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Substitution and complementarity in telecommunication; the case of telex and telephone

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Abstract

In this study an analysis is given of substitution and complementarity between telephone and telex. Using a cross-section approach one observes a considerable degree of complementarity between telex and telephone: this holds true for both ownership of communication equipment (lines) and for the use of these media. When time series data are used, a rather different result is obtained. Telex ownership and use showed a clear increasing trend until 1986 in most countries. After around 1987 a decrease in telex ownership and use can be observed which is related to the large scale introduction of telefax. We find that high income countries started to abandon telex earlier than low income countries. We also find an interesting sign of network externalities: countries of which the main communication partners were early in abandoning telex will also themselves be early in abandoning telex. The early decrease of telex line ownership in the US and Europe has induced an acceleration of the abandonment of telex lines in developing countries.

Keywords: telephone, telex, barriers, substitution, complementarity, international communication

1. Introduction

Telecommunication is a technology which is diffused at high growth rates in all parts of the world. Tariffs show a declining trend in real terms as a result of ongoing technological change, deregulation and economies of scale. It is no surprise, therefore, to observe that ownership and use of telecommunication equipment grow at a rate which is higher than that of gross national product in most countries.

Not all segments of the telecommunication market grow at the same rate. For example, long distance and international telecommunication is more dynamic than local telecommunication. Also certain telecommunication services start to be outdated. This holds true for example for telegrams the use of which is already declining during several decades. In the present paper we will pay special attention to the telex system which was very dynamic in the 1970's in most countries, but which suddenly started to decline around the mid-1980's due to the introduction of the telefax.

In this paper we study the relationship between telex and telephone use from an international perspective. Both complementarity and substitution relationships between the two systems will be considered. This is important, among others, for the theme of this special issue, which is on barriers to telecommunication. Barriers observed for one communication mode may induce a relatively high use of a substitute mode. Therefore, a multimodal framework is more appropriate for the analysis of barriers to telecommunication than a monomodal one (cf. Batten and Törnqvist, 1990).

The paper is organized as follows. Section 2 is addressed to the issue of technology diffusion and substitution. In Section 3 we present a micro-economic theory of choice of communication technology. Relevant features of the telephone and telex system are presented in Section 4. A statistical analysis of ownership of telephone and telex lines is given in Section 5. Special attention is paid to network externality effects in the diffusion of telex abandonment. Section 6 contains an analysis of international bilateral telex and telephone use with special attention to barrier effects. Section 7 concludes.

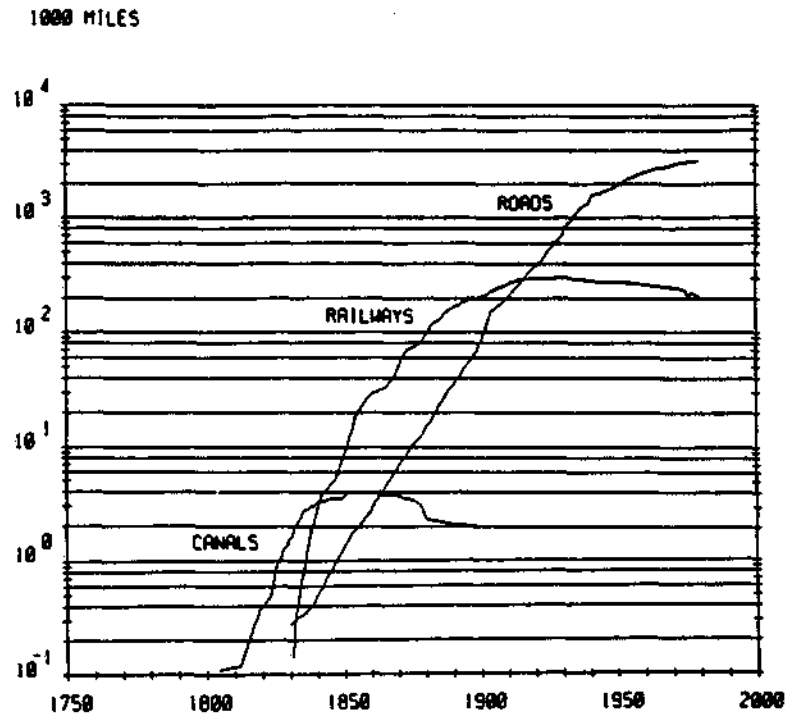
It appears that data availability and quality impose certain restrictions on the way the analyses can be carried out. These data problems will not be spelled out here, because they are already addressed in Rietveld et al. (1993) which is included in this special issue.

2. Technology diffusion and substitution

Technological change concerns the process of replacing old technologies by new ones. Research in this field is usually focused on the new technology: the factors which explain its introduction and the speed of its diffusion (cf. Stoneman, 1983). This is understandable given the large economic interests which are often involved in the adoption process, both from the side of the supplier and the user of the new technology. It is striking that the development trajectories of old technologies usually receive much less attention in research. Yet the old technologies are not without interest. First, old technologies may continue to be used in combination with new technologies for long periods (for example inland navigation rail versus road transport). Old technologies do not always disappear: substitution is not necessary complete. Second, old technologies may at a later stage undergo improvements which give rise to a phase of increasing use after a long period of decline (for example high speed trains). Third, old technologies may remain in use as a reserve technology which can be revitalized if other technologies would break down, for example because of lack of supply of inputs. Fourth, knowledge about the trajectory of an old technology may help to improve understanding of the trajectory of the new technology. Telex is an interesting example here: we know much more about aggregate telex use than about the use of telefax. Knowledge about the use of telex is likely to help improving knowledge about telefax.

In this section we present an example of substitution between technologies in the field of transport infrastructure, taken from Grübler and Nakicenovic (1991). Figure 1 shows the development of transport infrastructure in the USA where three waves can be observed related to respectively canals (most dynamic around 1835), railways (most dynamic around 1890) and roads (most dynamic

around 1945). The total stock in these systems remains rather stable at the end of the wave. For canals this is remarkable since most of the canals presently available are not of use anymore for commercial purposes because of their narrow size.



Source: Grübler and Nakicenovic (1991)

Fig. 1 Growth of length of transport infrastructures, U.S.

One observes a ratchet effect (physical infrastructure networks remain rather stable in size after an initial phase of rapid growth even if the intensity of use has strongly decreased), due to the long life of these networks, the often high costs of demolishing them and the desire to keep the network intact to ensure flexibility in case other networks collapse. In addition, outdated infrastructure is sometimes used for new purposes, unforeseen at the time of their construction: many canals are used mainly for recreational purposes nowadays.

Such a ratchet effect is not common in equipment used in transport networks since equipment has a shorter life. An example is the development of the number of horses and cars where the rapid increase in car ownership since

1900 led to an absolute decline of the use of horses and their eventual disappearance on the roads in the 1950's in most industrialized countries.

From this long run historical perspective we infer that both substitution and complementarity may occur between transportation technologies. An alternative approach to study the substitution-complementarity issue is to use micro-economic models of the choice of technology. This will be the subject of the next section.

3. A micro economic approach to the choice of communication technology

In this section we consider a firm that faces the choice of an optimal mixture of communication technologies. We distinguish three types: telephone, telex and face to face contact. These communication modes differ in two important respects:

1. Their cost structures are different. For example, the time costs involved in face to face contact are strongly distance dependent, whereas for telecommunication these costs are not distance dependent.
2. The productivities of the three communication modes are different. In face to face contacts one has the maximum transmitting capacity available so that contacts can be relatively short to transmit a certain message compared with the other modes. The difference between telephone and telex is that with telex there is no opportunity of immediate response so that communication takes more time.

A consequence of the latter point is that the choice of communication technology depends among other things on the type of message. Face to face contact is most suitable for complex messages; telex and telephone are especially useful for simple routine messages. The choice of mode is obviously influenced by the communication motive. For establishing a contact, face to face contacts are superior but for maintaining contacts, telecommunication may appear to be most cost efficient.

In the following we will develop a model for the choice of communication modes which is to some extent related to the approach of Maggi (1989). A first difference is that our formulation explicitly relates to the behaviour of the firm, whereas Maggi uses a more general utility approach. The background is that we explicitly want to add telex as an alternative, which is only relevant for firms. A second difference is that in contrast to our three modes, Maggi only distinguishes two modes (face to face contact versus telecommunication).

Consider a firm minimizing its production costs given a certain level of output. The firm uses three production factors: labour (W), Capital (K), and Information (I). the production function reads:

$$q = q\,(W,K,I)$$

Information is obtained by spending time according to three communication channels: face to face contact (FF), telephone (TP) and telex (TX). The contribution of using these channels to the aggregate level of information in the firm is described by the following information production function:

$$I = I\,(FF,TP,TX),$$

where FF, TP and TX denote the number of contacts according to the three communication modes. The costs of communication involved consist of two parts, i.e., the time costs and the costs related to tariffs of telephone, telex and travel. The first category can be represented by subtracting communication time from total time of workers L:

$$W = L - t_1FF + t_2TP + t_3TX$$

where W is the total time which remains for work (net of communication time). The factors t_1, t_2 and t_3 denote the number of minutes needed per contact.
The second category can be added as a separate component in the cost equation:

$$C = p_lL + p_kK + p_1FF + p_2TP + p_3TX$$

where p_l, p_k, p_1, p_2 and p_3 are the costs per unit of the corresponding factors.

It has to be noted that the time involved in communication and the tariff charged depends on the direction of the communication. For example, if one visits another person one looses travel time. Similarly, with telephone contact, the caller usually pays the bill. These differences can be included in the model

by distinguishing incoming and outgoing contacts. This might lead to a game theoretical approach but we will not pursue this line of research here, because we want to focus on the choice of mode, not on the choice whether one's contacts are outgoing or incoming. Therefore, we assume that there is a given balance between outgoing and incoming contacts per medium. An assumption of that type is also necessary for telex since (in contrast to telephone) the firm only gets information by means of telex when it receives a response to its telex messages.

A related point concerns the fact that communication mode choice is influenced by the mode choice of one's communication partners. If one's partner does not have a telex line this mode is ruled out. This induces a network externality which will be addressed in Section 5.

Minimization of costs given the output level $\bar{q}$ leads to the following first order conditions:

$$\partial q/\partial L = p_l/\lambda$$
$$\partial q/\partial K = p_k/\lambda$$
$$(\partial q/\partial I)\,(\partial I/\partial FF) = p_1/\lambda + (\partial q/\partial L)t_1$$
$$(\partial q/\partial I)\,(\partial I/\partial TP) = p_2/\lambda + (\partial q/\partial L)t_2$$
$$(\partial q/\partial I)\,(\partial I/\partial TX) = p_3/\lambda + (\partial q/\partial L)t_3$$

where λ is the shadow price of output.

For labour and capital these conditions indicate the usual equality of marginal productivity and marginal costs (prices of production factors). For the communication inputs a similar result is obtained, but here marginal costs include the opportunity costs of labour.

If both the production function q and the information function I would have a linearly homogeneous Cobb Douglas structure, the above demand system can be shown to have the following properties:

1. Cross-price elasticities among communication modes are positive: the demand for telex messages increases when the tariff for telephone increases and vice versa.

2. Own price elasticities of communication modes are negative: for example, the demand for face to face contacts decreases when travel costs p_t increase.
3. An increase in the price of capital leads to an increase in communication activity according to all modes.
4. The effect of an increase of the price of labour on communication activity is uncertain. If costs of communication are dominated by time costs, an increase in the price of labour will induce a reduction in communication activity. If on the other hand tariffs of using communication media are the dominant cost component, an increase in the price of labour will lead to an increase in communication activity
5. An increase in the time needed per contact in mode i (t_i) leads to a decrease in the use of the pertaining mode. This also has a spatial interpretation since an increase of distance induces an increase in time costs for face to face contacts, but not for telex and telephone use. Therefore, one may expect that the share of face to face contacts in the modal split is largest for short distance communication.

Our main conclusion with the above model is that there is a substantial degree of substitution between communication modes. This is of course related to the specific form of the production functions assumed: Cobb Douglas production functions imply a high degree of substitutability. With a Leontief type of production function of information one expects different results since then communication modes are assumed to be non-substitutable. It is not unreasonable to assume a certain degree of non-substitutability since communication modes differ in their appropriateness to serve various communication motives. Absence of substitution possibilities in the information production function will lead to negative cross-price elasticities in the demand of communication modes. This means for example, that a decrease in the telephone tariff will induce an increase in telex use. The reason is that such a decrease makes average communication costs lower which will not only lead to an increase in telephone use, but also in the use of the other modes because of the Leontief type of fixed

coefficients. Thus, in this case we arrive at a complementarity result for communication modes.

After this rather abstract discussion of the choice of communication modes we will give a more detailed account of features of telex compared with telephone.

4. Features of telephone and telex

The telegraph came into use around 1840. It did not take much time before international networks evolved: in 1867 a connection between the UK and America was established. In 1870, a connection between the UK and India was made, almost simultaneously with the completion of the Suez Canal. An important evolution was the introduction of the telex (teleprinter exchange) in the 1920's which allowed direct communication between individual subscribers.

	Telegraph (telex)	Telephone system
period of introduction	1840	1880
type of message transmitted	written text	- spoken text recently followed by: - written text (fax) - data
main user	business	business, more recently followed by households
penetration	low	high
spatial orientation	both domestic and international	mainly domestic

Table 1. Comparison of telegraph and telephone system

The use of the telephone started around 1880. One of the ways it was used during the first stage of its existence was to support the telegraph system (which was very popular at that time) by passing on texts of telegrams. In the first stages telephone networks were only local. In later stages inter-local telecommunication was developed. International telephone calls started to play a role of importance in the 1920's. It took a long time, until the 1970's, before international telephone calls became fully automatic.

A comparison of the telegraph and telephone system is given in Table 1. The telegraph (telex) can only be used for the transmission of written text. The telephone system originally started as a transmitter of voice. More recently telephone lines also came into use for data transmission between computers and for telefax. It is expected that in the future there will be a single ISDN network which has the possibility to transmit signals for an even broader range of uses including videotext.

As already indicated, one of the uses of telephone in its initial phase was complementary to the telegraph in the sense that it supported the telegraph system. In later stages, the telephone and the telegraph system moved into a situation of substitution. The increasing penetration of telephone in households induced a decrease in the use of telegrams by households. As a result, the telegraph became mainly used for business purposes, whereas telephone use started to be dominated by households. More recently the introduction of the telefax also meant that in interbusiness communication the telex met a serious competitor leading to another process of substitution and even an absolute decline in telex use in most industrialized countries.

From the fact that in the 1980's telephone use is dominated by households and telex use is dominated by firms it follows that their level of penetration must be rather different. This is also presented in Table 2 from where one may infer that in most countries the number of telephone lines is about 100 to 200 times higher than the number of telex lines.

Table 2 also shows that telephone use overwhelmingly has a domestic orientation. It is difficult to find a country where the share of outgoing interna-

tional calls is higher than 2% of the total number of calls. This is very different from the telex system where the international orientation is around 30% for many countries. For a country like Thailand the share of international calls is even above 50%.

	Lines per thousand inhabitants:		Share of outgoing international traffic in total traffic (%):	
	telex	telephone	telex	telephone
France	2.2	408	28	1.5
FRG	2.7	432	34	1.6
Italy	1.2	319	37	.8
Portugal	2.0	147	29	---
Poland	0.8	70	13	.3
Brazil	0.6	52	5	.1
Thailand	0.1	17	60	.2

Source: ITU (1991)

Table 2. Comparison of telex and telephone system (1986)

5. Trends in ownership of telephone and telex lines

Ownership of communication media strongly depends on the level of income. This is clearly illustrated in Table 2 where one observes that high income countries have much higher ownership of telex and telephone lines than low income countries.

A regression analysis for telephone reveals that the elasticity of lines per capita with respect to GDP per capita is significantly higher than one (Table 3). Thus, when income per capita increases, the ownership of telephone lines increases at a somewhat higher rate. A similar analysis for telex lines gives rise to the result that the income elasticity is slightly below one. As can be inferred from R^2 the share of unexplained variance in total variance is much higher in telex than in telephone (15% versus 37%). A possible reason is that there is much variation in the quality and price of telex services which is not taken into

account in this analysis. Unfortunately, as far as we know, there is no broad international data source for telecommunication tariffs (including variable and fixed costs) which allows for estimating price dependence of ownership of telex or telephone lines. Therefore, it is also impossible to investigate directly to what extent substitution or complementarity relationships exist between ownership of telephone and telex lines. A positive cross-price elasticity would point at a substitution relationship.

The issue of cross-price elasticities is also addressed by Taylor (1980) in his survey of telecommunications demand. The literature on this subject appears to be thin and the results are ambiguous. For example, for international telephone use, Lea and Lage (1978) find a positive telex tariff elasticity of telephone use, whereas Yatrakis (1972) finds a negative elasticity.

In order to carry out an indirect check of complementarity we formulate the following simple demand system:

$$X_1 = a_o\, Y^{a1}\, p_1^{a2}\, p_2^{a3}$$
$$X_2 = b_o\, Y^{b1}\, p_1^{b2}\, p_2^{b3}$$

where X_1 and X_2 denote ownership of telephone lines and telex lines, respectively; p_1 and p_2 denote the respective tariffs, and income is represented by Y. The coefficients a_2 and b_3 are expected to be negative. Positive values for b_2 and a_3 would indicate substitution effects. After substitution we obtain:

$$X_1 = c\, Y^{a_1 - b_1 a_3/b_3}\, p_1^{a_2 - b_2 a_3/b_3}\, X_2^{a_3/b_3}$$

If telex and telephone are just different segments of the communication market without any interference we expect that cross elasticities are zero ($a_3 = b_2 = 0$). Then the power for X_2 would also be zero. In the case of substitution ($a_3 \geq 0$) the power for X_2 would be negative since b_3 is negative. In Table 3 we find a positive power for a_3/b_3 which suggests that complementarity exists. A problem is, however, that the equation estimated in Table 3 is incorrectly specified since the own price effect had to be deleted because of lack of data.

Another possible basis for the equations in Table 3 would be that demand for telephone and telex lines does not only depend on income Y but also on a factor Z which expresses the intensity of contacts (trade, visits, tourism, etc.) of a country. Then demand for telex and telephone lines can be written as:

$$X_1 = a_o\, Y^{a1}\, Z^{a2}$$
$$X_2 = b_o\, Y^{b1}\, Z^{b2}$$

so that after using again a substitution procedure we arrive at:

$$X_1 = cY^{\,a_1 - b_1 a_2/b_2}\, X_2^{\,a_2/b_2}$$

According to this formulation, the positive sign for the factor X_2 found in Table 3 indicates that telephone and telex share certain determinants representing communication stimulating factors.

We conclude that this admittedly simple analysis supports the view that telex line and telephone line ownership are complementary. Given the level of income in a country, a high number of telex lines goes together with a high number of telephone lines. Thus, given the level of income, a strong communication orientation for one mode (telephone) appears to coincide with a strong communication orientation for the other mode (telex).

A clear disadvantage of the above approach is that it is static. It does not reveal that the number of telex lines has undergone a very marked development during the last 30 years in most countries. Some examples are given in Figure 2.

Between 1965 and 1980 the telex system displayed higher growth rates than the telephone system in most countries. An exception is Germany where the telephone system was consistently more dynamic during the whole period, and France, where the telephone system displayed very high growth rates during the second part of the 1970's. In the USA, the telex system already started to decline in absolute size after 1982. Most of the other countries only experienced a slowdown of growth after 1980. Absolute decline of the telex system became general after 1987.

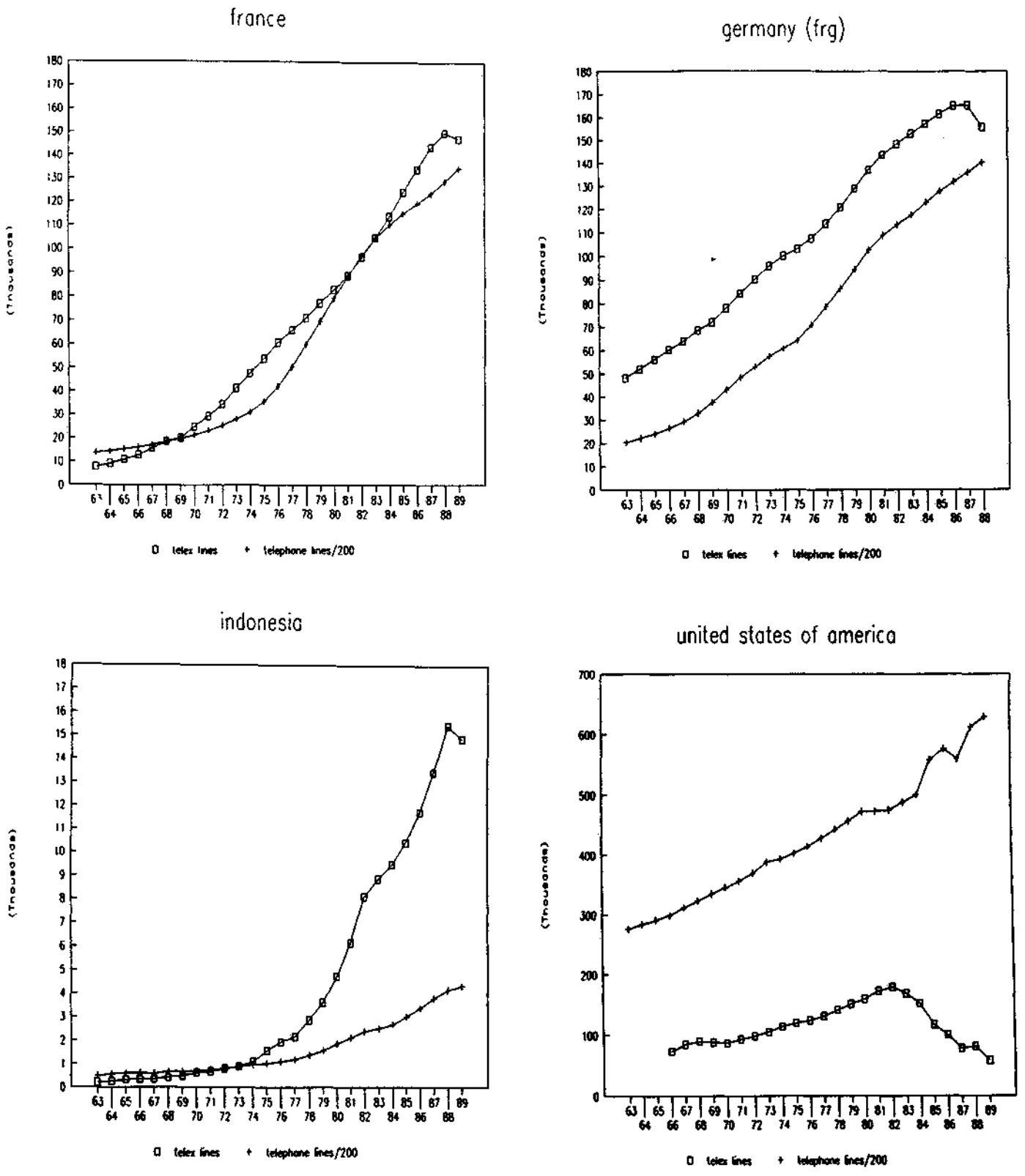


Figure 2. Development of telex and telephone system (1963-1989)

dependent variable	independent variables: constant	GDP per capita	telex lines per capita	telephone lines per capita	R^2
telephone lines per capita	3.02 (37.7)	1.15 (23.3)	-	-	.85
	3.31 (26.0)	.97 (12.4)	.19 (2.9)	-	.86
telex lines per capita	-1.52 (-12.7)	.93 (12.6)	-	-	.63
	-2.81 (-6.1)	.44 (2.4)	-	.43 (2.9)	.66

(t values in parenthesis, log transformation, N = 96)

Table 3 Statistical analysis of telephone and telex line ownership for 96 countries (1986).

An interesting feature of telecommunication media such as telex and telephone is that their adoption (and abandonment) depends on network externalities (cf Section 3). It is only meaningful to adopt telex if you know that there will be communication partners who will do the same. Similarly, the decision to abandon of telex will be influenced by the decision of one's major communication partners. Given the strong international orientation in telex, these partners will often be found abroad. This idea of network interdependence has been tested by relating the top year (TY) of ownership of telex lines observed in each country with the top year observed in the countries with which communication was most important. This is measured as the average top year in countries contributing to the first 50% of international outgoing calls, which will be denoted as TYCP. The regression results are as follows:

$$TY = 53.8 - .29(GDP/CAP) + .41\ TYCP \qquad R^2 = .57$$
$$\qquad\qquad (7.29) \qquad\quad (3.43)$$

It appears that both network externalities and income play an important role in the evolution process of telex. Rich countries start abandoning of telex earlier than poor countries. And countries having strong contacts with other countries which already started abandoning of telex will also abandon early. The latter result underlines the leading role of large rich countries in the world, such as the U.S., Japan and Germany. These countries tend to dominate the international communication patterns for many low income countries (cf. Rietveld et al., 1993). Consequently the developments in these countries lead to an acceleration of the abandonment of telex in low income countries. A similar mechanism can be observed for other international networks, such as the airline system or international freight transport. Here too low income countries are strongly induced to adapt to the standards prevailing in leading countries.

6. A comparison of international communication by telex and telephone

In most countries international telephone traffic grows rapidly. An average annual growth rate of 10% is not uncommon. The development of national telephone traffic is usually more moderate with annual growth rates of about half of this figure. When this situation will continue during a longer period, telephone traffic will gradually achieve a stronger international orientation compared with the still existing predominantly local and regional orientation (see again Table 1).

For telex use the development is very different. Telex use follows the pattern of a mountain parabola in many countries. After a period of sustained growth, the increase in telex use suddenly came to a halt in the second half of the 1980's. An analysis for 48 countries shows that telex use on average leads ownership of telex lines with about 1 to 2 years. The average peak period for telex line ownership is 1987.7. The peak period for domestic telex use is 1986.6, whereas for international telex use the average peak occurred at 1986.2. These

results underline again the importance of an international perspective for the analysis of telex: international telex use appears to be the most dynamic market segment.

To investigate the relationship between telex and telephone use we start by comparing data for some individual countries. For most of the countries presented in Table 4 the patterns for telex and telephone contacts are very similar: in Chile, Hungary, Indonesia and the Netherlands, the lists of the 10 most frequently called countries for telex and telephone strongly overlap. This is to a lesser extent the case with the Federal Republic of Germany (FRG) and for Saudi Arabia where a very different communication pattern is found. For Saudi Arabia the difference is clearly caused by guestworkers from various nearby countries, especially Egypt and Yemen who generate large communication flows by telephone. Telex flows originating in Saudi Arabia on the contrary are dominated by trade relationships. For the FRG a similar explanation can be given of the observed differences between telex and telephone.

Countries such as Yugoslavia and Turkey receive many calls from the FRG because of guest workers. The high share of the German Democratic Republic (GDR) is obviously related to the language identity and the numerous family ties between inhabitants of the FRG and the GDR. The absence of France among the ten major telephone communication partners of the FRG is difficult to believe and is most probably a matter of imperfection of the AT&T data[1].

A provisional conclusion on the basis of this evidence would be that international communication flows per telex and telephone follow in most countries rather similar patterns. If differences occur they can be explained in terms of differences of communication motives: telex is business oriented but international telephone calls may also have substantial private elements. There is no clear evidence at this level of aggregation of substitution of telephone by telex for bilateral relationships where the quality of telephone services is bad.

Indonesia

telex		telephone	
Singapore	26.2	Singapore	39.4
United States	13.1	Japan	15.6
Japan	10.2	Hong Kong	8.3
Hong Kong	7.5	United States	8.0
United Kingdom	6.9	Taiwan	3.8
Germany (FRG)	6.4	United Kingdom	3.3
France	3.8	Australia	3.1
Australia	3.6	Germany (FRG)	2.8
Netherlands	3.2	Malaysia	2.4
Taiwan	2.6	Netherlands	2.2
Rest	16.5	Rest	11.1

Chile

telex		telephone	
United States	29.0	United States	33.1
Argentina	8.4	Argentina	15.5
Brazil	7.8	Brazil	6.8
Germany (FRG)	7.3	Spain	4.3
United Kingdom	4.7	Peru	3.8
Spain	3.7	Germany (FRG)	3.3
Peru	3.6	Canada	3.0
Bolivia	3.1	Venezuela	2.9
France	3.1	France	2.7
Japan	3.0	United Kingdom	2.4
Rest	26.3	Rest	22.2

The Netherlands

telex		telephone	
Germany (FRG)	20.7	Germany (FRG)	32.3
United Kingdom	15.0	Belgium	20.7
France	8.7	United Kingdom	12.3
Belgium	8.2	France	6.7
United States	5.4	Switzerland	3.3
Italy	5.1	United States	3.3
Switzerland	4.5	Italy	2.8
Spain	2.7	Spain	2.0
Denmark	2.6	Austria	1.9
Sweden	2.3	Denmark	1.4
Rest	24.8	Rest	13.3

Hungary

telex		telephone	
Germany (FRG)	18.5	Germany (FRG)	26.8
Austria	13.2	Austria	15.3
Czechoslovakia	5.2	Switzerland	5.6
Soviet Union	5.0	Czechoslovakia	4.7
United Kingdom	4.9	Soviet Union	4.5
Italy	4.8	Germany (GDR)	4.4
Germany (GDR)	4.5	Sweden	4.0
Poland	3.8	Italy	3.8
Switzerland	3.6	United Kingdom	3.6
United States	3.6	Yugoslavia	3.2
Rest	32.9	Rest	24.1

Saudi Arabia

telex		telephone	
United States	13.5	Egypt	15.8
United Kingdom	12.8	Yemen	9.2
Germany (FRG)	7.4	Pakistan	7.3
Bahrain	6.4	United States	7.0
France	5.4	United Kingdom	6.1
Italy	4.9	Kuwait	4.9
Jordan	3.7	India	4.7
Japan	3.7	United Arab. Em.	3.9
United Arab. Em.	3.0	Jordan	3.8
Philippines	2.8	Bahrain	3.3
Rest	36.4	Rest	34.0

Federal Republic of Germany

telex		telephone	
United Kingdom	10.1	Austria	13.1
France	8.5	Switzerland	10.0
Italy	8.1	Netherlands	9.6
Netherlands	7.0	Italy	9.5
Switzerland	6.3	Germany (GDR)	9.2
United States	5.6	United Kingdom	8.0
Austria	5.3	Yugoslavia	5.0
Belgium	4.7	United States	5.0
Spain	3.2	Turkey	5.0
Denmark	2.9	Belgium	4.2
Rest	38.3	Rest	21.4

Source: ITU, AT&T

Table 4. Ten most frequently called countries by telex and telephone from 6 counties (1986)

The most notable difference between the telex and telephone data is that the aggregate share of the ten most frequently called countries is consistently higher for telephone calls. This implies that telex calls are more evenly spread among countries than are telephone calls. There seems to be a tendency that telex calls are less distance dependent. Nearby countries appear more frequently on the telephone lists than on the telex lists in Table 4.

For a less impressionistic comparison of telex and telephone data we will use a spatial interaction model of the gravity type. The gravity model aims at explaining bilateral communication relationships by means of features of nodes (mass variables of countries of origin and destination) and of links (communication costs, distance, barrier effects). An example of such a model for telephone can be found in Rietveld et al. (1993). It is based on a model formulated by Bröcker and Rohweder (1990) for the analysis of international trade. We will carry out the analysis with the share of outgoing international calls from country i to country j in the total volume of outgoing calls (x_{ij}) as the dependent variable. This means that we use an origin constrained spatial interaction model. The explanatory variables consist of node and link variables. For country j the following node variables are used:

- LP_j : number of telephone lines in country j
- LX_j : number telex lines in country j
- GDP_j : gross domestic product in country j

The link variables distinguished are:

- d_{ij} : distance between i and j
- L_{ij} : language dummy (= 1 when i and j have an officially recognized language in common)
- H_{ij} : historical dummy (= 1 when the countries i and j had colonial ties or were close political allies in 1957)
- N_{ij} : neighbour dummy (= 1 when the countries have a common border)
- M_{kij} : trade preference dummy (= 1 when the countries are members of a certain trade preference area k)

The origin constrained gravity model is formulated as follows:

$x_{ij} = z_i \, LP_j^{a1} \, LX_j^{a2} \, d_{ij}^{b} \exp \{c_L \, L_{ij} + c_H \, H_{ij} + c_N \, N_{ij} + \Sigma_k \, c_k \, M_{kij}\}$

where z_i is a balancing constant to ensure that

$\Sigma_j \, x_{ij} = 1$.

The model has been estimated by means of the regression technique outlined in Fotheringham and O'Kelly (1989, page 45). This entails the use of country specific dummies which have been deleted in the presentation in Table 5.

	Telex		Telephone	
Telephone lines destination	.31	(3.72)	.24	(2.62)
Telex lines destination	.27	(5.32)	.11	(1.89)
GDP destination	-.00	(-.05)	.07	(.77)
Distance	-.62	(-10.88)	-.78	(-12.53)
Neighbour dummy	.31	(2.93)	.24	(1.97)
Language dummy	.27	(3.12)	.42	(4.37)
Historical dummy	.80	(5.22)	1.20	(7.02)
Dummy for contacts between members of:				
EC	.08	(.43)	-.08	(-.35)
EFTA	-.62	(-1.83)	.09	(.23)
COMECON	1.35	(2.52)	.46	(.76)
CACM	.53	(1.14)	1.54	(2.94)
LAFTA	.24	(.89)	.02	(.06)
Andes group	-.04	(-.11)	.31	(.84)
ASEAN	-.13	(-.36)	.08	(.02)
Commonwealth	.18	(1.00)	.34	(1.67))
R^2	.88		.92	
log likelihood	-482.86		-542.53	
Sample size	519		519	

(t-values in parenthesis)

Table 5 Gravity model estimates for volumes of international telex and telephone flows (1986)

One might expect that for telex communication the share x_{ij} is adversely influenced by a high value of LP_j^{a1} (i.e., $a_1 \leq 0$). Table 5 shows that these expecta-

tions are not confirmed. There is no sign of substitution effects. Even the reverse holds true: telex communication between i and j is positively related to ownership of telephone lines in destination j. At the bilateral level, telex use and telephone use seem to reinforce each other.

The distance parameter for telephone use is somewhat larger (in absolute sense) than for telex use. This is in accordance with our observation that telex has a stronger international (and long distance) orientation than telephone. The results for the language, neighbour and historical dummies are rather similar for both media. Telex use appears to be slightly less sensitive to language differentials or the lack of historical links than telephone use. There is little structure in the dummies related to trade preference areas. One of the results which is in agreement with Table 4 is that telex use is relatively high among members of COMECON: there are four COMECON members among the 10 most frequently called countries from Hungary by telex.

7. Concluding remarks

Substitution and complementarity between the communication modes telephone and telex can be studied in various ways. In this study a cross-section and a time series approach are used. The results are rather different. With the cross-section approach one finds that there is a considerable degree of complementarity between telex and telephone; this holds true for both ownership of communication equipment (lines) and for the use of the media. It appears that the ownership of both telex and telephone lines is closely related to the income level in a country. A difference is that the income elasticity is slightly below 1.00 for telex and somewhat above 1.00 for telephone. Also with the use of telecommunication equipment one observes rather parallel patterns for telex and telephone. A difference is that telephone use is slightly more distance dependent than telex use. Also the influence of language differences and historical links is somewhat larger with telephone than with telex.

When time series data are used, a rather different picture emerges. Until about 1985 telephone and telex lines displayed a process of steady growth. In

some countries one even observes a growth rate which is consistently higher for telex than for telephone. This pattern changed with the large scale introduction of the telefax after 1985. The growth of telex use was suddenly reversed into a process of decline. It is here that substitution can be observed. It is most easily observable in the figures on telex. Its impact on the use of telephone lines is less easy to detect since use of telephone lines for telefax is not measured on a large scale basis. In addition, the number of telephone lines in the 1980's is about 100 to 200 times higher than the number of telex lines in most countries. If all telex lines were to be abandoned in a five year period and replaced by telefax lines this would only lead to an annual increase in the number of telephone lines between .1 and .2%, which is difficult to detect in view of the overall high growth rates in telephone lines in most countries. Although data on the penetration of telefax are not very complete, it is clear that they strongly outnumber the number of telex lines available at the peak year of telex (1987). Thus, the introduction of telefax led to a partial substitution of telex but it must also have affected the use of postal services and of the original voice related services of the telephone system itself.

An interesting result of our analysis concerns the role of network externalities. An actor's decision to abandon telex does not only depend on his own situation, but also on the decision of his major communication partners. We obtained evidence that the development path of telex ownership in developing countries has been significantly influenced by the industrialized countries. The early decrease of telex line ownership in the US and Europe has induced an acceleration of the abandonment of telex lines in developing countries.

Endnote

1. It appears that the Federal Republic of Germany is the largest communication partner of France with a share of 14.5% of all outgoing international calls.

References

AT&T, (various years) The World's Telephones

Batten, D.F. and Törnqvist, G. (1990) Multilevel network barriers: the methodological challenge The Annals of Regional Science, 24, 271-287.

Bröcker, J. and Rohweder, H.C. (1990) Barriers to international trade, methods of measurement and empirical evidence. The Annals of Regional Science, 24, 289-305.

Grübler, A. and Nakicenovic, N. (1991) Long waves, technology diffusion and substitution, International Institute for Applied Systems Analysis, Research Report 91-17.

Fotheringham, A.S. and O'Kelly, M.E. (1989) Spatial Interaction Models, Kluwer, Dordrecht

International Telecommunications Union, ITU (various years) Statistical Yearbook, Geneva.

International Telecommunications Union, ITU (1989) Table of international telex relations and traffic, Geneva.

Maggi, R. (1989) Towards an economic theory of barriers to communication, Papers of the Regional Science Association, 66, 131-142

Rea, J.D. and Lage, G.M. (1978) Estimates of demand elasticities for international telecommunications serves, Journal of Industrial Economics, 26, 363-381

Rietveld, P., Van Nierop, J. and Ouwersloot, H. (1993) Barriers to international telecommunication, this special issue.

Stoneman, P. (1983) The economic analysis of technological change, Oxford University Press, Oxford

Taylor, L.D. (1980) Telecommunications demand: a survey and critique, Ballinger, Cambridge

Yatrakis, P.G. (1973) Determinants of the demand for international telecommunications, Telecommunications Journal, 39, 732-746