THE PRICE ELASTICITY OF TELEPHONE DEMAND

by

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ABSTRACT

With the potential for competition within the Canadian Telecommunications industry increasing, and recent rate reductions in message toll rates, estimates of price elasticities have come to play an important role in forming the tariff decisions made by both the industry and their regulators. Also of concern to both parties is how consumers respond over time to changes in price. Keeping this in mind, the purpose of this thesis is to estimate toll price elasticities which incorporate dynamic adjustment.

The model developed uses a double log linear specification which incorporates an Almon polynomial lag structure. The results of the model indicate that Intra-British Columbia toll price elasticities are in the inelastic portion of the demand curve and that adjustment to price changes occur within a year. The model also highlights the importance of income in determining the demand for toll service. As competition unfolds in the Canadian Telecommunications Industry, further investigation of how income affects long distance demand will be required.

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SECTION I - INTRODUCTION

For over a decade, the British Columbia Telephone Company (B.C. Tel) has carried out a series of econometric investigations in order to refine its knowledge of message toll demand within the Province of British Columbia. This type of research has gained new significance with the possibility of competition in the telecommunications industry within Canada.

Competition in the message toll market has existed in the United States since the break-up of American Telephone and Telegraph (AT&T) in 1982. Until that time the provision of long distance voice transmission was viewed as a monopoly service and government regulation ensured that this service was provided in the manner the government deemed most appropriate. However, technological advances which occurred during the decade prior to 1982, made competition feasible on the highly profitable long distance routes.

Government regulation has distorted rate structures in the United States telecommunications industry, in order to encourage the telephone companies to provide universal service. Consequently, long distance services are highly profitable, while local service is non-compensatory.

In Canada, given our ribbon type population distribution along the forty-ninth parallel, this distortion of lucrative long distance routes and non-profitable local service is even more evident in our rate structure. To identify the magnitude of this distortion within the B.C. Tel network, B.C. Tel submitted the following cost figures in the 1982 Canadian Radio and Telecommunications

Commission (CRTC) Phase III Cost Enquiry[1]. Local calls within British Columbia were known to cost one dollar and ninety-two cents for every one dollar of revenue generated, while long distance calls cost thirty-four cents for every dollar of revenue. As a consequence of the release of these cost figures there has been significant pressure brought to bear on government regulators to allow competition in the long distance market. After watching the competition scenario unfold in the United States, Canadian regulators have postponed competitive entry into the long distance market within Canada until telephone rates are substantially rebalanced to reflect the costs of providing service. Canadian regulators are seeking to avoid the massive increases in local charges which occurred in some United States jurisdictions.

The first step in this restructure process began on July 1, 1987 with a 10 percent reduction in Trans-Canada message toll rates. This has been followed by Intra B.C. rate reductions of 19 percent in April 1988 and an additional 7.2 percent in July 1988. To properly understand the impacts of the reduction of message toll rates, B.C. Tel must be able to measure telephone demand. The price elasticities identified by the demand equation(s) are used by B.C. Tel as a method to assess the financial impacts of these price changes.

The purpose of this thesis is to model, for the intra-B.C. market, telephone or message toll demand. The approach that will be used departs significantly from past research. The model specification which ultimately wins acceptance employs substantially amended empirical definitions for all key explanatory variables. In addition

1 CRTC. Telecom Decision 86-516, 28 August, 1986

to the many changes in the accepted econometric model a more rigorous and formal diagnostic testing regime has been followed. The necessity for this increased testing has been expressed by Taylor (1981):

> "Since many of the econometric models of telephone demand are used in rate filings, the basic canons of econometrics need to be given a great deal of attention, for otherwise the results of the models, may be challenged on the grounds that proper econometric and statistical procedures have not been followed. Econometricians take many things for granted much of the time; to do otherwise would be tedious, repetitive and time-consuming. However, the people that ultimately have to be convinced at rate filings are not other econometricians, but rather people who may have little understanding or appreciation of econometric procedures. As a consequence, laxity and possible errors in procedure can be made to seem much more important than they in fact are."[2]

In the case of B.C. Tel, the CRTC holds public rate hearings to determine appropriate tariff or price changes. During the 1970's these hearings were an arena to exchange information. Since 1982, there have been a significant number of intervenors who would like to enter the telecommunications industry in a competitive manner. Each of these intervenors has either a resident or consultant econometrician whose job it is to debunk studies produced by telephone companies. This hostile criticism is very effective in undermining sound research given that the results are being presented to people who have no econometric background. To rebut such criticism it is necessary to test the model specification as rigorously as possible.

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2 Lester Taylor, "Problems and Issues in Modeling Telecommunications Demand," Conference on Telecommunications in Canada, March 1981 p.31.

The major goal of this research is to estimate, as accurately as possible, the price and income elasticities of demand for toll calling within British Columbia. To accomplish this many model specifications will be examined and the results tested.

As background to these efforts, Section II of this thesis will provide the reader with a review of the theory of telephone demand. It identifies the need to analyze demand at a highly disaggregated level while keeping in mind the characteristics of toll calling. Section III reviews the literature on telecommunications demand in Canada and analyzes how other researchers dealt with the problems of variable and model specification. Building on Sections II and III, a database is developed in Section IV while Section V specifies the econometric model which will be used to estimate long distance demand. Section VI presents the results of the estimation procedure and its diagnostic tests. The conclusions are contained in Section VII.

SECTION II - THEORETICAL REVIEW

Before we can proceed with an empirical analysis of demand for long distance calling, a review of the theoretical underpinnings of the subject is required.

Until the 1980's little research had been completed in the area of telecommunications other than studies commissioned or conducted by the telephone companies themselves. Since the primary objective of these studies was to justify rate increases, little more than a cursory mention was made of the underlying theory. During the 1980's, competition, or at least the threat of competition in Canada, has galvanized the Telephone Companies to revisit their past studies, and embark on theoretically sound research programs.

There are two underlying sources of demand for telephone services. The residence consumer's demand has its foundation in utility theory while the business customer's demand is determined by its production function.

For the individual, the use of the telephone, like the use of any other good, confers utility. The choice of how much to consume is dependent on the satisfaction derived from the good in relation to all the other goods which make up the individual's utility function. Demand functions for the goods identified in the individual's utility function result from solving the utility maximization problem subject to a budget constraint.

A firm's primary goal is to generate profits for its owners. This is accomplished by turning lower priced inputs into higher outputs. Economists analyze this process by constructing an abstract model of production. Unlike the individual's utility function, the choice of inputs in a production function are not determined by satisfaction derived, but by identifying the maximum output for a specific set of inputs. The production function identifies a given quantity which can be produced and provides a constraint on the firm's cost function. A firm minimizes costs subject to a production constraint. By minimizing costs the firm ensures it maximizes its profits.

There are, therefore, two underlying bases for telephone demand: utility maximization subject to a budget constraint or; cost minimization subject to a production constraint. This distinction means that when we undertake empirical analyses of telephone demand, we must separate calls by customer class. Until recently, separation by customer class did not occur in the majority of telephone demand studies. There has been a general reliance on the utility based theory of household behavior (residence demand) as the standard in telecommunications analysis. Given the different types of telephone demand this is inappropriate. The reason so many studies have committed this error appears to have been a lack of disaggregated data, but without this disaggregation, we can not accurately analyze long distance telephone demand.

According to the telephone industry a long distance phone call (generally referred to as a toll call) has seven inherent dimensions[3]. A customer's decision to pick up the telephone and place a call is governed by these dimensions or characteristics. Consequently, the seven characteristics play an important role in the determination of telephone demand and are required in order to formulate

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3 Taylor (1981).

the independent variables of the demand equation. The seven dimensions or characteristics are:

- o The originator's customer class (residence or business);
- o The duration of the call - substitutional aspects;
- o The service mode - (e.g. direct dial);
- o The hour of the day and the day of the week;
- o The length of haul (distance travelled);
- o The reach in terms of network jurisdiction - intra-provincial, interprovincial, or international; and
- o Call externalities.

II.1 Originator's Customer Class

There are two classes of customers which make telephone calls, residence and business. The decisions of each of these customer classes are determined by their utility and production functions respectively.

Since the two customer classes which originate toll calls do so under different constraints, two separate demand functions need to be specified. As will become evident from our analysis of toll calling characteristics, customer class disaggregation provides us with a starting point from which we can analyze the remaining six dimensions. From the perspective of the telephone company, separation by customer class is necessary in order to develop tariff's, for all telecommunications services.

II.2 Duration of the Call

The duration of a long distance telephone call has important theoretical implications and clarifies the requirement to specify two separate demand functions for residence and business customers.

It is reasonable to postulate that an individual will have differing tastes with respect to call duration depending on the circumstances of the call. If the individual is a residence customer, a long distance telephone call fills the need to communicate and to socialize. The majority of long distance calls the residence customer places are to people known prior to the call. There is, therefore, less pressure to focus the conversation. Because of this lack of focus, there is the opportunity for numerous digressions during the call, which adds to the duration. Even without digressions, people talk longer to people they know than those they do not.

If the same individual is at work he becomes a business customer and his calling characteristics, including call duration, change. Business customers use the telephone to communicate. They place long distance calls for a specific purpose. Even when the call is placed to a party they know, there is less digression. The long distance calls are focussed and only last long enough to extract the required information.

If we aggregate the individuals above, by their respective customer classes, there emerges a clear delineation in call duration which, in turn, justifies that different demand functions be estimated. Studies of call duration conducted by B.C. Tel show that the average duration of a business call is between 3 and 5 minutes. Residence long distance calls were shown to have an average call duration of between 5 and 7 minutes.

II.3 Service Mode

There are four types of service mode by which a customer can place a toll call. The four service modes are as follows:

- Direct Distance Dialling (DDD);
- Station Operator Handled (SOH);
- Person to Person (PTP); and
- Third Number Billing (3NB).

The service modes are an integral part of the demand function specification. All four service modes provide the same service (toll calling) but at varying costs to the user. Because of this "sameness" the service modes act as substitutes for each other.

Analysis of the data shows that the most common service mode is Direct Distance Dialling (DDD). Within the province of British Columbia DDD accounts for 94% of total long distance calling. Station Operator Handled (SOH) calling is the next most common service mode accounting for approximately 5% of total calling. The remaining two service modes Person to Person (PTP) and Third Number Billing (3NB) account for the remaining 1%.

Service modes differ only with respect to operator intervention and price. Given that society has no obvious prejudice against operators it can be inferred that price plays a significant role in the customer's service mode decision. This also means that we must specify separate demand functions by service mode.

Unlike call duration, which was affected by customer class, service mode is not. This is interesting since existing research into telecommunications demand has argued that business customers are less price sensitive than residence customers.[4] Analysis of British Columbia data contradicts this.

II.4 Hour of the Day, Day of the Week

Hour of the day and day of the week along with service mode play a significant role in the pricing structure used by the telephone company. It makes sense for telephone companies to alter prices according to the time of day and day of week since the long distance telephone network is designed to meet peak load demand. Higher prices during the peak load period allow telephone companies to "smooth-out" the peaks. This helps the companies avoid unnecessary capital investment. If we look at the telephone companies' tariffs they appear to be in accordance with the principles of marginal cost pricing (day/evening/late-night/and weekday/weekend differentials, and as we have discussed a lower charge for direct dialing as compared to other service modes). Another rationale for the pricing strategy is that the structure can be used to subsidize local service.

The demand function that is specified must take into account the hour of the day and the day of the week. If we think of the residence customers utility function, it becomes clear why disaggregated data is needed. The residence customer tries to maximize utility subject to a budget constraint. Since long distance calls are exactly the same, no matter what time they are made, one would expect the choice of calling to be governed by the need to

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4 S. Bozman, "Intra B.C. Long Distance Telephone Demand Price Elasticities - An Empirical Investigation", Unpublished Master's Thesis, University of Victoria, 1983.

maximize constrained utility. Business customers, who are maximizing output under cost constraints, should alter their calling by time of day, day of week, however, the hours most firms keep often prohibits this.

II.5 Length of Haul (Distance Travelled)

The length of haul of a telephone call is of interest because of its influence on call duration, price and substitutes. Each of these dimensions has direct bearing on the specification of the demand function and each will be examined separately.

Call duration, which is, as we have already discussed, affected by the call class is also affected by the length of haul. Calling statistics at B.C. Telephone show that calls occurring within British Columbia are, at an aggregate level, 5.3 minutes long. Calls placed to Alberta average 9.5 minutes while calls placed to the rest of Canada are 9.6 minutes long on average. Residences or businesses are likely to call friends, relatives or suppliers located within the province more frequently than those located outside the province. Given that calls are placed more frequently, call duration is shorter.

Price is also dependent on the length of haul. The duration component of the multi-part tariff varies directly with distance.

Substitutes also play a more important role the longer the distance a telephone call must travel. The natural substitute for a telephone call is a letter. Unlike a long distance call, the cost to send a letter within Canada does not vary with distance. At some point consumers make a choice between placing a telephone call and sending a letter. This choice is influenced both by price and time. Since the cost of a telephone call varies with distance and a letter sent in the post does not, there is likely to be a cross over point where the cost saving is traded off with time. Time in this instance has two components. First, the time it takes the letter to travel from the sender to the receiver and, secondly, the time it takes to write the letter. When specifying our econometric model we must therefore consider the influence of these substitutes.

II.6 **Network Jurisdiction**

Network jurisdiction is important in this thesis only from the point of view that it provides a boundary to the data set. In Canada there are only three network jurisdictions; intra-provincial calls, which originate and terminate within the borders of the province; interprovincial calls, calls which originate in one province and terminate in another province; and international calls, which originate within a province and terminate outside of Canada.

This thesis confines itself to analyzing intra-provincial toll calling, since it is the single most important market to B.C. Telephone and because over 70% of the toll calls made originate and terminate within the province.

II.7 **Call Externalities**

Call externalities play an important role in the analysis of telecommunications demand in general and long distance calling in particular. In order to complete a telephone call the participation of at least two parties is required. Each party involved in a telephone call, therefore, has utility affected. Whether or not the party that is being called benefits from the exchange is not relevant to the analysis. What is important is the fact that the completed call necessarily impacts on the called party and an externality is created.

A second type of externality results from new subscribers connecting to the telephone network. A benefit is conferred to all existing subscribers of the network because the number of telephones that can be reached is increased. This type of externality is called an access (or system) externality, whereas, the first externality described is a call (or use) externality.

In terms of the demand function, externalities are important because they affect the residence customers utility which in turn influences demand. The same arguments can also be made when we look at the business customers production function. Call externalities must therefore be incorporated into our demand function specification.

Ideally, the model that is developed will recognize the inherent dimensions in telephone demand. This will require that a highly disaggregated model be specified. A review of the literature will provide information on how disaggregation was accomplished by other researchers as well as possible model specifications and variable definitions.

SECTION III - LITERATURE REVIEW

Literature on telecommunication demand is almost non-existent prior to 1970. During the 1970's, particularly after the OPEC crisis generated widespread concern about monopoly pricing, academics and researchers within the telecommunications industry began their first investigation into the determinants of telephone demand. An excellent overview of the different approaches used during the 1970's is provided in Lester Taylor's (1980) book. The major conclusion that can be reached from the early research into telecommunications demand is that demand is sensitive to price changes.

As background to this analysis, it is necessary to review the Canadian literature on telecommunications demand. Given the different market structure of Canada and the United States, together with the different regulatory environment, the results of most U.S. studies are not directly applicable to Canadian situation. An appropriate starting point is the pioneering work conducted by E.A.J. Dreessen as described in three studies conducted between 1976 and 1979.

The Demand for Intra-B.C. Toll Calling - A Preliminary Report - July, 1977. E.A.J. Dreessen.[5]

The objective of Dreessen's first analysis was primarily to establish that telecommunications demand, within the Province of British Columbia, was subject to the

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5 E.A.J. Dreessen, "The Demand for Intra-B.C. Toll Calling - A Preliminary Report", British Columbia Telephone Company, July 1977.

laws of economic in the form of price elasticity. No specific econometric models were established in this paper, however, relationships were drawn between economic variables such as Gross Provincial Product (GDP) and toll calling, and the issues of market segmentation and mileage bands were discussed.

This paper can be viewed as the cornerstone on which the current research in Canada is based.

Aggregate Demand for L-D Intra B.C. Calling: Estimates and Forecasts, 1971-1977. E.A.J. Dreessen, 1978.[6]

Market and Time Period

Dreessen's second excursion into telecommunications demand was written in 1978. This paper was one of the first attempts to build a demand model for intra-provincial toll calling, on a level disaggregated enough to provide information for rate policy decisions. The intra-British Columbia long distance calling market, over the July, 1971 to September, 1976 time period, was examined. Seasonally adjusted monthly data was used.

Five models were presented in this paper. The models were:

- A log linear model;
- A log linear model with a Koyck lag on the dependent variable;

6 E.A.J. Dreessen, "Aggregate Demand for L-D Intra-Provincial Calling: Estimates and Forecasts 1971-1977", British Columbia Telephone Company, 1978.

- o A log linear model with first differences on both the dependent variable and the independent variables;

- o A log linear autoregressive model with lags of up to two years on all variables; and

- o A log linear flow adjustment model.

Each model employed essentially the same variables, but differed in their inter-temporal relationships. The residential, business and total market demand functions were calculated separately.

Variables

For any variable the subscript "t" is used to denote time. The variables employed by Dreessen were the following:

The dependent variable in all five models is the logarithm of the number of conversation minutes per station (a station is basically a telephone). In the case of residential demand, residential stations are analyzed, likewise for the business and total stations equations.

LDEPRMS = Log of minutes per residence mainstation.
LDEPBMS = Log of minutes per business mainstation.
LDEPTMS = Log of minutes per total mainstation.

Explanatory variables were:

LPRES71	= Log of residence toll revenue per minute, divided by Vancouver's CPI to yield log of real revenue per minute in 1971 dollars.
LPBUS71	= Log of business toll revenue per minute, divided by Vancouver's CPI to yield log of real revenue per minute in 1971 dollars.
LPTOT71	= Log of total toll revenue per minute, divided by Vancouver's CPI to yield log of real revenue per minute in 1971 dollars.
LPDI71	= Log of per capita personal disposable income in British Columbia, divided by Vancouver's CPI (1971=100).
LGPP71	= Log of gross provincial product per capita in 1971 dollars.
LLOCR71	= A local service price index for residence customers.
LLOCB71	= A local service price index for business customers.
LLOCT71	= An weighted average local service price index in 1971 dollars.
NETPERF	= A network performance index measuring the absence of blockages and failures in Direct Distance Dialling (DDD) traffic.
TRAFFIC	= The number of person-day traffic office positions or operators affected by the 1973 telephone strike.
POSTAL	= A dummy variable for the 3 month postal strike which occurred in 1975.
LADV71	= Toll calling advertising expenditures in the British Columbia market divided by the CPI.
PHOPOW	= The number of person-months in the "phone power" or business long distance/equipment sales force.

LPL71 = The monthly charges for intra provincial private line services, divided by CPI (1971=100).

OKTEL = A dummy variable for the four month Okanagan Telephone strike which occurred in 1973.

Equations.

The general forms of the estimated equations are presented below. For each of the general forms three separate demand functions were calculated, one for residence demand, one for business and one for total intra-provincial toll calling demand. Only the total intra-provincial toll calling equations are presented.

i) The log linear model.

In the paper, Dreessen first specified a log-linear model. The dependent variable was the log of minutes per station, the independent variables were taken from the list specified above. The major drawback of the log-linear form is that no inter-temporal relationships are allowed. This means that all adjustments in the dependent variable are assumed to take place within a month.

$$LDEPTMS_t = b_0+b_1LPTOT71_t+b_2LGPP71_t+b_3LLOCT71_t+b_4NETPERF_t +b_5OKTEL_t+b_6POSTAL_t+b_7TRAFFIC_t+b_8LADV71_t+b_9PHOPOW_t +b_{10}LPL71_t+e_t$$

ii) The log linear model with a Koyck lag.

As an alternative to the log-linear form, Dreessen's second specification, a "Koyck model" allows for intertemporal changes. The problem with the Koyck model is that a simplifying assumption, with respect to the lag structure, is imposed. The Koyck model assumes that all variables follow the same geometrically declining lag structure.

$$LDEPTMS_t = b_0+b_1LDEPTMS_{t-1}+b_2LPTOT71_t+b_3LGPP71_t+b_4LLOCT71_t +b_5NETPERF_t+b_6OKTEL_t+b_7POSTAL_t+b_8TRAFFIC_t +b_9LADV71_t+b_{10}PHOPOW_t+b_{11}LPL71_t+e_t$$

iii) The log linear model with first differences.

The third model estimated transforms the variables into first differences.

$$\begin{aligned} LDEPTMS_t-LDEPTMS_{t-1} = \ & b_0+b_1(LPTOT71_t-LPTOT71_{t-1}) \\ & +b_2(LGPP71_t-LGPP71_{t-1}) \\ & +b_3(LLOCT71_t-LLOCT71_{t-1}) \\ & +b_4(NETPERF_t-NETPERF_{t-1}) \\ & +b_5(OKTEL_t-OKTEL_{t-1}) \\ & +b_6(POSTAL_t-POSTAL_{t-1}) \\ & +b_7(TRAFFIC_t-TRAFFIC_{t-1}) \\ & +b_8(LADV71_t-LADV71_{t-1}) \\ & +b_9(PHOPOW_t-PHOPOW_{t-1}) \\ & +b_{10}(LPL71_t-LPL71_{t-1})+e_t \end{aligned}$$

iv) The log linear autoregressive model.

Dreessen does not provide a mathematical description of this model, however, within the text of this paper Dreessen states that all variables are transformed by taking partial differences. The autoregressive parameters used are derived from the error term of the untransformed equation. The same autoregressive parameters are used to transform every variable. For the total market equation, Dreessen used a 5 month lag, for the residence equation a 24 month lag and for business a 1 month lag.

v) The log linear flow adjustment model.

The fifth general model estimated is a flow adjustment model.

$$\begin{aligned} LDEPTMS_t = \; & b_0+b_1 LDEPTMS_{t-1}+b_2(LPTOT71_t+LPTOT71_{t-1}) \\ & +b_3(LGPP71_t+LGPP71_{t-1})+b_4(LLOCT71_t+LLOCT71_{t-1}) \\ & +b_5(NETPERF_t+NETPERF_{t-1})+b_6 OKTEL_t+b_7 POSTAL_t \\ & +b_8 TRAFFIC_t+b_9(LADV71_t+LADV71_{t-1}) \\ & +b_{10}(PHOPOW_t+PHOPOW_{t-1})+b_{11}(LPL71_t+LPL71_{t-1})+e_t \end{aligned}$$

Analysis of Results

Dreessen calculates price and income elasticity results for each general model identified above for the residence,business, and total markets. Table 1 presents this information.

TABLE 1

Dreessen Model Estimates

		LOGLIN	KOYCK	FIRDIF	AUTO	FLWAD
P^e *	Res	-1.270	-1.181	-0.604	-1.296	-1.101
	Bus	-1.010	-1.088	-1.386	-1.029	-0.922
	Tot	-0.991	-0.950	0.569	-1.124	-0.879
Y^e **	Res	-0.454	0.323	-0.207	0.246	0.560
	Bus	0.653	0.627	-0.899	0.690	0.749
	Tot	0.424	0.431	-0.543	0.472	0.581

* P^e Stands for Price Elasticity.

** Y^e Stands for Income Elasticity.

The results show that the price elasticity for toll service is slightly elastic, whether the residential, business or total market segments are examined. Dreessen does not discuss the income elasticity results in any way, however, the results show that most model specifications find that toll service is a normal good.

One of the problems with this paper is that too many explanatory variables are used in the model. For example, phone power sales force and toll advertising expenses are nearly perfect substitutes for one another in that they are both used to stimulate toll calling. Both the signs and significance of the coefficients of these variables change drastically between equations, indicating the presence of multicollinearity.

Another source of multicollinearity is the use of both a local service price index and toll price index. Although not stated explicitly in the analysis, the theoretical development means that the consumer of toll services is constrained to work within a fixed budget. Since access to the local telephone network is required to make a toll call, Dreessen concludes that both a local and a toll price are needed. This conclusion is in error given that by expressing all the price variables in real terms, the price relationship between local and toll services has already taken into account.

Elasticity is...: A Disaggregated Analysis of Intra-B.C. Toll Calling. E.A.J. Dreessen, 1979.[7]

Market and Time Period.

Dreessen's final investigation into the determinants of toll calling within British Columbia is described in his 1979 paper. The market analyzed is this study is the intra-British Columbia toll market. The time period covered is January, 1973 to December, 1978. The data was seasonally adjusted using the Census X-11 seasonalization package.

No equations are specified in this paper, however, the flow adjustment model used is described in detail in Dreessen 1978. The major difference between this paper and Dreessen's earlier work is that mileage bands and market segments are now used. In fact, sixty market segments were identified. This greater level of disaggregation is an improvement over earlier work.

The market segments used by Dreessen were the following:

- residence direct distance dialling, Monday through Friday, daytime;
- residence direct distance dialling, Monday through Thursday, evening;
- residence direct distance dialling, Friday evening;
- residence direct distance dialling, Saturday, daytime;

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7 E.A.J. Dreessen, "Elasticity is...: A Disaggregated Analysis of Intra-B.C. Toll Calling", British Columbia Telephone Company, 1979.

- o residence direct distance dialling, Sunday, daytime and evening;
- o residence direct distance dialling, Saturday, evening;
- o residence direct distance dialling, Monday through Sunday, late night;
- o residence, station operator handled, Monday through Friday, daytime;
- o residence station operator handled, Monday through Friday, evening;
- o business, direct distance dialing, Monday through Friday, daytime;
- o business, station operator handled, Monday through Friday, daytime; and
- o business, person to person, Monday through Friday, daytime.

For each of the listed market segments five mileage bands were examined:

- o 0 to 10 miles (mileage band A);
- o 11 to 25 miles (mileage band B);
- o 26 to 50 miles (mileage band C);
- o 51 to 100 miles (mileage band D); and
- o 101 to 870 miles (mileage band E).

Variables

For each market segment the dependent variable is the logarithm of the number of conversation minutes per station. To differentiate the variables subscripts will be used, "k" stands for the market segment of interest, while "t" denotes time.

$LDEPMS_{t,k}$ = Log of minutes per mainstation for market segment k.

The explanatory variables were:

$LPRIC71_{t,k}$ = Log of toll revenue per minute for market segment k, divided by Vancouver's CPI to yield log of real revenue per minute in 1971 dollars.

$LPDI71_t$ = Log of per capita (15 years and older) personal disposable income in British Columbia, divided by Vancouver's CPI (1971=100).

$LGPP71_t$ = Log of gross provincial product per capita (15 years and older) in 1971 dollars.

$LLOCR71_{t,k}$ = A local service price index for the market segment being analyzed.

$NETPERF_t$ = A network performance index measuring the absence of blockages and failures in Direct Distance Dialling (DDD) traffic.

$TRAFFIC_t$ = The number of person-day traffic office positions or operators affected by the 1973 B.C. Telephone strike.

$POSTAL_t$ = A dummy variable for the 3 month postal strike which occurred in 1975.

$LADV71_t$ = Toll calling advertising expenditures in the British Columbia market divided by the CPI.

$PHOPOW_t$ = The number of person-months in the "phone power" or business long distance/equipment sales force.

$LWEEKPRO_t$ = Dollar expenditures on weekend toll calling promotions divided by CPI (1971=100).

$OKTEL_t$ = A dummy variable for the four month Okanagan Telephone strike which occurred in 1973.

Equations.

i) Equations for Residential Telephone Demand.

$$\begin{aligned}LDEPMS_{t,k} = {} & b_0+b_1LDEPMS_{t-1,k}+b_2(LPRIC71_{t,k}+LPRIC71_{t-1,k}) \\ & +b_3(LPDI71_t+LPDI71_{t-1}) \\ & +b_4(LLOCR71_{t,k}+LLOCR71_{t-1,k}) \\ & +b_5(NETPERF_t+NETPERF_{t-1})+b_6OKTEL_t+b_7POSTAL_t \\ & +b_8TRAFFIC_t+b_9(LADV71_t+LADV71_{t-1}) \\ & +b_{10}(PHOPOW_t+PHOPOW_{t-1}) \\ & +b_{11}(LLWEEKPRO_t+LWEEKPRO_{t-1})+e_t\end{aligned}$$

ii) Equation for Business Telephone Demand.

$$\begin{aligned}LDEPMS_{t,k} = {} & b_0+b_1LDEPMS_{t-1,k}+b_2(LPRIC71_{t,k}+LPRIC71_{t-1,k}) \\ & +b_3(LGPP71_t+LGPP71_{t-1}) \\ & +b_4(LLOCR71_{t,k}+LLOCR71_{t-1,k}) \\ & +b_5(NETPERF_t+NETPERF_{t-1})+b_6OKTEL_t+b_7POSTAL_t \\ & +b_8TRAFFIC_t+b_9(LADV71_t+LADV71_{t-1}) \\ & +b_{10}(PHOPOW_t+PHOPOW_{t-1}) \\ & +b_{11}(LLWEEKPRO_t+LWEEKPRO_{t-1})+e_t\end{aligned}$$

Analysis of Results

Using the flow adjustment equation, coefficient b_2 estimates the long run price elasticity of telephone demand while long run income elasticity is measured by b_3.

The author suggests that the results were mixed. Unfortunately, no tests of significance for the regression coefficients are provided. The price elasticities for mileage bands A and B were less than zero or inelastic. For mileage bands C and D two market segments were found to be price elastic with values greater than negative 1 while the remaining market segments were inelastic. Finally, four of the twelve market segments for mileage band E were estimated to be price elastic.

The average income elasticities (referred to as state of the economy elasticities) was 3.0 indicating that toll demand is a normal good. Dreessen does not discuss the income elasticity results within his paper.

One of the surprising conclusion's of Dreessen's paper is that a Koyck model is more appropriate method of estimating telephone demand that the flow adjustment model. This conclusion is based on the statistical significance or the coefficients. Dreessen does not present any Koyck model results within his paper.

A problem in the paper is that the breakdown by mileage band is not detailed enough to make appropriate policy decisions. The last mileage band requires further disaggregation since the majority of British Columbia toll calls fall within this mileage category. This model also suffers from over specification as too many variables are included in the analysis.

Even with the problems identified this paper contributes to the literature on telephone demand in three ways: it is the first paper analyzing British Columbia toll demand to disaggregate the data into mileage bands; it is the only British Columbia study to mention the income variable; and it moves away from the flow adjustment model to the Koyck model. Although the models are over specified, Dreessen's papers are also an excellent source for variable definitions.

Intra B.C. Long Distance Telephone Demand Price Elasticities - An Empirical Investigation. Scott Bozman, 1983[8]

Market and Time Period

The Bozman paper looked at the intra British Columbia long distance calling market over a ten year time period, 1973 to 1983. Monthly data was used. The paper examined 12 market segments:

- residence direct distance dialling, Monday through Friday, daytime;
- residence direct distance dialling, Monday through Thursday, evening;
- residence direct distance dialling, Friday evening;
- residence direct distance dialling, Saturday, daytime;
- residence direct distance dialling, Sunday, daytime and evening;
- residence direct distance dialling, Saturday, evening;
- residence direct distance dialling, Monday through Sunday, late night;
- residence, station operator handled, Monday through Friday, daytime;
- residence station operator handled, Monday through Friday, evening;
- business, direct distance dialing, Monday through Friday, daytime;
- business, station operator handled, Monday through Friday, daytime; and

8 Bozman (1983).

- o business, person to person, Monday through Friday, daytime.

For each of the listed market segments seven mileage bands were examined:

- o 0 to 10 miles;
- o 11 to 25 miles;
- o 26 to 50 miles;
- o 51 to 100 miles;
- o 101 to 300 miles; and
- o 301+ miles.

The model used a double log linear specification incorporating a Koyck lag structure for the dependent variable. Zellner estimation techniques (three stage least squares) were employed.

Variables

The variables used by Bozman in his analysis are listed below. The subscript "i" denotes market segment while "j" stands for mileage band. Within the equations the subscript "t" stands for time.

Min_{ij}/RESTA	= Minutes per residential main station.
Min_{ij}/BUSTA	= Minutes per business main station.
NPDIBC	= Nominal personal disposable income for British Columbia.
RGDPBC	= Real Gross Provincial Product for British Columbia.
POPBC	= Population of British Columbia.
CPIVAN	= Vancouver consumer price index
PGDPBC	= The implicit GDP deflator for British Columbia.

REV_{ij}	=	Total revenue.
PS	=	Postal strike dummy.
TS	=	Telephone strike dummy.
DUM	=	A dummy variable for structural changes.
E	=	An error term with classical properties.

Equations

The equations estimated were as follows:

i) Equations for Residential Telephone Demand.

$$\log(Min_{i,j,t}/RESTA_t) = b_o + b_1\log(Min_{i,j,t-1}/RESTA_{t-1}) + b_2\log[NPDIBC_t/(POPBC_t x CPIVAN_t)] + b_3\log[REV_{i,j,t}/(Min_{i,j,t} x CPIVAN_t)] + b_4 PS_t + b_5 TS_t + b_6 DUM_t + E_t$$

ii) Equation for Business Telephone Demand.

$$\log(Min_{i,j,t}/BUSTA_t) = b_o + b_1\log(Min_{i,j,t-1}/BUSTA_{t-1}) + b_2\log[RGDPBC_t/PGDPBC_t] + b_3\log[REV_{i,j,t}/(Min_{i,j,t} x PGDPBC_t)] + b_4 PS_t + b_5 TS_t + b_6 DUM_t + E_t$$

Analysis of Results

Using these equations, the short run price elasticity of demand is coefficient b_3 while short run income elasticity is measured by b_2. In each case, long run elasticities are calculated by dividing the short run coefficient by one minus the coefficient on the lagged dependent variable (b_1). This is a standard Koyck transformation. Only the models' price elasticity results were presented in the paper. The income elasticity results were neither listed nor discussed.

Generally, Bozman found that short run price elasticities were less than one. Long run price elasticities were generally greater than one. The aggregate price elasticity for the intra-B.C. market was found to be -1.3. This figure was derived by revenue weighting the individual market segments.

Bozman's analysis contains several weaknesses which ultimately undermine the accuracy of his results.

The first problem is that GDP is erroneously double deflated in the business equations ($RGDPBC_t/PGDPBC_t$). Consequently, the business equation price elasticities are significantly biased in an upwards direction. The net affect of this bias is that the intra-B.C. aggregate price elasticity is incorrectly found to be greater than one.

A second major problem is the specification of the income variable. Both the dependent and price variables use a per capita form. However, an income variable is chosen which is inconsistent with this per capita specification. The use of such a variable invalidates the comparisons made between the results of this paper and those of previous B.C. Tel studies.

Another problem with the paper is that the market size variable is restricted to equal one without testing the appropriateness of this hypothesis. Setting the coefficient on mainstations equal to one means that a new telephone can only make calls, not receive them. This is obviously incorrect. No restriction should have been placed on the market size variable.

The final problem with the paper is the specification of the price index. The price index is a proxy for the actual tariffed price of a call. The price index is defined as real revenue per mainstation. The major problem here is that the mileage bands used by the study aggregate different tariff schedules and thus a very imprecise measure of price is generated.

The Welfare Implications of Externalities and Price Elasticities for Telecommunications Pricing. J.M. Griffin, 1980.[9]

Market and Time Period

While this paper cannot be labelled "Canadian research" it is one of the first papers to address the importance of market size. For this reason the paper is as important to the Canadian study of telecommunications demand as it is to the study of the subject in the United States. Unlike most of the studies done in the 1960's and 70's, which were either pure time series or cross sectional studies, the data set for this study was pooled quarterly seasonally adjusted data, time period 1966 to 1978, for five south western states.

Griffin asserts that his analysis of long distance demand offers a more robust data set source than previous

9 J.M. Griffin, "The Welfare Implications of Externalities and Price Elasticities For Telecommunications Pricing", Review of Economics and Statistics, No. 59, pp. 59-66, 1982.

national interstate demand studies because there is more price variation. The pooled model features, for the first time in the telephone demand literature, distributed polynomial lags. The study also uses the model's error structure to correct for both autocorrelation and heteroskedasticity.

A log linear model was used to estimate the coefficients. Polynomial lags on selected independent variables were incorporated. The model did not disaggregate the data by mileage band or customer class.

Variables

The dependent variable of Griffin's model is Q_t or the number of toll messages.

The model used four independent variables plus an error term. The subscript "t" is used to denote time while "k" stands for the lag length. The independent variables are:

Y_{t-k} = Income with a polynomial lag;

N_t = The population of the respective states;

$(P_{mts}/P_{cpi})_{t-k}$ = The real price of message toll service with a polynomial lag;

A_{t-k} = An advertising variable with a polynomial lag.

In Griffin's opinion, a unique feature of the model is its use of a "superior" measure of television advertising effects. This measure is an index of gross ratings points reflecting the actual frequency with which television advertising is viewed by the public. The use of gross ratings points avoids the serious multicollinearity and serial correlation problems associated with the use of advertising expenditures to measure the impact of advertising.

It is not clear that an advertising variable is required in an intra-provincial toll calling model. Telephone and toll call advertising is more prevalent in the United States due to deregulation.

Equations

The equation used by Griffin can be represented as follows:

$$LnQ_t = b_0 + \Sigma b_{1k} lnY_{t-k} + b_2 lnN_t + b_3 (lnN_t)^2 + \Sigma b_{4k} ln(P_{mts}/P_{cpi})_{t-k} + \Sigma b_{5k} lnA_{t-k} + e_t$$

Analysis of Results

It is Griffin's view that the structure of this equation captures the effects of price, income and advertising on telephone demand.

The use of lnN and $(lnN)^2$ is the result of the paper's assertion that the number of long distance phone calls is not an independent entity. Telephone calls depend on a party being called. There are N subscribers, and when a subscriber is on the phone he or she can call N-1 other people. This means that the number of possible calls are N(N-1). In order to account for the declining probability of calls with the expansion of the calling network, Griffin manipulates this term into the expression $lnN + (lnN)^2$.

The data used in the model was preconditioned to ensure the statistical acceptability of the results. Griffin choses generalized least squares (GLS) to estimate telephone demand. By using GLS and by checking the error term, Griffin ensured that the estimators are unbiased and heteroskedasticity or autocorrelation problems are corrected. He also presents, in an abbreviated form, some Ordinary Least Squares results.

A polynomial lag structure was constructed for the real income, price and advertising variables. In each case a second degree polynomial lag was used, with a constraint that the far endpoint equalled 0. The preferred lag distribution was 8 quarters, on each variable.

This study estimated that the long run price elasticity of interstate message toll service was -0.6. The long run income elasticity for long distance messages was estimated to be +1.32. The advertising variable was also significant although its coefficient, at -0.026, was very small.

The OLS price elasticity estimate of -0.56, was not a dramatic change over the GLS estimation. Comparing the two results, both are robust and consistent with respect to lag length. If confidence intervals are examined, it can be said that the results are the same.

A weak point of the Griffin analysis is that a proxy is used to estimate the number of telephone stations or lines. The proxy chosen was population or N. The use of population seriously overestimates the number of mainstations or telephones in the system. For example, a household consisting of four family members would probably have a single telephone line (i.e. a single telephone number). By using population the paper assumes that the same household has four separate lines.

The estimate of the effect of the market size variable (11.3), using the population proxy, was also inconsistent due to significant multicollinearity between the lnN and $(\ln N)^2$ terms. It should be stressed however, that the introduction of the market size variable, to capture externalities in long distance telecommunications, is a major contribution to telephone demand analysis.

Another weakness of the study is that data is pooled across U.S. states. Given differences between the states in terms of population size, income profiles, tariffs and calling characteristics, data pooling is of questionable appropriateness. Certainly, it is inappropriate for Canada.

The final problem the analysis is that when using quarterly data, the 1966 to 1978 period is not very long. Monthly information gives a much larger data set size and makes the results more robust.

B.C./Alberta Long Distance Calling. A. de Fontenay and J.T. Marshall Lee, 1982.[10]

Market and Time Period

This paper is important for this thesis in that it looks at alternative model specifications for the British Columbia /Alberta market. The work is also interesting in that it contends that other studies have used

10 A. de Fontenay, J.T. Marshall Lee, "B.C./Alberta Long Distance Calling", Economic Analysis of Telecommunications: Theory and Applications, (Amsterdam, 1983).

a double log linear model specification without testing its appropriateness.

The market that is being analyzed is British Columbia to Alberta calling, for the daytime residence, DDD, Monday through Friday market segment. The data is quarterly 1973 Q1 through 1979 Q4.

For the single market segment seven mileage bands were examined:

- 0 to 20 miles;
- 21 to 80 miles;
- 81 to 180 miles;
- 181 to 290 miles;
- 291 to 400 miles;
- 401 to 500 miles; and
- 500 + miles.

Variables

The variables used in this analysis are similar to those found used in Dreessen. The dependent variable $Q_{i,t}$ is minutes of calling per residence mainstation, where i stands for the mileage category and t for time.

The independent variables are as follows:

$P_{i,t}$	= Price.
Y_t	= Per Capita Income.
S_{1t}, S_{2t}, S_{3t}	= Seasonal dummy variables used to adjust the data.
PS	= Postal Strike.
OKTS	= Okanagan Telephone strike.
BCTS	= B.C. Telephone strike.

Equations.

The estimating equation developed in the de Fontenay and Lee paper is a translog demand function specified as:

$$\begin{aligned}\ln Q_{i,t} = {} & \Sigma_j\ \alpha_{i,j}\delta_{i,j} + \alpha_p \ln P_{i,t} + \alpha_y \ln Y_t + \beta_{p,y} \ln P_{i,t} \ln Y_t \\ & + 1/2\beta_{p,p}(\ln P_{i,t})^2 + 1/2\beta_{y,y}(\ln Y_t)^2 + a_1 S1_t \\ & + a_2 S2_t + a_3 S3_t + a_4 OKTS_t + a_5 BCTS_t + a_6 PS_t + u_{i,t}\end{aligned}$$

where $_j$ and $_i$ = 1,2, ... ,7

Analysis of Results.

This paper finds that the demand for long distance service is price sensitive. Price elasticities presented in the paper average -1.5 while income elasticities average 2.0.

The use of the translog demand function adds little to the analysis of telephone demand since the double log linear demand model produces comparable results. Therefore, for reasons of simplicity and parsimony the translog demand model will not be considered for use in this thesis.

The paper contains a problem with the market size variable. The lead of all earlier B.C. Tel studies was followed in that the market size variable and call externalities were dealt with by dividing the dependent variable by the number of mainstations. Mainstations were excluded as an independent variable. This procedure means that the market size coefficient is constrained to equal 1. De Fontenay and Lee noted that this assumption required testing. Unfortunately, no empirical justification for the market size specification is presented. If de Fontenay and Lee had conducted the appropriate tests they would have included market size as an independent variable to account for the network externalities that are inherent in the telecommunications system.

One important aspect of this paper is that it identifies, for the British Columbia/Alberta market, the importance of the income variable. The coefficient on income is approximately 2, meaning that a 1% increase in real personal disposable income would lead to an estimated increase of 2% in toll calling volume in the B.C./Alberta market.

A major weakness of this model is that quarterly data is used. This means that there are only 28 data points available for each of the 7 market segments. This is a relatively small sample size. Even if the coefficient values are significant the confidence intervals surrounding these estimates are sufficiently large that sound policy decisions can not be made.

Intra-B.C. Toll Demand Elasticities - Update: 84:02. D.G. Easton and R. Scott, 1984.[11]

<u>**Market and Time Period**</u>

This study revised the data set developed in the Bozman paper. In particular, the data series originating from the provincial government were updated and modified

11 D.G. Easton, R. Scott, "Intra-B.C. Toll Demand Elasticities - Update: 84:02", British Columbia Telephone Company, 1984

given revisions by the source. The paper also attempted to correct some of the obvious deficiencies of the earlier study. For example, the business equations were re-estimated without the double deflation of GDP, while the income variable used a per capita specification. The Easton/Scott study was also the first analysis by B.C. Tel to capture the importance of market size.

Five separate models were considered for use with the revised data, all of which incorporated the system/call externalities in an unconstrained manner. Ultimately the double log linear specification with the Koyck lag structure for the dependent variable was utilized. Zellner estimation techniques were used to calculate the coefficients.

Variables

The variable list used in this paper is identical to that used by Bozman[12], with the exception of the market size variable, and is described in detail in the preceding section.

The market size variable is:

MAIN = Total number of mainstations (total number of telephones excluding extensions).

Equations

The equations estimated were as follows:

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12 Bozman (1983).

i) Equations for Residential Telephone Demand.

$$\log(Min_{i,j,t}/RESTA_t)=b_o+b_1\log(Min_{i,j,t-1}/RESTA_{t-1})$$
$$+b_2\log[NPDIBC_t/(POPBC_t xCPIVAN_t)]$$
$$+b_3\log[REV_{i,j,t}/(Min_{i,j,t} xCPIVAN_t)]$$
$$+b_4PS_t+b_5TS_t+b_6DUM_t+b_7\log MAIN+E_t$$

ii) Equation for Business Telephone Demand.

$$\log(Min_{i,j,t}/BUSTA_t)=b_o+b_1\log(Min_{i,j,t-1}/BUSTA_{t-1})$$
$$+b_2\log[NGDPBC_t/(POPBC_t xPGDPBC_t)]$$
$$+b_3\log[REV_{i,j,t}/(Min_{i,j,t} xPGDPBC_t)]$$
$$+b_4PS_t+b_5TS_t+b_6DUM_t+b_7\log MAIN+E_t$$

Analysis of Results

The Easton/Scott study showed that both the short and long run price elasticities of demand were inelastic at an aggregate level. The overall long run elasticity was calculated to be -.34. The coefficient on the market size variable was found to be significant and greater than one. The Easton/Scott paper did not examine the income elasticity of demand.

Econometric Models of Demand for Bell Canada Message Toll Service. M. L. Davidson, S. Iacono, G. M. Reader, (1985).[13]

Market and Time Period

This paper examined message toll service demand or long distance telephone demand within the Bell Canada

13 M.L. Davidson, S. Iacono, and G.M. Reader, "Econometric Models of Demand for Bell Canada Message Toll Service", Bell Communications Research Conference, 1985.

operating territory. This operating area includes Ontario and most of Quebec.

The paper used quarterly data for a nine year time period, 1974 to 1983 to examine two market segments and two mileage bands. The two market segments were:

- o Customer dialed peak; and
- o Customer dialed off peak.

The two mileage bands selected were:

- o 0-100 miles; and
- o 101+ miles.

A log linear model was used to estimate long distance telephone demand. An Almon polynomial distributed lag structure was used on both price and income effects. The estimation technique employed was ordinary least squares (OLS).

Variables

The variables used in this analysis are listed below. The subscript "t" denotes time.

Q_t = Quantity demanded (at time t).
P_t = Real own price.
Y_t = Real income (retail sales).
M_t = Potential toll connections.
D_{it} = i^{th} Dummy variable.
e_t = Stochastic error term.

Within this paper, price deflated revenue is used as the quantity demanded variable. This means that the dependent variable measures both the number and duration of calls.

For each service category, the authors constructed chained Laspeyres price indices to proxy nominal prices. These series were then deflated using the CPI index for Ontario and Quebec to generate the real own price variable.

The proxy used for real income was retail sales in Ontario and Quebec again deflated by the CPI. Alternatives to using retail sales as the proxy for income were investigated by the authors. Ultimately the other proxies (total wages and salaries, personal disposable income and gross national expenditures) were rejected on the basis of statistical significance.

Market size in this analysis is a measure of the interdependence of long distance calling among telephone subscribers. This paper departs from past research through its definition of the market size variable and by not restricting the regression coefficient to equal one. Basically, the variable takes into account that new telephones subscribers not only make calls but also receive them.

<u>Equation</u>

This paper used a single estimating equation which aggregated residence and business demand. The equation was as follows:

$$LnQ_t = a+\Sigma b_k lnP_{t-k}+\Sigma g_k lnY_{t-k}+dlnM_t+o_i D_{it}+e_t$$

Analysis of Results

The paper does not calculate short run price or income elasticities. The long run price elasticity of telephone demand is coefficient b_k while long run income elasticity is measured by g_k. This paper finds that the demand for toll services is price and income inelastic, however only the price elasticity results are discussed in detail.

Three separate areas of this paper are problematic. The first difficulty is the level of aggregation. The paper analyzes the demand for toll calling at a very high level of aggregation. The price elasticity calculated is therefore very imprecise when dealing with actual Bell Canada tariff schedules. Calling is dependent on the precise time of day category and the day of the week, as well as distance. The former characteristics are omitted from the model. Sound pricing decisions would require more disaggregated information.

A very serious shortcoming of this analysis is the lack of distinction between residence and business toll demand. It was identified earlier that the principles of demand underlying residence and business toll calling differ. Therefore it is inappropriate to aggregate them together in a single equation as this study has done.

Aggregating data from two provinces together is also a problem. Although Bell Canada operates in both Ontario and Quebec, the calling characteristics of each province are quite different. For example, there are different ethnic populations, different urban/rural characteristics, different income profiles and different language characteristics (French vs English). The calling characteristics of each province should have been analyzed.

Given that there are obvious problems with the paper the validity of the results is questionable. The findings are not controversial but they can not be considered accurate enough to be the basis for policy decisions.

Summary

The review of the literature provides a solid foundation for the development of an econometric model of message toll demand in British Columbia. While each study reviewed has its own set of problems the information in the papers is invaluable. Each paper provides a key piece of information which can be used in this thesis.

The models developed by Erwin Dreessen provide us with possible specifications for both the dependent and independent variables. Dreessen also reinforces the need for highly disaggregated data.

The research of Scott Bozman outlines the need for a better representation of prices while the work of James Griffin demonstrates the need to accurately represent the externalities associated with the telephone system. Griffin's use of population to represent call externalities can be viewed as one of the major advances of the 1980's.

The work of de Fontenay and Lee provides an alternative functional form for modelling. While the results are interesting they show that the double log linear model specification is as good as more complicated equations and certainly easier to interpret. The conclusion reached by de Fontenay and Lee that income is a major determinant of telephone demand is also important. This thesis will attempt to verify this conclusion.

Easton and Scott refines the work of Griffin on market size and demonstrates its importance in the context of intra-B.C. toll calling demand. They also reinforce the need for a better representation of price.

The paper by Davidson, Iacono and Reader provides an alternative to the Koyck specification for dynamic adjustment. Their use of an Almon polynomial lag structure is a first in Canada for telecommunications demand modelling.

This thesis will synthesize and enhance the telecommunications demand modelling information developed by earlier authors.

SECTION IV - DATA

IV.1 Background

Fundamental to any econometric modelling is a sound database. Without consistency and continuity of data series, meaningful econometric results will not be forthcoming.

To ensure the consistency and continuity of the data series used in this analysis, diagnostic tests were preformed on the raw data. The first analysis was simply one of data verification. The hard copies of the data series were compared with the computer data files. Secondly, the raw data series was graphed in order to look for outliers, seasonal patterns, and underlying trends.

IV.2 Time Period

The time period being analyzed extends from 1973 to 1983. The choice of this time period was made for a number of reasons. Although telephone data is available from 1971 the quality of the data is questionable. Many data gaps exist between 1971 and 1972 which draws into question the validity of using this earlier time period. Even if data was available for the 1971-1972 period it would not be appropriate to use it because of a structural shift which occurred in long distance calling. Most long distance calls made in British Columbia prior to 1973 required operator intervention as opposed to the direct distance dialling that is now available.

The 1973 to 1983 time period was also chosen because it is of sufficient length not be adversely affected by business cycles or exogenous shocks. Also it is a time period in which price changes occurred. This is critical to the analysis. Prior to 1973 long distance telephone rates changed, on average, once every seven years. During the study period six long distance price changes occurred.

The 1973 to 1983 data set provides this analysis with 132 months of data on 84 market segments, or just over 11,000 data points.

IV.3 Market Segments

The following are the market segments examined within this study.

- residence direct distance dialling, Monday through Friday, daytime;
- residence direct distance dialling, Monday through Thursday, evening;
- residence direct distance dialling, Friday evening;
- residence direct distance dialling, Saturday, daytime;
- residence direct distance dialling, Sunday, daytime and evening;
- residence direct distance dialling, Saturday, evening;
- residence direct distance dialling, Monday through Sunday, late night;
- residence, station operator handled, Monday through Friday, daytime;
- residence station operator handled, Monday through Friday, evening;
- business, direct distance dialing, Monday through Friday, daytime;

- o business, station operator handled, Monday through Friday, daytime; and
- o business, person to person, Monday through Friday, daytime.

For each market segment, seven different mileage bands are examined. The mileage bands are:

- o 0 to 10 miles;
- o 11 to 25 miles;
- o 26 to 50 miles;
- o 51 to 100 miles;
- o 101 to 300 miles; and
- o 301+ miles.

IV.4 Variables

It is apparent from the review of the telecommunications demand literature that there is a standard set of explanatory variables which should be included in any modelling of long distance demand. The core variables are; a measure of the price of the service, the price of other goods, income, a measure of the externalities associated with telecommunications and a set of dummy variables which are used to de-seasonalize the data or account for extraneous shocks. While this core set of variables is contained in all the studies reviewed, the forms of the variables are quite different.

As an example, the price variable has been defined in a number of ways. Past B.C. Tel studies have defined price in terms of real revenue per minute. This definition of price was due to the lack of an appropriate price index. This paper develops the missing price index. Another example is the definition of income. Bell Canada uses retail sales as the income measure while B.C. Tel studies have used personal disposable income. This study utilizes the retail sales approach.

There are many reasons for the different definitions of the independent variables. The most common reason for the diversity of explanatory variables is a lack of data. To overcome this problem, economists use proxy variables. There is, however, another reason for the use of proxy variables and that is multicollinearity. Multicollinearity arises because of an interrelationship amongst the explanatory variables.[14] By using a proxy variable multicollinearity is often reduced.

This thesis differentiates itself from previous work through its definition of explanatory variables. Unlike previous B.C. Tel studies a price variable based on posted tariffs is defined. This thesis also explicitly recognizes both system and network externalities through its definition of a market size variable.

One of the major difficulties in using telephone data is that it is inherently seasonal. Toll calling varies dramatically according to the number of trading or business days in a month, the season and whether holidays or special events are taking place. For example, Mother's day and Christmas day are the two busiest days in the year for telephone calling.

To eliminate seasonality within the data the D11 option of the Statistics Canada Census X-11 program was used to correct the data set. This program assumes that seasonal

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14 G. Judge et al., The Theory and Practice of Econometrics, (New York, 1985) pp. 611.

fluctuation in the original series can be separated from the trend, cyclical, trading day and random fluctuation components.

Variable List

POPBC

This monthly series for British Columbia population (in thousands) was derived from quarterly provincial population estimates provided by the Central Statistics Bureau of the British Columbia provincial government. Monthly patterns of population growth of persons 15 years of age and over (Cansim Matrix 2096, Series D769174 and Series D769181) were used to redistribute the quarterly estimates to form the monthly data series. The data series was seasonally adjusted using the Census X-11 series.

RGDPBC

The monthly series for British Columbia real gross domestic product at market price (in millions of $1971) was derived from quarterly estimates contained in the British Columbia Economic Accounts 1963-1982. Quarterly estimates for 1983 were provided by the Central Statistics Bureau. The series was redistributed using the monthly patterns of employment for persons over 15 years of age in British Columbia The source for monthly employment patterns is Cansim Matrix 2096, series D769176 and D769183. This data series was also seasonally adjusted.

NPDIBC

Quarterly estimates of nominal British Columbia personal disposable income was obtained from the Central Statistics Bureau. The quarterly series was redistributed on a monthly basis using wages and salaries in British Columbia from Cansim matrix 1791 series D5235 and seasonally adjusted using Census X-11.

VANCPI

The Vancouver Consumer Price Index used in the study is monthly in format (1971 = 100). The series is from Statistics Canada (D13367), and was seasonally adjusted.

MSTAT (Mainstations)

Residence mainstations in British Columbia were taken from B.C. Tel telephone data, company form DP186. Total monthly residence mainstations include the following: individual lines, two party lines, multi-party lines, foreign exchange lines and toll stations. A foreign exchange line allows a customer to be located in one community while having the telephone number of another community. Toll stations are located in remote communities and do not allow free local calling.

Business mainstations were also obtained from the same telephone data report and include: individual lines; measured service lines; wide area telephone service (WATS) stations; private branch exchange (PBX) stations; private area branch exchange (PABX) stations or extensions; and Centrex stations.

In 1983, Business Telecom Equipment (BTE), a subsidiary of B.C. Tel took over responsibility for a substantial number of business mainstations. It was therefore necessary to add the information on the BTE DP186 form to the B.C.Tel series to maintain consistency in the business mainstation series.

All mainstation data was seasonally adjusted using the Census X-11 program.

MIN (Minutes)

Total conversation minutes are broken down on a monthly basis by: call type (DDD & DDD equivalent); billing code (send paid, collect and special collect, credit card, and third number); customer class (residence, business, coin, British Columbia government and unidentified); day of week (weekday, Friday, weekend); and settlement (Alberta, Trans-Canada, U.S.A., intra-British Columbia and Overseas).

Conversation minutes and toll revenues were extracted from the B.C. Tel toll sample file using a toll sample analysis program (X11TSA). This program allows a number of parameter specifications to be made which enables the extraction of highly disaggregated data. The data was seasonally adjusted.

MIN/MSTAT

The dependent variable analyzed in the models is total monthly calling minutes for residence or business customers respectively divided by the number of residence or business mainstations.

PRICE VARIABLE

Past demand studies conducted at B.C. Tel have ignored details of the approved rate schedules. Instead a simple construction - average revenue per minute - has been used to depict the price of long distance calling. The problem with using average revenue per minute is that it can vary on account of random or systematic shifts in call duration, even though approved long distance rates remain constant. This problem stems from the fact that approved long distance tariffs are "multi-part" consisting of a minute and a message charge. This implies that revenue per minute falls, as the mean duration of a call increases. To remedy, or at least lessen the difficulties associated with the use of average revenue, this analysis constructs a new price measure that is based explicitly on approved tariff schedules.

The price series developed for this analysis, P_t, contains both the fixed call component P_0 and P_1 the variable component. The fixed component is that portion of the long distance call which is independent of the call duration. It is normally called a message charge and includes any minute minimum charge and any special premium such as that levied for operator handled (SOH) or person-to-person (PTP) calls. As all, or any one of these surcharges, may apply to a particular call, P_0 is a composite variable.

Limitations in the billing system complicate the construction of the price variable P_0 because any fraction of a minute is rounded to the next. The variable component P_1 is simply the per minute charge.

Since the mileage bands defined in this study typically include several rate steps, the resulting price series need to be weighted. The total number of minutes for all calls made served as the weights.

In principle one might want to include both P_0 and P_1 in the analysis as explanatory variables, however, collinearity would undoubtedly be a problem. Even though P_0 is the message charge it contains the minute charge (P_1) levied for the first minute of the telephone call.

As a further step in developing the price variable it was necessary to devise a means of combining the two price components. The method chosen to do this treats calls and minutes (beyond the first minute) as distinct goods for which the user pays P_0 and P_1 respectively. A long distance call is then a composite good consisting of an initial minute expense, which includes both the message and minute charge because of billing limitations, and additional minute charges.

By viewing the initial minute and subsequent minutes of a call as distinct goods, the expenditure devoted to, or revenue earned from each component can be analyzed in the following manner:

$$\text{(Initial Revenue)}_t = \text{Calls}_t * P_{0t}$$

$$\text{(Additional Revenue)}_t = [\text{Minutes}_t - \text{(Initial Minute)}_t] * P_{1t}$$

The resulting price index is:

$$P_t = \{[\text{(initial revenue)}_t] * P_{0t} + [\text{minutes}_t - \text{(initial minute)}_t] * P_{1t}\} / [\text{(initial revenue)}_t + \text{(additional revenue)}_t]$$

The above denominator serves as a measure of imputed revenue and not, as in the case of previous studies, actual revenue. A comparison between actual revenue and imputed revenue was conducted, the result of that comparison showed a discrepancy of just under 2%.

To limit the difficulty of developing a price index, it was decided to fix the weighting scheme in the price index equation. The weights were fixed by choosing a month that was midway between tariff revisions. The minutes of the number of calls made in that time period then served as the weights.

RSLS (Retail Sales)

Past B.C. Tel studies have used Personal Disposable Income (PDI) as a measure of income, however, the PDI series is constantly revised thus drawing into question its reliability. It was, therefore, decided to look for another measure of income and retail sales was selected. The main advantage of using retail sales is that it is available on a monthly basis from Statistics Canada, in Retail Trade Catalogue number 63-005. There are two disadvantages in selecting this series, it does not include all elements of consumption expenditure and it is not restricted to the household sector. Even with these disadvantages retail sales has been used elsewhere[15] and it is reasonable to think that it might preform well as a predictor of intra-B.C. residential toll calling.

Since Retail Sales is not limited to the residential sector it may serve as an appropriate proxy in the business equation. Bell Canada aggregates both the residence and business markets and argues retail sales is an

15 Davidson et al., (1985).

appropriate proxy. The appropriateness of the use of retail sales in the case of B.C. Tel will be evaluated in the econometrics results chapter. All retail sales data used in the analysis was seasonally adjusted.

MKTSZE (Market Size)

This paper presents an original measure of telephone market size. In the past the total number of mainstations was used to measure market size. However, a mainstation does not always generate toll charges, for example when local calls are made. As the first step in generating an improved market size variable it was necessary to test whether calls between exchanges generated toll charges. To illustrate this, two exchanges, "i" and "j", will be used as examples. If calls from exchange i to exchange j resulted in toll charges, the total number of lines in each were multiplied together and the product added to the total number of mainstations for the mileage band which described the distance between i and j. If no toll charges resulted from a call from i to j, no addition was made to the market size variable. This process was carried out for every possible combination of exchanges in the B.C. Tel system.

Separate totals were accumulated for connections linking:

(a) only residence subscribers;

(b) residential subscribers and all others; and

(c) business subscribers and all others.

The "only residence subscriber" total or (a) was used in estimations performed for the weekend, evening and late night segments, while (b) and (c) were used for daytime. This of course assumes that the majority of businesses are open between 8 and 5, Monday through Friday.

In some cases the monthly figures used to develop the market size variable had to be interpolated from quarterly data. This is not likely to have a significant effect on the results as lagged forms of the variables will not be used in the equations. The market size variable was seasonalized using the Census X-11 program.

Postal Strike (PS)

In order to account for the exogenous shock of a postal strike, a dummy variable was formulated. The variable had the value of 1 for the duration of the strike and was 0 at all other times.

Postal service is not generally considered a close substitute for telephone service, however, it should have a positive influence on calling minutes during a postal strike.

B.C. Tel Strikes (BCTS)

A dummy variable designed to take into account the effect of a strike within the B.C. Tel system (e.g. B.C. Tel or Okanagan Telephone) was formulated. The variable had the value of 1 during a strike or 0 otherwise.

Evening Discount Change (EDCH)

During the timeframe covered by this study, a structural change to calling patterns occurred when an evening discount was introduced. The introduction of evening discounts had a negative effect on daytime calling while increasing the number of calls made in the evening. This variable has the value of 0 prior to February of 1975, when evening discounts were introduced, and the value of 1 following this date.

SECTION V - MODEL SPECIFICATION

V.1 Functional Form

The development of an appropriate model specification is, even when constructing the simplest of econometric models, a complex process. One must make judgements as to which explanatory variables should or should not be included, based on both economic theory and on a-priori information. The decision as to what functional form to specify for the equations and how the statistical fit of the model should be evaluated is determined not only by economic theory but the level of disaggregation of the data.

Although both economic theory and the literature call for highly disaggregated data, most telephone demand models that have been estimated are at a fairly aggregate level. An important strength in this paper is its level of disaggregation. Not only is the data disaggregated along customer class (residence and business) it has been disaggregated by call category and distance, as each of these defines a unique market.

In the review of the literature a number of dependent variables were specified. This thesis defines the quantity of toll calls demanded as minutes per mainstation. Minutes per mainstation times the toll price index yields the amount spent on toll calls on a per capita basis.

The review of the telephone demand theory established that the variables which affect toll calling demand do not do so in a linear manner. This was confirmed through graphing both the dependent and independent variables against time. The graphs showed a non-linear relationship which was corrected by logging the variables.

The decision to choose the double log linear form (both the dependent and the independent variables are logged) was based on the data and the results of the graphing process. The choice was also supported by previous research as a common thread among most of the studies reviewed was the use of a double log linear model.

A practical benefit of using the double log specification is the ease of interpretation of the coefficients of the independent variables. For example, the coefficients of the price and income variables are, respectively, the price and income elasticities. This ease of interpretation also means that the model can be explained to regulatory authorities, who for the most part have no background in economics or statistical theory.

Having chosen the functional form of the model two other decisions had to be made. The first was how to deal with intertemporal changes. The second was what type of estimation procedure should be used (for example, Ordinary Least Squares, Zellner or General Least Squares).

Most of the telecommunications literature has used the Koyck model to capture dynamic changes. The Koyck model postulates a geometric decay in the distributed lag, and imposes the same lag structure on all independent variables. This means the consumer's largest reaction to a price change is in the first month. These restrictions are unrealistic, but have been used previously because multicollinearity has precluded the meaningful estimation of separate lag structures for the independent variables.

At B.C. Tel, consumers do not become cognizant of the impacts of long distance rate changes until they receive their telephone bill. In many cases this can be up to a month after the price change. Given this delay it is unlikely that the largest response to toll price changes will be in the first month, as the Koyck model postulates. The Koyck model is, therefore, overly restrictive and will lead to inaccurate results when applied to B.C. Tel data.

To overcome the problems associated with the Koyck model this thesis investigated alternative distributed lag structures. The criteria used to decide the appropriate distributed lag were two fold. First the distributed lag had to allow more flexibility than the Koyck model. Second, it had to make logical sense when applied to telephone data. Taking these factors into consideration, it was decided to investigate the Almon polynomial lag.

The Almon lag[16] assumes that the coefficients on the independent variable follow a distributed structure which can be approximated by a polynomial. This allows much more flexibility than the Koyck lag does. The use of the Almon approach means that for each independent variable, it is possible to use a separate polynomial with a unique lag length to describe intertemporal changes.

Choosing the optimal lag length and the appropriate polynomial degree is a difficult process. Strict tests that can be used to determine the most appropriate lag length or polynomial degree for the model do not exist. The method that will be used in this thesis is

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16 S. Almon, "The Distributed Lag Between Capital Appropriations and Expenditures", Econometrica, Vol. 33, No. 1, pp.178-196, 1965.

to iteratively re-estimate the equations, varying both the polynomial degree and lag length. The optimal length and degree were determined on the basis of examining the adjusted R^2 and minimum standard error results for each iteration and selecting the best outcome. A decision was made to investigate only polynomials up to the forth degree and lag lengths of no more than fourteen months. The decision to limit the testable lag set was based on a survey of marketing managers who had analyzed previous tariff changes. The general consensus was that consumers fully adjusted their toll calling patterns to the new tariff structure within one year.

Based on the forgoing information the following model specification was developed. The summation signs indicate the variables to which polynomial lags will be applied.

$$\log(MIN/MSTAT)_{t,k,m} = \beta_0+\Sigma\beta_1\log P_{t,k,m}+\Sigma\beta_2\log(RSLS_t/POPBC_t) +\beta_3 EDCH_t+\beta_4 BCT_t+\beta_5 PS_t+\beta_6\log(VANCPI)_t +\beta_7\log(MKTSZE)_{t,m}+e_t$$

The subscript "t" of this equation denotes time (in months,1973-1983), "k" stands for the call category (type of residence or business call) and "m" is the mileage band.

Unlike the model detailed above, most studies on telephone demand have deflated monetary variables (price and income) and expressed them in real terms. This study will determine if this is a restrictive assumption by comparing the reaction of residence and business callers to real and nominal price changes. To test whether the monetary variables should be in real or nominal terms a second equation will be estimated using a real monetary variable specification.

$$\log(MIN/MSTAT)_{t,k,m} = \beta_0 + \Sigma\beta_1 \log(P/VANCPI)_{t,k,m} + \Sigma\beta_2 \log(RSLS_t/(VANCPI*POPBC_t)) + \beta_3 EDCH_t + \beta_4 BCT_t + \beta_5 PS_t + + \beta_6 \log(MKTSZE)_{t,m} + e_t$$

As above "t" is time, "k" is call category and "m" is mileage band.

The R^2 results of the two specifications will be compared and the model with the best explanatory power will be utilized.

The final decision needed before calculations can be made is what model estimation procedure will be employed. The telephone demand studies reviewed earlier used a variety of estimation techniques which included Ordinary Least Squares (OLS), Generalized Least Squares (GLS), and Zellner estimation.

This study uses Ordinary Least Squares as its primary method of estimation. The assumptions of the OLS model are expressed here in matrix form:

(I) $Y = X\beta + \mu$

(II) $\mu \simeq N(0, \Omega)$

(III) $\Omega = \sigma^2 I$

(IV) $(1/n)(X'X)$ is nonsingular, nonstochastic and finite.

The testable assumption that β is a vector of time-invariant coefficients is expressed in (I) while (III) specifies that the error terms are not autocorrelated and are homoskedastic. Assumption (II) stipulates that the elements of μ are drawn from a normally distributed population and (IV) rules out exact linear dependence among the independent variables.

If any of the assumptions above are violated there are estimation problems which will require corrective action. The model results will be examined to determine whether any of the following problems exist.

V.2 Regression Diagnostics

Serial Correlation

Serial correlation occurs most often in time series estimations, when the error terms of previous periods have been carried forward to the current period. While serial correlation generally does not affect the unbiasedness or consistency of the Ordinary Least Squares estimators, it does affect the standard error of the regression.[17] The standard test for serial correlation is the Durbin-Watson test.

Previous B.C. Tel studies have been unable to use the Durbin-Watson test because of their utilization of the Koyck lag structure.[18] This lag structure defines a lagged dependent variable. However, since the Durbin-Watson test identifies first order serial correlation, use of the lagged dependent variable within the model invalidates the test. Estimation using a polynomial distributed lag overcomes this difficulty. Additionally, the computer software used,

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17 R.S. Pindyck and D.L. Rubinfeld, Econometric Models and Econometric Forecasts, pp. 152-161, (Toronto, 1976).

18 Dreessen (1979), Bozman (1983).

SHAZAM, allows the computation of the exact distribution of the Durbin-Watson statistic based on the particular values in the X'X matrix[19] thus avoiding the inconclusive results which may arise when relying on the standard tables. Tests for twelfth order serial correlation were not conducted since the data was de-seasonalized using the Census X-11 software package.

In instances where serial correlation is deemed to be a problem, as defined by the exact Durbin-Watson test, Generalized Least Squares estimations will be conducted using the Cochrane-Orcutt procedure[20].

Heteroskedasticity

Although heteroskedasticity is usually associated with cross section analysis, there are instances where it invades time series. Like serial correlation, heteroskedasticity does not bias Ordinary Least Squares parameter estimates but causes them to be inefficient since the variances of the parameters are no longer minimized.

To test for the presence of heteroskedasticity the Park-Glejser test was preformed. This involves using the absolute value of the residuals $|e_t|$ to estimate:

$$|e_t| = \beta_0 + \beta_t X + w$$

where:

X is defined in matrix form.

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19 Judge et al. (1985), pp. 322-332.

20 R.S. Pindyck and D.L. Rubinfeld (1976), pp. 157.

Using this functional form the significance of both the intercept and the slope coefficients can be tested.[21] Homoskedasticity is assumed exist if the ß coefficients are insignificant.

Multicollinearity

Whereas assumption (IV) of the OLS specification rules out the existence of perfect collinearity between independent variables, in practice we more often experience the situation where two or more variables are highly correlated. In this situation, multicollinearity is said to exist. Multicollinearity reveals itself within an estimation through extremely high R^2 statistics together with insignificant coefficients on explanatory variables. To confirm the existence of multicollinearity either independent variables can be removed from the equation and the impacts on the coefficients of the remaining variables noted or the correlation matrix can be examined.

A major problem with this general approach to the identification of the presence of multicollinearity is that it is present, to some degree, in all time series analysis. This does not imply that it will seriously undermine the estimates. A technique developed by Belsley, Kuh and Welsch can be used to evaluate whether the presence of multicollinearity is harmful.[22] Belsley, Kuh and Welsch[23] develop a series of "condition indexes" and "variance decomposition proportions" which can be used to establish

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21 R.S. Pindyck and D.L. Rubinfeld (1976), pp. 151.

22 R.S. Pindyck and D.L. Rubinfeld (1976), pp. 89.

23 D. Belsley, E. Kuh and R. Welsch, Regression Diagnostics, (Toronto, 1980).

whether the estimated coefficients of the model can be relied upon.

Stability

Normally, B.C. Tel studies have not been tested for data stability. The one exception is Bozman[24] who concluded, through the use of a Chow test[25], that in a large number of sectors, and particularly in the business class, a structural shift had occurred within the data period. Since Bozman's analysis of the business sector contained a serious error it was necessary to re-analyze the data set.

In this study a Chow test was not applied to test for stability as the Chow test analysis gives equal weight to all of the independent variables. Instead a somewhat narrower approach was used because the most important variables in this analysis are price and income. The price variable has also changed substantially from Bozman's earlier work.

The test for stability involved defining a dummy variable vector that had values of zero for the first half of the sample period and values of one in the second half. This dummy variable vector was then multiplied with the price vector. This new vector was then included in the regression equation. The coefficient value of this newly created variable was added to the original price variable to measure the price elasticity of the second sub-period.

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24 Bozman (1983).

25 G. Chow, "Tests of Equality Between Sets of Coefficients in Two Regressions", Econometrica, Vol. 28, 1960, pp. 591-605.

The stability test was applied to all calling segments. Only the residence and business, DDD Day Monday to Friday, toll calling segments were analyzed for stability in detail, because they account for over 50 percent of B.C. Tel monthly intra-B.C. revenue.

SECTION VI - RESULTS

The results presented in this chapter are the product of numerous model runs which tested alternative independent variables and polynomial distributed lags of various degrees and different lag lengths. Additionally, tests for serial correlation, heteroskedasticity and stability were conducted to ensure that the results obtained were robust. A diagnostic measure of multicollinearity was also examined.

VI.1 Income Measure

Originally it was the intent of the writer to use a measure of provincial Gross Domestic Product (GDP) as the income variable in the business equations and provincial Personal Disposable Income as the income variable in the residence equations. When incorporated into the models however, these variables led to serious estimation problems as coefficient values behaved erratically. Upon investigation it was discovered that three separate sets of revisions to both Personal Disposable Income and Gross Provincial Product had occurred within the time span covered by the data. Given the series' lack of reliability it was decided to investigate alternative variable specifications.

A variable(s) that produced a significant and consistently signed coefficient when incorporated into the equations was needed. After examining alternatives it was decided to represent economic activity and household income by retail sales. The retail sales series has a number of advantages in that revisions are made infrequently and the information is available on a monthly basis. The same series can be used in both the residence and the business equations.

Retail sales are a good proxy for the economic health of the province. This was established by graphing the retail sales series over time with the GDP and PDI data. The three series were strongly correlated.

VI.2 Lag Structure

Intertemporal changes in both price and income were accounted for by use of Almon polynomial lags. A series of model estimates were required for each category and mileage band. It was decided to test polynomials up to the fourth degree with varying lags. Successive restrictions on the degree of the polynomial were imposed. The best F-test results were achieved with a first order polynomial.

The next step in the process was to examine alternative lag lengths. Given the use of monthly data and a priori knowledge from past rate changes, a lag length of fourteen months was used as a starting point.

Initially, income was not considered to have a separate lag length than the price variable. While this assumption proved to be wrong it was a reasonable starting point as all previous B.C. Tel models had relied on the Koyck specification which imposes the same lag structure on all variables.

The optimal lag length for both price and income were determined by reference to the adjusted R^2 statistics and the significance of the individual lag coefficients. In total, lag lengths were determined individually for price and income for 84 different market segments. Each of these is represented by its own equation.

In the residence categories lag lengths generally varied between three and twelve months for price while the lag lengths for retail sales (income) varied between two and four months. These results demonstrate that consumers do not react fully to a price change within the first month nor do they change their calling patterns immediately in response to a change in income.

In the business categories, the lag lengths for the price variable ranged from six to fourteen months. The lag lengths for retail sales were between one and four months. The optimal lag lengths in the business categories were generally shorter than in the residence equations when comparing the same mileage bands and calling classifications. The major exception was in the business person to person, day, 101 to 175 mile class. This segment had a lag length of 14 on price. A comparable residence segment does not exist.

Like the residence results, the business results confirm that the response to changes in retail sales work their way through the system in a substantially shorter time interval than do changes in price. This means that when forecasting minutes per station retail sales will have a more immediate impact than will price.

VI.3 Nominal versus Real Model

A nominal and a real version of both the residence and the business equations were estimated. The results of these two models were very similar. The choice to use the nominal rather than the real version of the model was based

TABLE 2

LONG RUN PRICE ELASTICITIES
LAG LENGTHS

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	9	12	11	10
Res DDD Eve Mon.-Thur.	9	12	11	10
Res DDD Eve Friday	9	12	11	10
Res DDD Day Saturday	8	10	11	9
Res DDD Eve Saturday	3	12	11	10
Res DDD Day&Eve Sunday	9	12	11	10
Res DDD LNight Mon.-Sun.	3	10	11	9
Res SOH Day Mon.-Fri.	4	11	11	11
Res SOH Eve Mon.-Fri.	4	11	11	11
Bus DDD Day Mon.-Fri.	12	12	10	8
Bus SOH Day Mon.-Fri.	11	11	11	11
Bus PTP Day Mon.-Fri.	6	8	10	8

TABLE 3

LONG RUN PRICE ELASTICITIES
LAG LENGTHS

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	12	10	10
Res DDD Eve Mon.-Thur.	12	10	?
Res DDD Eve Friday	12	10	10
Res DDD Day Saturday	12	8	9
Res DDD Eve Saturday	12	10	10
Res DDD Day&Eve Sunday	12	10	10
Res DDD LNight Mon.-Sun.	12	11	10
Res SOH Day Mon.-Fri.	10	11	10
Res SOH Eve Mon.-Fri.	11	10	12
Bus DDD Day Mon.-Fri.	11	11	8
Bus SOH Day Mon.-Fri.	11	11	11
Bus PTP Day Mon.-Fri.	14	11	8

TABLE 4

**LONG RUN INCOME ELASTICITIES
LAG LENGTHS**

	Mileage Band 0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	4	4	3	4
Res DDD Eve Mon.-Thur.	4	4	3	4
Res DDD Eve Friday	4	4	3	4
Res DDD Day Saturday	3	3	2	4
Res DDD Eve Saturday	3	4	3	4
Res DDD Day&Eve Sunday	4	4	3	4
Res DDD LNight Mon.-Sun.	4	2	4	3
Res SOH Day Mon.-Fri.	11	5	2	5
Res SOH Eve Mon.-Fri.	11	4	3	2
Bus DDD Day Mon.-Fri.	4	4	3	4
Bus SOH Day Mon.-Fri.	4	4	4	4
Bus PTP Day Mon.-Fri.	1	1	1	3

TABLE 5

**LONG RUN INCOME ELASTICITIES
LAG LENGTHS**

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	4	4	4
Res DDD Eve Mon.-Thur.	4	4	4
Res DDD Eve Friday	4	4	4
Res DDD Day Saturday	4	3	4
Res DDD Eve Saturday	4	4	4
Res DDD Day&Eve Sunday	4	4	4
Res DDD LNight Mon.-Sun.	2	3	5
Res SOH Day Mon.-Fri.	3	2	5
Res SOH Eve Mon.-Fri.	4	4	3
Bus DDD Day Mon.-Fri.	3	3	4
Bus SOH Day Mon.-Fri.	4	4	4
Bus PTP Day Mon.-Fri.	2	4	1

on an analysis of adjusted R^2. The nominal versions of both the business and the residential equations performed slightly better than their real equivalents given that over half of the adjusted R^2 results were higher. The final form of the estimating equation was:

$$\log(MIN/MSTAT)_{t,k,m} = \beta + \Sigma\alpha_n \log P_{t-n,k,m} + \Sigma\gamma_i \log(RSLS_{t-i}/POPBC_{t-i}) + \delta EDCH_t + \theta BCT_t + \Gamma PS_t + \phi \log(VANCPI)_t + \Omega \log(MKTSZE)_{t,m} + e_t$$

Within this model time is represented by subscript "t", lag length for price by "n", lag length for retail sales by "i", market segment by "k" and mileage band by subscript "m". The lag lengths for each model run are specified in Tables 2 through 5. The summation signs mean that price and retail sales respectively are summed from zero to their maximum lag lengths. The greek letters preceding the independent variables represent the coefficients.

For market segment categories unaffected by the evening discount change, such as Sunday day and evening calling, the EDCH dummy variable was excluded from the analysis.

VI.4 Model Estimation Results

The final form of the estimating equation represents 84 model runs composed of 12 market segment or service categories and 7 mileage bands. The results of these model runs will be presented in tabular form on a variable by variable basis.

Adjusted R Squares for Model Runs

The adjusted R^2 has been used in this analysis to measure how well the model explains the variations in the dependent variable. Adjusted R^2 takes into account the number of independent variables in the model, thereby avoiding the problem associated with a simple R^2. The results for adjusted R^2 are presented in Tables 6 and 7.

Of the eighty-four segments presented only four had adjusted R^2 statistics of less than 0.80. This means that in 95% of the segments at least 80% of the variance in the dependent variable was explained by the model. The four problem segments were not confined to any one calling category but all occurred within the 0-10 mileage band. Given that this mileage band accounts for only 1.8% of intra-B.C. calling minutes this was not considered to be a serious problem.

The model performed equally well for both the residence and business calling segments. For the station operator handled (SOH) categories the model explained slightly less of the variance than it did in the direct distance dialled (DDD) market classifications.

TABLE 6

ADJUSTED R^2

	Mileage Band 0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	0.916	0.976	0.985	0.973
Res DDD Eve Mon.-Thur.	0.971	0.981	0.993	0.991
Res DDD Eve Friday	0.887	0.951	0.971	0.969
Res DDD Day Saturday	0.829	0.955	0.928	0.896
Res DDD Eve Saturday	0.874	0.937	0.974	0.957
Res DDD Day&Eve Sunday	0.897	0.946	0.978	0.975
Res DDD LNight Mon.-Sun.	0.779	0.900	0.946	0.960
Res SOH Day Mon.-Fri.	0.800	0.727	0.856	0.912
Res SOH Eve Mon.-Fri.	0.769	0.920	0.942	0.953
Bus DDD Day Mon.-Fri.	0.931	0.917	0.960	0.964
Bus SOH Day Mon.-Fri.	0.462	0.739	0.848	0.882
Bus PTP Day Mon.-Fri.	0.540	0.938	0.938	0.949

TABLE 7

ADJUSTED R^2

	Mileage Band 101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	0.973	0.966	0.973
Res DDD Eve Mon.-Thur.	0.990	0.986	0.984
Res DDD Eve Friday	0.958	0.964	0.959
Res DDD Day Saturday	0.914	0.823	0.815
Res DDD Eve Saturday	0.954	0.948	0.955
Res DDD Day&Eve Sunday	0.965	0.970	0.968
Res DDD LNight Mon.-Sun.	0.947	0.951	0.958
Res SOH Day Mon.-Fri.	0.874	0.884	0.933
Res SOH Eve Mon.-Fri.	0.933	0.950	0.936
Bus DDD Day Mon.-Fri.	0.967	0.955	0.973
Bus SOH Day Mon.-Fri.	0.884	0.900	0.922
Bus PTP Day Mon.-Fri.	0.942	0.947	0.926

Long Run Price Elasticity

The long run price elasticity results are presented in Tables 8 and 9. Long run price elasticities are calculated by summing the individual regression price variable coefficients. For example, in a case of a three period lag, the coefficients for log P_t, log P_{t-1}, log P_{t-2}, and log P_{t-3} would be summed. The price variable lag lengths for each model run were presented in Tables 2 and 3. To determine whether the long run price elasticity is significant an analysis of the individual t-statistics associated with each price variable coefficient was undertaken. For the long run variable coefficient to be considered significant each of the summed coefficients had to be significant according to their individual t-statistics.

The results presented in Tables 8 and 9 show unadjusted long run price elasticities for all service categories and mileage bands. Fifty five of the eighty four model runs have significant long run price elasticity coefficients at a ninety-five percent level of significance. For those segments where the long run price elasticity coefficient was not significant it can be said that price signals are weak. This is particularly the case for the residence, DDD, late night category (all week, after 11pm and before 8am) where, according to the model, price changes have little effect on the minutes of calling per station. For no mileage band in this category is the long run price elasticity classified as significant.

With five exceptions all significant long run price elasticities are correctly signed as negative, meaning that a downward sloping demand curve exists. The perversely signed and significant long run price elasticities all occur in categories which require some form of B.C. Tel operator intervention. Three of the five significant positive signs occur in the Station Operator Handled (SOH) residence category while the remaining two are in the equivalent business segment. One can speculate that speaking with an operator has some non-price externality for the system user that is not accounted for by the price variable.

Of the significant price elasticities, forty-five segments are "inelastic" with absolute values of less than one. This predominance of inelastic values in significant segments, and indeed overall, means that the market for intra-B.C. Toll calling is price inelastic. A decrease in price will reduce the aggregate revenue received by the telephone company.

Ten of the model runs display long run price elasticities greater than one (elastic). Eight of the elastic results occur in mileage bands representing toll calling distances of over 101 miles. It should be noted that one of these results is incorrectly signed. The elastic results, which occur in both the residence and the business categories, lead to speculation that the long distance calling which occurs within these mileage bands is more of a luxury than a necessity. However, this possibility is not substantiated by this analysis as 15 of the results in the 101+ mileage bands are significant, correctly signed and inelastic.

TABLE 8

LONG RUN PRICE ELASTICITIES
UNADJUSTED

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	-0.266*	-0.569*	-0.419*	-0.518*
Res DDD Eve Mon.-Thur.	-0.017	-0.260*	-0.528*	-0.657*
Res DDD Eve Friday	0.107	-0.205	-0.544*	-0.572*
Res DDD Day Saturday	-0.136	-0.165*	-0.387*	-0.561
Res DDD Eve Saturday	-0.079	-0.241	-0.677*	-0.749*
Res DDD Day&Eve Sunday	-0.033	-0.454*	-0.588*	-0.413*
Res DDD LNight Mon.-Sun.	-0.091	-0.536	-0.999	-0.808
Res SOH Day Mon.-Fri.	-0.327*	0.090*	0.200	0.496*
Res SOH Eve Mon.-Fri.	-0.558*	-0.648*	-0.502*	-0.448*
Bus DDD Day Mon.-Fri.	0.026	-0.038*	-0.308*	-0.229*
Bus SOH Day Mon.-Fri.	-0.381*	-0.037	0.125	0.396
Bus PTP Day Mon.-Fri.	-1.584*	-1.217*	-0.710*	-0.083

*** Indicates Significance at the 95% Level**

TABLE 9

LONG RUN PRICE ELASTICITIES
UNADJUSTED

	Mileage Band 101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	-0.787*	-0.729*	-1.442*
Res DDD Eve Mon.-Thur.	-1.020*	-0.515*	-0.807*
Res DDD Eve Friday	-0.661*	-0.573*	-0.386
Res DDD Day Saturday	-1.282*	-1.157	-2.478*
Res DDD Eve Saturday	-1.042*	-0.384*	-1.449*
Res DDD Day&Eve Sunday	-0.365*	0.444	0.391
Res DDD LNight Mon.-Sun.	-1.676	-0.508	-0.296
Res SOH Day Mon.-Fri.	0.581*	1.510	0.566
Res SOH Eve Mon.-Fri.	-0.554*	-0.383*	-0.666*
Bus DDD Day Mon.-Fri.	-0.493*	-0.373*	-0.782*
Bus SOH Day Mon.-Fri.	0.524*	1.351*	1.656
Bus PTP Day Mon.-Fri.	-1.048*	-0.693*	-0.580

* **Indicates Significance at the 95% Level**

Long Run Income Elasticity

Income, as represented by retail sales, is a lagged variable. Tables 4 and 5 presented the income lag structures for each market segment. Generally, both business and residence long distance telephone callers adjust to income changes within 4 months. The actual lag lengths for income range between 1 and 11 months.

Long run income elasticities are presented in Tables 10 and 11 and are calculated in the same manner as long run price elasticities, in that the short run income elasticity coefficients were summed. In order for the long run income elasticity coefficients to be considered significant the individual short run coefficients had to be significant based on their t-statistics. Using this criteria, income was significant in sixty nine out of the eighty four segments analyzed. This indicates that income plays an important roll in determining the demand for long distance toll calling.

The sign on the long run income elasticity was expected to be positive since it is generally believed that long distance telephone demand is a normal good. In other words if income were to increase, other things being equal, the demand for long distance telephone service would also increase. Negatively signed long run income coefficients would imply that long distance calling is an inferior good.

Thirty-nine of the sixty-nine significant long run elasticity coefficients were positively signed with values of less than one. These results were shared between the business and the residential categories. For these 39 cases a rise in income leads to a less than proportional increase in calling.

Twenty-four significant segments had positive income elasticities greater than one. This means that a one percent increase in income leads to a greater than proportional increase in long distance calling demand. These results were distributed throughout the residence and business categories and did not dominate any particular mileage band.

Six of the sixty-nine significant market segments had negatively signed income coefficients. These negatively signed coefficients were confined to categories where operator intervention was required. Two possible conclusions can be drawn from these results. First, the negative income elasticity could be interpreted to mean that the calling public find operator assisted calls to be an inferior good. Second, there could have been a structural shift in long distance calling away from operator assisted segments. The latter possibility appears to be the more plausible explanation for the negatively signed coefficients.

TABLE 10

LONG RUN INCOME ELASTICITIES
UNADJUSTED

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	0.412*	0.107	0.610*	0.844*
Res DDD Eve Mon.-Thur.	1.073*	0.279*	0.504*	0.664*
Res DDD Eve Friday	1.730*	0.273*	0.509*	0.607*
Res DDD Day Saturday	0.486*	0.660*	0.637*	1.162*
Res DDD Eve Saturday	0.760*	0.081	0.600*	0.766*
Res DDD Day&Eve Sunday	1.270*	0.058*	0.465*	0.518*
Res DDD LNight Mon.-Sun.	2.518*	-0.536	0.083	0.668*
Res SOH Day Mon.-Fri.	2.437*	-0.197	-0.128*	-0.943*
Res SOH Eve Mon.-Fri.	2.379*	1.560*	1.442*	1.984*
Bus DDD Day Mon.-Fri.	0.528*	-0.241	0.822*	0.721*
Bus SOH Day Mon.-Fri.	0.646*	0.032*	0.309*	0.510*
Bus PTP Day Mon.-Fri.	2.521	-1.204*	0.116*	-0.008

* **Indicates Significance at the 95% Level**

TABLE 11

LONG RUN INCOME ELASTICITIES UNADJUSTED

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	1.140*	1.010*	2.050*
Res DDD Eve Mon.-Thur.	0.642*	0.674*	1.003*
Res DDD Eve Friday	0.943*	0.942*	0.571
Res DDD Day Saturday	1.294*	1.430	1.687*
Res DDD Eve Saturday	0.753*	0.702*	0.853*
Res DDD Day&Eve Sunday	0.557*	0.146	0.566
Res DDD LNight Mon.-Sun.	1.097*	0.830*	1.219*
Res SOH Day Mon.-Fri.	-0.804*	-0.837*	0.390*
Res SOH Eve Mon.-Fri.	2.350*	2.474*	2.964*
Bus DDD Day Mon.-Fri.	1.146*	0.943*	1.178*
Bus SOH Day Mon.-Fri.	0.767*	-0.229*	-0.440
Bus PTP Day Mon.-Fri.	0.848*	1.050*	-0.422

* **Indicates Significance at the 95% Level**

Evening Discount Changes (EDCH)

The evening discount change (EDCH) is a dummy variable which is used to determine whether changing the evening discount from 6pm to 5pm. had any impact on toll calling. The sign on the EDCH dummy should be negative for daytime calling categories if, as expected, it had the effect of reducing the number of daytime calling hours. The sign on evening categories is expected to be positive since the EDCH added an additional hour to evening calling.

The categories which remain unaffected by the EDCH are late night calling, Sunday calling, Saturday daytime calling and residence Station Operator Handled calling, day and evening. For these categories the EDCH variable was dropped from the analysis.

The results of the EDCH dummy variable are presented in Tables 12 and 13. Forty one of the forty nine segments affected by the evening discount change were statistically significant. The categories that were significant were all correctly signed according to the criteria discussed above. The EDCH had positive values for nineteen evening calling categories. Negative, significant, values were recorded in twenty-one daytime calling segments.

All but two of the insignificant results were in the business DDD daytime calling category indicating that the discount change had little affect on business calling. This result is not surprising, since most businesses operate between 8am and 5pm. It is unlikely that a business would alter their hours of operation to take advantage of the discount period change.

TABLE 12

EVENING DISCOUNT CHANGE

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	-0.974*	-0.160*	-0.076*	-0.849*
Res DDD Eve Mon.-Thur.	0.197*	0.107*	0.119*	0.107*
Res DDD Eve Friday	0.229*	0.153*	0.127*	0.108*
Res DDD Eve Saturday	0.226*	0.151*	0.173*	0.154*
Bus DDD Day Mon.-Fri.	-0.034*	0.119*	0.012	0.023
Bus SOH Day Mon.-Fri.	-0.155*	-0.190*	-0.133*	-0.122*
Bus PTP Day Mon.-Fri.	-0.062	-0.297*	-0.202	-0.148*

* **Indicates Significance at the 95% Level**

TABLE 13

EVENING DISCOUNT CHANGE

	Mileage Band 101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	-0.723*	-0.0904*	-0.109*
Res DDD Eve Mon.-Thur.	0.094*	0.102*	0.596*
Res DDD Eve Friday	0.142*	0.152*	0.0580
Res DDD Eve Saturday	0.139*	0.175*	0.110
Bus DDD Day Mon.-Fri.	0.007	0.004	0.044*
Bus SOH Day Mon.-Fri.	-0.136*	-0.150*	-0.226*
Bus PTP Day Mon.-Fri.	-0.173*	-0.158*	-0.392*

* **Indicates Significance at the 95% Level**

Postal Strike (PS)

The Postal Strike dummy variable (PS) was included because there is a generally held view that long distance calling is a substitute for letter writing and, therefore, the postal service. If this view is true, one would expect an increase in toll calling to take place as a result of a postal strike.

The results of the postal strike dummy variable are presented in Tables 14 and 15. Of the eighty-four segments analyzed only twenty-four were statistically significant. All coefficients that were statistically significant were correctly signed but have small coefficient values. Since over half the categories were insignificant on can conclude that long distance toll calling is a weak substitute for the postal service.

B.C. Tel Strike (BCTS)

It is generally held that a B.C. Tel strike will have a negative impact on toll calling. To test this generally held view, a B.C. Tel strike dummy variable is included in the analysis. The expected sign on the dummy variable is negative. The results of this dummy variable are included in Tables 16 and 17. Thirty-five of the eighty-four market segments were statistically significant. Of the statistically significant results, three segments were not the expected sign. Somewhat surprising is the large number (forty-nine) of insignificant segments which indicates that a B.C. Tel strike has little impact on long distance calling. This result perhaps reflects the fact that today's technology needs little, if any, human intervention. Thus long distance calling can continue to take place even in the absence of telephone personnel such as operators and repair people.

Market Size (MKTSZE)

The results in Tables 18 and 19 capture the effect of market size on toll calling. Market size is considered to be important because it captures both network and system externalities. The sign on the market size variable is expected to be positive which means that an increase in the market size would stimulate toll calling. Forty of the eighty-four market size coefficients were statistically significant. Of the forty significant coefficients thirty-six were the expected sign. Forty-four segments were not significantly different from zero.

The results suggest that market size is a moderately important determinant of monthly calling minutes per station. The results also confirm that it would be incorrect to restrict the coefficient value on market size to equal one.

Vancouver Consumer Price Index (VANCPI)

The coefficients associated with the Vancouver Consumer Price Index (VANCPI) are presented in Tables 20 and 21. The VANCPI was included to account for the effect that changes in the price of other good have on long distance calling. The VANCPI captures both the effects of changes in the price of complements and substitutes for toll calling, therefore, no a-priori conclusions can be made about the coefficient's sign. Forty of the eighty-four market segments were significant. Of the significant coefficients, 17 were positively signed and 23 had negative values. The negatively signed coefficients were concentrated in the Station Operator Handled categories.

Serial Correlation

Serial correlation tends to be present in all time series models. This means that the errors associated with the observations of previous periods carry over into future time periods. The primary problem resulting from serial correlation is that standard errors are biased resulting in incorrect inference procedures.

Telephone data contains some serial correlation as a result of the billing cycle. Estimates are made on a monthly basis of revenues, messages and minutes of calling. This occurs because B.C. Tel's accounting procedures require that the books are closed prior to the end of the month, meaning that actual data for the entire month is not available. For example, the books can close on the 27th of the month, necessitating an estimation of the forthcoming revenues, minutes and messages for the remainder of the period. If the estimation is inaccurate a corresponding correction will occur in the next month. Obviously, this means that the error terms are not completely independent of each other.

The problem that faces a telephone demand researcher is to determine the degree to which the serial correlation affects the estimation. The standard method to determine the degree of serial correlation present in any model is the Durbin-Watson statistic. A problem with the standard Durbin-Watson statistic is that there is "grey" or indeterminate area within which the test can not show whether serial correlation is present. Initially, when the Durbin-Watson statistics for the estimated equations were

TABLE 14

POSTAL STRIKE

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	0.028	0.019*	0.007	0.006
Res DDD Eve Mon.-Thur.	0.028	0.051*	0.004	0.033*
Res DDD Eve Friday	0.051	0.058*	0.026	0.049*
Res DDD Day Saturday	-0.042	-0.038	-0.005	-0.009
Res DDD Eve Saturday	0.063	0.072*	0.042*	0.031
Res DDD Day&Eve Sunday	0.041	0.067*	0.037*	0.080*
Res DDD LNight Mon.-Sun.	0.028	0.111*	0.033	0.073*
Res SOH Day Mon.-Fri.	-0.056	0.119*	0.004	0.055
Res SOH Eve Mon.-Fri.	-0.089	-0.039	-0.037	-0.005
Bus DDD Day Mon.-Fri.	0.022	0.055	0.031*	0.029*
Bus SOH Day Mon.-Fri.	-0.004	-0.002	0.028	0.020
Bus PTP Day Mon.-Fri.	-0.263	-0.034	0.015	0.035

*** Indicates Significance at the 95% Level**

TABLE 15

POSTAL STRIKE

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	-0.002	0.040sR	0.040
Res DDD Eve Mon.-Thur.	0.049*	0.054*	0.041*
Res DDD Eve Friday	0.0299	0.054*	0.037
Res DDD Day Saturday	0.015	0.011	-0.016
Res DDD Eve Saturday	0.077*	0.023	0.020
Res DDD Day&Eve Sunday	0.0812*	0.069*	-0.011
Res DDD LNight Mon.-Sun.	0.069*	0.028*	0.003
Res SOH Day Mon.-Fri.	0.031	0.091*	0.069*
Res SOH Eve Mon.-Fri.	-0.006*	0.019	-0.021
Bus DDD Day Mon.-Fri.	0.021	0.045*	-0.002
Bus SOH Day Mon.-Fri.	0.003	-0.034	-0.019
Bus PTP Day Mon.-Fri.	0.030	0.052	0.039

* **Indicates Significance at the 95% Level**

TABLE 16

B.C. TEL STRIKE VARIABLE

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	-0.021	-0.017	-0.0241*	-0.028*
Res DDD Eve Mon.-Thur.	0.019	-0.021	0.003	-0.017
Res DDD Eve Friday	-0.035	-0.044*	-0.025	-0.0244
Res DDD Day Saturday	-0.006	-0.032*	-0.036	-0.050
Res DDD Eve Saturday	0.226	0.151*	-0.017	-0.003
Res DDD Day&Eve Sunday	-0.0311	-0.056*	-0.021	0.017
Res DDD LNight Mon.-Sun.	-0.411*	-0.203*	-1.147*	-0.150*
Res SOH Day Mon.-Fri.	0.162*	-0.002*	0.033	0.001
Res SOH Eve Mon.-Fri.	-0.317	-0.188*	-0.148*	0.172*
Bus DDD Day Mon.-Fri.	-0.030	-0.017	-0.014	0.004
Bus SOH Day Mon.-Fri.	-0.222*	-0.142*	-0.113*	-0.136*
Bus PTP Day Mon.-Fri.	-0.049	-0.256*	-0.420	-0.348*

* **Indicates Significance at the 95% Level**

TABLE 17

B.C. TEL STRIKE VARIABLE

	Mileage Band 101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	-0.031	-0.065*	-0.012
Res DDD Eve Mon.-Thur.	-0.035*	-0.015	-0.025
Res DDD Eve Friday	-0.045*	-0.003	-0.042
Res DDD Day Saturday	-0.052	-0.063	-0.099
Res DDD Eve Saturday	0.008	0.011	0.019
Res DDD Day&Eve Sunday	0.041	0.043	0.072
Res DDD LNight Mon.-Sun.	-0.204*	-0.166*	-0.176*
Res SOH Day Mon.-Fri.	0.022	0.017	-0.029
Res SOH Eve Mon.-Fri.	-0.200*	-0.196*	-0.202*
Bus DDD Day Mon.-Fri.	-0.022	-0.009	0.004
Bus SOH Day Mon.-Fri.	-0.125*	-0.087*	-0.129*
Bus PTP Day Mon.-Fri.	-0.308*	-0.249*	-0.370*

*** Indicates Significance at the 95% Level**

TABLE 18

MARKET SIZE

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	0.208	1.130*	0.547*	0.200
Res DDD Eve Mon.-Thur.	0.132	0.773*	0.592*	0.502*
Res DDD Eve Friday	-0.680	-0.773*	0.586*	0.529*
Res DDD Day Saturday	0.959*	0.637*	0.773	-0.034
Res DDD Eve Saturday	0.054	0.927*	0.348	-0.163
Res DDD Day&Eve Sunday	-0.330	0.843*	0.580*	0.521*
Res DDD LNight Mon.-Sun.	-1.730	1.170*	2.167*	1.602*
Res SOH Day Mon.-Fri.	-0.468	1.865*	1.749*	3.086*
Res SOH Eve Mon.-Fri.	-0.950	0.962*	1.254*	0.096
Bus DDD Day Mon.-Fri.	0.034	0.765*	-0.318*	-0.376*
Bus SOH Day Mon.-Fri.	-0.089	0.751*	0.623*	0.369
Bus PTP Day Mon.-Fri.	-6.55*	0.759	0.073	-0.721

* **Indicates Significance at the 95% Level**

TABLE 19

MARKET SIZE

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	0.387	0.715*	-0.551
Res DDD Eve Mon.-Thur.	0.701*	0.905*	0.638
Res DDD Eve Friday	0.108	0.347	1.272*
Res DDD Day Saturday	0.868	0.479	0.676
Res DDD Eve Saturday	0.281	0.285	0.761
Res DDD Day&Eve Sunday	0.415	1.231*	0.966*
Res DDD LNight Mon.-Sun.	1.022*	1.244*	0.743*
Res SOH Day Mon.-Fri.	2.062*	1.088	1.229*
Res SOH Eve Mon.-Fri.	-0.227	-0.705*	-0.647
Bus DDD Day Mon.-Fri.	-0.122	0.088	0.239
Bus SOH Day Mon.-Fri.	0.213	0.495	0.568
Bus PTP Day Mon.-Fri.	0.020	-1.123	0.780

* **Indicates Significance at the 95% Level**

TABLE 20

VANCOUVER CONSUMER PRICE INDEX

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	0.134*	-0.086*	0.047	0.235
Res DDD Eve Mon.-Thur.	-0.085	0.038	0.160*	0.208*
Res DDD Eve Friday	-0.112	-0.049	0.109	0.134*
Res DDD Day Saturday	-0.115	0.637*	-0.042	0.229
Res DDD Eve Saturday	0.086	-0.038	0.224*	0.403*
Res DDD Day&Eve Sunday	-0.040	0.139	0.192*	0.200*
Res DDD LNight Mon.-Sun.	0.330	0.105	-0.146	0.046
Res SOH Day Mon.-Fri.	-0.420*	-0.564*	-0.480*	-0.415*
Res SOH Eve Mon.-Fri.	0.134	-0.423*	-0.726*	-0.437*
Bus DDD Day Mon.-Fri.	0.081	-0.095	0.231*	0.260*
Bus SOH Day Mon.-Fri.	0.152	-0.289*	-0.346*	-0.281*
Bus PTP Day Mon.-Fri.	3.290*	-0.341*	-0.697*	-0.304*

* **Indicates Significance at the 95% Level**

TABLE 21

VANCOUVER CONSUMER PRICE INDEX

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	-0.010	-0.087	0.377*
Res DDD Eve Mon.-Thur.	0.052	-0.076	-0.018
Res DDD Eve Friday	0.092	0.041	-0.189
Res DDD Day Saturday	-0.120	0.053	-0.122
Res DDD Eve Saturday	0.187*	0.169	0.037
Res DDD Day&Eve Sunday	0.162*	-0.072	-0.028
Res DDD LNight Mon.-Sun.	-0.201*	-0.332*	-0.193*
Res SOH Day Mon.-Fri.	-0.225	0.392	-0.235
Res SOH Eve Mon.-Fri.	-0.558*	-0.380*	-0.546*
Bus DDD Day Mon.-Fri.	0.015	-0.019	-0.090
Bus SOH Day Mon.-Fri.	-0.221*	0.169	0.567*
Bus PTP Day Mon.-Fri.	-1.180*	-0.601*	1.040*

* **Indicates Significance at the 95% Level**

TABLE 22

COCHRANE ORCUTT CORRECTION FOR SERIAL CORRELATION

	Mileage Band 301+ Miles			
	Res DDD Day Mon.-Fri.	Res DDD Day&Eve Sunday	Bus SOH Day Mon.-Fri.	Bus PTP Day Mon.-Fri.
Adjusted R^2	0.873	0.806	0.013	0.710
LRP^e **	-1.523*	0.271	-0.322	0.593*
LRY^e ***	1.765*	0.660	1.104*	0.562*
EDCH	-0.138*		-0.034	-0.269
MKTSZE	0.006	0.756	-1.290	0.700
VANCPI	0.227*	0.037	-0.679	-0.955
PS	0.041	-0.026	0.044	0.032
BCT	-0.041	0.038	-0.110*	-0.156*

* **Indicates Significance at the 95% Level**

** **Stands for Long Run Price Elasticity**

*** **Stands for Long Run Income Elasticity**

TABLE 23

COCHRANE ORCUTT CORRECTION FOR SERIAL CORRELATION

	Mileage Band 11-25 Miles		
	Res DDD Eve Mon.-Thur.	Res DDD Eve Saturday	Bus DDD Day Mon.-Fri.
Adjusted R^2	0.591	0.216	0.520
LRP^e **	-0.171*	-0.102	-0.151*
LRY^e ***	0.855*	0.648	0.302*
EDCH	0.195*	0.244*	-0.047
MKTSZE	0.044	-0.035	0.160
VANCPI	0.006	-0.018	0.062
PS	0.002	0.014	0.006
BCT	0.002	-0.011	-0.008

* **Indicates Significance at the 95% Level**

** **Stands for Long Run Price Elasticity**

*** **Stands for Long Run Income Elasticity**

TABLE 24

COCHRANE ORCUTT CORRECTION FOR SERIAL CORRELATION

	Mileage Band 0-10 Res DDD Day&Eve Mon.-Sun.	Mileage Band 51-100 Res DDD Eve Friday	Mileage Band 176-300 Res DDD Day Saturday
Adjusted R^2	0.868	0.640	0.401
LRP^e **	-0.121	-0.506*	-0.976*
LRY^e ***	1.995*	0.800*	1.086*
EDCH		0.079	
MKSZE	0.389	0.354*	1.852*
VANCPI	-1.206	0.083	-0.453
PS	-0.079	0.032	-0.022
BCT	0.189*	-0.017	-0.060

* **Indicates Significance at the 95% Level**

** **Stands for Long Run Price Elasticity**

*** **Stands for Long Run Income Elasticity**

calculated several of the results were in the indeterminate region of the test. To overcome this problem it was decided to use the exact Durbin-Watson statistic. Using the values of the equation's X'X matrix, the exact distribution of the Durbin-Watson statistic is calculated and thus no indeterminate values exist.

For those categories in which serial correlation was a problem, Generalized Least Squares (GLS) estimates were produced using an iterative Cochrane-Orcutt procedure. The criteria used to stop the Cochrane-Orcutt process was estimates of rho changing by less than 0.005 or 20 iterations.

The results using the Cochrane-Orcutt procedure are presented in Tables 22 through 24. In total, ten categories required re-estimation because of serial correlation problems. No service category can be singled out as being affected by serial correlation more than any other. This is not the case if we analyze the table by mileage band. The 301+ mileage band appears to be the most affected by serial correlation (four occurrences) followed by the 11-25 mileage band (three occurrences). Serial correlation problems also occurred in single segments of the 0-10, 51-100, and 176-300 mileage bands.

The results presented in Tables 22 and 24 are similar to the original estimate presented in Tables 2 through 21. In four of the ten segments estimated, price elasticities increased slightly. In the remaining categories they were reduced. In seven of the ten segments income elasticities were slightly increased while the remaining categories were slightly reduced.

The conclusion that can be reached from this analysis is that while serial correlation is present and serious in ten of the eighty-four segments it has only a very small impact on the estimated coefficients.

Heteroskedasticity

Although heteroskedasticity is a less common problem for time series analyses, to ensure the robustness of the results, tests for heteroskedasticity were undertaken.

Heteroskedasticity, or unequal variance in the error term, produces unbiased but inefficient estimates of the regression coefficients and biased estimates of their standard errors. A number of tests are available to determine if heteroskedasticity is present. The test used in this analysis is based on the work of Park and Glejser[26]. Glejser suggests regressing the absolute values of the estimated residuals on the original set of independent variables. An F-test to establish the significance of the resulting adjusted R^2 was used to determine the presence or absence of heteroskedasticity.

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26 R. Pindyck and D. Rubinfeld, (1976), pp. 150-151.

TABLE 25

RESULTS OF F-TEST FOR HETEROSKEDASTICITY

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	1.121	1.717	0.355	1.275
Res DDD Eve Mon.-Thur.	2.522*	2.774*	1.708	1.957
Res DDD Eve Friday	1.804	0.971	1.090	0.919
Res DDD Day Saturday	0.721	1.214	0.741	1.202
Res DDD Eve Saturday	1.554	3.243*	0.588	0.940
Res DDD Day&Eve Sunday	2.369	3.402*	1.123	1.309
Res DDD LNight Mon.-Sun.	2.209	1.948	2.110	0.675
Res SOH Day Mon.-Fri.	3.274*	9.861*	1.552	7.203*
Res SOH Eve Mon.-Fri.	1.036	2.027	2.658*	2.412
Bus DDD Day Mon.-Fri.	0.985	4.051*	1.017	0.633
Bus SOH Day Mon.-Fri.	1.320	1.974	1.882	0.888
Bus PTP Day Mon.-Fri.	1.852	24.378*	4.682*	4.958*

* **Indicates Significance at the 95% Level**

TABLE 26

RESULTS OF F-TEST FOR HETEROSKEDASTICITY

	Mileage Band 101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	0.764	1.248	0.607
Res DDD Eve Mon.-Thur.	3.665*	3.661*	2.588*
Res DDD Eve Friday	2.207	1.702	1.184
Res DDD Day Saturday	0.942	2.592*	3.284*
Res DDD Eve Saturday	1.222	1.982	1.089
Res DDD Day&Eve Sunday	2.127	2.628*	1.841
Res DDD LNight Mon.-Sun.	1.811	1.277	2.478
Res SOH Day Mon.-Fri.	1.134	6.934*	1.572
Res SOH Eve Mon.-Fri.	2.713*	3.338*	2.377
Bus DDD Day Mon.-Fri.	0.865	0.826	1.100
Bus SOH Day Mon.-Fri.	3.856	2.208	1.425
Bus PTP Day Mon.-Fri.	4.922*	1.457	7.923*

* **Indicates Significance at the 95% Level**

The results of these tests are presented in Tables 25 and 26 and indicate that heteroskedasticity is present in 23 segments. While this might seem a rather large number of categories they represent less than 17% of annual calling minutes. Therefore, it is legitimate to say that heteroskedasticity is not a serious problem for the results.

Stability

Stability is of concern in any time series analysis that is used for forecasting. The longer the time period for which the model is being estimated, the greater the likelihood that structural changes have occurred. In order to ascertain whether the regression coefficients were consistent over time, a test to determine whether the price coefficient was stable was conducted. The price variable was the most likely to have experienced a structural change.

The results of this analysis is presented in Tables 27 and 28. They indicate that in most cases price elasticities change very little when the time period is split in half. Of major concern was what had happened within the residence and business DDD daytime, Monday to Friday results as these two categories account for over fifty percent of total intra-B.C. calling minutes. Only three of the residence and business DDD daytime Monday to Friday results were beyond the bounds of the confidence intervals of the original price coefficient estimators. The exceptions are all associated with calls in the first two mileage bands. As these mileage bands account for only a small proportion (0.96%) of calling minutes, these exceptions were not considered to represent a serious problem.

TABLE 27

STABILITY OF PRICE ELASTICITIES

PRICE ELASTICITIES FOR SECOND HALF OF THE DATA SERIES (OBSERVATIONS 61 THROUGH 132)

	Mileage Band			
	0-10	11-25	26-50	51-100
Res DDD Day Mon.-Fri.	-0.108	-0.549	-0.385	-0.514
Res DDD Eve Mon.-Thur.	-0.101	-0.130	-0.525	-0.572
Res DDD Eve Friday	-0.032	-0.044	-0.393	-0.431
Res DDD Day Saturday	-0.095	-0.115	-0.329	-0.479
Res DDD Eve Saturday	-0.078	-0.175	-0.680	-0.643
Res DDD Day&Eve Sunday	-0.116	-0.302	-0.493	0.267
Res DDD LNight Mon.-Sun.	-0.255	-0.286	-0.688	-0.465
Bus DDD Day Mon.-Fri.	-0.406	-0.209	-0.291	-0.230

* **Indicates Significance at the 95% Level**

TABLE 28

STABILITY OF PRICE ELASTICITIES

PRICE ELASTICITIES FOR SECOND HALF OF THE DATA SERIES (OBSERVATIONS 61 THROUGH 132)

	Mileage Band		
	101 - 175	176 - 300	301 +
Res DDD Day Mon.-Fri.	-0.756	-0.777	-1.460
Res DDD Eve Mon.-Thur.	-0.665	-0.320	-0.237
Res DDD Eve Friday	-0.762	-0.249	-0.184
Res DDD Day Saturday	-1.072	-0.895	-1.273
Res DDD Eve Saturday	-0.685	-0.176	-1.171
Res DDD Day&Eve Sunday	-0.172	0.726	0.682
Res DDD LNight Mon.-Sun.	-0.736	-0.024	-0.191
Bus DDD Day Mon.-Fri.	-0.450	-0.363	-0.776

* **Indicates Significance at the 95% Level**

One segment which was not analyzed was operator assisted calling. This is because a structural shift has undoubtedly taken place. Telephone companies across North America have actively dissuaded operator assisted calling through massive price increases. In the case of B.C. Tel rates have been increased by approximately 800%.

Multicollinearity

One of the assumption in regression analysis is that an exact linear relationship between the independent variables of the model does not exist. In practise exact linear relationships among the independent variables is uncommon. What is common ,however,is the more formidable problem of having independent variables with a high degree of multicollinearity. The regression coefficients of models that suffer from severe multicollinearity may become unreliable since one cannot accurately distinguish the separate influences of variables that move together.

Multicollinearity between independent variables is always present to some degree in time series analysis. Therefore, the problem at hand is to formulate a test which indicates the degree to which the estimates are affected. Whether or not the estimates are harmed by multicollinearity depends on what they are being used for. For example, forecasting with a model suffering from severe multicollinearity problems would likely lead to inaccurate results.

Belsley, Kuh, and Welsch (1980)[27] have suggested a technique for evaluating multicollinearity. It is based on

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27 D. Belsley,E. Kuh, R. Welsch, (1980), pp. 115-117.

what the authors call "condition indexes" and "variance-decomposition proportions" derived from a singular-value decomposition of the X'X matrix. This technique has been incorporated in the Statistical Analysis Systems (SAS) software and was used to produce Tables 29 and 30 for the residence DDD Day category, 51-100 miles. The decision to only analyze this category was based on its overall importance to the intra B.C. toll market.

The basic rule suggested by Belsley, Kuh, and Welsch is that one should expect degrading or harmful multicollinearity whenever a condition index is in the range of 11-30 and at least two variance-decompositions proportions exceed 0.5.

Using the criteria set out by Belsley, Kuh, and Welsch, the results presented in Tables 29 and 30 show three condition indices with values where one would expect degrading collinearity (61.66, 260.434, and 2079.5) however, only one of those categories has more than two variance-decomposition proportions exceeding 0.5. The variables affected by collinearity are the constant, Retail Sales, Evening Discount Change(EDCH), Vancouver Consumer Price Index (VANCPI) and Marketsize (MKTSZE). The coefficients of these variables must therefore be used with some caution. Investigation of auxiliary regressions as suggested by Belsley, Kuh, and Welsch were not considered because of the use of the Almon lag structure.

TABLE 29

COLLINEARITY DIAGNOSTICS

VARIANCE DECOMPOSITION PROPORTIONS AND CONDITION INDEXES

Mileage Band
51-100 Miles

	Eigenvalues 1	2	3	4
Condition Number	1.000	2.415	2.584	4.935
Constant	0.0000	0.0000	0.0000	0.0000
Price	0.0001	0.0000	0.0000	0.0066
Ret.Sales	0.0000	0.0000	0.0000	0.0000
EDCH	0.0006	0.0000	0.0000	0.0455
VANCPI	0.0000	0.0000	0.0000	0.0005
BCT	0.0019	0.4495	0.4796	0.0038
MKTSZE	0.0000	0.0000	0.0000	0.0000
PS	0.0021	0.4429	0.5176	0.0075

TABLE 30

COLLINEARITY DIAGNOSTICS
VARIANCE DECOMPOSITION
PROPORTIONS AND CONDITION INDEXES

Mileage Band
51-100 Miles

	Eigenvalues 5	6	7	8
Condition Number	10.726	61.166	260.434	2079.500
Constant	0.0000	0.0004	0.0121	0.9875
Price	0.0111	0.8306	0.1352	0.0163
Ret.Sales	0.0000	0.0036	0.3093	0.6870
EDCH	0.1727	0.1019	0.0103	0.6690
VANCPI	0.0117	0.2180	0.0577	0.7119
BCT	0.0053	0.0475	0.0118	0.0055
MKTSZE	0.0000	0.0002	0.0017	0.9982
PS	0.0130	0.0009	0.0061	0.0099

SECTION VII - CONCLUSION

The objective of this thesis was to model, for the intra-B.C. toll calling market, long distance telephone calling demand. One of the practical outcomes of this effort was that estimates of both price and income elasticities were generated. These elasticities permit the estimation of the impacts, changes in price or income have, on intra-B.C. toll calling demand. This information is critical to telephone companies as it permits them to calculate the financial impacts of rate changes. It also provides a measure of the impact of general economic conditions on telephone demand. Such information is critical for long-range planning.

The specification which proved to be the most accurate representation of intra-provincial toll calling was a double log linear model. Intertemporal changes were taken into account through the use of Almon polynomial lags. This sophisticated lag structure proved superior to a Koyck specification which had been commonly used within the theoretical literature. The Almon lag structure more accurately reflects real world adjustments to price and income changes, for example, it permits the use of unique lag lengths for each independent variable.

A number of conclusions can be drawn from the econometric analysis presented in this thesis. The model shows that toll demand is not determined by a single variable in isolation or by a single time period. Instead telephone demand is a complex process which changes over time and in response to a variety of exogenous variables.

The econometric model results demonstrate that long distance toll calling within the province is sensitive to changes in both price and income. Long distance telephone demand is also determined by market size, discount period changes, postal strikes and telephone strikes.

With respect to price the model shows that the elasticity for intra-provincial toll calling is negative and less than 1, or inelastic. The lowering of long distance rates will have an adverse impact on the financial performance of B.C. Tel. These results contradict the contentions of intervenors at B.C. Tel rate hearings who have asserted repeatedly in the past that overall intra-B.C. toll calling has a price elasticity greater than one in absolute value. If the position of the intervenors was correct, it would mean that a toll rate reduction would stimulate the demand for intra provincial toll calling generating, for the telephone company, sufficient revenue to compensate for the reduction in price.

This thesis contradicts such a view and therefore also calls into question the deregulation viewpoint which states that competition could occur within the long distance calling market at no cost to the existing monopolist. Since long distance calling now subsidizes the cost of local service a telephone company negatively impacted by long distance telephone rate reductions would likely be forced to raise local charges to cover the shortfall.

An increase in local charges would ultimately impact most on residential customers as the majority of business calls are long distance. This calling characteristic means that, for firms, the increased price of local calling would be mitigated by cheaper long distance rates.

All the studies reviewed during the research for this thesis included some measure of income in their model, yet none commented on its significance in determining the demand for toll calling. The results presented here suggest that income plays a very important role. The elasticities associated with income are statistically significant and remain, for the most part, inelastic. This thesis provides evidence that income elasticities are generally greater than price elasticities.

The income elasticity results mean that for a given increase in income, telephone calling will rise, but by less than the full amount of the income increment. Therefore, positive changes in income increase the demand for intra-provincial toll calling. This study also found that consumers adjusted their toll calling faster to changes in income than to changes in price.

Given the price and income elasticity results this thesis shows that it is important that the telephone company not consider price changes in isolation from income. Doing so would lead to a misleading financial impact assessment of a price change. For example, the revenue impacts of a tariff rate decrease could be completely offset by a rise in user's incomes. Additionally, if consumer's incomes were to increase at the same time as rates were reduced the telephone company could actually see an increase in their revenues as the price change could be more than offset by the income change. Such a revenue increase could lead to the misleading impression that it was the decrease in tariffs that led to the positive revenue results. Thus the telephone company could then reduce rates even further only to find a later loss in revenues. This loss would be amplified if the rate reduction was coincident with an economic downturn leading to a reduction in consumer incomes.

On a practical level, it could already be the case that confusion exists about the joint implications of the price and income elasticities. B.C. Tel has reduced, during the first 7 months of 1988 its intra-B.C.long distance rates twice. The full economic impacts of these changes will not become evident until early 1989 yet the strong financial position of the firm is already being associated with the rate reductions (i.e. intra-B.C. long distance demand is price elastic). The increased revenues could, however, be solely due to rising income levels.

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