test are presented in table 6-13 below.

TABLE 6-13

Percentage of Gain or Loss From Multi-Firm VS. Single-Firm Production: Case Study AGT (Year 1980)

ϕ =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
ω =												
0.0	-16											0.0
0.1		-25										0.1
0.2			-32									0.2
0.3				-37								0.3
0.4				-38	-39							0.4
0.5					-40	-40						0.5
0.6						-40	-39					0.6
0.7						-40	-38	-37				0.7
0.8						-16	-38	-35	-32			0.8
0.9							-37	-33	-29	-25		0.9
1.0								-31	-26	-21	-16	1.0
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

Important and interesting conclusions can be drawn from Table 6-13 above. First of all, we discern from this table that every value has a negative sign which indicates cost savings resulting from the joint production of local and toll services. Second, these cost savings are occasionally quite large, their magnitude obviously depending on the various alternative combinations that the two competitors use to produce the AGT's outputs. Third, these cost savings are not limited only to the year 1980, but on the contrary, our subadditivity test, performed for the years covering the period from 1974 to 1985 (the years for which our test was feasible) indicate negative values for all alternative combinations of both outputs and for the whole period under investigation.

Thus AGT's production costs tend to be lower than the sum of the costs of two separate entities. In order to get a more precise idea of the magnitude of cost savings we reproduce in Table 6-14 below the maximum per cent loss that would result from having two firms produce the total of both outputs.

TABLE 6-14

Maximum Per Cent Loss From Multi-Firm VS. Single-Firm Production: Case Study: AGT			
Year	% of Loss	Year	% of Loss
1974	-9	1980	-16
1975	-10	1981	-17
1976	-11	1982	-17
1977	-12	1983	-17
1978	-13	1984	-18
1979	-14	1985	-19

The above table suggests that single-firm production is more cost-efficient than multi-firm production. Unleashing market forces in AGT's market may thus be premature since increases in costs would result. We can thus argue that reasons such as those advanced by the the Economic Council of Canada (1986, *Minding the Public's Business*) that publicly owned AGT should be deregulated as a means to increase its efficiency must be questioned. It is not consistent with empirical econometric work. Nevertheless, comparing Table 6-8 to 6-14, we observe that the maximum percentage gain from single-firm production is much higher for Bell Canada than for AGT.

It is important to bear in mind the fact that our sample used in estimating the cost structure of AGT was very small and, as a result, we were obliged to impose many constraints in order to be able to estimate its production and technological characteristics. The limited inferential ability of small samples is notorious in econometrics. The above conclusions must be taken, then, as only suggestive.

In summary, we can conclude that the single-firm models of Bell Canada and AGT provide us with a number of interesting findings concerning the nature of the production process used by both these companies. Our knowledge may be further increased by using information previously gathered that allows us to perform some tests on a two-output two-firm model. This is done in the next section.

TWO-FIRM MODELS

TECHNOLOGICAL SIMILARITIES BETWEEN BELL CANADA AND AGT: ESTIMATING A TWO-OUTPUT, THREE-INPUT COST FUNCTION OF THE TWO FIRMS

Observing the production characteristics of the two firms from the separate estimation of their cost functions we notice that certain technological similarities are exhibited between these two firms. In an attempt to explore these similarities further and to increase the efficiency of our estimates a two-firm model was constructed. This model, as presented by equation (5-24) above, allows all parameters to differ between AGT and Bell Canada, but like other researchers we impose the same variance-covariance matrix upon the two firms[12]. The dummy variable introduced accounts for the inter-firm shifts in the parameters of the equation (5-19) of the previous chapter.

As with the estimation of the single-firm models, the assumptions of symmetry and first order homogeneity in input prices are both imposed in order to reduce the number of parameters estimated and to increase the inference ability of our model. Even when the above restrictions are imposed, severe problems of multicollinearity are encountered since a limited number of time series observations are used in estimating these parameters. The problem mainly originates from the small number of observations available for AGT.

In order to be able to estimate this model, more restrictions must be imposed. In the decision of what additional restrictions to impose, the single-firm model estimates come to our aid. From these models we observe that a number of parameters have the same value or values close enough to be considered equal, for the two firms. Thus, the Cap^2, the Cap-Lab and the Tech parameters are close enough to be considered equal for both firms. Moreover, the estimation of the single-firm models made clear that estimation problems were mainly posed by certain parameters, especially second-order technology

---

[12] A model similar to ours has been constructed by Kiss and Lefebvre in an attempt to analyse and forecast factor input growth and productivity improvement of Bell Canada and AGT. In their model they employed one output only. Our model differs from theirs in that we use two outputs instead of one, a different technology index and a greater sample size.

ones and the second-order interaction terms of technology with the inputs and outputs.

Since in the single-firm models these parameters are not significantly different from zero, such restrictions were further imposed in order to increase the efficiency of our estimates. Imposing all these restrictions we arrive at the following estimates of the parameters for Bell Canada:

TABLE 6-15
TWO-FIRM MODEL: CASE STUDY BELL CANADA

Parameter Estimates - Two-Output, Three-Input Cost Function (t-statistics in parentheses)			
Parameter	Estimates	Parameter	Estimates
Intercept	24.13 (-1.99)	Local-Toll	-3.410 (1.99)
Local	0.402 (8.42)	Cap^2	0.175 (9.39)
Toll	0.312 (-4.64)	Lab^2	-0.109 (5.43)
Cap	-0.340 (-2.44)	Cap-Lab	-0.0639 (-4.46)
Labour	0.746 (9.18)	$Tech^2$	0.0091 (0.11)
Tech	-0.0919 (2.64)	ρ_c	0.326 (2.00)
Local-Local	3.192 (-5.19)	$\rho_{SL}=\rho_{SK}$	0.998 (357.23)
Toll-Toll	1.882 (-3.88)	Local-Toll	-4.895 (4.31)
	R^2		Durbin-Watson
Cost Function	0.9997		1.653
Capital Share	0.9046		1.972
Labour Share	0.9964		1.755

Note. The variables in the regression were not normalized

Comparing the estimates of the above table to the estimates of Table 6-1, we observe that most of the parameters have similar values, especially the first- and the second- order output parameters. What interests us here is chiefly the sign and the magnitude of the second-order cross-interaction output parameters. The local-local and toll-toll interaction parameters are both positive, indicating that production costs increase as local or toll output production increases. The local-toll interaction parameter has a negative value, indicating that Bell Canada's production cost decreased as a result of producing jointly both local and toll calls. This finding can be further documented by applying, once more, the natural monopoly test.

Applying the subadditivity test using Bell Canada's parameters obtained from the two-firm model indicates Bell Canada the realizes very substantial cost savings producing both local and toll services. However, due to the fact that the cost savings are much more important than those reported in table 6-7 we conclude that these cost savings are overestimated[13]. Therefore, our assumption that Bell Canada and AGT have certain cost similarities, may not be correct. We can then argue that the most appropriate model, for public policy purposes, is the single-firm model. This conclusion is also confirmed when we apply the subadditivity test for AGT, employing the parameters obtained from the estimation of the two-firm model. Before we do so it is time to present the estimates of the parameters for AGT as they are obtained from the estimation of the two-firm model.

[13] Most of the times, potential hypothetical competitors incur costs twice as much as those of Bell Canada to produce part of the latter's output.

TABLE 6-16
TWO-FIRM MODEL: CASE STUDY AGT

Parameter Estimates - Two-Output, Three-Input Cost Function (t-statistics in parentheses)			
Parameter	Estimates	Parameter	Estimates
Intercept	4.605 (1.61)	Local-Toll	-1.123 (2.14)
Local	0.689 (-4.44)	Cap^2	0.175 (9.39)
Toll	0.223 (3.45)	Lab^2	-0.109 (5.43)
Cap	0.160 (2.79)	Cap-Lab	-0.0639 (-4.46)
Labour	-0.465 (-2.74)	$Tech^2$	0.0091 (0.11)
Tech	-0.0919 (2.64)	ρ_C	0.326 (2.00)
Local-Local	2.144 (2.42)	$\rho_{SL}=\rho_{SK}$	0.998 (357.23)
Toll-Toll	1.900 (1.74)	Local-Toll	-1.123 (2.10)
	R^2		Durbin-Watson
Cost Function	0.9997		1.781
Capital Share	0.9046		1.892
Labour Share	0.9964		1.557

Note: The variables in the regresssion were not normalized

As with Bell Canada, the magnitude of the parameters of Table 6-16 above exhibit certain similarity to the ones presented in Table 6-12 for the two-output case for AGT. Once again, we observe that the second-order cross-interaction output parameter has a negative sign indicating cost complementarities from the joint production of local and toll calls. Its magnitude (in absolute terms) is smaller than the magnitude of Bell Canada's second-order cross-interaction output parameter, indicating that AGT's cost savings resulting from the joint production of local and toll calls are smaller (yet very important) than Bell Canada's corresponding cost savings. The table below presents the results from the application of the subadditivity tests for the two-firm model, using the estimates obtained for AGT.

TABLE 6-17

Percentage of Gain or Loss From Multi-Firm VS. Single-Firm Production: Case Study AGT (Year 1980)[14]

ϕ =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
ω =												
0.0	7											0.0
0.1		2										0.1
0.2			-18									0.2
0.3				-5								0.3
0.4				-6	-6							0.4
0.5					-7	-7						0.5
0.6						-7	-6					0.6
0.7						-7	-5	-5				0.7
0.8						7	-5	-4	-2			0.8
0.9							-5	-2	-.2	2		0.9
1.0								-1	2	4	7	1.0
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	

The table above reveals that for most of the combinations indicated by the rim values the production structure of AGT is subadditive. Cost savings are realized as a result of having it solely producing the local and toll output together. However, for certain combinations of local and toll production, two separate entities would produce them more cheaply than AGT alone as the positive values of the table make clear.

It can thus be argued that, if certain parameters are imposed to have the same value for both Bell Canada and AGT (both firms having the same technology) the cost function of AGT tends to become additive. In other words, if AGT uses a technology similar to that used by Bell Canada for producing its limited output, costs for the former increase tending to render it an "unnatural monopoly". It can thus be argued that the technological structure of AGT may not resemble that of Bell Canada as was originally thought. The technological structure of AGT is well adapted for its market as

[14] This subadditivity test has been performed using the estimates of AGT for the two-firm model.

the results of the *single-firm* model make clear. Therefore, this must be the model to be used for public policy purposes[15].

CONCLUSIONS

We have examined and performed various tests on a number of important properties of the cost structure of both Bell Canada and AGT. A two-output, three-input translog cost function for Bell Canada was first estimated for a sample spanning the time period from 1952 to 1986. Since our purpose was to examine whether the production structure of Bell Canada and AGT satisfy the conditions necessary for being a natural monopoly, more emphasis was given to the subadditivity test.

Applying this test to Bell Canada we found that, in fact, important cost savings are realized from the joint production of both outputs, suggesting thereby that the cost structure of Bell Canada is locally subadditive. Although this test does not determine global subadditivity, the information on local subadditivity is significant and informative for public policy purposes.

Thus, the results reported in Tables 6-7 and 6-8 suggest that deregulation and thereby an unleashing of the market forces in Bell Canada's market may increase social costs. This conclusion is further reinforced if we take into account the fact that Bell Canada's natural monopoly may not be sustainable.

We have analysed the cost structure of AGT as well. First a single-output, three-input translog cost function was estimated and a number of important production characteristics have been examined. We concluded that moderate overall economies of scale are realized by AGT. In an attempt to find out whether this firm is indeed a natural monopoly, we examined a two-output, three-input translog cost function. A number of restrictions had to be imposed, in addition to the symmetry and homogeneity restrictions, since the number of observations was limited to 18 (1968-1985) and the number of parameters to estimate was great.

15 The positive sign of certain values in the above table may be due to the fact that we imposed too many restrictions on the parameters, forcing necessarily the two firms to exhibit cost similarities, although in practice this may not be so.

Performing the subadditivity test for AGT we found that cost savings result from the joint production of local and toll outputs. However, the cost savings realized, although considerable, are smaller than those realized by Bell Canada. Nevertheless, it seems that the cost savings are constant throughout the examination period. This result is contrasted to the one found for Bell Canada where cost savings seem to have started diminishing since 1983.

In sum, the evidence suggests that if governments had deregulated the long distance telephone market costs would have increased by, approximately, 20% in the AGT's market and by 40% in Bell Canada's market. Society would have been worse off.

CHAPTER 7

CONCLUSIONS AND POLICY RECOMMENDATIONS

The telecommunications industry is undergoing tremendous changes throughout the world. In the last few years telecommunications transmission has moved from the status of a virtual monopoly to one of ostensible competition. Leading the world in that movement is the United States. Public policy makers in that country have determined that competition should be substituted for governmental control in both the transmission and customer premises equipment markets. Starting as early as 1968 with what was initially thought to be a limited introduction of competitive forces into the provision of customer premises or terminal equipment market alone[1], the deregulatory movement reached its climax in 1982 when the Court approved the settlement reached by the U.S. Justice Department and AT&T according to which the latter agreed to divest the local exchange facilities held by the Bell operating companies[2].

This deregulatory movement has created a bandwagon effect. Countries such as Britain and Japan have gone almost as far as the U.S. in their deregulatory policies in their respective telecommunications industries. Other countries such as France and Germany are about to consider a restructuring of their telecommunications systems. Canada is, at present, involved in the deregulatory movement and has already liberalized the customer premises equipment market[3], at least that market segment under federal jurisdiction. Although the liberalization of the customer premises equipment market does not pose serious problems as far as economic efficiency is concerned, the deregulation of the telecommunications *transmission* market requires knowledge of that system's technology.

---

1 At first this competition came primarily in the business terminal equipment market while later on it expanded into the residence market as well. This was due to the hallmark Carterphone decision. According to this decision customers were allowed to attach certified equipment to the telecommunications network, a possibility that was previously prohibited.

2 The complete break up of the Bell System became effective on January 1st 1984.

3 See *Attachment of Subscriber-Provided Terminal Equipment*, CRTC Telecom Decision 82-14, November 23, 1982.

Traditionally, regulation has been justified on the basis that a natural monopoly exists. In markets where substantial economies of scale and scope are present, inefficiencies would be created and therefore additional costs to society would be imposed by allowing more than one supplier in that specific market. Local networks, because of their heavy sunk costs, may in fact be natural monopolies. The issue is whether the trunk (long-distance) market is a natural monopoly as well. The empirical studies carried out in Canada and the U.S are not conclusive. Among the studies surveyed in Chapter 4, only two, one in the U.S. and another in Canada, reveal that returns to scale are at best constant for each firm (AT&T or Bell Canada) and may well be increasing. Actually, there is only one study, that undertaken by Evans and Heckman (1983), which addresses directly the question of cost subadditivity (the simultaneous existence of economies of scale and scope).

Due to the lack of sufficient evidence on this subject, at least as far as the Canadian telecommunications industry is concerned, and the pressures at present to find solutions to the problem of natural monopoly, this dissertation examines the question of cost subadditivity from an empirical point of view. Studies, such as this one, which investigate the nature of the telecommunications production technology, serve two major purposes. First, they lead to a better understanding of the present telecommunications debate (i.e., whether that industry or part of it "still" constitues a natural monopoly). Second, they identify policy options which, if adopted, may increase efficiency and competitiveness in an industry where the rapid pace of technological advances poses tremendous challenges to both regulators and regulated firms as well.

In an attempt to address the issues of natural monoply and to acquire further knowledge about the telecommunications technology (thereby aiding policy makers in making responsible decisions) this thesis performs some empirical tests on cost subadditivity of both a privately owned company, the largest in Canada, Bell Canada, and a government-owned, relatively small one, AGT. It applies the "Evans and Heckman" (E & H) test of natural monopoly and investigates various alternative cost structures for both companies. To the best of our knowledge, this is the first attempt to apply the "E & H" test to the Canadian telecommunications industry. Previous Canadian studies have addressed a number of issues in the Canadian telecommunications industry, but they have not carried out in an explicit way the cost subadditivity test. Thus, they can only provide us with *ad hoc* information on an issue that is at the heart of the present regulatory debate.

The following points differentiate our study from the previous ones. *First*, the sample period of previous Canadian studies was limited to 27 observations for the period (1952-1978). Our study covers a longer time period, from 1952 to 1986. By increasing the number of observations, the number of degrees of freedom is increased as well, rendering thereby the inferential ability of our model more reliable.

A *second* difference between this study and the previous ones is found in the estimation of the translog cost function. We assume that both Bell Canada and AGT face exogenously determined prices for both the factor inputs used in their production process as well as for their output levels. Although all previous studies use the same assumption as far as the exogeneity of factor inputs' prices are concerned, this is not true for the determination of the output levels. In the study by Smith and Corbo (1978), the monopoly output was assumed to have been exogenously given while the competitive output level was endogenously determined. Due to the assumption of endogeneity of the competitive output they were able to use a revenue share equation in addition to the translog and the two cost-share equations. Thus, although they estimated a four-equation system, we estimate a three-equation one. The other Canadian studies (Fuss and Waverman, 1981) estimate a three-output translog cost function, under the assumption that at least one output is endogenously determined. Evans and Heckman (1983, 1988) in their AT&T study, reject the endogeneity assumption of both input prices and output levels after performing a Wu test.

A *third* difference between this study and the previous ones is found in the treatment of technical change. Previous studies have used such diverse technology indexes as the percentage of telephones connected to direct distance dialing facilities or the percentage of telephones connected to modern switching facilities. Our study lacks an appropriate index of technology. In the absence of any index capable of capturing the introduction of new technical changes, we used a time trend as a proxy for technological change. This may affect our results enormously compared to other studies. It is thus important to bear this difference in mind whenever comparisons of our results to the results of other studies are made.

Fourth, this dissertation constitutes the first *independent* (not affiliated to any company) study to make comparisons between the production characteristics of two such diverse companies as Bell Canada and AGT. Another study that makes a comparison between Bell Canada and AGT is the one done by Kiss and Lefebvre (1984), two Bell Canada researchers[4]. Our study differs from that of Kiss and Lefebvre, in that, firstly, we use a broader sample base for both companies (Bell Canada and AGT). Secondly, we use a *two*-output, three-input model for both companies, whereas Kiss and Lefebvre use a single-output, three-input model for both firms. Although for Bell Canada there are two studies that use two outputs, our study is the first one to use two outputs for AGT. Thirdly, Kiss and Lefebvre use confidential technology indexes in order to capture the introduction of new technologies in these two companies. Unfortunately, such confidential information was not available to us. Therefore, we used a time trend as an index of technology. Fourthly, even in the one-output case, the number of parameters estimated by Kiss and Lefebvre was severely limited due to the lack of sufficient degrees of freedom. As a result, the information obtained concerning the nature of technology for AGT was incomplete. Because our study had a greater number of observations, we could obtain information on virtually all the parameters. As a result, policy conclusions can be better formulated[5].

Specifying our model in the same manner as Evans and Heckman, and imposing the symmetry and homogeneity hypotheses, we proceeded to estimate the cost functions of single-firm and two-firm models. In the latter type of model the information from the two firms is combined on the basis of hypothetical similarities in technology.

Through a rather lengthy process, alternative model specifications reflecting various hypothetical technological characteristics were formulated.

---

4 Their objective was different however. They wanted to analyse and forecast factor input growth and productivity improvement in the two Canadian telecommunications carriers. See F. Kiss and B.J. Lefebvre, 1984.

5 It is true that policy conclusions require a lot more than econometric refinements. However, such refinements may help the present telecommunications debate.

A final selection of the most plausible models was made on the basis of both economic and statistical criteria. These models and their results were presented in the preceeding chapter. Here we may briefly summarize the most important points of each of the previous chapters and provide a list of the most interesting findings of the empirical analysis presented in chapter 6. Lastly, conclusions and policy recommendations are presented.

After setting out, in chapter 1, the issues confronting the Canadian telecommunications industry, at present, and the policy dilemmas facing both government, regulators and the industry itself, we proceeded to examine the forces and factors that contributed to the creation of the present situation.

Chapter 2 dealt with the economic, technological, regulatory and political forces that have challenged the fundamental premises upon which the telecommunications industry has developed in the last fifty years. We argued that policies such as those pursued by the U.S. government in dismantling AT&T, the world's largest multi-product firm, have greatly influenced and to a certain extent shaped the telecommunications policy that will be followed in Canada. It was argued that the present deregulatory movement has been the result of rapid technological changes and economic and political pressures. It was further argued that the U.S. government dismembered AT&T without having *sufficient* prior information on the nature of technology used by this company. Recent empirical studies in the U.S. have suggested that AT&T may have been effectively a natural monopoly[6].

The U.S. experience with deregulation, as was presented in chapter 2, led us to suggest, at least tentatively, that economic efficiencies may have been sacrificed and instability may have been created in the whole telecommunications system as a result of the policy of entry deregulation of the long-distance segment of the market. The adoption of high access charges as a means for safeguarding the integrity as well as the financial viability of local exchange carriers (bottleneck monopolies) have created new opportunities for by-passers. The introduction of market forces in the long-
77HFourthly,even in the one-outged customers from by-passing the network.
The creation of campuses may render the local exchange monopolies non-

6 See A. Charnes, W.W. Cooper and T. Sueyoshi, 1988.

sustainable, jeopardizing thereby the government's goal of service universality. Competition and therefore structural deregulation may not be the appropriate means for increasing allocative as well as productive efficiency in the telecommunications industry. This conclusion becomes even stronger when it is associated with the argument that the telecommunications system is indeed a natural monopoly (at least the local exchange network). Deregulation may drive up overall costs without providing attendant social benefits.

As a result, judging from the U.S. experience, it was argued that a reliance on market forces to cause a realignment of prices to costs of production would not necessarily increase social welfare. Uneconomic by-pass may be made impossible and social welfare may be increased if a "managed" rate-rebalancing scheme *is* adopted *within the present market structure*. This outcome is dictated by the fact that the Canadian telecommunications industry is a natural monopoly. Furthermore, in chapter 3 we argued that this natural monpoly may not be sustainable. Society would sacrifice the most efficient market structure if entry is permitted. We have then concluded that, contrary to what the advocates of deregulation argue, the recent technological changes have had the result of eroding *only the pricing* arrangements that have been traditionally adopted by both the industry and regulators. The cost structure of the Canadian telecommunications industry still shows signs of natural monopoly. This conclusion has been suggested by the econometric analysis presented in chapter 6.

In an attempt to integrate both the theoretical structure and the empirical analysis a review of the theory developed by Baumol, Panzar and Willig (1982) dealing with the technological characteristics of multi-product natural monopoly was also presented in Chapter 3.

In Chapter 4 the findings of the previous empirical studies dealing with the production characteristics of AT&T and Bell Canada were presented. From this selective survey, we concluded that the empirical evidence concerning the subadditivity of the production structure of both AT&T and Bell Canada was inconclusive. All studies undertaken in the U.S. for AT&T demonstrate that the production structure of this company exhibits considerable economies of scale. These results have been challenged by Evans and Heckman who, applying a sophisticated methodology and new tests, addressed directly the question of cost subadditivity. Their results have, in turn, been challenged by a recent study done by Charnes, Cooper and Sueyoshi (1988) and two other studies done by Sueyoshi alone (forthcoming).

As far as the Canadian studies are concerned, all of the studies surveyed demonstrate that considerable economies of scale exist in the production process of Bell Canada. These results have been challenged by the Fuss and Waverman study (1981) which shows that the production structure of Bell Canada exhibits constant or diminishing returns to scale. It is worth mentioning that no Canadian study addresses the question of cost subadditivity by applying E & H methodology.

Dissatisfied with the existing empirical evidence and in an attempt to better understand this subject we thoroughly investigated various alternative model specifications. On the basis of both economic and statistical criteria we have chosen the transcedental logarithmic cost models presented in Chapter 5 as the final ones. We then examined the production characteristics of both Bell Canada and AGT using these models.

Chapter 6 presents the results of our empirical model. On the basis of the information obtained from the estimation of Bell Canada's and AGT's cost structures, we concluded that the hypothesis that their cost structure is subadditive cannot be rejected. Both companies exhibited considerable overall economies of scale at the sample mean and throughout the investigation period. Subadditivity tests, similar to those applied by Evans and Heckman for AT&T, suggested that considerable cost savings could be realized by having *alone* either Bell Canada or AGT produce the total of local and toll outputs in their respective markets.

Our estimates suggest that if, in 1980, competition had been permitted to Bell Canada's and AGT's markets, costs of production would have increased by approximately 20% and 40% in the AGT and Bell Canada markets respectively. The same pattern is also observed for the other years of our sample.

Indeed, for the period between 1974 and 1985, AGT could produce its output configuration (local and toll) approximately 10% to 20% more cheaply than any two competitors, each one producing part of that output configuration. Cost savings of this magnitude are realized throughout our sample, although some improvement was observed in the second-half of our sample. A tentative explanation of this improvement may be AGT's decision to introduce the new analogue and digital electronic technology earlier and at a faster rate than Bell Canada.

As far as Bell Canada is concerned, it seems that two competitors, each one producing part of its output configuration, could incur costs of magnitude oscillating between 30% and 70% higher from 1961 to 1982. Although the cost savings realized as a result of having only Bell Canada producing the total of local and toll calls seems to be overestimated, they decline to 20 per cent in 1986. As a matter of fact, we observe a turn-about in Bell Canada's cost structure since 1983. Some tentative explanations have been advanced in order to explain this finding.

First, the year 1983 coincides with the liberalization of the customers' premises equipment market and Bell Canada's structural reorganization. Deregulation and possibly new technologies may have affected significantly Bell Canada's cost structure. The same trend is not observed for AGT. On the contrary, in the latest years, the cost savings for AGT seem even to increase, if AGT remains the sole supplier in its market. We may then tentantively suggest that AGT seems to have adapted itself better than Bell Canada to the turbulent environment that new technologies and regulatory changes have brought about in recent years. As a matter of fact AGT has introduced new digital electronic and analogue electronic[7] technologies at a faster rate than Bell Canada, since 1979 and 1972 respectively. AGT's increased pace of introduction of new technologies in conjunction with its ever increasing local market and Bell Canada's slow pace of introduction of new technologies and its slowly growing local market may explain the observed differences in their cost structures[8].

---

7 For example, the percentage of telephones (relative to the total number of telephones in service) using analogue electronic technology was 5.1% in AGT and only 2.4% for Bell Canada in 1972 while in 1981 it was 48.3% for AGT and only 19.1% for Bell Canada. The same phenomenon is observed for digital electronic technology. In 1979 1.3% of AGT's telephones were using this technology, and only 0.1% for Bell Canada. In 1986 these figures were 12% for AGT and 3.1% for Bell Canada. These figures are reported in Kiss F. and B. Lefebvre, 1984.

8 According to Kiss and Lefebvre (1984), the annual average output growth rate was 14.9% for AGT and 8.20% for Bell Canada for the period 1969-1981. For the same period the production of local

Second, Bell Canada's cost structure turn-about may be explained by the apparently high adjustment costs that this company incurs in installing its new capital equipment. Indeed, Bernstein (1987)[9] writing in a different context, has estimated a short-term cost function for Bell Canada and found that significant adjustment costs are incurred by Bell Canada in installing new capital into its production process. As a matter of fact he estimated that for $1.00 of marginal capital costs, Bell Canada must incur an additional cost of $0.30 to install the new capital into its production process. Since the year 1981 marks the beginning of introducing digital electronic equipment at a very rapid pace (0.1 % in 1979, 3.1 % in 1981) the adjustment costs brought about by this digitalization may account for the increase in Bell Canada's costs. Nevertheless, Bell Canada's cost savings, though diminishing, are still quite important.

In sum, we can say that our empirical estimates suggest that both Bell Canada's and AGT's cost structures may have natural monopoly characteristics over many of their output configurations[10]. It appears that two firms in either market (Bell Canada's or AGT's market) would have been unable to produce their output configurations more cheaply than a single firm.

We may thus suggest that the CRTC's 1985 decision[11] not to allow CNCP Telecommunications to enter Bell Canada's long distance public voice monopoly market (MTS and WATS) was socially desirable. However, Bell Canada should not take such a decision for granted. As new technologies and increased competition in other segments of the market may affect its subadditive cost structure, the CRTC may eventually wish to accomodate some competition in Bell Canada's market. This threat of competition may have positive effects on the behaviour of Bell Canada as is suggested by contestability theory. However, it is important for the Canadian regulatory commissions to have a good

services showed accelaration in AGT and decelaration in Bell Canada. By contrast, long distance services showed neither an accelaration nor a decelaration in either firm. For the same period the gap in the growth in local calls between the two firms was 6.67% per annum while for long distance calls it was 4.66%.

9 Jeffrey I. Bernstein: " An Examination of the Equilibrium Specification and Structure of Production for Canadian Telecommunications", (Journal of Applied Econometrics, forthcoming).

10 Those realized between 1961 and 1986 by Bell Canada and between 1974 and 1985 by AGT.

11 CRTC, Interexchange Competition and Related Issues, Telecom Decision 85-19, August 29,1985 (Ottawa: CRTC, mimeo).

knowledge of the production characteristics of our telecommunications system before they adopt any deregulatory policy. Should the CRTC consider any change in its policy concerning entry deregulation of Bell Canada's market, the CRTC should first make sure that the erosion of the subadditive cost structure of Bell Canada is permanent and not transitory as a result of adjustment costs to new technologies and new industry environments.

The conclusions that have been obtained are striking, but it is important, however, to draw the reader's attention to some difficulties encountered during the estimation of our empirical model. The models' weaknesses and the differences between this and other Canadian studies will be highlighted as well. The existence of problems and weaknesses will permit us to identify areas for future research.

First, it is notorious in econometrics that the results derived from the estimatior of cost functions, such as the ones estimated here, depend critically on the specification of the technical change indicators used to measure the diffusion of innovations. Our results are thus dependent on the time-trend variable used as an index of technology. Different estimates (less satisfactory ones) have been obtained when alternative proxy variables (such as a dummy variable) were used. Our results become thus less comparable to the results of the previous empirical studies since the latter have used various alternative technology indices other than the one used here.

Second, the empirical results may also depend on the way used to normalize the variables of the model[12]. Our estimates are more "reasonable" when we do not normalize our variables. This is another element that differentiates our results from the previous ones and makes them less comparable to others.

Third, the present study, like all previous ones, failed to acccunt for structural changes that have dramatically changed the Canadian telecommunications industry since the early 1980s. This seems to be a serious weakness since we are unable to explain, under the present formulation of our

12 Econometricians use a variety of ways to normalize the variables of their models. They may choose the sample mean of the variable or a specific annual value of the variable or any other way.

model, the turn-about that has occurred in the cost structure of Bell Canada around the 1980s. Future research should be directed to this preoccupation.

Fourth, although our model with two outputs and three inputs addresses the question of natural monopoly adequately well, it lacks probably disaggregation. The inclusion however of more inputs and outputs will cause serious problems of multicollinearity. This is due to the fact that the translog specification requires a large number of parameters. A common problem to all studies is the limited number of degrees of freedom. The same problem plagues our models as well despite the fact that we had more observations than the previous models.

Fifth, the measurement of outputs as well as the measurement of inputs requires some improvement. This is especially true with the AGT's capital price measure used in this study. It is capital 's residual rate of return which is based on rather strigent equilibrium assumptions. What is actually needed is a suitable measure of the true opportunity cost of capital.

Nevertheless, despite the above problems and weaknesses the fact is that our technique for testing subadditivity of the production processes of both Bell Canada and AGT seems to be quite robust. The soundness of our proceedure is probably confirmed by the fact that the same statistical technique was used by Evans and Heckman and arrived at diametrically opposite conclusions regarding AT&T, namely that there was no instance of natural monopoly for AT&T for the whole period under investigation (20 years). By contrast, the empirical part of our research suggests that the cost structure of Bell Canada and AGT may be subadditive for the sample period examined. Deregulating the Canadian telecommunications industry, at the present time, in the manner was done in the U.S., may not be in the public interest.

Such a conclusion should not be construed as an aphorism against competition. Proponents of deregulation of the telecommunications industry extol the merits of competition neglecting important facets of technology that characterizes this industry. The empirical analysis of chapter 6 suggests that the Canadian telecommunications industry may be a natural monopoly. In chapters 2 and 3, we suggested that this natural monopoly may not be sustainable. Moreover, the Canadian telecommunications market may not be contestable either. In this case contestability theory tells us that competition is not in the public interest. Entry and price regulation is the most appropriate public policy. Unpleasant surprises may come from an unplanned entry deregulation that has as a goal to increase competition for the sake of competition. The U.S. deregulatory experience with the airline and telecommunications industries may serve as an example[13].

Deregulatory policies that promote short term objectives such as competition may be doomed to failure especially in those industries whose technology has natural monopoly characteristics. It is argued in the economic literature[14] that the small firms with no past experience are unable to pursue strategies that promote the advantages that the flexible telecomunications technology confer upon them. Such small firms have very short term planning horizons and concentrate their efforts upon technologies yielding a quick return. In that sense deregulation and thus competition may, in the short run, stimulate the development of new techniques.

The promotion of competition through deregulatory actions may not automatically promote or increase the competitiveness of firms in the industry as a result of the operation of market forces. Promoting economic efficiency depends substantially on the nature of the cost structure of the incumbent. If its cost structure is subadditive and non-sustainable economic efficiency, both allocative and productive (cost), can be achieved only under a regulated monopoly.

The empirical finding that economies of scale and scope exist in the activities of both Bell Canada and AGT, in conjunction with the specificity of the Canadian market (limited size), lead us to conclude that a U.S.-style break up and deregulation of the telecommunications industry is inappropropriate for Canada, at least in the short run. The introduction of competition may be considered as feasible policy only if new technologies

---

13 Kahn, referring to the divestiture of AT&T from its operating companies states: "... I 'estimate' a small but positive probability that ten or twenty years from now we will look back and conclude that the entire venture was a ghastly mistake ..." (Yale Journal on Regulation, p. 139, 1984)

14 See Scherer, F. M., *Industrial Market Structure and Economic Performance*, Chicago: Rand McNally, 1980.

should *permanently* erode the subadditive cost structure of the Canadian telecommunications industry in the future.

BIBLIOGRAPHY

ALLEN, R. G. D., Mathematical Analysis for Economists, London: Macmillan & Co., 1938.

AMEMIYA, T., Advanced Econometrics, Harvard University Press, Boston, 1985.

AMEMIYA, T., "The Maximun Likelihood and Nonlinear Tree Stage Least Sqares Estimator in the General Nonlinear Simultaneous Equatios Model", Econometrica, 45, pp. 265-296, 1977.

APPELBAUM, E. "Testing Neoclassical Production Theory", Journal of Econometrics, 7, 1978.

APPELBAUM, Elie and LIM, Chin "Contestable Markets Under Uncertainty, Rand Journal of Economics, 16, 1985.

BAILEY, E.E."Price and Productivity Change Following Deregulation: The U.S. Experience", Economic Journal, 96, 1986.

BAILEY, E.E. and FRIEDLANDER, A.F. "Market Structure and Multiproduct Industries", JEL, Vol. XX, No 3, September,1983.

BAILEY, E.E. and W. BAUMOL, "Deregulation and the Theory of Contestable Markets", Yale Journal on Regulation, 1983.

BAILEY, E.E. "Contestability and the Design of the Regulatory and Antitrust Policy", AER, Proceedings, 71, 1981.

BARTEN, A.P., "Maximum Likelihood Estimation of Complete Systems of Demand Equatios", European Economic Review, May, 1967.

BAUGHCUM, A. and G. R. FAULHABER, (eds), Telecommunications Access and Public Policy, Ablex Publishing Company, Norwood, New Jersey, 1984

BAUMOL, W.J., "On the Proper Cost Test for Natural Monopoly in a Multiproduct Industry", American Economic Review, 67, December, pp. 809-822, 1977.

BAUMOL, W.J., "Minimum and Maximum Pricing: Principles for residual Regulation", The Eastern Economic Journal, 1979.

BAUMOL, W.J., "Quasi-Permanence of Price Reductions: A Policy for Prevention of Predatory Pricing", The Yale Law Journal, 1979.

BAUMOL, W.J. and BRADFORD,D. F., "Optimal Departures from Marginal Cost Pricing", American Economic Review, Vol. 60, No. 3, 1970.

BAUMOL, W.J., and BRAUNSTEIN, Y. M., "Empirical Study of Scale Economies and Production Complementarity: The Case of Journal Production", Journal of Political Economy, Vol. 85, No. 5, 1977.

BAUMOL, W.J., BAILEY, E. E. and WILLIG, R., "Weak Invisible Hand Theorems on the Sustainability of Multiproduct Natural Monopoly", AER, 1979.

BAUMOL, W.J., "Contestable Markets: An Uprising in the Theory of Industry Structure", AER, 72, 1982.

BAUMOL, W.J., PANZAR, J., and WILLIG, R., Contestable Markets and the Theory of Industry Structure, Harcourt Brace Jovanovitch, Inc., 1982.

BAUMOL, J. and WILLIG, R. D. "Contestability: Developments since the Book", Oxford Economic Papers, 38, 1986.

BAUMOL, W., PANZAR, J.C. and WILLIG, R.D. "Contestable Markets: An uprising in the Theory of Industry Structure: Reply", AER, 73, 1983.

BAUMOL, W., PANZAR, J.C. and WILLIG, R.D. "On the Theory of Perfectly-Contestable Markets", in Joseph E. Stiglitz and G. F. Mathewson, eds, New Developments in the Analysis of Market Structure, MIT Press, Cambridge, MA, 1986

BAIN, J.S. Barriers to New Competition, Cambridge, Mass: Harvard University Press, 1965.

BELL CANADA, The Bell Canada Total Factor Productivity Study, Input and Output Volume & Price Indexes, 1988.

BERNARD, J.T., F. LESSARD, S. THIVIERGE, "La demande d'énergie du secteur commercial québécois", L'Actualité Économique, Revue d'analyse économique, Vol. 62, no. 1, pp. 5-22, 1986.

BERNDT, R. E. and M. S. KHALED, "Parametric Productivity Measurement and Choice Among flexible functional Forms", Journal of Political Economy, 1979.

BERNDT, R. E. and N. E. SAVIN, "Estimation and Hypothesis Testing in Singular Equations Systems with Autoregressive Disturbances", Econometrica, September-November, 1975.

BERNSTEIN, J.I., "A Corporate Econometric Model of the British Columbia Telephone Company", in ANDERSON, O.D. (ed) Forecasting Public Utilities, North-Holland, 1980.

BERNSTEIN, J.I., "Multiple Outputs, Adjustment Costs and the Structure of Production for Bell Canada" International Journal of Forecasting, 1988 (forthcoming).

BERNSTEIN, J.I., "An Examination of the Equilibrium Specification and Structure of Production for Canadian Telecommunications" Journal of Applied Econometrics (forthcoming).

BERNSTEIN, J.I., "Dynamic Factor Demands and Adjustment Costs: An Analysis of Bell Canada's Technology" Information Economics and Policy, vol. 3, no. 1, pp. 1-24, 1988.

BERNSTEIN, M. H., Regulating Business by Independent Commission, Princeton University Press, Princeton, 1955.

BISWANGER, H. P., "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution", Amer. J. Agr. Econ., 1974a.

BISWANGER, H. P., "The Measurement of Technical Change Biases With Many Factors of Production", AER, 1974b.

BLANKART C.B., "Limits to Privatization", European Economic Review, Vol. 31, pp. 346-351, 1987.

BOS, D., "Privatization of Public Enterprises", European Economic Review, Vol. 31, pp. 352-360, 1987.

BOS, D., "A theory of the Privatization of Public Enterprises", Journal of Economics, suppl. 5, pp. 17-40, 1986.

BRESLAW, J.A. and SMITH, J.B., "Efficiency, Equity and Regulation: An Econometric Model of Bell Canada", Discussion Paper No. 81-01, Institute of Applied Economic Research, Concordia University, Montreal (January), 1981.

BRESLAW, J.A. and SMITH, J.B., "Efficiency, equity and regulation: An optimal pricing model of Bell Canada", Canadian Journal of Economics, 15(4), pp. 634-648, 1982.

BRESLAW, J.A. and SMITH, J.B., "Some encouraging firm level evidence for duality theory", Discussion Paper No. 83-04, Institute of Applied Economic Research, Concordia University, Montreal (February), 1983.

BRESLAW, J.A. and SMITH, J.B., "Des observations empiriques encourageantes pour la théorie dualiste", L'Actualité Economique, Revue d'analyse économique, vol. 59, no. 2, juin, 1983.

BRESLAW, J.A. and SMITH, J.B., "Efficiency, equity and regulation: An econometric model of Bell Canada", Final Report to the Department of Communications, March 1980.

BRESLAW, J.A., "Simulations of Bell Canada under various rate scenarios", Department of Communications, DGCE No. 151, Government of Canada, Ottawa, 1980.

BROCK, William A., "Contestable Markets and the Theory of Industry Structure: A Review Article", Journal of Political Economy, 91, 1983.

BROCK, William, The Telecommunications Industry, Cambridge: Harvard University Press, 1981.

BROCK, W. and D.S. EVANS, "Creamskimmung" in EVANS, D.S., (ed), Breaking Up Bell: Essays in Industrial Organization and Regulation, New York: North-Holand, 1983.

BROCK, W. and J. A. SCHEINKMAN, "Free Entry and the Sustainability of Natural Monopoly: Bertrand Revisited by Cournot" in Evans, D. S., (ed), Breaking Up Bell: Essays in Industrial Organization and Regulation, New York: North-Holand, 1983.

BROWN, R. S., D. W. CAVES and L. R. CHRISTENSEN, "Modelling the Structure of Cost and Production for Multiproduct Firms", Journal of political Economy, 1978.

BUCOVETSKY S., and J. CHILTON, "Concurrent renting and selling in a durable-goods monopoly under threat of entry", Rand Journal of Economics, Vol. 17, No. 2, Summer 1986.

CALEM, P. S., and D. F. SPULBER, "Multiproduct Two Part Tarrifs", International Journal of Industrial Organization, 1984.

CANADA, Minister of Supply and Services, Federal-Provincial Examination of Telecommunications Pricing and the Universal Availability of Affordable Telephone Service, Working Papers, Ottawa, 1986.

CANADA, Department of Communications, The Supply of Communications Equipment in Canada", Minister of Supply and Services Canada, 1985.

CARR, J., "A Suggestion for the Treatment of Serial Correlation: A Case in Point", Canadian Journal of Economics, (5)2, pp. 301-306, 1972.

CHARNES, A., W. W. COOPER and T. SUEYOSHI, "A Goal Programming/Constrained Regression Review of the Bell System Breakup", Management Science, January, 1988.

CHRISTENSEN, L. R., CUMMINGS, D. and SCHOECH, P.E., "Econometric estimation of scale economies in telecommunications", Final revision, manuscript, 1981.

CHRISTENSEN, L. R., D. W. JORGENSEN and L.J. LAU, "Transcendental Logarithmic Production Frontiers", Review of Economic Studies, 55, 1973.

CHRISTENSEN, L.R. and GREENE, W.H., "Economies of scale in U.S. electric power generation", Journal of Political Economy, 84(4), August, pp. 655-676, 1976.

CHRISTENSEN, L.R., JORGENSON, D.W. and LAU, L.J., "Conjugate Duality and Transcendental Logarithmic Production Functions", Econometrica, 39, 1971.

CHRISTENSEN, L.R., CUMMINGS, D. and SCHOECH, P.E., "Econometric estimation of scale economies in telecommunications" in COURVILLE, L, de FONTENAY, A. and DOBELL, R. (eds.), Economic Analysis of Telecommunications: Theory and Applications, North-Holland, New York, Amsterdam, Oxford, pp. 27-53, 1983.

CHRISTENSEN, L.R. and W. H. Greene, "Economies of Scale in U.S. Electric Power Generation", Journal of Political Economy, 84, 1976.

CHRISTENSEN, L.R., JORGENSON, D.W., and LAW, L.J., "Conjugate duality and the transcendental logarithmic production function", Econometrica, 39, July, pp. 255-256, 1971.

COPELAND, B. L. Jr. and A. SEVERN, "Price Theory and Telecommunications Regulation: A Dissenting View", Yale Journal on Regulation, Vol. 3: 1, 1985.

CORNELL, N. W. and D. W. WEBBINK, "The Present Direction of the FCC: An Appraisal", AER, May, 1983.

CONRAD, C.A., "The advantage of being first and competition between firms", International Journal of Industrial Organization, Vol. 1 pp. 353-364, 1983.

CORBO, V., "Rate adjustment guidelines for regulated industries: A model for Bell Canada", Institute of Applied Economic Research, Concordia University, Montreal (May), 1976.

CORBO, V., BRESLAW, J.A., VRLJICAK, M.M. and VAPESSARAN, A.R.M., "A simulation model of Bell Canada: Final report", Special Study 78-001, Institute of Applied Economic Research, Concordia University, Montreal (March), 1978.

CORBO, V., BRESLAW, J.A., DUFOUR, J.M. and VRLJILAD, J.M., "A simulation model of Bell Canada: Phase II", Special Study No. 79-002, Institute of Applied Economic Research, Concordia University, Montreal (March), 1979.

COURVILLE, L., A. DE FONTENAY and R. DOBELL (eds), Economic Analysis of Telecommunications: Theory and Applications, North Holland, New York Amsterdam, Oxford, 1983.

COUSTEL, J., "Telecommunications Services in France: The Regulated Monopoly and the Challenge of Competition", Telecommunications Policy, September, 1986.

CRANDALL, R. W., "Surprises from Telephone Deregulation and the AT&T Divestiture" AER, vol. 78, no. 2, May, 1988.

DALTON, M. M. and MANN, P. C., "Telephone Cost Allocation: Testing the Variability of Costs", Land Economics, Vol. 64, No. 3, 1988.

DAVIS, B.E., CACCAPPOLO, G.J. and CHAUDRY, M.A., "An econometric planning model for American Telephone and Telegraph Company", The Bell Journal of Economics and Management Science, 8(1), Spring, pp. 29-56, 1979.

DEMSETZ, H.M, "Why Regulate Utilities?" Journal of Law and Economics, 1968.

DENNIOUS, R. D., "The Subsidy Myth: Who Pays for the Local Loop?", Telecommunications Policy, September, 1986.

DENNY, M., FUSS, M. and EVERSON, C., "Productivity, CHUNG, J. W., "On the Estimation of Factor Substitution in the Translog Model" RE&S, vol. LXIX, no. 3, 1987.

DENNY, M., FUSS, M., EVERSON, C. and WAVERMAN, L., "Estimating the effects of diffusion of technological innovations in telecommunications: The production structure of Bell Canada", Canadian Journal of Economics, 14(1), pp. 24-43, 1981a.

DENNY, M. FUSS, M. and WAVERMAN, L., "The measurement and Interpretation of Total Factor Productivity in Regulated Industries, with Application to Canadian Telecommunications", in COWING' T.G. and STEVENSON, R. (eds.), Productivity Measurement in Regulated Industries, Academic Press, New York, pp. 179-218, 1981b.

DENNY, M., FUSS, M. and WAVERMAN, L. , "Productivity and Technical Change in Canadian Telecommunications: The case of Bell Canada", Final Report to the Department of Communications (March), 1979.

DENNY, M., FUSS, M. and WAVERMAN, L., "Substitution Possibilities for Energy: Evidence from U.S. and Canadian Manufacturing Industries", in BERNDT, E.R. and FIELD, B.C. (eds.), Modeling and Measuring Natural Resource Substitution, The MIT Press, Cambridge, Mass, 1981.

DENNY, M., FUSS, M., and WAVERMAN, L., "Productivity and Technical change in Canadian telecommunications: Bell Canda", Interim report to the Department of Communications (December), 1978.

DENNY, M. and C. PINTO, "An Aggregate Model with Multiproduct Technologies", in M. FUSS and D. McFADDEN Production Economics: A Dual Approach to Theory and Applications, Amsterdam, North-Holland, 1978.

DESPOTAKIS, A. K., "Economic Performance of Flexible Functional Forms", European Economic Review, 1986.

DHRYMES, P. J., Distributed Lags: Problems of Estimation and Formulation, San Francisco: Holden-Day, 1971.

DHRYMES, P. J., Introductory Econometrics, New York: Springer-Verlag, 1978.

DIEWERT, W.E., "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function, Journal of Political Economy, 79(3), May/June, pp. 481-507, 1971.

DIEWERT, W.E., "Exact and Superlative Index Numbers" Journal of Econometrics, 1976.

DOBELL, A.R., TAYLOR, L.D., WAVERMAN, L., LIU, T.H. and COPELAND, M.D.G., "Communications in Canada", Bell Journal of Economics and Management Science, 3(1), Spring, pp. 175-219, 1972.

DWIVEDI, T.D., and V.K. SRIVASTAVA, "Optimality of least squares in the seemingly unrelated regression equation model", Journal of Econometrics, Vol. 7, pp. 391-395, 1978.

EATON, C. B. , and Lipsey, R.G., "Exit Barriers Are Entry Barriers: The Durability of Capital as a Barrier to Entry", Bell Journal of Economics, Autumn, 1980.

EGAN, L. B. and WEISMAN, L. D., "The US Telecommunications Industry in Transition", Telecommunications Policy, June, 1986.

ELDOR, D., SUDIT, E.F. and VINOD, V.H., "Telecommunications, CES production function: A reply", Applied Economics, 11, pp. 133-138, 1979.

ELDOR, D., SUDIT, E.F., "Alternative Specifications of Returns to Scale and Joint Estimation of Factor Demand and Production Functions in Telecommunications", Review of Business and economic Research, Fall, 1982.

ELY, R. D. et al. Outlines of Economics, Fourth Revised Edition, The MacMillan Company, New York, 1927.

EVANS, D. S. and HECKMAN, J. J., "Natural Monopoly and the Bell System: Response to Charnes, Cooper and Sueyoshi", Management Science, vol. 34, no. 1, January, 1988.

EVANS, D. S. and HECKMAN, J. J., "Multiproduct cost function estimates and natural monopoly tests for the Bell System", in EVANS, D.S. (ed.), Breaking Up Bell, North-Holland, New York, Amsterdam, Oxford, pp. 253-282, 1983.

EVANS, D. S. and HECKMAN, J. J., "A Test for subadditivity of the cost function with an application to the Bell System", The American Economic Review, 74(4), September, pp. 615-623, 1984.

EVANS, D. S., (ed), Breaking Up Bell: Essays in Industrial Organization and Regulation, New York: North-Holand, 1983.

EVANS, D.S. and HECKMAN, J.J., "Natural Monopoly" in EVANS, D. S., (ed), Breaking Up Bell: Essays in Industrial Organization and Regulation, New York: North-Holand, 1983.

FAULHABER, G. R., Telecommunications in Turmoil: Technology and Policy, Ballinger, Cambridge, MA, 1987.

FISHELSON, G., "Telecommunications, CES production function", Applied Economics, 9, pp. 9-18, 1977.

de FONTENAY, A., HOFFBERG, M., SHUGARD, M. and WHITE, R., "Local Competition and Resale of Network Services in the USA", Telecommunications Policy, March, 1987.

FRIEDLAENDER, A. F., WINSTON, C. and K. WANG, "Costs, Technology, and Productivity in the U.S. Automobilie Industry", Bell Journal, vol.14, no.1, Spring, 1983.

FRIEDMAN, M., Capitalism and Freedom, Chicago: University of Chicago Press, 1962.

FUSS, M. and WAVERMAN, L., "The regulation of telecommunications in Canada", Technical Report No. 7, The Economic Council of Canada, Ottawa, 1981.

FUSS, M. and WAVERMANN, L., "Multi-product, multi-input cost functions for a regulated utility: The case of telecommunications in Canada", Working Paper No.7810, Institute for Policy Analysis, University of Toronto (June), 1978.

FUSS, M. and WAVERMAN, L., "Multi-product, multi-input cost functions for a regulated utility: The case of telecommunications in Canada", presented at the N.B.E.R. Conference on Public Regulations, Washington (December), 1977.

FUSS, M., "A survey of recent results in the analysis of production conditions in telecommunications", in COURVILLE L., de FONTENAY, A. and DOBELL, R. (eds.), Economic Analysis in Telecommunications: Theory and Applications, North-Holland, New York, Amsterdam, Oxford, pp. 3-26, 1983.

GALLANT, A. R., "Seemingly Unrelated Nonlinear Regression", Journal of Econometrics,3, 1975.

GALLANT, A. R., "On the Bias in Flexible Functional Forms and an Essentially Unbiased Form" Journal of Econometrics, February 1981, pp. 105-123.

GAUDRY, M.J.I., and WILLS, M.J., "Estimating the Functional Form of Travel Demand Models", Transportation Research, Vol. 12, pp. 257-289, 1978.

GELLERMAN, R. F., "Subscriber Financing of Telecommunications Investment", Telecommunications Policy, March, 1986.

GENTZOGLANIS, A., Vertical Integration and Monopoly Regulation: A Case-Study of the Bell Canda-Northern Telecom Complex, Unpublished M.A. thesis, McGill University, Montreal, 1981.

German Ministry of Posts and Telecommunications, Restructuring of the Telecommunications System, Report of the Government Commission for Telecommunications, R. v. Decker's Verlag, Heidelberg, 1988.

GIST, P. and MEADOWCROFT, S. A., "Regulating for Competition: The Newly Liberalized Market for Private Branch Exchanges", Fiscal Studies, August, 1986.

GLOBERMAN, S., "Economic factors in telecommunications policy and regulation", in Stanbury, (ed) Telecommunications, Policy and Regulation, Montreal, 1986.

GLOBERMAN, S. and W. T. STANBURY, "Local Measured Service or Rate Rebalancing? Efficiency and Distributional Considerations" in "SCHULTZ, R., and P. BARNES, Local Telephone Pricing: Is there a Better Way? The Centre for the Study of Regulated Industries, McGill University, Montreal, 1984.

GORECKI, P.K., "The importance of being first: The case of prescription drugs in Canada", International Journal of Industrial Organization, Vol. 4, pp. 271-395, 1986.

GORMAN, I.E., "Conditions for economies of scope in the presence of fixed costs", Rand Journal of Economics, 16(3), Autumn, pp. 431-436, 1985.

GUILKEY, D. K. and C.A. KNOX LOVELL, "On the Flexibility of the Translog Approximation", International Economic Review, February 1980, pp. 137-147.

HABER, L. J., "Factor Transferability: The Efficiency of Single Product and Multiproduct Firm", Eastern Economic Journal vol. VII, no. 2, April, 1981.

HILL, G. T., and Utterback, J.M., Technological Innovation for a Dynamic Economy, New York: Pergamon Press, 1979.

HILL, J., Deregulating Telecoms, Quorum Books, 1986.

HOLLER, M. J., "The theory of contestable markets: Comment", Bulletin of Economic Research, Vol. 37, No. 1, pp. 65-67, 1985.

JACQUEMIN, A., Sélection et pouvoir dans la nouvelle économie industrielle, Economica-Cabay, Paris-Louvain-la-Neuve, 1985.

JANISH, H. and Y. KURISAKI, "Reform of Telecommunications Regulation in Japan and Canada", Telecommunications Policy, March, 1985.

JOHNSON, E. "Telecommunications Market Structure in the USA: The Effects of Deregulation and Divestiture", Telecommunications Policy, March, 1986.

JUDGE, G. G., HILL, R. C., GRIFFITHS, W. E., LUTKEPOHL, H., and LEE, T., Introduction to the Theory and Practice of Econometris, 2nd edition, John Wiley & Sons, Inc, 1988.

JUDGE, G. G., HILL, R. C., GRIFFITHS, W. E., LUTKEPOHL, H., and LEE, T., Theory and Practice of Econometris, 2nd edition, John Wiley & Sons, Inc, 1987.

KAHN, A. E., "Surprises of Airline Deregulation" AER, vol. 78, no. 2, May, 1988.

KAHN, A. E., The Economics of Regulation: Principles and Institutions, Vol. II, New York, Wiley, 1971.

KAHN, A. E., "The Road to More Intelligent Telephone Pricing", Yale Journal on Regulation, Vol. 1: 139, 1984

KAMIEN, M. I. and Swartz, N. L., Market Structure and Innovation, Cambridge, Cambridge University Press, 1982.

KAPLINSKY, R., "Firm size and technical change in a dynamic context", The Journal of industrial economics, Vol. XXXII, No. 1, pp. 39-59, Sept. 1983.

KASERMAN, D. L. and J. W. MAYO, "Market-Based Regulation of a Quasi-Monopoly: A Transition Policy for Telecommunications", Policy Studies Journal, vol. 15, no. 3, March, 1987.

KAY, J.A., "Public enterprises, privatization and nationalization", European Economic Review, Vol. 31, pp. 343-345, 1987.

KAY, C. and TURNER, D., Antitrust Policy: An Economic and Legal Analysis, Cambridge, M.A., Harvard University Press, 1959.

KENCH, J.,"La convergence des techniques: incidence sur les télécommunications publiques, la radiodiffusion et la télévision", Journal des Télécommunications, vol. 53, 1986.

KISS, F. and LEFEBVRE, B.J., "Econometric Models of Telecommunications Firms: A Survey", Revue Economique, Vol. 38, No. 2, 1987.

KISS, F. and LEFEBVRE, B.J., "Comparative analysis and econometric forecasting of factor inputs and productivity: Some empirical results in Canadian telecommunications", presented at the Fourth International Symposium on Forecasting, London (July), 1984.

KISS, F., KARABADJIAN, J. and LEFEBVRE B.J., "Economies of scale and scope in Bell Canada" in COURVILLE L., de FONTENAY, A. and DOBELL, R. (eds.), Economic Analysis in Telecommunications: Theory and Applications, North-Holland, New York, Amsterdam, Oxford, pp. 55-62, 1983.

KISS, F., "Productivity gains in Bell Canada" in COURVILLE L., de FONTENAY, A. and DOBELL, R. (eds.), Economic Analysis in Telecommunications: Theory and Applications, North-Holland, New York, Amsterdam, Oxford, pp. 85-113, 1983.

KISS, F., KARABADJIAN, S. and LEFEBVRE, B.J., "Economies of scale and scope in Bell Canada: Some econometric evidence", presented at the Telecommunications in Canada conference at L'École des Hautes études commerciales (March), 1981.

KMENTA, J. and R. F. GILBERT, "Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regression" Journal of the American Statistical Association, 63, 1968.

LANCASTER, K., "Innovative Entry: Profit Hidden Beneath the Zero", The Journal of Industrial Economics, September/December, 1982.

LAU, L.J. and YOTOPOULOS, P.A., "A test for relative efficiency and application to Indian agriculture", American Economic Review, 61, March, pp. 94-109, 1971.

LEVY, D.T., and L.J., HABER, "An advantage of the multiproduct firm: The transferability of firm-specific capital", Journal of Economic Behavior and Organisation, Vol. 7, pp. 291-302, 1986.

LITTLECHILD, S. S., "The Structure of Telephone Tariffs" International Journal of Industrial Organization, 1983.

LLOYD, P.J., "Why do firms produce multiple outputs?", Journal of Economic Behavior and Organization, Vol. 4, pp. 41.-51, 1983.

MAGEE, L., "The behaviour of a modified Box-Cox regression model when some values of the dependent variable are close to zero", The Review of Economics and Statistics, Vol. LXX, No.2, 1988.

MAGNUS, J.R., "Maximum likelihood estimation of the GLS model with unknown parameters in the disturbance covariance matrix", Journal of Econometrics, Vol. 7, pp. 281-312, 1978.

MAY, J.D. and DENNY, M., "Post-war Productivity in Canadian manufacturing", Canadian Journal of Economics, XII(1), February, pp. 29-41, 1979.

McFADDEN, D., "Cost, revenue and profit functions", in FUSS, M. and McFADDEN, D. (eds.), Production economics: A Dual Approach to Theory and Applications, I, North-Holland, Amsterdam, 1978.

MACMANUS, J.C., "Federal Regulation of Telecommunications in Canada" in Telecommunications in Canada, edited by Edward English, Toronto, Methuen, 1973.

MEYER, J.R. and W. B. TYE, "The Consequences of Deregulation in the Transportation and Telecommunications Sector: The Regulatory Transition", AER, May, 1985.

MEYER, J.R., WILSON, R.W., BAUGHCUM, M.A., BURTON,E. and CAOUETTE, L., "The economics of competition in the telecommunications industry", Charles River Associates, Boston (August), Subsequently published by Oelgeschlager, Gunn and Hain, Publishers, Cambridge, 1982.

MILLER, J., (ed), Telecommunications and Equity: Policy Research Issues, New York: North-Holand, 1986.

MIRMAN, L. J., TAUMAN, Y. and ZANG, I., "Ramsey Prices, Average Cost Prices and Price Sustainability", International Journal of Industrial Organization, 1984.

MORRISON, S. A. and C. WINSTON, "Intercity Transportation Route Structures under Deregulation: Some Assessments Motivated by the Airline Experience", AER, May, 1985.

MORRISON, C.J. and BERNDT, E.R., "Short-run labor productivity in a dynamic model", Journal of Econometrics, 16, pp. 339-365, 1981.

MORTENSON, D.T., "Generalized costs of adjustment and dynamic factor demand theory", Econometrica, 41, July, pp. 657-666, 1973.

NADIRI, M.I. and SCHANKERMAN, M.A., "Variable cost functions and the rate of return to quasi-fixed factors: An application to R&D in the Bell System", Working Paper No. 597, National Bureau of Economic Research, Cambridge, 1980.

NADIRI, M.I. and SCHANKERMAN, M.A., "The structure of production, technological change, and the rate of growth of total factor productivity in the U.S. Bell System", in COWING, T., and STEVENSON, R. (eds.), Productivity Measurement in Regulated Industries, Academic Press, New York, pp. 219-247, 1981.

NERLOVE, M., "Returns to scale in electricity supply", in CHRIST, C. (ed.), Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Greenfeld, Stanford University Press, Stanford, California, 1963.

NEUMAN, K. and B. WIELAND, "Competition and Social Objectives: The Case of West German Telecommunications" Telecommunications Policy, June, 1986.

NOAM, E. M, (ed), Telecommunications Regulation Today and Tomorrow, New York: Law and Business, Inc., 1983.

NOLL, R. G., "Let Them Make Toll Call": A State Regulator's Lament", AER, May, 1985.

NOLL, R. G., "The Twisted Pair: Regulation and Competition in Telecommunications" Regulation, Vol. X; No. 3-4, 1987.

OBERHOFER, W., and J. KMENTA, "A general Procedure for obtaining maximum likelihood estimates in generalized regression models", Econometrica, Vol. 42, No. 3, pp. 579-592, May 1974.

OLLEY, R.E. and LE, C.D., Total Factor Productivity of Canadian Telecommunications Carriers, Ottawa, Department of Communications, January 1986.

OLLEY, R.E., "Study of AGT Total Factor Productivity" Evidence in Chief, Alberta Government Telephones, January 19, 1987.

PANZAR, J.C. and WILLIG, R.D., "Free Entry and the Sustainability of Natural Monopoly", Bell Journal, Spring, 1977.

PANZAR, J.C. and WILLIG, R.D., "Economies of scale and economies of scope in multi-output production", Bell Laboratories discussion Paper, No. 33, 1975.

PHILLIPS, A., "The Reintegration of Telecommunications: An Interim View", in Crew, A., M., (ed) Analysing the Impact of Regulatory Change in Public Utilities, D.C. Heath and Company, 1985.

POOL, de SOLA, "Competition and Universal Service; Can we Get There from Here?", in SHOOSHAN III, ed., Disconnecting Bell: The Impact of the AT&T Divestiture, Pergamon Press, New York, 1984

POPE, R. D. and A. HALLAM, "Separability Testing in Production Economics", Journal of American Agricultural Economics, vol. 70, no. 1, February, 1988.

PORTER, M.E., Competitive Strategy, New York: Free Press, 1980.

POSNER, R. A., "Taxation By Regulation" Bell Journal of Economics and Management Science, 1971.

POSNER, R. A., "Natural Monopoly and its Regulation" Journal of Political Economy, 1969.

RAJ, B., and VINOD, H.D., "Bell System scale economies estimated from a random coefficients model", Journal of Economics and Business, 34(3), pp. 247-252, 1982.

RASHID, S., "Quality in Contestable Markets: A Historical Problem? QJE, February, 1988.

REINGANUM, J.F., "A two-stage model of research and development with endogenous second-mover advantages", International Journal of Industrial Organization, Vol. 3, pp. 275-292, 1985.

RIORDAN, M.H., and O.E. WILLIAMSON, "Asset specificity and economic organization", International Journal of Industrial Organization, Vo. 3, pp. 365-378, 1985.

SCHANKERMAN, M. and NADIRI, I. M. , "A Test of Static Equilibrium Models and Rates of Return to Quasi-Fixed Factors, With an Application to the Bell System", Journal of Econometrics, 1986.

SCHERER, F.M. Industrial Market Structure and Economic Performance, Chicago: Rand McNally, 1980.

SCHMALENSEE, R. , "Economies of Scale and Barriers to Entry", Journal of Political Economy, December, 1981.

SCHMALENSEE, R. , "Product Differentiation Advantages of Pioneering Brands" AER, June, 1982.

SCHMALENSEE, R. , "Industrial Economics: An Overview", The Economic Journal, 98, 1988.

SCHMIDT, J. S. and R. M. Corbin, "Telecommunications in Canada: The Regulatory Cricis", Telecommunications Policy, 1983.

SCIBERRAS, E. , "The Australian Telecommunications Subscriber Equipment Industry", Telecommunications Policy, 1986.

SCIBERRAS, E. and B.D. PAYNE, Telecommunications Industry: Technical Change and International Competitiveness, St. James Press, 1986.

SCHMIDT, P., "A note on the estimation of seemingly unrelated regression systems", Journal of Econometrics, Vol. 7, pp. 259-261, 1978.

SCHULTZ, R., and Alan ALEXANDROFF, Economic Regulation and the Federal System, University of Toronto Press, Minister of Supply and Services Canda, 1985.

SCHULTZ, R., and P. BARNES, Local Telephone Pricing: Is there a Better Way? The Centre for the Study of Regulated Industries, McGill University, Montreal, 1984.

SCHUMPETER, J.A., Capitalism, Socialism and Democracy, New York: Harper and Row, 1950.

SCHWARTZ, Marius, "The Nature and Scope of Contestability Theory", Oxford Economic Papers, 38, 1986.

SCHWARTZ, M. and REYNOLDS, R. J. "Contestable Markets: An uprising in the Theory of Industry Structure: Coment", AER, 73, 1983.

SHARKEY, W. W., "Existence of Sustainable Prices for Natural Monopoly Outputs", Bell Journal, 1981.

SHARKEY, W. W., The Theory of Natural Monopoly, Cambridge University Press, Cambridge, 1982.

SHEPHARD, R.W., "Concepts of Competition and Efficient Policy in the Telecommunications sector", in NOAM, E. M., (ed), Telecommunications Regulation: Today and Tomorrow, Harcourt Brace Jovanovich, New York, 1983.

SHEPHARD, R.W., "'Contestability' vs Competition", AER, 1982.

SHEPHARD, R.W., "Sustainability, Deregulation, and Separate Subsidiaries: Or Natura non Facit Saltum" in TREBING, H. M., ed., Challenges for Public Utitlity Regulation in the 1980s, MSU Public Utilities Papers, 1981.

SHEPHARD, R.W., Cost and Production functions, Princeton University Press, Princeton, New Jersey, 1970.

SICKLES, R., GOOD, D. and JOHNSON, R. L., "Allocative Distirtions and the Regulatory Transition of the U.S. Airline Industry", Journal of Econometrics, 1986.

SMITH, J.B. and CORBO, V., "Economies of scale and economies of scope of Bell Canada", Institute of Applied Economic Research, Concordia University, Final Report to the Department of Communications (March), 1979.

SNOW, M.S., "Telecommunications Literature: A Critical Review of the Economic, Technological and Public Policy Issues", Telecommunications Policy, pp. 153-183, 1988.

SNOW, M.S., "The State as Stopgap: Social Economy and Sustainability of Monopoly in the Telecommunications Sector", Review of Social Economy, vol. XLVI, no. 1, April, 1988.

SNOW, M.S., "Natural Monopoly in INTELSAT: Cost Estimation and Policy Implications for the Separate Systems Issue", Telematics and Informatics, Vol. 4, No. 2, 1987.

SNOWBERGER, V., "Sustainability Theory: Its Implications for Governmental Preservation of a Regulated Monopoly", QRE&B, 1978.

SPENCE Michael, "Contestable Markets: An uprising in the Theory of Industry Structure: A Review Article", JEL, 21, 1983.

SPULBER, D. F., "Scale Economies and Existence of Sustainable Monopoly Prices", Journal of Economic Theory, 1984.

SPULBER, D. F., "Second-best Pricing and Cooperation", Rand Journal of Economics, vol.17, no.2, Summer, 1986.

STANBURY, W. T., (ed), Telecommunications, Policy and Regulation: The Impact of Competition and Technological Change, The IRPP, Montreal, 1986.

STANBURY, W. T., "Decision Making in Telecommunications: The Interplay of Distributional and Efficiency Considerations" in STANBURY, W. T., (ed), Telecommunications, Policy and Regulation: The Impact of Competition and Technological Change, The IRPP, Montreal, 1986.

STIGLER, G. J. and C. FRIEDLAND, "What Can Regulators Regulate? The Case of Electricity", JL&E, 1962.

SUBISSATI, E., "Subsidized Entry, Regulated Competition and Public Policy in Telecommunications in Canada", in MILLER, J., (ed), Telecommunications and Equity: Policy Research Issues, New York: North-Holand, 1986.

SUDIT, E.F., "Additive nonhomogeneous production functions in telecommunications", The Bell Journal of Economics and Management Science, 4(2), Autumn, pp. 499-514, 1973.

SUEYOSHI, T. and ANSELMO, P.C., "The Evans and Heckman subadditivity test: Comment", The American Economic Review, 76(4), September, pp. 854-855, 1986.

SUEYOSHI, T., "A Goal Programming/Constrained Regression and Alternative Approaches to Statistical Estimation", Unpublished Ph.D. dissertation, 1986.

SUEYOSHI, T., "Duality Theory of Data Envelopment Analysis" (forthcoming).

SUEYOSHI, T., "Data Envelopment Analysis: Review of AT&T Breakup" (forthcoming).

TEECE, D.J., "Towards an economic theory of the multiproduct firm", Journal of Economic Behavior and Organization, Vol. 3, pp. 39-63, 1982.

TEECE, D.J., "Transactions cost economics and multinational enterprise: An Assessment", Journal of Economic Behavior and Organization, Vol. 7, pp. 21-45, 1986.

THREADWAY, A.B., "On the rational multivariate flexible accelerator", Econometrica, 39, September, pp. 845-856, 1971.

THREADWAY, A.B., "The globally optimal flexible accelerator", Journal of Economic Theory, 7 February, pp. 7-39, 1974.

TREBING, H. M. (ed), Essays on Public Utility Pricing and Regulation, East Lansing: Michigan State University, 1971.

TREBING, H. M. (ed), The Impact of Deregulation and Market Forces on Public Utilities: The Future Role of Regulation, East Lansing: Michigan State University, 1985.

VINOD, H.D., "Nonhomogeneous production functions and applications to telecommunications", The Bell Journal of Economics and Management Science, 3(2), Autumn, pp. 531-543, 1972.

VINOD, H.D., Application of ridge regression to a study of Bell System scale economies", Journal of the American Statistical Association, 71, December, pp. 835-841, 1976.

VINOD, H.D., "Applications of new ridge regression methods to a study of Bell System scale economies", Federal Communication Commission, Docket No. 20003, Bell Exhibit No. 42 (april), 1975.

VITON, P.A., "A translog cost function for urban bus transit", The Journal of Industrial Economics, Vol. XXIX, no. 3, pp.287-304, March 1981.

WAVERMAN, L., "The regulation of intercity telecommunications" in PHILLIPS, A. (ed.), Promoting Competition in Regulated Markets, The Brookings Institution, Washington, pp. 201-239, 1975.

WEISAECKER, C.C. von, Barriers to Entry, New York: Springer-Verlag, 1980,

WEITZMAN, Martin L. ,"Contestable Markets: An uprising in the Theory of Industry Structure: Coment", AER, 73, 1983.

WENDERS, J. T., The Economics of Telecommunications: Theory and Policy, Ballinger Publishing Company, 1987.

WENDERS, J. T., "The Economic Theory of Regulation and the U.S. Telecommunications Industry", Telecommunications Policy, March, 1988.

WENDERS, J. T., "The Implications of Economic Efficiency for US Telecommunications Policy", Telecommunications Policy, March, 1986.

WILLIAMSON, O. E., Market and Hierarchies, New York: Free Press, 1975.

WILLIAMSON, O. E., "Franchise Bidding for Natural Monopolies- In General and With Respect to CATV", Bell Journal of Economics, 1976.

WILLIAMSON, O. E., "Transaction Cost Economics: The Governance of Contractual Relations" Journal of Law and Economics, October, 1979.

WILLIAMSON, O. E., The Economic Institutions of Capitalism, New York, Free Press, 1985.

WILLIG, R. D. and W. J. BAUMOL, "Using Competition as a Guide" Regulation, No. 1, 1987.

ZELLNER, A., "An efficient method for estimating seemingly unrelated regressions and tests for aggregation bias", Journal of the American Statistical Association, 57, June, pp. 384-368, 1962.