AN ECONOMETRIC MODEL OF THE DEMAND FOR TRUNK CALLS IN THE NETHERLANDS DURING 1950-1981

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ABSTRACT

Trunk calls account for more than 50% of the total telephone traffic revenues of the Netherlands Telecommunications Service. It is therefore important to analyse the effects of the relevant influential factors on the trunk traffic. An econometric model has been designed for that purpose. This model is used, among other things, for the short and medium-term forecasting of the total number of trunk calls and the total revenues of those calls.

1. INTRODUCTION

Since 1950 there has been a strong increase in telephone density in the Netherlands. The number of telephone stations, expressed as a percentage of one hundred residences, increased from 23 in 1950 to 103 in 1981. The number of non-business telephone stations per one hundred residences increased by approximately 900% in the same period. This tremendous growth of telephone stations resulted in an increase in the total number of trunk calls.

It is worthwhile considering the trunk calls made per telephone station. The interlocal traffic per telephone station increased up to 1972 but decreased after that year. The development of interlocal traffic per telephone station is illustrated in figure 2. The revenues of trunk calls increased in the past thirty years from 55 million Dutch guilders in 1950 to approximately one thousand million Dutch guilders in 1981, which is more than 50% of the total revenues of telephone calls (local, trunk and international).

In view of the importance of trunk calls in terms of traffic and revenues, it is necessary to gain an insight into the causes of the development of trunk calls. This insight may be used for, among other things:

- forecasting of trunk calls and the revenues of those calls given the future development of the explanatory variables;
- the economic cost-benefit analysis of investments in telephone stations and related means of traffic such as telephone exchanges and cables.

In analysing the development of trunk calls an econometric model was designed which will be described in this paper. With this model it is possible to evaluate the effects which changes in factors such as telephone stations, tariffs and incomes had on interlocal traffic in the 1950-1981 period.

In part 2 of the paper, the model specification is set out and the determinants of the development of the number of trunk calls is discussed. The econometric model is quantified in part 3 and the estimated elasticities of the influential factors are considered. Additionally, the stability and the prediction power of the model are discussed briefly in part 4. Finally, some conclusions are given.

2. AN ECONOMETRIC MODEL FOR TRUNK CALLS

2.1. The model specification

When looking at the question of revenues, the actual number of trunk calls is not suitable for an analysis for the following reasons:

- If there is an income increment, the average duration of all trunk calls may be increasing, while the actual number of such calls remains the same. This change in interlocal traffic would therefore not be noticed, if one were to analyse the number of trunk calls;
- It is difficult to define an economic price of a trunk call, in particular because in an econometric model without an incorporated market mechanism the price has to be independent of the disturbance in the equation and thus independent of the number of trunk calls.

Neither the number of pulses nor the number of paid minutes of all trunk calls is suitable for an analysis because of the special character and the substantial changes to the tariff structure. The price of a phone call depends on:

- the point of time in the week and the time of day;
- the geographical distance;
- the duration of the call. For a great number of calls the price is more or less proportional to the duration of the call. However, some trunk calls have a fixed price which is unrelated to the duration.

In view of such considerations we decided to use the quantity index figure of Paasche and the price index figure of Laspeyres in the model specification. An explanation of how the index figures are calculated here can be found in the appendix.

Furthermore, assumptions concerning the type of causal relationship between the levels of income and prices on the one hand and the values of the elasticities on the other hand induced us to specify the model as follows:

\[
\ln(\text{IT}/\text{S}) = a_0 + a_1 \text{IP} + a_2 /\text{PL} + a_3 \text{NAS} + a_4 /\text{YW} + a_5 /\text{YD} + a_6 \text{CON} + a_7 /\text{D} + u
\]

where

\(\text{IT}/\text{S}\) : the Paasche quantity index figure of trunk calls per subscriber (1970=100);
\(\text{IP}\) : the real price index figure of Laspeyres for trunk calls (1970=100);
\(\text{PL}\) : the real Laspeyres price index figure of letters and postcards (1970=100);
\(\text{NAS}\) : the number of non-automated subscribers who need an operator to set up calls;
\(\text{YW}\) : the real average disposable income, representing the general development of wealth (1970=100);
\(\text{YD}\) : the fictitious income of the private subscribers, but only as far as it is decreasing because of the entry of new subscribers from the lower income groups (1970=100);
\(\text{CON}\) : the business cycle indicator;
\(\text{D}\) : the telephone penetration per household;
\(u\) : the disturbance, which is (iid) \(N(0,\sigma^2)\).

It can easily be verified that the elasticity, \(\text{Ex}\), in this model equals \(aX\), if \(X\) is the corresponding variable in the model specification and \(-a/X\), if \(X^{-1}\) is used in the model. This type of a model specification implies decreasing price and income elasticities, if the price is decreasing and the income is increasing respectively (1).

2.2. The explanatory variables

Special attention will now be paid to the explanatory variables in the model. The variables can be divided into two categories, those which can be influenced by PTT itself and those which are external.

2.2.1. The PTT instruments

2.2.1.1. The real price index figure of Laspeyres for trunk calls, IP

The real price index figure of Laspeyres decreased in the 1950-1981 period from 231 in 1950 to 45 in 1981 (1970=100). Undoubtedly this price fall induced a growth of the interlocal traffic per subscriber. The variable price sensitivity of trunk calls is measured by incorporating the term \(a_1 \text{IP}\) in the model.

2.2.1.2. The real Laspeyres price index figure of letters and postcards, PL

In the period under review the most important means of transporting information were the postal and telephone networks. The decision as regards the medium to be used depends on aspects such as velocity and quality of the medium and a more direct measure such as the charges for telephone calls, letters and postcards.

The hypothesis that the demands for trunk calls, letters and postcards are influencing each other, can be put to the test by incorporating the real Laspeyres price index figure of letters and postcards in the model.

The quotient, \(-a_2/\text{PL}\), is called the cross price elasticity and if it represents the responsiveness of trunk calls to a change in the prices of letters and postcards. The concept of cross price elasticity allows us to give a precise definition to substitutes and complements. If trunk calls and letters/postcards are substitutes for one another, the cross-elasticity will have a positive value; analogously, they are complementary if the cross-elasticity is negative. A priori, nothing can be said about the sign of the coefficient \(a_2\), this depends on the extent of the substitution of post and telephone or the complementarity of both dominates.

2.2.1.3. The number of non-automated subscribers, NAS

In 1950 13% of all subscribers had a non-automated telephone station. In 1962 the automation of the Dutch telephone network was completed.

Previous studies concerning the development of telephone traffic indicated that the subscribers with a non-automated telephone station phoned less than the automated subscribers because of the difficult procedures necessary to set up a call. The non-automated subscribers were dependent on operators, they had more chance of congestion of the telephone exchange and so on.

The model tests the hypothesis that the decreasing number of non-automated subscribers in the 1950-1962 period positively influenced the number of trunk calls per subscriber.
2.2.2. The external factors

2.2.2.1. The income variables YW and YD

The variable YW represents the real annual income of the modal worker in the Netherlands and incorporates the growth of wealth.

The other income variable YD is fictitious and represents the decline of the real income of the private subscribers. This decline is caused only by the entry of new private subscribers with a lower income. The presumption here is that households have a telephone, if and only if, their actual income exceeds or equals a certain threshold income, \( Y_0 \), which does not vary from one household to another. Only from one year to another may \( Y_0 \) be going down due to an increasing penetration rate.

If we define \( Y_H \) as the nominal average income of all households with a telephone, then by means of the aforesaid presumption \( Y_D \) can be calculated as follows. Given the income distribution in the Netherlands in a year and the penetration rate \( r \), then \( Y_H \) in that year equals the average income of \( 100 \times r \% \) households on the right hand side of \( Y_0 \).

The reason for the use of two income variables in the model is that the elasticity of \( Y_W \) measures the effect of a general change in purchasing power while the elasticity of \( Y_D \) represents the effect of an increasing penetration rate in lower social classes. From this point of view \( Y_D \) represents a social rather than an economic characteristic. The value of the elasticity in respect of \( Y_D \) depends on the shape of the income distribution in the Netherlands. The explanation is that households in a lower social class use their telephone less and in general have a lower income. This phenomenon emerged from several investigations. Furthermore, the income differences depend on the shape of the income distribution.

2.2.2.2. The business cycle, CON

Besides factors such as income and prices, which structurally affect the demand for trunk calls, the business cycle is included in the model as a possible determinant of trunk calls, measuring the short term effects of the economy of the Netherlands on the development of interlocal traffic.

Since the oil crisis of 1973/1974, the business cycle of the Netherlands has been in a phase of contraction except for the 1977-1979 period when there was a moderate upturn. The troughs in mid-1975 and at the beginning of 1981 were particularly severe. A downturn of the economy gives rise to a lower degree of economic activity in industry and therefore to a decrease in the number of trunk calls, while inversely a recovery of the business cycle causes an increase in economic activity and a corresponding increase in the number of trunk calls.

The business cycle is an abstract concept; on the basis of economic and statistical criteria, approximately twenty economic variables can be identified as being relevant to the business cycle. After extensive analysis we have selected two variables, shorter working hours due to less economic activity temporarily, and a composite index built up from five individual business cycle indicators by means of factor analysis. This composite index gives a complete and nuanced view of the general business conditions of the Netherlands. Moreover, as this index comprises all sectors of the economy, it fits the heterogeneous character of the demand for trunk calls, which can be evenly divided into business and non-business calls. The construction and content of the composite index is extensively described in a PTT paper (2). Information on this analysis is available from the authors upon request.

2.2.2.3. The telephone penetration rate, D

The telephone penetration rate, defined as the fraction of households with a telephone, rose from 0.07 in 1950 to 0.84 in 1981. This variable reflects the influence of the network structure, since the growth of telephone density in the small
towns and villages with a relatively small local network was stronger than in the urban areas during the 1950-1981 period. So for this reason the average number of local calls per subscriber decreased, while the average number of trunk calls increased. However, if the telephone density approaches the saturation point, the growth percentages will be more equal and the positive effect of the network structure on trunk calls per subscriber will diminish.

3. THE ESTIMATED ELASTICITIES OF TRUNK TELEPHONE TRAFFIC

In figure 2, $R^2$ represents the coefficient of determination (adjusted for degrees of freedom), which measures the percentage variations in the demand for trunk traffic per subscriber which is explained by the total variation of all explanatory variables in the model. D.W. is the value of the Durbin-Watson test statistic, which may be interpreted as an indicator for serial correlation. The $t$-values are mentioned in parentheses. The estimation of the coefficients is based on yearly data which are available from the authors upon request. The usual subscript $t$ is consequently omitted.

$$\ln(\text{IT/S}) = 5.74 - 0.0015\text{IP} - 13.40/\text{PL} - 0.0016\text{NAS} - 42.0/\text{YW} - 39.7/\text{YD} + 0.0014\text{CON} - 0.015/D$$

$$R^2 = 0.998 \quad \text{D.W.} = 1.31$$

Figure 2. The development of trunk traffic per subscriber, 1950-1981

From the estimated values of the coefficients and the actual values of the variables, the elasticities in each year can be derived. Table 1 gives a survey of these calculated elasticities in 1950 and 1981.

<table>
<thead>
<tr>
<th>variable</th>
<th>1950</th>
<th>1981</th>
</tr>
</thead>
<tbody>
<tr>
<td>price of trunk calls, IP</td>
<td>-0.34</td>
<td>-0.06</td>
</tr>
<tr>
<td>price of letters and postcards, PL</td>
<td>+0.17</td>
<td>+0.12</td>
</tr>
<tr>
<td>non-automated subscribers, NAS</td>
<td>-0.16</td>
<td>0</td>
</tr>
<tr>
<td>the income, YW</td>
<td>+0.89</td>
<td>+0.35</td>
</tr>
<tr>
<td>the income, YD</td>
<td>+0.16</td>
<td>+0.61</td>
</tr>
<tr>
<td>telephone penetration rate, D</td>
<td>+0.22</td>
<td>+0.02</td>
</tr>
</tbody>
</table>

Table 1. Estimated elasticities in 1950 and 1981

From table 1 it can be seen that since 1950 all elasticities have gone to zero except for YD.

- In particular, the price elasticity of trunk calls increased from -0.34 until -0.06, which must be attributed to the real price fall of trunk calls because of the general technological progress in the last three decades.

- The cross price elasticity of telephone and post decreased from 0.17 to 0.12. The difference, in fact $-a_{PL}^{IP} - PL$, may be interpreted as the size of substitution, i.e. around 5% of the trunk calls in 1981 was due to the rising prices of letters and postcards during the 1950-1981 period (3).

- The telephone operators dealt with 27% of all trunk calls in 1950. The corresponding elasticity in 1950, $a_{NAS} = -0.16$, suggests that automation caused an increase in interlocal traffic of around 60% ($= 16/27 \times 100\%$).

- From figure 2 it can be seen that the interlocal traffic per subscriber has been diminishing since 1972, as has the calculated model value. From the model specification used it emerges that this phenomenon must be ascribed to the fall of the income variable YD. Furthermore, the high value of the student test statistic, $8.0$, legitimizes the use of the aforesaid

As regards the character of the variable CON, the concept of elasticity is not suitable for evaluating the effect of a change because of the enormous variations of this business cycle indicator in the 1950-1981 period.
presumption of the uniform income threshold for all households. As a matter of fact this presumption is too strong, but the empirical evidence justifies this simplification, which apparently gives a good description of the real development of interlocal traffic, especially since 1972. The elasticity in respect of YD increased from 0.16 to 0.61. However, if the telephone density reaches the saturation point, then the value of YD will not change anymore, and so the effect of YD on interlocal traffic will fade away.

- The elasticity in respect of the other income variable, YW, decreased from 0.89 to 0.35. This was caused by the growth of wealth during the 1950-1981 period.

- As mentioned earlier, we used two indicators of the business cycle to measure the effect of business cycle fluctuations on the demand for trunk calls per subscriber. The composite index appears to be insignificant in the regression equation. This must probably be attributed to the fact that both the income variables YW and YD and the composite index partly reflect the cyclical fluctuations in the non-business sector. The incorporation of the latter index, besides the income variables, apparently causes a redundancy of business cycle indicators in the model. The economic variable, shorter working hours due to less economic activity temporarily, was significant. In the recession years 1958, 1967, 1975 and 1981 this indicator negatively influenced interlocal traffic by respectively 2.4%, 1.2%, 4.4% and 1.6%. By definition, 'shorter working hours' is truncated in a rising economy. It shows only the troughs in the business cycle. Hence, the influence of the business cycle in a period of expansion is difficult to detect.

- The elasticity in respect of the telephone penetration, D, has dropped from 0.22 to 0.02. The significant value of the student test statistic of the corresponding coefficient confirms the aforesaid hypothesis that the growth of the penetration rate has a positive, but decreasing, effect on interlocal traffic per subscriber.

4. THE PREDICTION POWER AND THE STABILITY OF THE MODEL

To get an impression of the stability and the prediction power of the model the coefficients are estimated during the 1950-1978 period. The relative differences between these coefficients and those of the 1950-1981 period appear to be less than 2%.

Using the coefficients and realizations of the exogenous variables in 1979, 1980 and 1981 are -0.6%, +0.6% and -1.0% respectively. These results indicate that the prediction power of the model is fairly good.

5. CONCLUSIONS

As regards the matter of the variable elasticities, the results are satisfying, especially in respect of the fictitious income. Furthermore, the subscription rate does not have a significant influence on interlocal traffic per subscriber.

It is worth the effort of calculating the Laspeyres and Paasche index figures in the model specification, as well as the income variables YH and YD. These calculations appear to be both practical and interpretable. The good fit and the prediction power of the model indicate that it can be employed as a useful tool in budget and planning procedures.

BIBLIOGRAPHY


APPENDIX

a. The price index figure of trunk traffic

It is difficult to construct in an unambiguous way a price variable of interlocal traffic. After considering the various arguments, we chose the price index figure of Laspeyres (1970 = 100). This price index in year \( t \) is equal to the ratio of the fictitious average expenditure per trunk call in 1970 if one had applied the tariff structure of year \( t \) in 1970, and the real average expenditure per trunk call in 1970. The formula of this price index equals:

\[
(1) \quad IP_t = \frac{\sum_{i=1}^{c_t} p_{t,\text{imp}} \times \sum_{i=1}^{g_{i,t}} (n_{i,t} + \text{imp}_{i,t})}{\sum_{i=1}^{c_{70}} p_{70,\text{imp}} \times \sum_{i=1}^{g_{i,70}} \text{imp}_{i,70}} \times 100
\]

where

- \( p_{t,\text{imp}} \): the price of a pulse in year \( t \);
- \( c_t \): the number of calls in year \( t \);
- \( g_{i,t} \): the number of pulses in year \( t \);
\( c_t \): the number of various categories of trunk calls in year \( t \);

\( e_i^t \): the number of trunk calls in 1970 which would have belonged to category \( i \) if one had applied the tariff structure of year \( t \);

\( n_i^t \): the number of pulses which was generated in year \( t \) after passing the 'clearance time' of trunk calls of category \( i \).

Explanations: in the 1950-1955 period a short time after the beginning of a telephone call, an extra number of pulses was generated beyond the answering pulse;

\( \text{imp}_i^t \): the average number of pulses of trunk calls in 1970 in category \( i \) if one had applied the tariff structure of year \( t \).

For the average number of pulses \( \text{imp}_i^t \) there holds:

\[
(a2) \quad \text{imp}_i^t = \left[ 1 - e^{-\frac{s_i^t}{d_i^t}} \right]^{-1}
\]

where

\( s_i^t \): the length of the pulse period of call category \( i \) in year \( t \);

\( d_i^t \): the average duration of the trunk calls in 1970 if one had applied the tariff structure of year \( t \) in category \( i \).

Formula (a2) can be derived as follows:

If we suppose that the duration of a call has an exponential distribution, then the average number of pulses per call depends on the average duration of a call and on the length of the pulse period, i.e. the time between the generation of two pulses. We define the variables:

\( s \) is the length of the pulse period;

\( d \) is the average duration of a call;

\( i \) is a stochastic variable representing the number of pulses of a call;

\( t \) is a stochastic variable representing the duration of a call.

Define:

\[
(a3) \quad P_n = P( i = n ), \quad n = 1, 2, \ldots
\]

There holds:

\[
(a4) \quad P_n = P( (n-1)s < t < ns )
\]

Because \( t \) has an exponential distribution with \( \lambda = 1/d \), there holds:

\[
(a5) \quad P_n = (e^{s/d} - 1)e^{-ns/d}
\]

The mean of the number of pulses is equal to:

\[
(a6) \quad E_i = \sum_{n=1}^{\infty} \frac{n}{n!} (e^{s/d} - 1) \frac{n}{n!} (e^{-ns/d}) = \\
= (e^{s/d} - 1)e^{s/d} \sum_{n=1}^{\infty} \frac{n}{n!} (e^{-n+1}s/d)
\]

\[
\sum_{n=1}^{\infty} (e^{-n+1}s/d) = \text{Cauchy product of} \sum_{n=1}^{\infty} (e^{-ns/d})
\]

Because of absolute convergence, there holds:

\[
(a7) \quad \sum_{n=1}^{\infty} (e^{-ns/d})^2 = \left( \sum_{n=1}^{\infty} (e^{-ns/d}) \right)^2
\]

it follows from (a6) and (a7):

\[
(a9) \quad E_i = (1 - e^{-s/d})^{-1}
\]

Q.E.D.

b. The quantity index figure of trunk traffic

In relation to the choice of the price index figure of Laspeyres the quantity index figure of Paasche is used as the dependent variable in the analysis. The quantity index figure of Paasche equals:

\[
(b1) \quad IT_t = \frac{0_t/IP_t}{0_{70}/IP_{70}} \times 100
\]

where \( 0_t \) are the revenues of the trunk calls in year \( t \).