Telecommunications demand and pricing structure: An econometric analysis

Marc Aldebert,
France Telecom R&D

Marc Ivaldi,
Institut D'Economie Industrielle
Groupe de Recherche en Economie MAthématique et Quantitative
Ecole des Hautes Etudes en Sciences-Sociales

Chantal Roucolle*,
Groupe de Recherche en Economie Mathématique et Quantitative
Ecole des Hautes Etudes en Sciences Sociales
France Telecom R&D

Abstract

The main objective of this paper is to analyse residential demand by traffic destination, using a translogarithmic indirect utility function. We focus on five traffic directions, in order to construct a model adapted to evaluate the characteristics of telecommunications demand in a competitive market. The resulting price elasticities express high reactivity to own price changes for the main traffic directions, as well as little interactions between the different types of traffic. Moreover the high values of income elasticities confirm the importance of income effects when analysing residential telecommunications demand. This model shows useful for welfare analysis. The computation of customers' income equivalent variation shows, on average, a higher willingness to pay for some traffic directions than the bill actually paid. Finally we show that the optimal prices for the operator, in a cost minimisation point of view, are higher than the observed prices for local and national traffic directions. This emphasises the existence of important cross-subsidies among the different segments of customers.

Keywords: system of demand, telecommunications, pricing structure, welfare analysis.
JEL classification: C33, D12, D4, L96

---

*Corresponding author: Marc Ivaldi, Institut D'Economie Industrielle, Université Toulouse 1 Sciences Sociales, Manufacture des Tabacs (Bat. F), 21 Allée de Brienne, 31000 Toulouse, France.
Tel.: 33 5 61 12 85 90; fax.: 33 5 61 12 86 37 ; email: ivaldi@cict.fr
We would like to thank D. Encaoua, A. Perrot, R. Renault, JC. Rochet for their helpful suggestions. We also benefited from comments by seminar participants at ASSET-99 and EUREQua. The views expressed in this article are those of the authors and should not be imputed to France Télécom.

I- INTRODUCTION

With regard to traditional telecommunications services, the deregulation of residential markets imposes a new challenge on incumbents facing competition within the market. The main consequence of competition is the loss of market shares. Following the opening of the French residential telecommunications market, France Télécom has lost 13 % of its residential long distance traffic by the end of 1999. To remain attractive, the incumbents have to quantify customers' adaptive behaviours facing a tariff restructuring. One of the strategic issues is to prevent customers from switching to a competitor, by adjusting the offered services to individual demand properties.

Moreover, an other consequence of deregulation concerns the operators' objective, in terms of profit maximisation. This objective changes drastically when the structure of the market evolves from a regulated monopoly to a competitive context. In the first case, the operator maximises its profits subject to regulation constraints, at least universal service obligation. In the second case, the operator maximises its profits subject to a technological constraint. If the universal service obligation is not relevant anymore, the only constraint is to remain attractive. Thus, the operator has to introduce, in its maximisation program, some individual rationality conditions such as constancy of utility level or total telecommunications bill. Nevertheless, even in a competitive context, the historical operators have to satisfy the universal service obligation, although the new entrants have to pay them a compensation. Finally, with the changes of market structure, the substantial cross-subsidies in the pricing of products can no longer be sustainable. In France, the usual practice was to keep the price of local services low compared to the price of long distance calls. The objective was to charge more non elastic goods, i.e. long distance traffic in this case especially generated by the firms, than the elastic one, i.e. local traffic especially generated by residential customers.

The historical operators must therefore adapt their tariffs to the new market structure. When considering tariffs on residential market, the willingness to decrease cross-subsidies is clear, as the prices of long distance and international traffic decrease whereas the price of local traffic remains constant. On the other hand, many non linear tariffs appear, from flat rate to traditional tariffs, meaning that operators aim at proposing the best tariff for each customer. This attitude is well studied in the economic theory of adverse selection models: by choosing a specific tariff, the customers reveal their own preferences. Nevertheless, economic theory allows adverse selection models to be solved in the case of a single product monopoly, whereas in a competitive context, the relevance of asymmetric information models have to be verified empirically. Moreover, the technologies in the telecommunications field keep improving, this results in the introduction of new products. Thus the operators can also differentiate customers by offering different quality of goods. On mobile market, different handsets are associated with different tariff structures.

As said before, the necessary economic tool to implement efficient tariff policies is the residential individual demand function. When considering the demand for telecommunications services, we have to take into account many characteristics (e.g., Wolak, 1993). First of all, there is a distinction between access demand and demand for use. Most of the time, the access demand is not considered in empirical studies, as the data given by the operators are only available for customers, who, of course, are connected to the network. The second characteristic deals with access or network externalities and externalities of use. A network externality occurs when a new customer decides to connect to the network: the number of people who can be reached increases without any cost for the customers already connected. There is an externality of use, either positive or negative, because in the case of a received call, the called customer has nothing to pay, but he has a cost or a benefit to answer depending on the nature of the call. The third characteristic is the existence of options values. Each customer connects to the network because he has a willingness to pay for both potential and certain traffic. That's why some customers connect to the network just in case they would have to make calls, but they do not consume anything.

Finally, the key characteristic of telecommunications demand is the multidimensionality of telephone services: they are usually defined by the type of traffic (local, neighbourhood, long distance...), the duration, the date and time of day, etc. Thus a call is not a unique good, this results in many prices. The almost perfect model of demand should then encompass these features, especially the distinction between different types of traffic. Indeed, as an operator can choose to enter the market only for one direction -for example long distance traffic- it would be very useful for the incumbents to precisely know customers' behaviour for each traffic destination in order to anticipate their possible switch to the competitor. Nevertheless the literature dealing with residential telecommunications demand globally fails to analyse the "whole" demand: most of the existing models focus on the demand for a specific type of traffic (see Taylor, 1994, for numerous examples of demand for local traffic).

Since the 70s, the development of residential telecommunications demand modelling has followed the evolution of the residential telecommunications market, from its infancy to its mature phase. In the early 70s, as the residential network grew faster and faster, the analysis focused on access demand. The objective was to determine the optimal network size. Then, in order to find out which customers' categories are winners or losers of a hypothetical cross-subsidy decrease, individual characteristics are introduced in the analysis of demand functions. The occurrence of non linear tariffs as well as optional tariffs has been speed up by the telecommunications market deregulation. As noted before, because of this new competitive context, the tariff policy should be considered as an adverse selection problem, based on individual demand function, including individual characteristics.

Now that heterogeneity of telecommunications services and individual demand functions appear as the fundamental properties of residential demand studies, two approaches can be explored to reach the objective of a better knowledge of customers' behaviour. The first possible type of model to describe residential consumption are discrete choice models. In the model developed by Train and Al. (1987), the customers have the choice between portfolios. These portfolios are defined on one timetable and for one traffic direction, and they are composed by a number and an average duration of the calls for each couple: (timetable, traffic direction). Each portfolio has a specific cost known by the customers. By choosing a portfolio, the consumers reveal their preferences and reach their optimal level of utility, since rational behaviour is supposed. The second type of model allowing the distinction between traffic directions includes models of demand system where each equation deals with one direction and depends on the prices of all the traffic directions (e.g., Wolak, 1996). Estimating jointly all the demand functions, the interrelations between the different types of traffic are taken into account.

The objective of this paper is thus to implement an economic tool simultaneously characterising the demands for different types of traffic. We decide to follow the second approach described above: the demand system modelling. The starting point of our analysis is based on the dual approach in customer micro-economic theory. Using a translogarithmic form for the indirect utility function, the share equations for different types of traffic are estimated.

This methodology has already been used in numerous papers[1]; we have to adapt it to our field, namely the residential telecommunications demand in France. Such a model allows us to compute own and cross-price elasticities, and thus to anticipate customers' traffic responses to a price modification. This may be particularly relevant in a context of market deregulation. Besides these classical properties, this type of model can also be used as an economical politic tool. Thanks to the estimation of an indirect utility function, it's possible to find out the value of individual income equivalent variation; moreover, by including non-observable individual heterogeneity, this evaluation could become even more precise. If one interprets the income equivalent variation as a measure of the willingness to pay for observed consumption, the operator could revise telephone service subscription charges or prices according to the values obtained. Finally, the knowledge of demand and cost functions for residential customers allows the operator to compute some optimal prices when his objective is to minimise his costs subject to the constancy of individual bills. The functions estimated are useful to compare optimal prices and the prices actually paid by each customer.

II- AVAILABLE DATA

We observe a representative sample of French residential customers. A first data-set gives individual detailed consumption both in minutes and in telecom units. The consumption is observed from October 1st 1996 to July 30th 1997[2]. These informations allow us to measure

---

[1] See for example:

- Pollak, R., Sickles, R., and Wales, T., 1984, The CES-translog: specification and estimation of a new cost function, The review of economics and statistics.

- Chung, J. W., 1987, On the estimation of factor substitution in the translog model, The review of Economics and Statistics.

[2] At the time the data were observed, France Télécom was a regulated monopoly on the residential segment.

the total telecommunications bill as well as the bill for each type of traffic. A second data-set gives, for the same customers, many individual characteristics such as the level of income, the household structure (number of people and age for each member of the family), the SPC for the head of the household, etc. Combining the information of the two data-sets, we can compute the bill for each type of traffic as a percentage of income. Actually, we observe income classes and we consider each customer's income to be the median of the class he belongs to. A more efficient process to set individual income would be to generate an income distribution based on individual socio-demographic characteristics.

The most important hypothesis assumed in the model is that consumption structures related to traffic directions are unrelated and are fixed, whatever the direction. Traffic structure means number, choice of day and time for the calls. Thus, if a change in local traffic structure occurs, the traffic structure for the other directions remains unchanged. Interactions between traffic directions only consists in substitutions of total time spent calling. Because of this hypothesis, we can study separately the different types of traffics. Five traffic directions are distinguished: local, national or long distance, international, towards-mobile and other traffic. This last category includes the use of *minitel*, automatic clock,... Table 1 gives the description of traffic direction consumption and traffic shares expressed as percentages of income and total telecommunications bill. The individual prices per minute are necessary to determine expenditure shares.

During the studied period, the consumption is also expressed in telecom units (TU). One TU has a fixed price: 0.742 French francs, all taxes included, and each TU started is charged to the consumers. But the duration of the telecom units depends on the type of day, the time of the call as well as the type of traffic. Then, the differences in individual consumption

---

Moreover the tariffs were based on the number of telecom units consumed.

structures result in individual prices per minute. Hence, for a type of traffic we have a price distribution. The individual price, paid by consumer *n*, for traffic direction *i* is expressed as:

$p_i^n = \frac{0.742 \times TUnumber_i^n}{mn_i^n}$, where $TUnumber_i^n$ is the total number of TUs charged to the consumer *n*, for the direction *i*, and mn_i^n is the total traffic duration, in minute, for consumer *n*, towards direction *i*, over the observed 10 months. This gives an individual average price for the period considered, for the five traffic directions. Thus the average individual price per minute captures customers' heterogeneity related to consumption structures for the five traffic directions. The prices are expressed in French francs per minute, all taxes included. The main drawback in this price determination is that, in the final model, the quantity consumed is both endogenous (used in computing the price) and exogenous (this is mainly what the model tries to explain). This is typically the well known problem of translogarithmic models. However, in our specific case, we can show that individual average prices per minute are perfectly exogenous. Two reasons explain this exogeneity. First, the consumption decision depends on the availability of the called person. In that sense the choice of consumption is limited. The second reason is a consequence of tariffs non linearity. In order to control totally the price per minute of a call, the consumer has to measure exactly its duration. This is obviously never the case as no-one use a chronometer while making a call.

III- PRESENCE OF ZERO DEMAND FOR SOME TRAFFIC DIRECTIONS

A high number of customers do not use all of the five types of traffic: only 35 % use international traffic and just more than 40 % use consumption towards mobile. The economic theory proposes three possibilities to explain zero demand. It may be a problem of purchase frequency resulting of a too short observation period. As we observe detailed consumption

Table 1 - Traffic shares and consumption observed[3]

	Mean	Minimum	Maximum
Traffic shares as percentages of income			
Local share	0.74	00	11.97
National share	0.55	00	9.34
International share	0.13	00	12.15
Towards-mobile share	0.07	00	5.77
Other traffic share	0.24	00	12.08
Traffic shares as percentages of total telecommunications bill			
Local share	49.70	00	100
National share	31.86	00	100
International share	4.42	00	89.24
Towards-mobile share	3.28	00	81.14
Other traffic share	10.74	00	90.56
Total traffic consumption in minutes per month			
Local traffic consumption	205.82	00	892.87
National traffic consumption	46.92	00	293.17
International traffic consumption	2.35	00	51.41
Towards-mobile traffic consumption	1.54	00	35.17
Other traffic consumption	10.54	00	227.50

[3] We removed some customers from the queues of the distributions (less than 1 % for each traffic direction).

during 10 months, we can reject this first possibility to explain zero demand. A zero demand may be a consequence of an endogenous rationing phenomenon. When the price of a good is too high, the solution of the consumer's optimisation program is a corner solution. We observe consumption during a sufficiently long period and we can notice that the distributions of numbers of calls are bimodal in zero and two for international and towards mobile traffic directions. Then we can reject the assumption of the endogenous rationing phenomenon. Finally, the last possibility to explain zero demand is the presence of an exogenous rationing, in which case a consumer does not use a good because he does not have access to it. In the case of telecommunication consumption, exogenous rationing applies: consumer does not use some traffic directions because they have no-one to reach to these directions.

The problem resulting of a zero demand is that price is not observable for the corresponding traffic direction. The usual practice is to set a price determined from the observed price distribution. We decide to set low prices, meaning that even a low price is too high to consume, which is consistent with the assumption of exogenous rationing. We choose the average of the first decile of each price distribution. These prices can be interpreted as some reserved prices for the corresponding traffic directions. Tables 2 and 3 give the values of the prices chosen for each traffic direction in a case of zero demand and the exogenous variables finally used in the model estimation. The exogenous variable "composite good price" is the difference between income and total telecommunications bill. We will see in section IV the economic justification for this good.

Table 2 - Prices assigned to zero demand

Traffic directions	Local	National	International	Towards-mobile	Other traffic
First decile value	0.258	0.949	2.032	2.520	1.269
Average fist decile	0.229	0.856	1.487	2.160	0.993

Table 3 - Exogenous variables of the model[4]

Exogenous variable	Std Dev.	Minimum	Maximum
Local price	0.11	0.160	1.257
National price	0.26	0.271	3.180
International price	2.00	0.761	14.840
Towards-mobile price	1.35	1.841	14.840
Other traffic price	1.90	0.227	44.520
Composite good price	7117.58	1246.98	49988.72
Income	7163.10	1500.00	50000.00

Note : composite good price and income are expressed in French francs.

[4] See in annex I the price distributions.

IV- ECONOMIC BACKGROUND

The starting point of the analysis is customers' individual utility maximisation. We assume customers to have a rational behaviour in the choice of the five telecommunications goods, namely local, national, international, towards-mobile and other traffic directions, and an aggregated good. We suppose this aggregated good to be a portfolio of all other consumption goods. The difference in portfolio prices is a consequence of the difference in portfolio qualities: the quality depends on the quantities and qualities of the goods included in the portfolio. The customer chooses a unique portfolio. The quantities of telecommunications consumption and the quality of the composite good are chosen in such a way to maximise the utility, subject to the individual budget constraint. This program allows us to determine the Marshallian demand functions.

Let us call :

- $x_i * (p, p_z, R)$, the Marshallian demand for traffic direction *i*; *p* is the individual price vector of the telecommunications good, $p = (p_i)_{i=L,N,I,M,O}$, *L* means Local traffic, *N*, National or long distance traffic, *I*, International traffic, *M*, towards-Mobile traffic and O, Other traffics; *R* is the individual income;
- $Z * (p, p_z, R)$, the Marshallian demand for the aggregated good whose quality is *z* and price is p_z; the quantity is assumed to be one;
- $U(x, Z)$, the individual utility function.

Then, if we call $V(p, p_z, R)$ the indirect utility function, *V* is defined by:

$$\left.\begin{array}{l} V(p,p_z,R) = \underset{x,Z}{Max}\, U(x,Z) \\ such\ that\ \ px+p_z=R \end{array}\right\} \Leftrightarrow V(p,p_z,R) = U\big(x^*(p,p_z,R),Z^*(p,p_z,R)\big). \qquad (2)$$

The indirect utility function is non increasing with price, non decreasing with income. It is homogenous of degree zero in (p, p_z, R) and quasi-convex in price. Using the indirect utility function and Roy's identity we can determine the Marshallian demand functions. Roy's identity is written:

$$x_i(p,p_z,R) = -\frac{\partial V(p,p_z,R)\big/\partial p_i}{\partial V(p,p_z,R)\big/\partial R} = x_i^*(p,p_z,R) \qquad \forall\, i = L,N,I,M,O,Z. \tag{3}$$

Once the functional form of indirect utility is known, it is easy to measure demand for each good as far as prices and income are individually observed. We use the duality theory just described to retrieve the parameters of the indirect utility function from the Marshallian demand functions, because we can observe prices for each good consumed and because prices vary across consumers. The next step of the analysis is the choice of the functional form for the indirect utility function. We approximate this function by a translogarithmic flexible form. By using a flexible form, we do not impose any particular constraint on the direct utility function. Thus the price elasticities are not constrained a priori and we obtain individual elasticities, i.e., a distribution for each kind of elasticity. The translogarithmic indirect utility function is written:

$$ln\left(V(p,p_z,R)\right) = \alpha_0 + \sum_i \alpha_i \, ln\, p_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \, ln\, p_i \, ln\, p_j \tag{4}$$

$$\text{with } i,j=L,N,I,M,O,Z,R \text{ and } p_r=R.$$

This function has to fulfil some conditions to be consistent with economic theory. First of all, as the Hessian matrix has to be symmetric, the indirect utility function parameters have to be symmetric. Thus we have: $\beta_{ij} = \beta_{ji}, \ \forall i, \ \forall j$. As a consequence of utility maximisation, the indirect utility function is homogeneous of degree zero in (p, p_z, R). This property implies the following restrictions on the parameters:

$$\sum_i \alpha_i = 0 \quad i=L,N,I,M,O,Z,R \text{ and } \sum_j \beta_{ij} = 0 \quad j=L,N,I,M,O,Z,R \text{ and } \forall i. \tag{5}$$

Substituting the income parameters (β_{iR}) in the indirect utility function, we can write:

$$ln\big(V(p,p_z,R)\big) = \alpha_0 + \sum_i \alpha_i \, ln\frac{p_i}{R} + \frac{1}{2}\sum_i\sum_j \beta_{ij} \, ln\frac{p_i}{R} ln\frac{p_j}{R} \tag{6}$$

$$\text{with } i,j=L,N,I,M,O,Z.$$

In the following, without any other specification, the indices will mean L, N, I, M, O, Z.

As we said, the demand functions are derived from the indirect utility thanks to Roy's identity. When using a translogarithmic form, we usually focus on expenditure shares. For each good the share equation expresses the percentage of income spent on the considered good. The sum of the shares among all the goods equals one. Let's call w_i the share for good *i*, then we can write:

$$w_i(p,p_z,R) = \frac{p_i x_i(p,p_z,R)}{R} = -\frac{p_i}{R}\frac{\partial V/\partial p_i}{\partial V/\partial R} = -\frac{\partial\, lnV/\partial\, ln\, p_i}{\partial\, lnV/\partial\, ln\, R} \qquad \forall i. \tag{7}$$

With the translogarithmic form for the indirect utility function, the share equations are written:

$$w_i(p,p_z,R) = \frac{\alpha_i + \sum_j \beta_{ij} \, ln\frac{p_j}{R}}{\sum_j \alpha_j + \sum_j\sum_k \beta_{jk} \, ln\frac{p_j}{R}} \qquad \forall i. \tag{8}$$

Our objective is then to estimate the system made up of the six share equations. As the share equations are homogeneous of degree zero in parameters, an identification constraint has to be imposed. The usual constraint is: $\sum_i \alpha_i = -1,$ which implies $\alpha_R = 1$ to allow the homogeneity constraint of the indirect utility function to be satisfied (cf. equation 4.4). Moreover, if we assumed preferences to be homothetic, then there would be some additional constraints on parameters: $\beta_{iR} = 0 \Leftrightarrow \sum_k \beta_{ik} = 0 \quad \forall i$. In this case, the share equations would become log-linear with respect to the prices. As discussed in Wolak (1996) we assume non-homothetic preferences. Hence this last constraint on parameters is not imposed.

V- ECONOMETRIC FRAMEWORK

We now have to define a stochastic structure which accounts for differences between the observed expenditures shares and those predicted. We add to the share equations a zero-mean error ε_i, which can be correlated with the errors from the other share equations for a given customer, yet the errors are independently distributed across customers. If we notice $\varepsilon = (\varepsilon_i)$, the vector of additive share equation disturbances for a given customer, these assumptions are written: $E(\varepsilon) = 0$ and $E(\varepsilon\varepsilon') = \Omega$, where Ω is a symmetric, positive semidefinite matrix. The disturbance can be interpreted as the unobservable portion of the indirect utility function, thus the general form of this function is: $V(p, p_z, R, \varepsilon)$. Because of the difficulty to explain how the disturbances explicitly enter the indirect utility function, we only require that ε enters in a way that yields additive disturbances to the share equations satisfying the moment restrictions described above. As a consequence, the i^{th} individual share equation is written:

$$w_i(p,p_z,R) = \frac{\alpha_i + \sum_j \beta_{ij} \ln \frac{p_j}{R}}{\sum_j \alpha_j + \sum_j \sum_k \beta_{jk} \ln \frac{p_j}{R}} + \varepsilon_i \qquad \forall i. \tag{9}$$

Finally, the last necessary assumption on the ε for the stochastic structure to be consistent with the utility maximisation is that, because of summability of the observed budget shares, the sum of the ε_i over all the goods is identically null whatever the customer. Given the disturbances in any six minus one equation, the disturbance of the remaining equation can be determine from the budget constraint. Only five among the six equations are then required for a complete econometric model of demand. Whatever the five share equations used in the estimation, the results remain unchanged. As we are interested in telecommunications demand rather than global consumption, we decide to keep in the model the five share equations dealing with the demand for the five traffic directions. To determine the optimal parameters, we use the maximum likelihood method.

Because of the high standard deviations values of exogenous variables, it is necessary to normalise these variables, i.e., to divide all the variables by their respective average. This allows the model to converge to a single optimal solution. The initial values are determined after an OLS estimation on the model where the hypothesis of homothetic preferences is assumed. However the model is robust to any modification of the initial values.

VI- ESTIMATION AND RESULTS VALIDITY

The estimated parameters are indicated in Table 4. They are normalised for confidentiality reasons. As the share equations are fairly non linear, the values of the estimated parameters as well as their signs can not be interpreted directly. However, the « direct-terms », α_i, have greater absolute values than the « cross-terms », β_{ij}. Then the direct terms in the indirect utility function seem to have more influence than the cross terms. Among the 26 estimated parameters, 14 can be considered different from zero with a risk lower then 10 %. The likelihood ratio test confirms the significance of the global model.

The null hypothesis H_0 of this test assumes the nullity of the cross-term parameters in the indirect utility function, i.e. the β_{ij}. We test this hypothesis against the opposite, H_1. Under H_0, the log-likelihood of the model $ln V_0$ is 27954, under H_1 it is $ln V_1 = 28533$. The test statistic of the likelihood ratio test, $2 \times (ln V_1 - ln V_0)$, is distributed has a X^2 distribution with 21 degrees of freedom (there are 21 cross terms, β_{ij}, in the model). As $2 \times (ln V_1 - ln V_0) = 1158$ is higher than $41.4 \; \left(= t_{\chi^2_{21}(0.5\%)}\right)$, we reject the null hypothesis with less than 0.5 % chance of error. It is thus relevant to consider that the consumption of one traffic direction is dependant of both its own price and the prices of the other directions.

In most of the empirical studies related to residential telecommunications demand, it is assumed separabiliy in the indirect utility function between telecommunications goods and the other goods and services. This assumption is often a consequence of a lack of information related to the goods other than telecommunications goods or related to the individual incomes. In our case, these informations are available. Then, we can construct a non additively separable indirect utility function. The objective of this specification is to allows us to take into account the income effects in a direct way. However, because of the low level of expenditure shares in telecommunications goods (on average less than 2 % of the income) compared to the expenditure share in composite good, we have to test the assumption of non separability. The principle of the test is the same as the likelihood ratio test just described. Here the null hypothesis expresses that under additive separability the 5 cross terms between telecommunications goods and the composite good are zero. The test leads to reject the null hypothesis with less than 5 % chance of error. The specification of the indirect utility function as a non separable function is then validated.

Moreover we can verify that, for the estimated values of the parameters, the indirect utility function is quasi-convex in prices. For the average customer of the sample, the eigenvalues of the Hessian matrix of the indirect utility function are positive. Thus the Hessian matrix is positive semidefinite.

Finally, table 5 gives the shares forecasted by the estimated model. Only the observations with positive forecasts are kept in the model. About 15 % individuals have negative forecasts for international traffic. The great majority of customers who have a negative predicted share for one traffic direction are customers who do not use this traffic direction. In all the following, we will exclude these observations. On average, the predicted shares are close to the observed shares. However the model tends to under-estimate the total telecommunications consumption. By adding up the predicted shares the under-estimation equals 0.11 %[5]. The comparison of the forecasted and the observed shares, expressed as percentages of the total telecommunications bill, shows that the highest differences occur for local and other traffic directions. With respect to the composite good consumption, the model assumes that customers choose the quality, whereas the quantity equals one. This hypothesis is not imposed a priori. It is verified empirically as the average prediction for composite good consumption is 1.0003 (cf. table 6).

[5] Estimation expressed as percentage of income used for telecommunications.

Table 4 - Estimated parameters, normalised for confidentiality reasons

Parameter	Variable	Estimation	Std-dev.	Student stat.
α_L	$ln(p_L/R)$	-1.0000 (***)	0.0002	-27.62
α_N	$ln(p_N/R)$	-0.7825 (***)	0.0003	-16.65
α_I	$ln(p_I/R)$	-0.1349 (*)	0.0006	-1.51
α_M	$ln(p_M/R)$	-0.0921 (**)	0.0003	-2.24
α_O	$ln(p_O/R)$	-0.3460 (***)	0.0003	-6.23
α_Q	$ln(p_Q/R)$	-156.3746 (N.S.)		
β_{LL}	$ln(p_L/R)^2$	0.5698 (***)	0.0005	6.55
β_{LN}	$ln(p_L/R)ln(p_N/R)$	-0.2444 (***)	0.0005	-3.36
β_{LI}	$ln(p_L/R)ln(p_I/R)$	-0.1190 (***)	0.0003	-2.57
β_{LM}	$ln(p_L/R)ln(p_M/R)$	-0.0762 (N.S.)	0.0004	-1.28
β_{LO}	$ln(p_L/R)ln(p_O/R)$	0.0381 (N.S.)	0.0003	0.76
β_{NN}	$ln(p_N/R)^2$	0.4000 (***)	0.0007	3.62
β_{NI}	$ln(p_N/R)ln(p_I/R)$	0.1841 (***)	0.0004	3.13
β_{NM}	$ln(p_N/R)ln(p_M/R)$	0.0873 (N.S.)	0.0005	1.18
β_{NO}	$ln(p_N/R)ln(p_O/R)$	-0.0175 (N.S.)	0.0004	-0.29
β_{II}	$ln(p_I/R)^2$	-0.1286 (N.S.)	0.0006	-1.27
β_{IM}	$ln(p_I/R)ln(p_M/R)$	0.0841 (*)	0.0004	1.44
β_{IO}	$ln(p_I/R)ln(p_O/R)$	0.0381 (N.S.)	0.0004	0.58
β_{MM}	$ln(p_M/R)^2$	-0.0524 (N.S.)	0.0007	-0.48
β_{MO}	$ln(p_M/R)ln(p_O/R)$	0.0048 (N.S.)	0.0003	0.08
β_{OO}	$ln(p_O/R)^2$	0.0619 (N.S.)	0.0007	0.59
β_{LQ}	$ln(p_L/R)ln(p_Q/R)$	19.8238 (***)	0.0059	21.04
β_{NQ}	$ln(p_N/R)ln(p_Q/R)$	22.1016 (***)	0.0064	21.78
β_{IQ}	$ln(p_I/R)ln(p_Q/R)$	9.6492 (***)	0.0080	7.61
β_{MQ}	$ln(p_M/R)ln(p_Q/R)$	1.5571 (*)	0.0076	1.29
β_{OQ}	$ln(p_O/R)ln(p_Q/R)$	2.5206 (*)	0.0122	1.30
β_{QQ}	$ln(p_Q/R)^2$	-62.5095 (**)	0.1759	-2.24

Note : (*), (**), (***) indicate significant parameters with confidence level respectivelly equal to 90 %, 95 % et 99 % ; (N.S.) indicates non significant parameters.

Table 5 - Share predictions and observations

	Mean (10^{-2})	Minimum (10^{-2})	Maximum (10^{-2})	Observed share (10^{-2})
Share predictions as percentage of income				
Local	0.7573	0.0681	8.0244	0.7885
National	0.6115	0.2022	7.3483	0.6351
International	0.1352	0.0012	3.5638	0.1415
Towards-mobile	0.0715	0.0000	0.5233	0.0784
Other traffic	0.2407	0.1151	1.0314	0.2851
Composite good	98.1838	79.6226	99.1650	98.0714
Share predictions as percentage of total telecommunications bill				
Local	40.87	6.09	63.68	46.58
National	34.07	11.70	58.10	34.48
International	5.76	0.11	17.78	4.25
Towards-mobile	4.41	6.26^{E}-4	12.49	3.46
Other traffic	14.89	4.96	31.48	11.24

Table 6 - Consumption prediction of composite good

Composite good	Mean	Std Dev	Minimum	Maximum
Consumption prediction	1.0003	0.0106	0.9499	1.0907

VII- PRICE AND INCOME ELASTICITIES AND MORISHIMA ELASTICITIES

7.1- PRICE AND INCOME ELASTICITIES

Thanks to the estimated parameters, we can determine the values of own price, cross price and income elasticities. As said before, the developed model allows us to compute individual elasticities. Then we obtain some elasticity distributions. Let's call η_{ii} the own price elasticity for direction *i*. The own price elasticity expresses the variation of consumption *i*, in minute, when the price of direction *i* increases by one unit. These elasticities are assumed to be negative because the demand decreases as price increases. With the translogarithmic specification of the indirect utility function, η_{ii} can be expressed:

$$\eta_{ii} = \frac{\partial x_i(p,p_z,R) / \partial p_i}{x_i(p,p_z,R) / p_i} = -1 + \frac{\partial ln(w_i)}{\partial ln(p_i)}. \tag{11}$$

Let's call η_{ij} the cross price elasticity of demand *i* for price *j*. The cross price elasticity expresses the increase in consumption *i* when the price of direction *j* increases by one unit.

$$\eta_{ij} = \frac{\partial x_i(p,p_z,R) / \partial p_j}{x_i(p,p_z,R) / p_j} = \frac{\partial ln(w_i)}{\partial ln(p_j)}. \tag{12}$$

The computation of cross price elasticities allows us to determine whether the goods are substitutes or complementary.

Let's call η_{iR} the income elasticity for direction *i*. The income elasticity measures the increase in consumption for direction *i* when the income increases by one unit.

$$\eta_{iR} = \frac{\partial x_i(p,p_z,R) / \partial R}{x_i(p,p_z,R) / R} = 1 + \frac{\partial ln(w_i)}{\partial ln(R)} . \tag{13}$$

Table 7 gives the elasticities, evaluated for the average customer. When focusing on the average customer, the own price elasticities have the expected negative signs, although for some customers, there are positive own price elasticities for international (54.44 % of the sample) and towards-mobile (12.30 % of the sample) traffics. The corresponding elasticities have to be interpreted carefully. Indeed, they are average figures taking into account the whole sample whereas many customers have a zero demand for international and towards-mobile traffics. Then, the elasticities are lowered in absolute value.

The own price elasticities are higher than one in absolute value for local, national and other traffic demands. For these traffic directions, the average customer is then sensitive to own price changes. These elasticities are comparable with the elasticities obtained by Wolak[6] (1996). However, Wolak (1996) had a demand for local traffic less elastic than the demand for national traffic. In our model they are almost equal. The international and towards-mobile traffic demands are the less elastic. We find the lowest elasticities, in absolute value, for the traffic directions whose prices are the highest, meaning that for these traffic directions there is no « superfluous » traffic. Finally we obtain a relevant value for the own price elasticity of the composite good demand. This is an other index of the consistency of the global model.

The cross price elasticities are generally lower, in absolute value, than the own price elasticities. The cross price effects are then lower than the own price effects. This is consistent with the higher values of direct parameters, obtained in the estimated model. This result is not

---

[6] Frank A. Wolak, 1996, finds an average own price elasticity for an American customers sample equals to -0.88 for local demand and -2.07 for national demand.

always true for international and towards-mobile demand elasticities. This can be a consequence of the highest values of the prices per minute of this two directions, compared to the prices of local and national traffics and the relative insensitivity of the demand related to an own price change. Depending on the sign of the cross price elasticities, the goods are complementary (negative sign) or substitutes (positive sign). As we mentioned earlier, by substitution we mean substitution in total time spent calling. Local demand is substitute to all traffic directions but other traffic demand. National demand is substitute to local and other traffic demands. International and towards-mobile demands are complementary with all traffic directions but local traffic direction. Finally other traffic demand is substitute to local and national traffic demand. Otherwise the cross price elasticity analysis shows that local demand has the first use: excluding the first line and the first column related to local demand, the remaining cross price elasticities are almost all negative. Although when focusing on the first line and the first column, they are almost all positive.

When the price of the composite good increases by one unit, the telecommunications demands decrease; the national and international demands are the most affected. Finally, one can note that whenever the income increases, all the telecommunications demands increase. Moreover the values of the income elasticities are high, meaning that the income effect is important (see in Appendix II the average consumption associated with each income class). This emphasises the relevance of taking into account the income effect when analysing residential telecommunications demand. Note that the income elasticities have to be interpreted as an increase in consumption when consumer drops from one income class to the upper and closest class.

Table 7 - Own and cross price elasticities and income elasticities for the average customer

Prices⇒ Demand ⇓	Local	National	International	Towards-mobile	Other traffic	Composite good	Income
Local	**-1.435**$^{(***))}$ (0.046)	0.376$^{(***))}$ (0.089)	0.175$^{(***))}$ (0.041)	0.084 (0.055)	-0.022 (0.077)	-19.422$^{(***))}$ (0.780)	20.848$^{(***))}$ (0.687)
National	0.407$^{(***))}$ (0.064)	**-1.331**$^{(***))}$ (0.070)	-0.156$^{(**))}$ (0.068)	-0.091 (1.091)	0.037 (0.087)	-25.852$^{(***))}$ (2.360)	27.591$^{(***))}$ (1.906)
International	0.893 (0.796)	-1.056 (0.963)	**-0.109**$^{(***))}$ (7.166)	-0.532 (0.467)	-0.226 (0.483)	-62.638 (48.875)	64.275 (43.437)
Towards-mobile	0.849 (1.231)	-0.692 (11.138)	-0.741 (1.149)	**-0.491**$^{(***))}$ (1.050)	-0.026 (0.570)	-14.926 (19.181)	16.632$^{(*))}$ (9.166)
Other traffic	0.016 (3.311)	0.186 (0.145)	-0.044 (0.169)	-0.002 (0.175)	**-1.154**$^{(***))}$ (0.171)	-6.970 (1.752)	8.574$^{(***))}$ (2.005)
Composite good	-0.0008 (0.0058)	0.0004 (0.0079)	-0.0006 (0.0108)	0.0001 (0.0114)	0.0005 (0.0168)	**-0.654**$^{(***))}$ (0.0067)	1.260$^{(***))}$ (0.366)

Notes : Std dev., in parenthesis, are computed thanks to the method proposed by Kmenta (86).

(*), (**), (***) indicate significant parameters with confidence level respectivelly equal to 90 %, 95 % et 99 % .

Table 8 - Morishima elasticities of substitution for the average customer

M_{ij}	j i	Local	National	International	Towards-mobile	Other traffic
Local		1.842$^{(***))}$ (0.081)	2.327$^{(***))}$ (0.799)	2.283$^{(*))}$ (1.233)	1.450 (3.309)
National	1.707$^{(***))}$ (0.117)		0.275 (0.964)	0.639 (11.158)	1.516$^{(***))}$ (0.153)
International	0.284 (7.173)	-0.047 (7.184)		-0.632 (7.055)	0.065 (7.168)
Towards-mobile	0.575 (1.050)	0.399 (1.166)	-0.042 (1.026)		0.488 (1.033)
Other traffic	1.132$^{(***))}$ (0.184)	1.191$^{(***))}$ (0.183)	0.927$^{(*))}$ (0.519)	1.128$^{(**))}$ (0.571)	

Notes : Std dev., in parenthesis, are computed thanks to the method proposed by Kmenta (86).

(*), (**), (***) indicate significant parameters with confidence level respectivelly equal to 90 %, 95 % et 99 % .

7.2- COMPARISON WITH ELASTICITIES IN OTHERS STUDIES

The elasticities found here are somehow different from the general idea that consumers are not much sensitive for local traffic and weakly sensitive for national or long-distance traffic. The demand elasticities for local traffic, related to the price of the service range usually between –0.09 and –0.88. Park, Wertzel and Mitchell (83) found a value of –0.09 in a study dealing with the effect on local demand when the tariff evolves from a flat rate to a traditional two-part tariff. The local demand elasticity found by Wolak (96) is –0.88, in a study where local and long-distance demands are estimated jointly with the demand for other goods and services. This elasticity is close to ours, because we develop the same type of approach based on cross section data, involving long run elasticities. For the other studies, the elasticities are lower because, as we explain later, they should be interpreted as short-run elasticities. The long-distance traffic demand elasticities are used to be higher than elasticities for local calls, in absolute value. In previous studies, short-run elasticities are estimated to be around –0.5. They are even higher when they are considered as long-run elasticities. Gatto and Ali (88) find an elasticity equal to –0.72. The highest elasticity is found by Wolak (96) : –2.07. This value is even higher than ours.

The fundamental differences between our model and the ones previously developed, is that first of all we use individual data rather than aggregated ones. Then we use cross-sectional data whereas much of the previous studies use time series. We think that a static model with individual cross-sectional data is more likely to reflect long-run elasticities than a dynamic model estimated with aggregated time series. In our model, as the sample is assumed to be representative in terms of age, the population is studied over its entire life-cycle, i.e. we could derive from these data the behaviour of an average household over time. By contrast, in other models, consumers are aggregated, and it is not possible anymore to identify changes in behaviour of a household followed over its entire life-cycle. We are just able in this case to capture an average reaction of the population from a period to an other, due to a change in prices. In that way, we can talk about short-run elasticities. The argument supporting the fact that long-run elasticities are greater than short-run ones is quite intuitive. In the short-run, some variables are fixed and a typical household faces some rigidities to adapt its consumption to (say) an increase in price, whereas in the long-run its consumption is likely to decrease more as everything is flexible.

Finally dealing with international traffic, the mean elasticity found in our paper is low compared to price elasticities found in others studies. Garin-Muñoz and Perez-Amaral (97) sum up elasticities of number of minutes consumed, related to international traffic. These elasticities range from –1.31 to –0.32 depending on the countries of destination and the type of data used (time series or panel annual). The main difference between our and these studies is that we do not focus on international traffic, but we study this traffic jointly with four others ones. This results on the existence of zero demand for international traffic although the zero demand are excluded from the studies Garin-Muñoz and Perez-Amaral (97) talk about. In these studies international demand is conditional on a positive demand while it is not the case in our model. This phenomenon lowers the absolute values of elasticities. We can observe that the elasticity computed for the average customer among the customers who have a positive international traffic consumption, equals –0.41. This value is comparable to the ones summed up by Garin-Muñoz and Perez-Amaral (97).

7.3- MORISHIMA ELASTICITIES

The Morishima elasticities of substitution are some measures of ease of substitution. Blackorby and Russel (1989) show that they are sufficient statistics for assessing the effects of changes in price ratios on relative consumption good shares. The Morishima elasticity of substitution between goods *i* and *j*, M_{ij}, can be defined by the relation:

$$\frac{\partial ln(w_i / w_j)}{\partial ln(p_i / p_j)} = \frac{\partial ln(p_i x_i^{\ h} / p_j x_j^{\ h})}{\partial ln(p_i / p_j)} = 1 - M_{ij}, \tag{14}$$

where x_k^h, whatever *k*, is the Hicksian demand for good *k*.

Equation (14) shows that an increase in the price ratio results in an increase in the share of good *i* compared to the share of good *j* if the Morishima elasticity between goods *i* and *j* is less than unity. There is no apparent reason for Morishima elasticities to be symmetric in *i* and *j*, contrarily to some other kind of elasticities of substitution, like Allen elasticities.

Table 8 gives the Morishima elasticities for the average customer. The elasticities of substitution related to local consumption are higher than unity (first line). Whatever the traffic direction considered, when the local relative price increases, the local relative share decreases. The same observation can be formulated for the relative share of other traffic. Moreover the elasticities related to local relative share are in almost all the cases the highest; then, local traffic demand seems to be the most sensitive to its own price ratio modification. The national relative shares decrease when the relative prices with local and other traffic directions increase (elasticities higher than unity). With the two other traffic directions the national relative share increases (elasticities lower than unity). This last result is found for international and towards-mobile relative shares, whatever the traffic direction considered. Indeed for those traffic directions the Morishima elasticities are all lower than unity.

VIII- INCOME EQUIVALENT VARIATION AND WILLINGNESS TO PAY FOR SOME TRAFFIC DIRECTIONS

Once the indirect utility function is known, it is possible to have a measure of the welfare change when the consumers are affected by changes in their economic environment. When a consumer moves from an initial situation (p^0 , R^0) to a final situation (p^1 , R^1), the resulting welfare change is measured by the difference: $V(p^1,R^1)-V(p^0,R^0)$. If this difference is positive, the consumer benefits from the policy change, if it is not, this policy grieves him.

Because both direct and indirect utility functions are ordinal functions, the differences in utility values can only be interpreted as relative values. However for some purposes it is convenient to have a monetary measure of changes in consumer welfare. The equivalent and compensating variations are standard monetary measure of welfare change. We focus on equivalent variation, which is a reasonable measure of the willingness to pay for some goods. The equivalent variation EV is defined by: $V(p^1,R)=V(p^0,R+EV)$. EV is the amount to add to the income in order to keep the indirect utility constant when the prices move from p^0 to p^1. Because of indirect utility monotonicity properties, this quantity has to be negative if the prices increase, and positive in the opposite case. The main advantage of equivalent variation compared to compensated variation is that it measures the income change at current prices and, when comparing several tariff policy changes, it keeps the base prices fixed at a status quo. With the translogarithmic structure, the equivalent variation is defined by:

$$ln\left(V(p^1,R)\right)=ln\left(V(p^0,R+EV)\right) \tag{15}$$

$$\Leftrightarrow \alpha_0+\sum_i \alpha_i\, ln\frac{p_i^{\,1}}{R}+\frac{1}{2}\sum_i\sum_j \beta_{ij}\, ln\frac{p_i^{\,1}}{R}\, ln\frac{p_j^{\,1}}{R}$$
$$=\alpha_0+\sum_i \alpha_i\, ln\frac{p_i^{\,0}}{R+EV}+\frac{1}{2}\sum_i\sum_j \beta_{ij}\, ln\frac{p_i^{\,0}}{R+EV}\, ln\frac{p_j^{\,0}}{R+EV}.$$

The equivalent variation can not be analytically determined; we use the Newton numeric algorithm.

We aim at measuring the willingness to pay for the different traffic directions. To fulfil this objective, we first determine the individual prices for which the demand becomes zero.

Then, thanks to equation (15) we can have a measure of the equivalent variation corresponding to this fictive tariff policy. In this particular case, the equivalent variation measures the amount to deduce from the income when the consumption of one traffic direction becomes zero, so as to keep the indirect utility at the level corresponding to a hypothetical zero-demand. Notice that nothing is changed for the other prices, that is we increase the price of only one traffic direction. The equivalent variation can be considered as the willingness to pay for the corresponding traffic direction. It is an individual monetary evaluation of each consumption. It is then interesting to compare it with the actual bill.

We can verify (cf. table 9) that, for local, national and other traffic directions, the prices cancelling the demand are higher than the observed prices. The results for international and towards-mobile traffics are not given, as they are not consistent with the economic theory.

The values of equivalent variations obtained from the computations are negative, thus it is consistent with some price increases. We transform them into positive values to facilitate their understanding (cf. table 10). For each traffic direction the equivalent variation deals with the monetary equivalent of the consumption. When an increase in local price is such that the demand becomes zero, the monetary equivalent allowing the utility to remain at the level where local demand is zero, is on average, 74.26 French francs. The highest willingness to pay corresponds to the other traffic demand. We saw (cf. Paragraph 7.1) that this demand is less elastic than local and national demands. These two results are consistent: the consumers have a higher willingness to pay for the goods whose consumption is either closed to the saturation level, or less elastic.

An interesting extension is to compare the willingness to pay and the bill actually paid for each traffic direction. Table 11 gives the ratio between these two quantities. The last column indicates the percentage of customers who have a strictly positive demand for the traffic considered. In the case of a zero demand the ratio can not be computed. However in this case the equivalent variation should be zero as no increase in price is necessary to cancel the demand. On average, for the three traffic directions considered, the equivalent variations are higher than the bills paid. A more precise analysis shows that:

- for local traffic, 51.55 % of consumers have a higher willingness to pay than their bill
- for national traffic, 62.62 % of consumers have a higher willingness to pay than their bill
- for other traffics, 92.29 % of consumers have a higher willingness to pay than their bill.

However the operator can not increase drastically the prices for these three traffic directions because such a policy would grieve some customers, more than 48 % for local traffic. The consequence would be a decrease in the quantities consumed. This is also an equity problem. This analysis shows that some uniform tariffs across consumers are not optimal if the operator's final objective is to capture consumers' individual surplus.

IX- AN OPTIMAL PRICE ANALYSIS

The last step of our analysis is to determine whether the prices individually paid by the consumers are optimal from the operator point of view. Assume the operator can arbitrarily modify the individual prices. Actually, at the time the data were observed, this was not the case as France Telecom was a regulated monopoly. The idea of the optimal price analysis is to determine how the operator would modify the price levels, in order to improve it's objective function without penalising its customers. This equity condition becomes even necessary if the operator faces competition within the market. Because of this constraint, the operator introduces some individual rationality conditions either constancy level of the indirect utility function, or constancy of the total telecommunications bill.

Table 9 - Prices cancelling the demands

Traffic direction	Mean	Std Dev.	Minimum	Maximum	Observed prices	Percentage of customers[7]
Local	2.48	1.77	0.72	17.03	0.37	97.56 %
National	10.56	6.85	1.76	38.25	1.12	95.68 %
Other traffic	870.85	694.72	16.40	3164.27	2.25	92.35 %

Table 10 - Equivalent variations corresponding to zero demand

Equivalent variation	Mean	Std Dev.	Minimum	Maximum	Observed bill	Percentage of customers[7]
Local	74.26	46.62	0.35	242.94	52.67	97.09 %
National	79.72	64.15	0	331.13	29.64	97.79 %
Other traffics	83.19	48.99	0	235.95	6.50	95.53 %

Table 11 - Ratio: equivalent variation / non zero bill

Ratio	Mean[8]	Std Dev	Minimum	Maximum	Percentage of non zero demand
EV/ bill local	1.41	1.19	0.06	7.60	100.00 %
EV/ bill national	2.69	3.50	0.12	19.36	96.41 %
EV/ bill other traffics	12.79	13.83	0.19	67.28	88.93 %

[7] We removed consumers from the queues of the distributions of both the prices cancelling the demands and the equivalent variations.

[8]We removed consumers from the queues of the distributions; the remaining percentages of customers are 98.56, 92.91 and 82.57 respectively for local, national and other traffic directions.

As the operator's profit on residential segment is expressed by the difference between the sum of individual bills and the corresponding production cost, two programs are possible for the operator, depending on the rationality constraint chosen. He can either maximise its profits under constancy of the indirect utility level, or minimise its costs under constancy of total telecommunications bill. Because the total bill is immediately observable, we choose the second program which can be written:

$$\underset{\left(p_L^n, p_N^n, p_I^n, p_M^n, p_O^n\right)_{n=1,\dots,N}}{Min} \sum_i C_i\left[X_1\left(\left(p^n, p_z^n, R^n\right)_{n=1,\dots,N}\right), \dots, X_5\left(\left(p^n, p_z^n, R^n\right)_{n=1,\dots,N}\right)\right] \quad (16)$$

$$\text{subject to} \quad \sum_i p_i^{\,n} x_i^{\,n}(p^n, p_z^n, R^n) = \overline{B}^n, \quad \forall\ n=1,\dots,N.$$

$X_i\left(\left(p^n, p_z^n, R^n\right)_{n=1,\dots,N}\right)$ in (16) is the total demand for traffic direction *i*, which equals the sum of individual demands for this traffic direction. $C_i\left(X_1(.),\dots,X_5(.)\right)$ is the total cost supported for direction *i*. This cost depends on both the demand for traffic direction *i* and the demands for the other traffic directions. That is there exist some direct costs and some cross-costs. R^n and $\overline{B}^n$ are, respectively, customer's *n* income and total telecommunications bill and $x_i^{\,n}(p^n, p_z^n, R^n)$ is customer's *n* demand for direction *i*.

To simplify the previous program, it is assumed that the total cost for traffic direction *i* only depends on the corresponding demand for direction *i*, and that it is constant across customers. Let's call C_i the price of one minute of traffic to direction *i*.

Computing a unique optimal price per minute for each traffic direction is not an efficient policy. We saw earlier that when the operator proposes a price per minute, the customers actually pay different prices because of their different traffic structures. Much is at stake to compute some individual optimal prices and to compare them to the individual observed prices. Following this policy, the program (16) becomes:

$$\forall\ n=1,\ldots,N,\ \underset{p_L^n,p_N^n,p_I^n,p_M^n,p_O^n}{Min} \sum_i C_i x_i^{\ n}(p^n,p_z^n,R^n) \quad subject\ to \quad \sum_i p_i x_i^{\ n}(\,p^n,p_z^n,R^n\,) = \overline{B}^{\,n}\,. \tag{17}$$

Such a policy is just indicative of the differences between optimal and observed prices. It can not be applied since it would be a perfect discriminatory.

To solve the program (17), we have to solve the Khun and Tucker conditions. In our case, this is equivalent to solve the five first order conditions, because the budget constraint is bounded, and because we focus on the convex parts of the demands (i.e. we exclude customers for whom one of the own price elasticity of the demand is positive). As the system to solved is highly no linear, it is resolved thanks to the Newton algorithm. The initial conditions satisfying the individual bill constraints are the observed income, price of composite good and total telecommunications bill. Moreover, the Hessian matrix is often singular, thus the system can not be solved for many customers. That's why we concentrate on a more aggregated approach and we compute optimal prices for the average customer of the sample satisfying the convexity conditions, and for the average customers of each income class.

9.1- Optimal prices for the average customer of the sample

The average customer of the sample, used to compute the optimal prices, is characterised by an income level equals to 12 556.72 French francs. His telecommunications bill is 301.29 French francs and consequently the price of the composite good he chooses, is 12 255.43 French francs. The results of the optimisation program are summed up in table 12.

The optimal prices are higher than the observed prices, for local, national and other traffic directions (cf. table 12). The opposite result is found for the two other directions. The differences are especially the highest for local, towards-mobile and other traffic directions. In order to decrease its costs, while the individual bill remains constant, the operator has, above all, to increase local and other traffic prices (especially, the optimal price for local traffic is more than twice the observed price). The operator also has to decrease by more than 63 % towards-mobile price. The cost obtained with this optimal tariff policy decreases by 22.33 % compared to the initial observed cost. Because of the values of own price elasticities, with such a policy the amount of local traffic consumed would be the most disturbed.

Note that the optimal prices are the prices the customer should actually pay. We saw that because of the non linearity of prices among the hours and the days of the calls, there is a difference between the price per minute announced by the operator[9], and the price per minute paid by the customer. Thus, to reach the optimal prices computed in this analysis the operator can tune the different components of the tariffs (length of the peak-period, minimum of perception, prices,...).

9.2- Optimal prices for each income class

A first degree discrimination is not allowed by the authorities, however it's always possible to select customers thanks to auto-selection procedures. In this case the operator, who does not observe the individual characteristics, offers a menu of tariffs: (quantities, prices); each customer chooses a couple according to his own characteristics. The objective of this section is to show whether the income could be a useful variable in a discriminatory process.

Figure 2 shows that, for all traffic directions but international traffic, and if the highest income class is excluded, the differences between optimal and observed prices are the highest for the middle income classes. In the case of international traffic, the difference increases with the income.

[9] In practice the operator does not announce one unique price per minute, but several prices depending on the time of the call, the type of day...

Table 12 - Optimal and observed prices for the average customer

Traffic direction	Local	National	International	Towards-mobile	Other traffic
Optimal price	0.810	1.614	2.182	1.172	3.453
Observed price	0.377	1.097	2.342	3.187	2.076
Percentage of variation	+115 %	+47 %	-7 %	-63 %	+66 %
Own price elasticity	-1.386	-1.230	-0.389	-0.492	-1.146

Note that the income class 8 750 seems to be badly represented as each price curve presents an irregularity at this level. Otherwise the results, found in Paragraph 9.1, remain true. The optimal prices for local traffic are generally higher than the observed prices. However this trend is reversed for the lowest income class. This same phenomenon can be observed for both highest and lowest income classes of national and other traffic directions. The optimal prices of towards-mobile traffic demand remains under the observed prices. The fluctuations of optimal prices are compared to the fluctuations of own price elasticities and monthly consumption in minutes (see Appendix II and III). We see that, for all traffic directions but international traffic, an increase in optimal prices deals with an increase of elasticities, in absolute value, while the consumption also increases. Although when the optimal prices decrease, the elasticities remain constant or keep on growing, in absolute value, while the consumption slows down.

Finally, although the observed price curves are more or less constant, the optimal price curves fluctuate with income. The optimal price analysis, taking into account the level of customers' income, essentially shows that a global tariff policy, independent of customers characteristics, seems to be inefficient. Of course some more precise analysis should consider many more individual characteristics than only the income level. Moreover the sensible differences between optimal and observed prices emphasise the importance of cross-subsidies between the different customers' segments especially for the main traffic directions: local and national traffics.

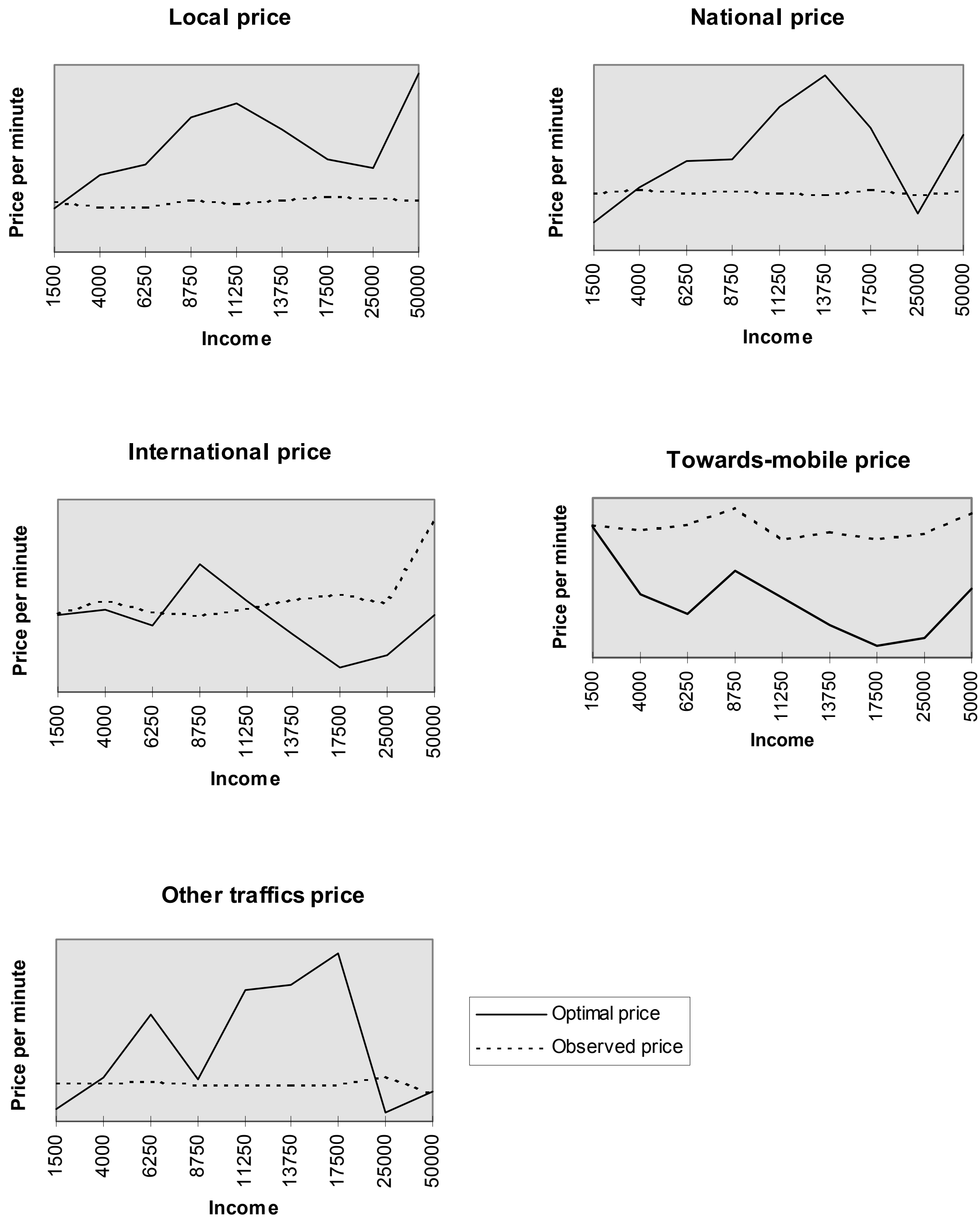


Figure 1 - Optimal and observed prices

Note: for confidentiality reasons, the scales of the Y axes are not indicated.

X- CONCLUSION

The objective of this paper is to estimate residential demand for telecommunications traffic. The independence of consumption structure assumed across traffic directions, allows us to consider separately five types of traffic: local, national, international, towards-mobile and other traffic directions. The indirect utility function is approximated by a translogarithmic flexible form. Thanks to the available data, the income shares are estimated both for the five types of traffic and for a composite good dealing with all other consumption goods.

The global significance of the estimated model confirms the existence of interrelations between each traffic demand and the prices of all the other types of traffic. However, the low values of cross price elasticities tend to moderate the magnitude of these cross effects. The absolute values of own price elasticities are relatively high for local, national and other traffic demands; consumers are sensitive to a price restructuring for these demands. The interest of this study is then justified, especially in the new competitive telecommunications context where the consumers can switch to the competitor for a unique traffic direction. Moreover the high values of income elasticities emphasise the importance of taking into account the income effect when analysing residential telecommunications demand. The estimation of the indirect utility function allows us to measure the individual income equivalent variation. The idea is to determine whether the willingness to pay for a traffic direction is higher than the bill actually paid. The answer is positive, at least for the local, national and other traffic directions. The individual monetary evaluation of these traffic consumptions is, on average, higher than their cost. Finally, using jointly the estimated demand functions and the corresponding costs for the operator, we compute optimal prices. We assume the operator can choose the prices in order to minimise its costs. We also assume that for equity and competitive reasons, at the optimum, the individual bills have to remain constant. The optimal prices for local, national and other traffic are, on average, higher than the observed prices. Dealing with the two other directions, the optimal prices are, on average, under the observed prices. A more precise analysis among income level shows that the main differences between optimal and observed prices generally occur at the middle income classes. Because of high differences between optimal and observed prices, we conclude in the existence of important cross-subsidies between customers' segments. However we notice some limitations in the relevance of some results. Two reasons can be advanced to explain them. First of all, the high number of zero demands for some traffic directions might disturb both the conclusions for the corresponding demands and for the whole model. The second restriction is that in the telecommunications field, the consumers have generally a bad information on prices and moreover they are unable to evaluate precisely their consumption in minutes.

The estimated model and the results presented in this paper are the first step in our residential telecommunications demand analysis. Many more applications can be developed with this model. The estimated functions can be useful to measure consumption responses in the case of a tariff restructuring. The difficulty arises in the way the price modifications individually affect consumers' prices. Indeed, the price changes are not uniform among consumers because of the differences in individual traffic structures. Finally, the estimated model can be improved in some ways. The most relevant change would be the introduction of individual characteristics. Many more individual characteristics are available, although we only use individual income. A way to introduce socio-demographic variables is performed by Wolak (1996). He adds these variables to direct price terms in the indirect utility function. Taking into account individual characteristics will certainly improve the model. Many empirical studies show their importance in residential consumption prediction.

APPENDIX I

OBSERVED PRICE DISTRIBUTIONS

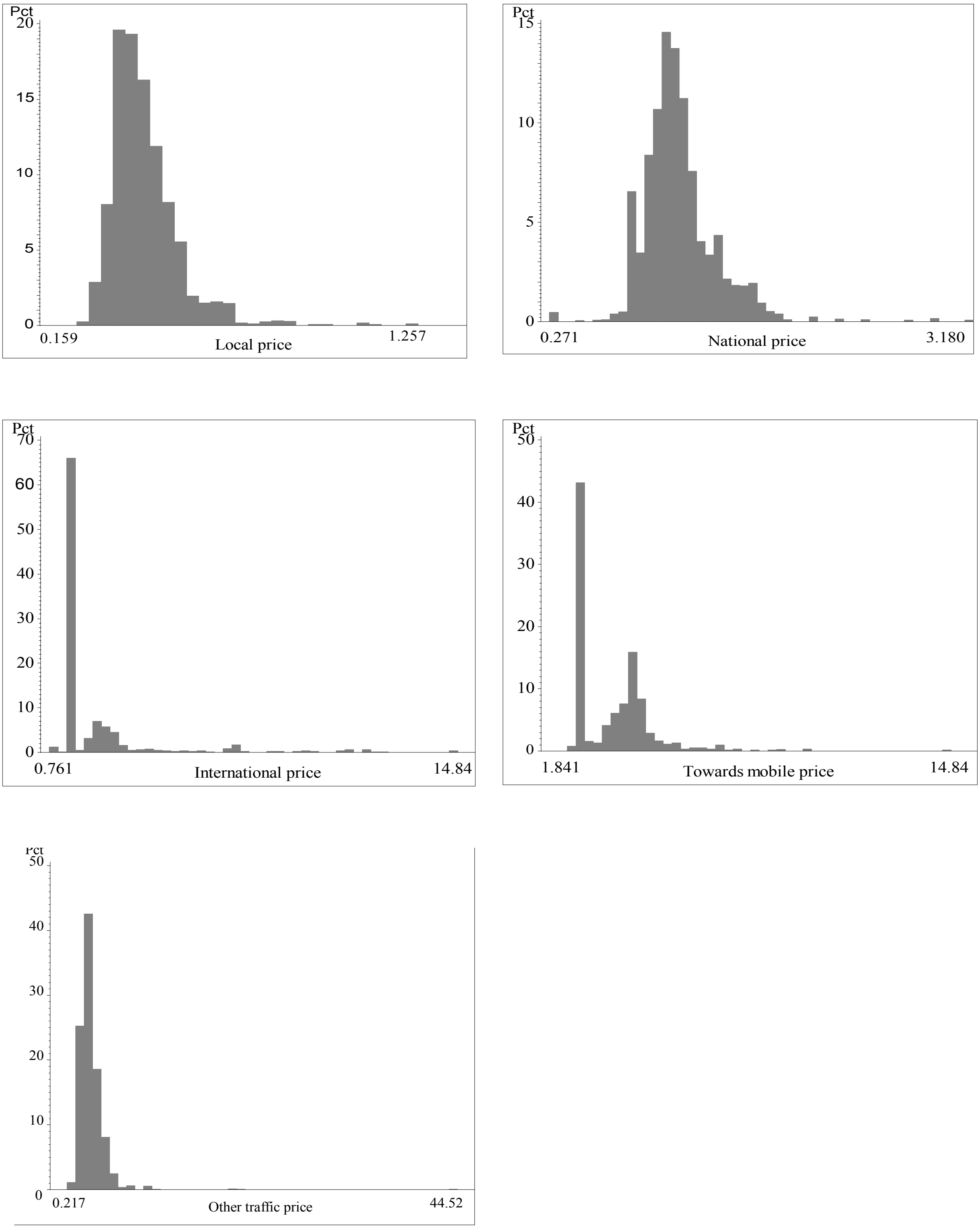


Figure 2 - Observed price distributions.

Note: The high bars at the left of the distributions are the consequences of our price assignment. The X axe deals with the observed price per minute in French francs, all taxes included. The Y axes deal with the percentage of customers.

APPENDIX II

TOTAL AVERAGE CONSUMPTION AND INCOME CLASS

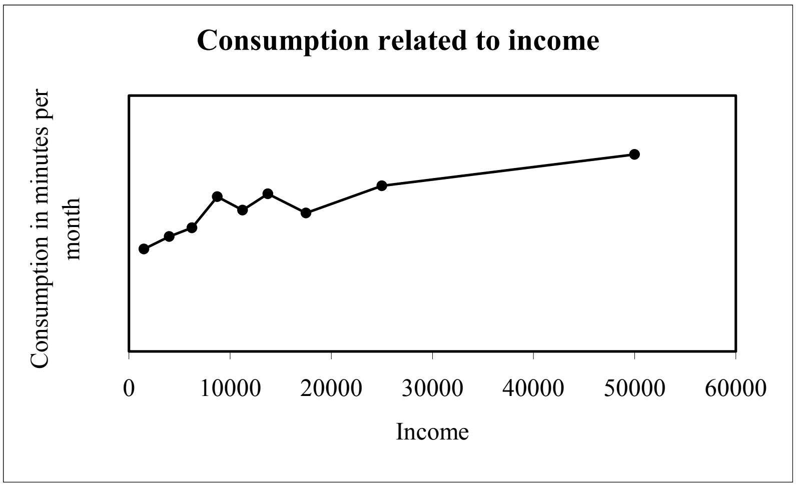


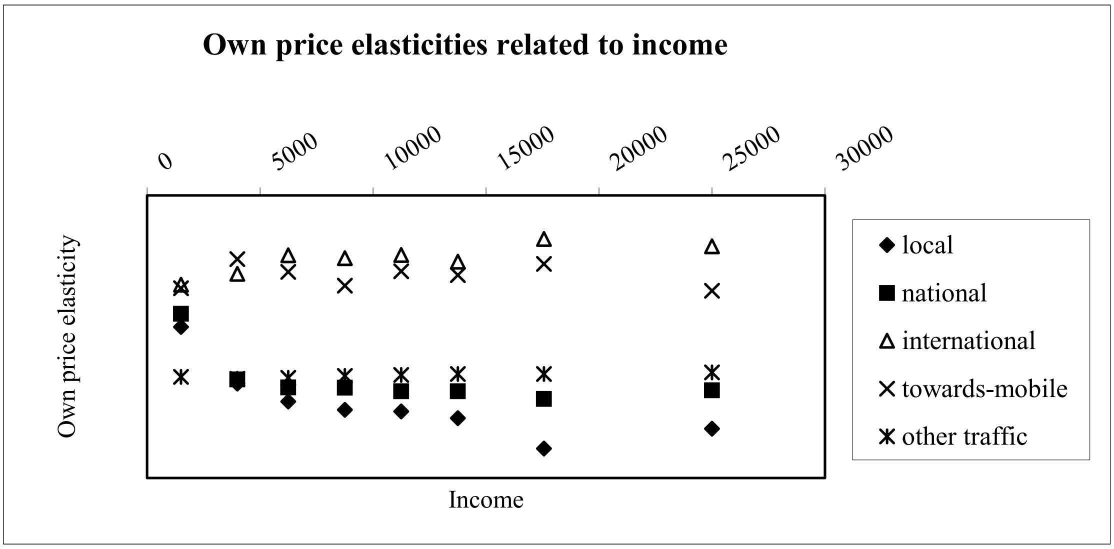
Figure 3 - Minutes of telecommunications consumption, average per month and per income class, sum across the traffic directions.

Note: for confidentiality reasons, the scales of the Y axes are not indicated.

This graph is consistent with the high values of income elasticities. The total consumption, expressed in minute per month, increases with income.

APPENDIX III

AVERAGE OWN PRICE ELASTICITY AND CONSUMPTION PER TRAFFIC DIRECTION AND INCOME CLASS



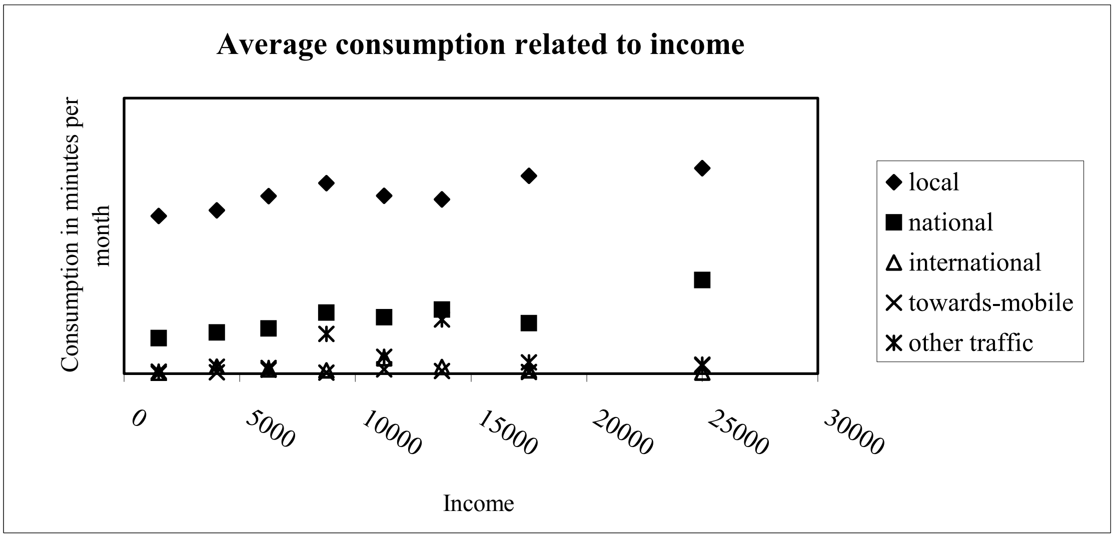


Figure 4 - Average own price elasticities and minute of telecommunications consumption per month; evolution according to income class for the five traffic directions.

Notes: the last income class has been removed to clarify the graphs; for confidentiality reasons, the scales of the Y axes are not indicated.

TABLES

FIGURES

REFERENCES

Bousquet, A. and M. Ivaldi, 1996, Optimal pricing of telephone usage: an econometric implementation, GREMAQ, University of Toulouse II, Working Paper.

Bernt, E., 1991, The practice of Econometrics classic and contemporary, Addison-Wesley Publishing Company, Inc.

Blackorby, C., and R. Russel, 1981, The Morishima Elasticity of Substitution; Symmetry, Constancy, Separability, and its relationship to the Hicks and Allen Elasticities, Review of Economic Studies 63, 147-158.

Blackorby, C. and R. Russel, 1989, Will the real elasticity of substitution please stand up ? A comparison of the Allen-Uzawa and Morishima elasticities, American Economic Review 79, 882-888.

Christensen, L., D. Jorgenson and L. Lau, 1975, Transcendental logarithmic utility functions, The American Economic Review 65, n°3, 367-383.

Colombino, U., 1998, Evaluating the effects of new telephone tariffs on residential user's demand and welfare. A model for Italy, Information Economics and Policy 10, 283-303.

Garin-Munoz, T. and T. Perez-Amaral, 1997, Econometric modelling of Spanish very long distance international calling, Universidad Complutense de Madrid, Dpto Economia Cuantitativa, Working paper.

Kmenta, J., 1986, Elements of Econometrics, Macmillan Publishing Company, New-York, Second Edition.

Kridel, D., D. Lehman and D. Weisman, 1993, Options value, telecommunications demand and policy, Information Economics and Policy 5, 125-144.

Maddala, G. S., 1988, Introduction to econometrics, second edition, Prentice-Hall, Inc.

Park, R.E,B.M. Wertzel and B.M. Mitchell, 1983, Price elasticites for local telephone calls, Econometrica, Vol. 51, n°6, November 1983, 1699-1730.

Taylor, L., 1993, Telecommunications demand in theory and practice, Dordrecht, Neteherlands, Kluwer Academic Publishers.

Train, K., D. McFadden and M. Ben-Akiva, 1987, The demand for local telephone service: a fully discrete model of residential calling patterns and service choices, Rand journal of economics 18, No.1, 109-123.

Wolak, F., 1993, Telecommunications demand modelling, Information Economics and Policy 5, 179-197.

Wolak, F., 1996, Can universal service survive in a competitive telecommunications environment ? Evidence from the United States consumer expenditure survey, Stanfort University, Department of Economics, Working paper.