DEMAND FOR RADIO FREQUENCY SPECTRUM

WORKLOAD AND CONGESTION

Telecommunications Economics Branch

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1. INTRODUCTION

Land mobile radio has become increasingly popular in business as a method of improving productivity. Taxi companies, constructions firms, trucking and delivery operations are finding that land mobile radio is an indispensible technology in their commercial operations. Without radio, dispatch and control would become more tenuous, and mobile capital would not be utilized as effectively. It can be said that radio communication within each business speeds up the tempo of economic activity and reduces the unit cost of production of goods and services.

But the widespread use of land mobile radio has given rise to problems peculiar to itself which require increasing attention. Because of the externalities associated with radio communication, most notably interference, some sort of public control and regulation has to be exercised over the radio frequency spectrum. In fact, in the General Radio Service (GRS), whose users are less subject to disciplined procedures, the actual channels made available are the result of conscious policy decisions by a public regulatory body - the Department of Communications - through a system of licensing. The issuing of licenses and associated tasks form a major portion of the workload of this Department's district offices. The rising demand for licenses which is anticipated has caused at least one regional office to seek some sort of forecast of near future workloads of the district offices under its control.

The problem of office workload is but one faced by the Department over spectrum allocation. Another is the pressure new users bring to existing land mobile radio bands. As more users within a given geographic area are stacked onto the limited number of frequencies available, the problem of congestion becomes more serious. This crowding manifests itself in an inability of one user to contact another, sporadic interference between users on adjacent channels and increasing difficulty in trying to find suitable channels to authorize for new users. As the problem of noise and interference worsens, the utility of the spectrum for commercial operators lessens. Eventually, the crowding occurring in major urban centres, especially those near large United States cities, must be alleviated either through the allocation of new bands or through improved technology designed to utilize existing bands more intensively without congestion.

Congestion is an economic problem as well as a technological one because the decision to allocate so much radio frequency spectrum to a particular use should, if possible, also weigh the value of the spectrum to the commerical user. Otherwise, a misallocation of a finite economic resource, the radio frequeny spectrum, would occur; and economic performance would suffer as a consequence. In practice, of course, not all competing uses of the spectrum can be evaluated in strict economic terms, for the cultural impact of broadcasting is tremendous and important. Clearly, policies orientated by economic arguments must be tempered by an appreciation of the cultural facts as well as the realization that economic evaluations are imperfect at best. By the same token, however, the economic argument cannot be totally overlooked for it suggests the extent of the net loss or gain in dollar terms which will arise from a policy change

A first approach to an economic study of the spectrum dealing with the issues above is, naturally, to measure the demand and to identify the causal factors underlying this demand. In the case of land mobile radio, the demand for spectrum can be conceptualized in economic terms as being similar to the demand for any other productive input to the firm's economic activity. In other words, the theoretical starting point is given by the standard analysis of "derived demand". By assuming that this demand is measured by the number of mobile radio licences, as we do, one can use the same analysis for investigating workload as well as congestion.

For workload forecasting, the assumption is made that each licence represents a constant or average amount of work activity for the district offices. Such activities include licence processing, general administration, monitoring spectrum users, handling complaints regarding radio interference, inspection of installations and, finally, coordinating spectrum usage with adjacent regions. Licence processing includes licence requests, cancellation and amendments. In Chapter 5 we will detail the translation from derived demand to an equation suitable for estimation purposes.

The remainder of this introduction will introduce the economic problem as defined by standard economic theory. Chapter 2 reviews previous forecasting work and discusses the relationship to be found between the present and earlier works, while Chapter 3 describes the licence data source and its shortcomings. Some efforts that have been made to repair the time series are also discussed. Chapter 4 demonstrates the impossibility of forecasting new licences on the basis of a time series of the number of new licences issued in the past. This result reinforced our resolve to take the derived demand approach, and this work forms the substance of Chapter 5. Finally, the conclusion reviews the limitations inherent in the study and considers the possible next research step to take.

1.1 Remarks on the Economics of Spectrum Congestion

The radio spectrum has the unusual property for an economic resource of being perfectly renewable at no cost. Nonetheless it has a scarcity value since not all parts of the spectrum are equally desirable and crowding about the most popular bands results. The degree of spectrum utilization varies at different hours of the day and different days of the week. For services other than police and taxi, the non-working hours are unlikely to be crowded and little congestion will occur. Indeed, when congestion does not occur, the economic value of the spectrum is zero, for then there is no cost to present radio operators of adding one extra user. In fact, it is the presence of competing users, whether actual or potential, which gives the spectrum its economic value.

From an economic standpoint, it is desirable that the spectrum be allocated efficiently. The spectrum must be properly priced if efficiency is to be achieved. How this is to be done, either in theory or practice, depends on institutional arrangements over property rights. At present, the spectrum is priced at nominal rates and assigned on a first-come-first-served basis. This practice is not designed with a view to avoiding wasteful use of the spectrum. Indeed, individuals will use the spectrum until the marginal revenue product equals the administered price, thereby over using the spectrum and leading to premature congestion.

An alternative which is mindful of efficiency considerations is to auction the spectrum, letting commercial buyers bid for different frequencies, thus revealing the economic worth to their production activity of the spectrum. Thus the firms will bid only as long as the value of the marginal product equals or exceeds the price of the spectrum. Under such a scheme, losers will be those whose marginal value product is less than the price of the spectrum, leading to an efficient allocation. Further proposals of both a theoretical and practical nature have been put forward as alternative methods of evaluation. One example is the calculation of the spectrum shadow price, while another is administrative techniques such as the right to borrow frequencies. These and other possible alternatives demonstrate the variety of ways in which the spectrum might be managed. Not all approaches are administratively feasible nor amenable to the required economic measurement. The policy question which then arises is how are the administrators of the spectrum to realize or approximate allocative efficiency of this input into production, and at the least possible cost to the tax payer.

1.2 New Technological Developments

Recent technological developments not yet marketed promise to reduce land mobile spectrum congestion. Although congestion is not too serious at present, (perhaps with the exception of Montreal and Toronto) this problem is expected to spread to other centres in the future in the absence of the new technology and equipment. A number of factors are probably responsible for slowing the marketing of these new developments. Some users of the spectrum have been allocated more spectrum than they need, and therefore have no incentive to be efficient or to pay the cost to adopt the newer equipment. On the other hand, without mass production, the cost of adoption is probably too high at present for significant demand to manifest itself.

Advanced transmitter and receiver design, improved network engineering, and changes in frequency assignment practices would all go far to reduce the present problems of congestion in the land mobile radio service

Technically, advances in switching, signal compression, single side band transmission, highly stabilized frequency control, and digitization will each play its part in helping to reduce interference and allow a greater number of users to benefit from the service. Taken together, better network engineering and a more rational assignment of frequencies would likely have a greater and more timely effect.

Of course, all of these developments will mean greater cost to both producers and buyers. The amount of capital equipment involved, and development costs sunk into any system implies a wholly altered economic picture for land mobile radio. Indeed, the very act of conceiving radio systems, as we are at present, in cost benefit terms, demonstrates the prevalence and importance of economic considerations.

2. REVIEW OF SPECTRUM DEMAND FORECASTS

This technical review includes some of the econometric studies on forecasting congestion and workload, providing us with an overview of the difficulties involved and a possible starting point for the research we will undertake.

The 1972 study "Demand for Land Mobile Communications" by A. Zalatan and M. Simoneau, had both a long term and a short term objective. The objective for the long term was to identify potential future shortages of spectrum in major Canadian cities. The short term objective was to assist the Telecommunications Regulatory Service to develop a short term Canadian negotiating position regarding recent U.S. Federal Communications Commission decisions affecting land mobile radio frequency allocations.

The spectrum demand for Montreal and Toronto regions was estimated by means of regression techniques, where the total number of licences, rather than new licences for a number of industrial sectors, was the dependent variable. Independent variables for the 12 sectors, such as forestry, police, taxis, etc., are usually some combination of employment or output in the sector and total population for the city in question. The variable being explained amounted to no more than a trend, due to the choice of total licences as the independent variables. R-squares are high and Durbin-Watson statistics are respectable, and almost all variables are significant.

This study is acceptable if one is willing to use total licences rather than new licences as a dependent variable but for our study this approach would be rather weak. In common with all econometric work using the Integrated Radio Licencing System (IRLS)* file it suffers from data problems due to the treatment of licence cancellations.

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* See Chapter 3 for a description of the IRLS file

Serge LaBuissonniere, (1976) in his work on the "Forecast Demand for Land Mobiles by Band for Toronto", had two goals. The objectives of the study were to evaluate and predict spectrum congestion in large urban centres and also to identify the impact of United States spectrum utilization. Again, total licences were used as the dependent variable, but he does acknowledge the cancellation problem and its importance. The data prior to 1972 are biased by the fact that some records of licences issued have disappeared. For example, if a licence was entered in 1962 and cancelled in 1969, it would not appear at all. In order to correct the time series, an equation using time and time-squared was fitted for each of three representative cities. Pooling of several cities by size was done for each of these three observations. The statistical tests were conducted as if the pooling did not take place and the invalid assumption that one has the equivalent of nine different observations, one for each city, was maintained. This is not valid since each of the three pooled observations consisted of the mean of each of the three cities, giving only three points for the subsequent statistical curve fitting.

After reconstructing his data, LaBuissonniere runs a regression for the period from 1964 to 1974 for land mobile radio. This is to be used to forecast out to 1985, rather a long period ahead. The regression theoretically was to include population, per capita revenue, and technology, but technology (measured by time) proved to be insignificant. The study notes that 75 per cent of land mobile radios are in the tertiary sector which includes transportation, public administration services, commerce, and communications. This justifies the use of urban population since the demand for the above is a function of urban size. It is also argued that "general wealth" directly influences the demand for tertiary goods and services. No t-statistics are given, but the R-squared (.921) is high. Over all, since the data reconstruction was not successful, he has almost no data, just three points, hardly enough to do any analysis. Moreover, the three points were not free of bias since the number of licences in each region reflected sudden increases due to the decentralization that was occurring, and which will be explained in the next chapter.

A 1976 study of mobile radios in the Atlantic region, "Demands for Mobile Radios in the Atlantic Region: Trends and Forecasts" by C. Lee was designed to help predict workload for the Atlantic region, using given station categories, mobile, land, ship, coast and radio. The first two classes are broken down by service categories. Data consisted of time-series of the net number of licences in force from 1960-1975, using the 1975 year-end tape of the IRLS file, but no mention is made of the inaccuracies of data prior to 1972.

Regressions are presented for mobile radios in the private commercial, provincial, and municipal government service categories. The same variables are used in all regressions and are: population, a lagged dependent variable, net income of non-farm unincorporated business in constant dollars, and lastly, time. Each of the three equations has a high R-squared with two having a Durbin-Watson statistic indicating no serial correlation. In the private commercial equation all variables were significant, except unincorporated business income, which had the wrong sign and was left in the equation without explanation. In the provincial government equation, population was the only significant coefficient out of four. In the last equation there are no coefficients which were significant. Too many coefficients are either insignificant or have the wrong sign, a fact probably due to multicollinearity.

Due to lack of almost any accurate data and half the coefficients being insignificant the study provides little guidance for our own work. Two out of the four independent variables, time and lagged dependent, are not causal and in addition time and population are probably highly correlated.

Eric West's report, "Study of Spectrum Allocation Policy and Methods of Modelling to Assist in the Formation of Spectrum Policy", (1977) consists of a brief discussion of data availability, quality problems and alternative forecasting models and forecasts. He fits a time series model, using new licences, to each district office under the severe limitation of possessing only four years of data. As an alternative, cross-sectional data could have been used (or cross-sectional and time series could have been pooled) to increase the size of the sample, but this option was not followed. A large number of possible models (smoothing, regression and time series) are fitted to the data but not presented in the report. He tried various economic measures which are not specified, ending up with population measures and lagged dependent variables. His economic and population measures, he claims, make no contribution to the models. It would be useful to have some indication if more observations and the absence of the time variable would make this no longer the case. The model he finally settles on has no causal variables, just time and a lagged dependent variable. Moreover, only four observations give but one degree of freedom for the regression, since he estimates three coefficients. In conversation with Eric West, he admitted that the forecasts to 1980, on the basis of such few observations, made little sense and the most one could do is forecast out one period (1977). In addition, he described the data as containing many errors. Although, the R^2 and t-statistics are deleted in the report, he said that numberous R^2 s were high, whereas in most models the t-statistic was <u>not</u> over 12.7, a value representing significance for a 5 per cent two-tailed test with only one degree of freedom, (t-statistics were closer to one in actuality).

Using the IRLS data on the number of land stations, Quasar Systems Ltd. in 1977 prepared a report called "Land Mobile Systems: A Forecast for Major Urban Centres". The object of the study is to forecast the number of land-mobile radio systems likely to be in operation in the year 2000, while the conclusion arrived at was that if existing demand continues, the spectrum could become saturated in major Canadian urban centres by the 1980s.

Exponential trends are fitted for 14 centres of population. With only four pieces of data for each centre, two coefficients were fitted leaving only two degrees of freedom. No t-statistics for the coefficients were given. Again with only four observations, forecasting 23 years ahead can hardly be justified. The method of forecasting is to use the exponential trends to forecast to 1985 and to tie forecasts from 1985 to 2000 to population growth.

Over all, the studies are simplistic in nature and highly constrained by data limitations. The number of independent variables when causal variables are used are too few to explain the phenomena. Theory suggests that the derived demand for a factor of production is a function of output, and input quantity and prices. Inputs did not figure at all. Too many of the studies used non-causal variables, such as time. Forecasts were for too many periods beyond the period of fit, given how few data points were used. Some used data which was not a consistent series. One thing to be learned from these studies is that a separation by service categories, as used by Zalatan and Simoneau, may be very productive, but a note of caution is needed. They used total licences rather than new licences which is very close to a trend, and this may explain the reason for their good results. Finally, the studies have sufficiently alerted us to the severity of the data problems that there remains no longer any question in our minds about the necessity of rendering the data into a consistent time series before any estimations for forecasting, or for any other purpose, can be seriously entertained. This data issue is one to which we now turn.

3. RADIO LICENCE DATA AND ITS RECONSTRUCTION

The purpose of this chapter is to describe the licence data source, identify problems and show how they can be overcome.

3.1 Radio Licence Data Source

All available information on all radio licences (except GRS) issued in Canada resides in the Department's computerized Integrated Radio Station Licence System (IRLS). This system is the primary data source for our study.

The IRLS was designed to manage the financial aspects of the licencing process, and thus only licences in force during the current fiscal year appear on the system. However, analytical uses of the information require historical data. For this reason, "year-end files" were created: each year-end file is a snapshot of the IRLS at a particular point in time. Year-end files exist for fiscal years 1972-73 to the present. For each record on the file it is possible to determine whether the licence in question was active, cancelled or relocated during the given year.

Because of the hierarchical, variable length record structure and size of the IRLS (from 3 to 92 lines per licence), it is usual to extract relevant information onto a smaller file for analytical purposes. Such an extract was created for the Eric West study described in Chapter 2. The tape created consisted of one record from each available year-end file for each radio licence issued by the Atlantic region. The extract criterion was to select all records issued by district offices in the Atlantic Region (D.O. 661 to 669). A list of the items extracted is contained in Appendix A. This extract formed the database for our preliminary research.

3.2 Historical Data Problems

One of the sub-objectives of the current research was to determine the feasibility of reconstructing historical data from the information contained in the year-end files. Because of the manner in which the IRLS is maintained, it is impossible to determine the actual number of licences issued in any year prior to 1972. For example, a licence issued in 1965 and cancelled in 1970 will not appear on any year-end file. The information which does exist for licences issued in 1971 and earlier is the number, by year of issue, which "survived" until 1972, 1973,.... to the present. The difficulty described above is referred to as the "cancellation problem".

At any geographical level below the national level two other problems in developing consistent annual time series present themselves - the relocation problem and the decentralization problem. There are three causes of the relocation problem. These are, regional boundary changes, district office boundary changes, (including the opening, from time to time, of new district offices) and transfers of licences from one account to another. These changes result in extreme variability in the time series of the number of licences issued from year to year by the offices affected. This variability adversely affects the ability to detect any underlying trend in the data. In particular, during the course of the present research it was decided, because of the severity of the problem at the district office level, to aggregate data to at least the provincial level for forecasting purposes. It should also be noted that relocations between district offices located in the same region, or relocations involving a transfer of a licence from one account to another within one district office, result in double-counting of the relocated licences on the file corresponding to the year in which the relocation took place.

The decentralization problem arose in the early 1970's when administration of a number of licence types such as provincial government licences, and licences of large companies was transferred to the regions. These licences had formerly been administered by headquarters (District Office 707) and thus did not appear on the Atlantic Region extract until they were decentralized. This process was supposed to have occurred mainly during 1973 and 1974.

A fourth problem affecting the historical data is the alleged inaccuracy of some dates of issue on the IRLS. It has been stated that until a few years ago, when amendments to a licence were made, especially for the purpose of adding a frequency, the original date of issue was often replaced by the amendment date. This problem would be expected to have a relatively greater effect on the accuracy of date of issue of older records. The only method of checking the extent of this practice, is matching of IRLS records with the corresponding original licence forms. Such a matching has not been attempted.

A final difficulty is encountered when one tries to use radio licence data at a frequency less than annual. Table 1 shows the distribution according to the Atlantic Region extract of new licences issued by month for fiscal year 1972-73 through 1976-77. From the table it appears that virtually no licences are ever issued during March. This is not the case. Licences are issued during March, but most are added to the IRLS only during April because of the workload associated with the beginning of a new fiscal year on April 1. Thus, the unadjusted data understate the number of licences issued in March, and overstate the number issued in April.

TABLE 1

ATLANTIC REGION

DISTRIBUTION OF NEW LICENCES ISSUED BY MONTH FY 1972-1976

YEAR 19	APR %	MAY %	JUN %	JUL %	AUG %	SEP %	OCT %	NOV %	DEC %	JAN %	FEB %	MAR %	TOTAL %
72	17.5	14.7	10.8	6.3	6.5	6.5	7.6	8.0	14.4	4.8	2.7	0.1	100
73	20.7	15.8	9.1	11.2	10.0	5.3	6.2	7.0	4.6	8.1	2.0	-	100
74	18.0	13.6	10.1	7.2	9.6	5.7	6.7	9.0	4.9	5.3	9.7	-	100
75	26.6	9.1	10.7	11.6	7.5	6.4	6.2	3.9	8.1	5.3	4.2	0.1	100
76	17.1	10.7	11.4	9.7	10.5	6.7	8.3	5.5	4.2	8.5	7.3	0.1	100

3.3 Reconstruction of Historical Data

Some of the problems discussed above can be overcome in a straightforward manner through familiarity with the details of the IRLS. In particular, a new extract from the IRLS has been specified which will allow us to overcome the decentralization problem, and the March/April difficulty. The new extract also has other features. It includes extra data items such as the date of application, which can be used in determining the length of the queue to obtain a licence, and the physical location of the radio station to which the licence refers. The latter could possibly be used to adjust the time series to take into account boundary changes. The record layout and selection criteria for the new extract may be found in Appendix B.

One major problem remains to be examined, that of the backward extension of the time series of licences issued for years prior to 1972 in order to increase the number of data points for analysis. A possible solution is to estimate historical cancellation rates (and relocation rates if necessary) on the basis of 1972/73 to 1977/78 data. A determination of the appropriateness of this procedure depends on the stability of these rates in recent years. We agree with Dr. West's statement, that if the rates are extremely variable "from year to year, region to region and code to code, the resultant uncertainty in the estimates would be so extreme as to completely overshadow any possible gain in forecasting accuracy due to having a longer historical series".[1] Thus, our next step is to review recent cancellation rates based on the more complete data available in the new extract.

[1] E. West Demand for Radio Station Licences - Atlantic Region p.5-6

4. TREND FORECAST AND TIME SERIES ANALYSIS: ATLANTIC REGION

One method of forecasting is based on a forward projection of a past, stable trend. To examine if this procedure of trend forecasting can be followed, the time series of new licences for one region (Atlantic) was analysed for the presence of a discernible trend in among the irregularities of the series. Several tests were tried comprising curve fitting to different types of growth patterns plus the fitting of Box-Jenkins ARIMA models.

Prior to any fitting of the data, however, it became acutely apparent that the raw data required much attention as to consistency and other problems. As was described in the previous chapter, data corrections had to be made to obtain a monthly time series representing new licences issued by the Atlantic region. A monthly basis was taken in order to increase the number of observations corresponding to five years of data, although quarterly data were constructed with the intention of providing a series free of the worst of the monthly fluctuations.

One peculiarity in the data was the apparently low number of licences which were issued in the month of March and the large number for April. In some cases it appears that applicants delayed their request until the start of the fiscal year since the annual fees are due every April. In addition to this, applications after March 9 are not processed until April 1. This particular distortion was treated by smoothing over the two months. The last data problem concerned seasonal adjustment. It was clear on inspecting quarterly data for the five years that a seasonal pattern exists. With really only three consistent years available for analysis, this was clearly not enough data for correcting for seasonal factors.

Time trends of eight different types were run on the original five years of monthly data (up to 1977) for the Atlantic region. The R-squared was zero in most cases and close to zero in others. When the last three years only were run the situation improved, but not to a satisfactory level. The following are the time trends with their R-squared in brackets: straight line (.091), experimental (.0645), power function (.1348), hyperbolic function (.1899), modified hyperbolic function (.0), rational (.0254), Gompertz function (.0) and growth function (.0). Even though the hyperbolic function has an R-squared of .19, this is too low for forecasting. The results indicate that a trend in the monthly data having a non-zero slope does not exist. Consequently, the best one can say is that the underlying trend for new licences, after the randomness in the data is removed, is a constant number issued each year.

Six ARIMA models were tried on the monthly licence data over three years.

The best of the six specifications was the second order moving average model:

$$Z(t) \doteq -10.3195 + A(t) - .6534\,A(t-1) + .3717\,A(t-2)$$

where A(t) denotes the disturbance at time t.

Other models that did not meet the above test included the following: first order autoregressive process, first order moving-average process, second order autoregressive process, first order autoregressive moving-average process, and seasonal moving average process.

Using another program, the autocorrelation function of different lags was produced. It indicated that the series was equal to a constant plus white noise. Visual inspection of the data supports this conclusion.

The ARIMA model expressed in the above equation is, by its structure, unsound for forecasting purposes. It shows that much of the movement in the time series can be accounted for by random disturbances lagged several times. This model explains the series as being generated by random shocks which appeared the previous two months in the past, and are superimposed on the contemporaneous shock. This moving average system has none of the inertia that characterises an autoregressive system and its forecasts would be merely transitory movements about a mean which would rapidly die off.

5. ECONOMETRIC MODEL OF DEMAND FOR LAND MOBILE

In constructing time-series models, we presumed to know nothing about causal relationships that affect the growth of new licences. However, the theory of derived demand tells us that the demand for a factor of production is related to output, technology and input prices. Hence, our next approach was to try to construct causal models which explicitly relate the growth of new mobile radio licences to explanatory variables related to the production process.

New mobile radio licences encompass many types of economic activities, both commercial and public service. The commercial activity such as construction, maintenance, security, taxis, are themselves sufficiently diverse that in the aggregate it is hardly possible to distinguish radio as a fixed cost or variable cost of production. We take the view that the radio base station is clearly a fixed cost while the number of mobiles has sufficient attributes of a variable cost to warrant its treatment as such. Thus with short term fluctuations in provincial and national economic output we expect to observe a related fluctuation in the demand for land mobile units and hence in licences issued. Intuitively, we would expect the two movements to be pro-cyclical but this need not necessarily be the case, where a downturn could possibly cause a substitution towards radio using economic activities. While this latter possibility is seen not to be particularly likely, an empirical confirmation of our intuition will not be unwelcomed in any case.

By the manner in which radio is used it may be thought that radio units and labour services are complementary rather than substitutable; each taxi driver has one unit. However, the possibilities of the radio may allow one person to do the work of many, showing the potential for substitution between spectrum on the one hand and labour and capital on the other (e.g. taxi and taxi drivers).

Consequently, it is not unnatural to regard spectrum as a factor input to the production process, at least for private industry.

On the other hand, non-commercial use of radio, specifically for urban services, are much less ruled by economic conditions than is the case for commercial use. The demand for radio by police, ambulance and more recently urban transit, is evidently tied to the service budgets provided by the various levels of government. This fact warrants a separate treatment for these services from commercial demand. At this stage, no separate analysis was made which we justify as follows. As a rough first approximation, we assumed, not entirely without cause, that government expenditures are responsive to the state of the economy, at least with some lag and certainly over the long run. This basic pattern will undoubtedly be disturbed by extraneous political factors, producing a great deal of "noise" in the series, yet the underlying economic causation should remain. The other assumption is that each urban service minimize cost under the budget constraint. As a corollary, economic efficiency considerations are presumed to influence the ratio of capital, labour and spectrum services used to provide the urban service in question.

In light of the foregoing discussion, our assumptions which underly the spectrum demand specification corresponds closely to the usual derived demand theory mentioned earlier.

The derived demand for radio services by business users is not completely independent of the demand for other factor inputs. Thus, not only will radio demand be affected by the price of other inputs but the equation expressing this demand is but one of a simultaneous system of interrelated equations. At this stage, however, we assume the equation for new licences is statistically independent of the rest of the equation system and estimate using OLS techniques.

5.1 Atlantic Region

A simplified demand equation was estimated for the Atlantic region, with the number of new mobile licences as the dependent variable, and (deflated) Gross Provincial Product and input prices as explanatory variables. The new licence data was available by province only on an annual basis. File extracts from the IRLS can be made to produce quarterly data series but no such file has been made at this stage. Strictly speaking the price variable should include the influence of both labour and capital costs, but the price of capital services did not emerge as statistically significant in the initial runs and hence does not appear below.

Since sufficient observations were not available to estimate either a pure time-series or a cross-section equation, the cross-section and time-series data were combined or "pooled". The unit of observation was the province, and the period of fit was 1973-1976, yielding 16 observations.

The simplest technique of pooling data is to combine all cross-sectional and time-series data and perform ordinary least-squares regression on the entire data set. To use this procedure one must assume a constant intercept and slope, that is, that cross-section parameters do not shift over time. Given the shortness of the period of fit, this appeared to be a reasonable assumption.

The fitted equation relates new licences to economic activity and relative prices:

$$NL = 433 + \underset{(5.78)}{33.53}\ GDPR - \underset{(-.726)}{64.89}\ PEW$$

$$R^2 = .8035$$

where NL = new licences

GDPR = Gross domestic (provincial) product divided by the GNP deflator

PEW = price of radio equipment divided by the price of labour

As shown above, the R^2 was reasonably high, and the two variables in the equation had the correct signs. As expected, greater economic activity gives rise to a stronger demand for radio services and indeed the most important variable in the regression appears to be Gross Domestic (Provincial) Product in constant dollars. The GNP deflator was used to deflate GDP since we could not obtain a reliable deflator for each province individually.

A plot of the residuals indicated the absence of heteroscedasticity in the model. At any rate, lack of data would have prevented the fitting of more sophisticated pooled models.

The insignificance of the relative price variable is not altogether surprising for two reasons. Firstly, there is no variation in the price of radio equipment across provinces and the average price of labour also was relatively uniform. Secondly, the noise introduced by aggregating across both commercial and non-commercial users probably obscured the relevance of this variable, suggesting that a disaggregation by industry might prove fruitful. Finally, the equation specification could likely be improved once we work at the industry level and include characteristics of radio use specific to particular users.

Given the value for the R^2, short run forecast of licence demand can be made on the basis of econometric model forecasts of GDPR. However, forecasting attempts should wait upon a more thorough examination of demand disaggregated by industry, which we expect would provide a higher proportion of explained variation than what appears here.

5.2 Canada

A greater heterogeneity is introduced in the data when we pass from the level of one region to the whole of Canada. For one thing, the mix of industries will be different province by province. However, we do gain by the increased number of observations provided by the inclusion of the other provinces.

For Canada as a whole, a demand function was estimated relating new licences to output, input prices, and technology. Output was measured by real gross domestic product at the provincial level. Input prices chosen were the price of labour which is a substitute for mobile radios, other capital which is also a substitute for mobile radios, and of course, the price of radio equipment.

The dependent variable is the number of new mobile licences issued at the provincial level in a given calendar year. Except for municipal government licences, for which there may be multiple radios per licence, one mobile radio corresponds to one mobile licence.

The regression used pooled cross-sectional and time series data, with the ten provinces providing the cross-sectional base. Due to the cancellation and decentralization problems, data before 1973 were considered suspect and were therefore not employed. Thus 1973 was the starting point of our series. 1976 was set as the end date, because gross domestic (provincial) product was only available to that year, yielding 40 observations, a reasonable sample size.

As for the Atlantic region, all the cross-section and time series data were combined, and ordinary least-squares regression performed on the entire data set. This technique was used because there was no reason to suspect that the cross-sectional structure was changing over time.

The results of the best regression are presented below. One additional variable was tried, the ratio of the price of equipment to the price of capital. However, it was insignificant, and had the wrong sign, and therefore was omitted from the final estimating equation.

$$\underset{}{NL} = \underset{(5.47)}{13579} + \underset{(7.9)}{18\ GDPR} - \underset{(-5)}{2369\ PEW}$$

$R^2 = .8$

where NL = new licences

GDPR = gross domestic (provincial) product in constant $

PEW = price of mobile radios ÷ price of labour

The equation performed remarkably well, with an R^2 of .82. The plot of the residuals does not indicate heteroscedasticity. All the variables included are significant.

Several equations were fitted, some with a proxy for technological change and/or with a suitable price variable. As it happened, these additional variables did not show up as significant and were discarded. This fact does not, however, reject the possibility that such variables could re-emerge as important within the context of a more thorough investigation.

The comments which applied to the Atlantic region apply here also. Moreover, any forecast at the Canada level has less applicability to the workload of district offices, or even regional offices, than does a forecast for the region itself. But a Canada study can be indicative to any particular region in that it provides a sense of the "average demand" for the country.

6. CONCLUSION

The most significant observations arising out of this study are; firstly, the poor state of the data base and secondly, forecasting results are possible from regression analysis. We do not believe that the estimations obtained here offer a basis for workload forecasting, for we are too alert to the imperfection in the data and have reservations on regressions which mix all industries. But the study has identified the problems with the data base and formulated remedies, as well as showed the viability of forecasting. With clean data and industry by industry regressions a much surer foundation for forecasts can be built.

The derived demand hypothesis applied to the analysis of the demand for mobile radio units is of itself worthwhile testing. A good specification modelled to the specific industry should say something regarding the effect of radio on employment and on over all productivity for each industry. The policy importance of such research should be readily apparent and on this count alone we are led to recommend further and more careful studies of spectrum demand by business users. The case for such studies is further enhanced, of course, when the same estimated equations will offer the forecasting means that regional offices appear to want.

It is fair to say from our results that the level of economic activity affects the workload of regional offices. So far our work has only hinted at the complex of economic variables which could bear upon the making of good forecasts. We strongly recommend a continuation of this study along the lines adopted here, using a reconstituted data base and a more carefully constituted theory and equation specification. Then the difficult but crucial task of regionally specific forecasts can be addressed and treated, and it is hoped yield the kind of information regional offices desire and in which they can have confidence.

DEPARTMENT OF COMMUNICATIONS

COMPUTER SYSTEM FILE STRUCTURE

CANADA

MINISTÈRE DES COMMUNICATIONS

COMPOSITION DU FICHIER DU SYSTÈME D'ORDINATEUR

APPENDIX A

FILE IDENT. — Ident. du fichien

PAGE OF de

FIELD Secteur	SIZE Grandeur	POSITION	TYPE	DESCRIPTION
1	3	1-3	N	Admin. Office
2	7	4-10	N	Company Code
3	1	11	N	Licence Code 1 - land 2=mobile 3=SHIP 4 = coast 5 = earth 6 = A/C 7 - space
4	1	12	N	Licence Region
5	6	13-18	N	Licence Number
6	4	19-22	A	Service Categories
7	7	23-29	A	Fee amount with 2 decimal
8	1	30	N	Fee status - 0 = Fee 1 = No Fee
9	3	31-33	N	No. of Municipal Stations (except ship licences)
10	5	34-38	N	SIC code
11	1	39	N	New Licence Flag 1 = New Licence 0 = Not New
12	6	40-45	N	Date of issue = Day/Mo./Yr.
13	4	46-49	A/N	Licence amendments
14	2	50-51	N	Frequency occurences on licence
15	2	52-53	N	Year of data file
16	1	54	N	Term Flag 0 = Active 1 = Cancelled 2 = Related

Blocking Factor 90 Records per Block

APPENDIX B

Specifications for Creation of IRLS Extract

1. Extract Criteria

Select all records for which licence region = 6 or for which licence region is not 6 but Administrative Office = 661 through 669.

There should be one record for each licence on each year-end file for 1972 to 1976.

Output Record

A record layout is attached

Extract File

- Sequential file on 9 Track, 1600 Bpi tape; SL
- Approximately 200,000 Records
- DCB = (RECFM = FB, LRECL = 82, BLKSIZE = 8200) ie 100 records per block

FILE IDENT. — Ident. du fichier

APPENDIX C

FIELD Secteur	SIZE Grandeur	POSITION	TYPE	DESCRIPTION
1	1	1	N	Licence region
2	3	2-4	N	Admin Office
3	1	5-5	N	Licence code
4	6	6-11	N	Licence number
5	4	12-15	A	Service categories
6	1	16-16	N	Fee status
7	7	17-23	N	Fee amount with 2 decimal
8	5	24-28	N	SIC code
9	1	29-29	N	New Licence Flag
10	2	30-31	N	Day of application
11	2	32-33	N	Month of application
12	2	34-35	N	Year of application
13	2	36-37	N	Day of issue
14	2	38-39	N	Month of issue
15	2	40-41	N	Year of issue
16	1	42-42	N	Termination Flag(0=Active, 1=Cancelled, 2=Changed)
17	7	43-49	A/N	Reference Company Code
18	1	50-50	A/N	Reference Region
19	3	51-53	A/N	Reference Admin Office
20	1	54-54	N	Maintenance Code
21	1	55-55	A/N	Lic amendments/Y-T-D-no fee
22	1	56-56	A/N	Lic amendments/Y-T-D-fee
23	2	57-58	A/N	Day of record termination
24	2	59-60	A/N	Month of termination
25	2	61-62	A/N	Year of record termination
26	3	63-65	A/N	Number of municipal stations
27	2	66-67	N	Year of data file
28	1	68-68	N	X 4 conversion month
29	1	69-69	N	X 2 input month
30	2	70-71	A/N	Latitude - degrees
31	2	72-73	A/N	Latitude - minutes
32	2	74-75	A/N	Latitude - seconds
33	3	76-78	A/N	Longitude - degrees
34	2	79-80	A/N	Longitude - minutes
35	2	81-82	A/N	Longitude - seconds