SPATIAL INTERACTION MODELS OF INTERNATIONAL TELECOMMUNICATION FLOWS [1]

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[1] Paper prepared for presentation at the 40th Congress of the European Regional Science Association, August 29 - September 1, 2000, Barcelona, Spain. Support from the Ameritech Foundation through an Ameritech Faculty Fellowship is gratefully acknowledged.

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ABSTRACT

Despite the growing role of international telecommunications in the new global economy, the spatial structure of these flows, their socio-economic determinants, and their relationships with other international flows are not very well understood. This research makes use of a sample of 4137 country-to-country annual telephone flows (minutes of conversation) for the year 1995, involving 103 origin and 204 destination countries. This sample, obtained from the International Telecommunications Union (ITU), provides an opportunity for more comprehensive analyses and modeling than those in past related studies, where generally only one originating country is involved. These data are matched with country-to-country trade flows from the IMF, and country-level telecommunication (e.g., main lines, Internet hosts), socio-demographic, and economic variables obtained from the ITU, the UN Statistical Yearbook, and the CIA World Factbook. Various spatial interaction models are then estimated, involving several variables characterizing the origin and destination countries, great-circle distance, spatial contiguity, commonalities in language and religion, political and former colonial relationships, membership in special trade groups, and actual trade flows. In addition, intervening opportunities and competing destination variables are introduced into the model to test the effects of the international spatial structure on telephone flows. The results underscore the critical role of a country's (1) level of telecommunication equipment, (2) size of the business sector, (3) exports and imports, and (4) touristic attraction. The importance of distance, contiguity, commonalities in language and religion, and membership in culturally homogeneous regions and trade groups, is confirmed, as is the complex role of spatial structure. Among the most intriguing results is the empirical confirmation that electronic mail via the Internet may substitute for international telephone flows.

1. INTRODUCTION

International telecommunications, spurred by expanding international trade, internationalization of production and the resulting demand for rapid information transfer, large-scale tourism and other migrations, and other growing social and cultural exchanges, have increased significantly in recent years. For instance, the total traffic over the public international network has grown from 14.8 billion minutes in 1985 to 60 billion minutes in 1995, at an annual rate of 15% (ITU and TGI, 1996). With important technological advances leading to decreasing costs, international telephone calls have become much more frequent, though shorter, and have virtually eliminated the use of once-competing telegraph and telex services. While we are clearly moving towards an international information economy, it is surprising, however, to find out that there has been relatively little recent research on the determinants of international telecommunication demand, the geographic distribution of this traffic, and its relationship with other international flows, such as trade and tourism.

The purpose of this paper is to analyze the role of economic, demographic, cultural and geographic factors in determining the volume and spatial distribution of international telephone flows, making use of a new and very rich set of data, involving 103 origin and 204 destination countries. These data are matched with several country-related technological and socio-economic data, allowing for analyses of the effects of telecommunication equipment, including Internet access, trade and tourism, income per capita, geographical distance, and language, cultural, religious, political, and geographical commonalities. Extended gravity models are estimated, that also account for the effects of the international spatial structure on the pattern of telephone flows.

The remainder of the article is organized as follows. Section 2 consists in a review of the relevant literature. The modeling methodology is presented in Section 3. The data sources, functional specification, and empirical results are discussed in Section 4. Conclusions and areas for further research are outlined in Section 5.

2. **LITERATURE REVIEW**

Early econometric models of international telecommunication demand generally include separate equations for telephone, telegraph, and telex services. Most of these models were developed in the 1970s, when telephone service was not as dominant as it is today. Lago (1970), using 73 observations on telecommunication flows between the U.S. and 23 countries over the period 1962-1964, estimate a model where the number of telephone messages between the U.S. and any country i in any year is related to the volume of trade between the U.S. and i, the U.S. investment in i, the value of U.S. travel expenditures to i, the U.S. population whose parents came from i, the number of telephones in i, a dummy variable related to use of radio circuits in i, the speed of service in i (all connections were operator-assisted), the number of common hours during a working day schedule between the U.S. and i, the price of a 3-minute call, the cost per telegram word, the telex cost for 3 minutes, and the monthly rental cost of leased telegraph circuit service between the U.S. and i. Lago's results show that (1) time commonality, foreign-parentage population, and number of telephone sets are insignificant variables, (2) trade, tourism, and U.S. investment abroad are significant variables for telephone service, and (3) the own-price elasticity of telephone service is greater than one, with no substitutions with

the other services. Naleszkiewicz (1970) estimates similar equations while regrouping destination (from the U.S.) countries according to their economic development status and considering four categories of explanatory variables: (a) flows of capital between countries, as proxied by foreign assets and liabilities; (b) flows of goods and services, as measured by imports, exports, national income, and gross national product (GNP); (c) country wealth, as measured by money supply and demand for deposits; and (d) country industrialization, as measured by industrial production. Yatrakis (1972), using the numbers of calls over 46 international routes in 1967, estimates models similar to Lago's and Naleszkiewicz's, while including additional explanatory variables such as per capita income, the average fare of a first-class airline round trip, the percentages of a country GDP attributable to the extractive and manufacturing sectors, the number of ships of 1000 tons capacity registered with the origin country, government expenditures as a percentage of the GDP, the average annual dividends paid and received on foreign investments, the numbers of emigrants to and immigrants from all destination countries, the percentage of the population living in urban centers, and measures of language similarity and spatial contiguity among the pairs of interacting countries. The last two variables turn out to be highly significant. All the previous contributions involve fairly simple regression (OLS) techniques. More sophisticated is the slightly later work of Rea and Lage (1978), who use the error component regression model to deal with cross-section time-series data on the number of outgoing messages from the U.S. to 37 major countries over the period 1964-73. While their equations are, in general, similar to the previous ones, and their results also point to a price-elastic demand for telephone service, they conclude, in contrast to earlier work, that the value of total trade (exports + imports) between the U.S. and the foreign country is not a significant variable.

More recently, Fiebig and Bewley (1987) use the Box-Cox transformation in the estimation of a lagged model for telephone traffic between Australia and ten foreign countries, where the number of paid minutes for outgoing telephone traffic at time t is a function of that traffic at time t-1, the real GDP of Australia, a telephone price index, bilateral trade, and short-term migrations. A similar equation is estimated for telex service. The lagged endogenous variable is used to capture habit formation and inertia effects, and also provides a way to distinguish between short-term and long-term elasticities. Tests regarding the optimal Box-Cox parameters suggest that the double-log functional form is acceptable, while the linear one is not. Bewley and Fiebig (1988) further analyze Australia-originating international telephone calls by modeling how the numbers of calls and conversation minutes are shared among the following three services: (1) direct dialing, (2) operator-connected station-to-station, and (3) operator-connected person-to-person. This was the first study to analyze substitution among services for international telecommunications. Rietveld and Janssen (1990), mixing 462 observations on interregional calls within the Netherlands (22 districts) and 27 observations on international calls between the Netherlands and foreign countries, estimate gravity models where the explanatory variables are the district/country gross domestic products, the origin-destination distance, and dummy variables characterizing 11 individual and groups of foreign countries, intended to measure the barrier effect of borders. This is the first time that a distance variable is introduced into such a model. It turns out to be highly significant, with an elasticity of -1.23. The coefficients of the dummy variables are negative and, in most cases, significant, pointing to barrier effects. Focusing on the 27 international calls observations only, they use both distance and the cost of calling in the

same model, but the coefficient of distance becomes insignificant, due to the high correlation between these variables. Kellerman (1990), using data from American Telephone and Telegraph (1977-88), analyzes the outgoing telephone calls from 18 countries to their 10 most frequently called countries, relating these flows to imports, exports, and arriving tourists. Incoming tourism turns out to be a leading variable for the U.S. and the U.K. In another study focusing on U.S. outgoing telephone calls, Kellerman (1992) relates the annual growth in these calls over the period 1961-1988 to the annual growth rates in people flows (non-immigrants admitted to the U.S., U.S. citizens departing the U.S.), in commodity flows (imports, exports), and in capital flows (U.S. direct investment abroad, foreign purchases of long-term securities). However, the obtained R^2 are relatively low, and the results do not show any consistent lagged relationship between the various growth rates. In a related study, Dokmeci and Berkoz (1996) analyze international telephone calls from Turkey over the period 1963-1990, regressing them on other international movements. They find that incoming tourism, followed by exports and GNP, are the most important explanatory variables. Perez Amaral et al. (1995) analyze aggregate monthly outgoing international traffic from Spain's business sector, during the period 1980-1991, as a function of the number of business lines, the gross domestic output, the number of nights spent by foreign nationals in Spanish hotels, and the telecommunication traffic from the U.S. to Spain. Hackl and Westlund (1995), departing from the traditional assumption of constant price elasticity, show that the demand for telecommunications between Sweden and its major trading partners (Germany, U.K., U.S., Denmark, Finland, Norway) is best described by time-varying coefficient equations estimated with the moving local regression technique and with monthly data over the period 1976-1990. In addition to price, the relevant explanatory variables include trade volume and industrial production indices for Sweden and the foreign countries.

A third stream of study involves accounting for callback effects. Acton and Vogelsang (1992), analyzing the annual telephone traffic between the U.S. and 17 West European countries over the period 1979-1986, and borrowing from the framework first proposed by Larson et al. (1988) in their study of point-to-point routes within the U.S., incorporate the phenomenon of call stimulation or substitution by including the return telephone flow in their estimated equations. However, instead of using a simultaneous equation approach, they estimate a reduced form of the equation, where the demand for calls (minutes) from the U.S. to a foreign country is a function of the originating and terminating prices of both telephone and telex services, the U.S. and foreign country gross domestic products (GDP), the number of European telephones, trade volumes, and the composition of production in the destination country (agriculture, restaurants and hotels, transportation, banking and financial services, manufacturing), and country-specific dummy variables to capture other effects. The results indicate that the own-price and GDP variables are significant, but that cross-price and trade and telephone equipment variables are not. Appelbe and Dineen (1993) report on the results of a similar approach to Canada-Overseas MTS demand. Using quarterly data for the period 1988 to 1991, they analyze calling patterns between Canada and the U.K., France, Italy, Holland, Germany, Hong Kong, Japan, Australia, and the Carribbean, using a 4-quarter lag for prices and a 3-quarter lag for income. They report a low callback effect coefficient of 0.10, in contrast to coefficients of 0.52 and 0.33 for Canada-Canada and Canada-U.S. calling patterns reported in Appelbe et al. (1988). Sandbach (1996) estimates an origin-destination model with traffic data on 154 routes between developed countries and in both directions. The non-

price variables include the numbers of lines in the origin and destination countries, the GDP per capita in the origin country, the time difference between countries, the inverse of distance, and dummy variables related to language commonality and the Germany-Turkey routes (picking up the impact of the German guest worker community). The price variables include the price of an outgoing call, and variables involving the difference between incoming and outgoing call prices, to capture call stimulation and reversal effects. However, these effects are not statistically significant, probably because of the relatively low level of price disparity. Garin-Munoz and Perez-Amaral (1998) estimate demand functions for outgoing telephone traffic from Spain to 27 African and Oriental countries over the period 1982-1991. The explanatory variables include the minutes of incoming traffic, the price of an outgoing call, the volume of trade between Spain and the foreign country, and the number of tourists in Spain from this country. They use instrumental variables to control for the simultaneity between outgoing and incoming calls. The incoming calls, price, and tourists variables turn out to be significant, but the trade variable does not. Finally, Karikari and Gyimah-Brempong (1999), using traffic data between the U.S. and 45 African countries over the 1992-1996 period, implement a simultaneous equations approach and regress the number of calls in one direction to the lagged traffic in this direction, the return traffic, the price of an outgoing call, the GDP per capita, the volume of trade, the differential in outgoing and incoming prices, and the product of the number of households, as a measure of the community of interest.

Except for Yatrakis (1972), Kellerman (1990), and Sandbach (1996), all the previous studies involve only one origin country, and generally small samples, which makes it difficult to generalize the results with a strong degree of certainty. The number and type of explanatory variables vary from study to study, and their choice is generally not related to a clear theoretical framework, except for the role of telephone prices (Taylor, 1980) and callback effects (Larson et al., 1988). Communities of interest, whether related to trade, culture, language, religion, politics, or geography, are poorly accounted for. The impacts of emerging telecommunications technologies (e.g., the Internet) are not assessed, and nor is the possible impact of the international spatial structure, and the related competitive and/or agglomeration effects.

3. **MODELING METHODOLOGY**

The analysis of international telephone calls is approached within the framework of spatial interaction modeling. Let $\mathbf{V}_i$ and $\mathbf{V}_j$ be vectors of variables characterizing countries i and j, and $\mathbf{R}_{ij}$ a vector of resistance or facilitation factors for the flow F_{ij} from i to j. The standard spatial interaction model has the general form:

$$F_{ij} = f(\mathbf{V}_i, \mathbf{V}_j, \mathbf{R}_{ij}) \qquad (1)$$

In general, the variables in $\mathbf{V}_i$ and $\mathbf{V}_j$ include demographic, economic, and technological characteristics in the two countries that affect telephone flows both positively and negatively (e.g., population, GDP, industrial activity, telecommunication facilities, etc.), and the variables in $\mathbf{R}_{ij}$ include distance and telephone prices, that are expected to influence flows negatively, people and trade flows, and language and other cultural affinities, that are expected to influence flows positively.

The spatial interaction literature suggests, both theoretically and empirically, that improved models are to be obtained by accounting for the effects of the spatial structure, particularly in eliminating the estimation bias of the distance parameter. One approach, proposed by Fotheringham (1983a, 1983b), is to introduce into the model a competing destination (CD) factor, that measures the accessibility of the destination j to all (or a subset of) the other destinations. If the interaction decreases with this factor, competition is deemed to exist among the destinations, and the closer a specific destination j is to other destinations, the smaller the interaction terminating at j. In the opposite case, agglomeration effects are deemed to take place. CD factors are used, among others, by Ishikawa (1987) in modeling migration and university enrollments in Japan, Guy (1987) in modeling shopping travel, Fik and Mulligan (1990) in modeling airline traffic, and Fik et al. (1992) in modeling interstate labor migration. Both competition and agglomeration effects are uncovered in these different studies. Another approach involves the use of an intervening opportunities (IO) factor, based on the ideas developed by Stouffer (1940, 1960), who argues that the observed attenuating effects of distance represent the absorbing effects of those opportunities located between the origin and the ex post destination. IO factors are used, among others, by Barber and Milne (1988) in modeling internal migration in Kenya, by Fik and Mulligan (1990) and Fik et al. (1992), together with CD factors, and by Conçalves and Ulysséa-Neto (1993) in modeling public transportation flows. In the area of telecommunications interactions, Leinbach (1973) and Hirst (1975) implicitly account for the effect of spatial structure on the telephone flows within West Malaysia and Tanzania, and Guldmann (1999) does so explicitly in his analysis of telephone flows within a U.S. region.

While reviewing the above studies, one can observe a significant variability in the formulation of the CD/IO factors and in the definition of the geographical space over which they are computed. [See Guldmann (1999) for further discussion of this issue]. As the literature provides little guidance, and because the international geographical space (i.e., the whole planet) has never been, to the best of our knowledge, investigated with regard to the possible effects of the spatial structure, several factors will be investigated in this study, in the spirit of exploratory analysis. Let X_k be a variable characterizing the competing or intervening country k, and D_{km} the distance between countries k and m. The spatial structure variable SSV_m characterizing country m is computed as follows:

$$SSV_m = \Sigma_k X_k / (D_{km})^{\lambda} \qquad (2)$$

The set of countries k selected in the summation of Equation (2) is an important decision variable. It could represent all countries (except m), or countries within a given distance from m, or countries with specific cultural or other characteristics, irrespective of their locations. The distance exponent λ is either exogenously selected, or a sensitivity analysis is conducted, with the chosen value maximizing the explanatory power of the interaction model. If the variable SSV_m is linked to the origin country i, it naturally represents an intervening opportunity factor. If it is attached to the destination country j, it represents a competition factor. Both types of effects may be present, and therefore the final form of the model is:

$$F_{ij} = f(\mathbf{V}_i, \mathbf{V}_j, \mathbf{R}_{ij}, SSV_i, SSV_j) \qquad (3)$$

4. **EMPIRICAL ANALYSES**

4.1 Data

Country-to-country traffic data, in minutes of conversation, have been obtained, in electronic form, from the International Telecommunications Union (ITU) through Telegeography, Inc., and include 4137 origin-destination routes, with 103 origin and 204 destination countries for the year 1995. These countries are listed in Table A.1 in the Appendix, together with the outgoing and incoming numbers of links and flows. This sample covers 52.3 billion minutes, or about 87% of the total worldwide traffic flow in 1995. The peak and off-peak rates, in U.S. dollars, for a 3-minute direct-dialed call from 55 countries to their top 20 destinations have drawn from ITU and TGI (1996), providing a match for 952 traffic routes (or 23%). A second set of telecommunications data, obtained in electronic form from the ITU, includes country-level indicators such as numbers of different types of lines and phones, aggregate local, national, and international traffic, various prices and connection charges, numbers of subscribers to advanced telecommunication features (e.g., ISDN, facsimile, radio-paging), demographic and socio-economic variables (e.g., GDP, population, households, radio and television receivers, etc.), and financial information on the country telecommunication companies. While the number of variables is very large, there are many missing data, particularly for developing countries, which reduces the overall usefulness of this data source. A third set of data has been derived from the CD-ROM World Factbook, compiled by the CIA, and includes quasi-complete data on each country population age and gender structure, literacy rate, religion, languages, labor force, unemployment rate, GDP purchasing power parity, and the shares of the GDP among agriculture, industry and services. Memberships in various international organizations and economic, trade, and cultural groups, have also been derived from the World Factbook. Their definitions and compositions are available in the Appendix. Each country has been assigned to a continent and a subcontinent, as defined in the World Factbook (see Table A.1). International tourism data have been derived from the U.N. Statistical Yearbook (43rd Edition, 1996), also on CD-ROM. Finally, the latitudes and longitudes of the capitals or main cities of all countries have been drawn from the ArcWorld GIS coverage produced by the Environmental Systems Research Institute, Inc. (ESRI), and used as inputs to compute great-circle distances. The time zones of all countries have been drawn from the Website of the Time Service Department, U.S. Naval Observatory (http://tycho.usno.navy.mil) and used to compute the time difference between each pair of country.

4.2. Explanatory Variables

In order to explain the variations in the independent variable – the telephone traffic flow F_{AB} from country A to country B-, several categories of independent variables have been considered. Some characterize the origin and destination countries separately, and others characterize the couple of countries (A, B), some are continuous and others are dummy variables. Basic descriptive statistics on the continuous variables are presented in Table 1, and the frequency distributions of the dummy variables are available in Table A.2 in the Appendix.

The first category is termed "**Telecommunication Equipment**". The ITU Indicators data set includes many potentially useful variables (e.g., facsimile and cellular phone subscribers), but the large number of missing data made their use impossible. Given these constraints, the variables finally selected are:

- MTLA / MTLB: number of main access lines in country A/B;
- INTHSA / INTHSB: number of Internet hosts in country A/B;
- ISDSA / ISDSB: number of ISDN subscribers in country A/B.

While the MTL variable is fairly standard (Standbach, 1996), the two other variables have never been used. In addition to measuring the level of sophistication of a country in information technologies (IT), they may also point to substitution and complementary effects. For instance, the availability of Internet access may stimulate phone calls, or may provide a way to reduce them through alternatives such as e-mail or search of information on the World Wide Web (WWW).

The second category is termed "**Economic Development**". While several variables in the CIA data set have been considered, such as the size of the labor force, the unemployment rate, the shares of the GDP among the major activity sectors, and literacy rates, they turned out to be insignificant or, in some cases, with the wrong signs. The variables finally selected are:

- INCA / INCB: Gross Domestic Product (GDP) per capita in country A/B;
- PBMLA / PBMLB: Percentage of business access lines in country A/B:
- ADEC: dummy variable = 1 if countries A and B belong to the Advanced Economies Group (IMF definition).

It is worth noting that the GDP variable, provided by the CIA database, is based on purchasing power parity, and not simply on the conversion of the GDP measured in local currency into U.S. dollars, using exchange rates, as has been the case in past studies. The INC variable can thus be expected to better reflect the role of income in telephone usage decisions. The variable PBML, derived from the ITU Indicators data set, is important because it reflects the size of the economic sector in a country, and also because businesses generate a much larger volume of calls per line than residential users. The ADEC variable reflects the general role of economic development in international telecommunications.

The third category is termed "**International Trade**". In addition to the actual export and import flows, several dummy variables have been used to characterize mutual membership in a trade group. Such variables have long been used in trade gravity models (e.g., Brocker and Rohweder, 1990; Zhang and Kristensen, 1995; Frankel and Wei, 1998). The variables selected are:

- EXP: exports from country A to country B:

Table 1: Basic Statistics – Telephone Flows and Related Variables

Variable	Number of Observations	Mean	Minimum	Maximum
Origin – Destination				
Telephone Flow (minutes)	4137	12,642,770	1	3,046,125,000
Exports ($ million)	4137	877	0	152,896
Imports ($ million)	4137	893	0	148,304
Distance (kilometers)	4137	2,880.5	39.9	11,784.0
Time Zone Difference (hours)	4137	2.46	0	12
Origin Country				
Number of Main Lines	103	5,779,647	2,503	164,624,400
Number of Internet Hosts	103	88,766	0	6,054,959
Number of ISDN Subscribers	103	23,112	0	961,610
Percentage of Business Lines	103	30.90	9.00	70.00
Income Per Capita ($)	103	8,730	591	27,575
International Tourists	103	4,972	2	60,033
Destination Country				
Number of Main Lines	204	3,399,471	2025	164,624,400
Number of Internet Hosts	204	46,514	0	6,054,959
Number of ISDN Subscribers	204	14,371	0	961,610
Percentage of Business Lines	204	30.87	7.05	77.00
Income Per Capita ($)	204	6,827	374	29,045
International Tourists	204	2,777	1	60,033

- IMP: =imports by country A from country B;
- ANDEAN: =1 if A and B belong to the Andean Community of Nations;
- APEC: =1 if A and B belong to the Asia-Pacific Economic Cooperation;
- ASEAN: =1 if A and B belong to the Association of Southeast Asian Nations;
- CACM: =1 if A and B belong to the Central America Common Market;
- CAEU: =1 if A and B belong to the Council of Arab Economic Unity;
- ECWAS: =1 if A and B belong to the Economic Community of West African States;
- EFTA: =1 if A and B belong to the European Free Trade Association;
- EU: =1 if A and B belong to the European Union;
- LAIA: =1 if A and B belong to the Latin American Integration Association;
- MERCOS: =1 if A and B belong to the Southern Cone Common Market;
- NAFTA: =1 if A and B belong to the North American Free Trade Association.

The fourth category is termed "**International Tourism**". Detailed country-to-country tourist flows are not available to match the telephone flows. The UN Statistical Yearbook provides only continent-to-country tourist flows, and therefore it was necessary to use the aggregate number of incoming international tourists. The variable selected is:

- TOURA / TOURB: number of international tourists visiting country A/B.

The fifth category is termed "**Cultural Relationships**", including:

- LANG: =1 if A and B speak the same main language;
- RELIG: =1 if A and B have the same major religion;
- ACCT: =1 if A and B belong to the Agency for the French-Speaking Community (which promotes French language and culture).

The sixth category is termed "**Political and Former Colonial Relationships**":

- CMWTH: =1 if A and B belong to the Commonwealth of Nations;
- CBSS: =1 if A and B belong to the Council of Baltic Sea States;
- FSU: =1 if A and B belong to the Former Soviet Union;
- FZ: =1 if A and B belong to the Franc Zone;
- OPEC: if A and B belong to the Organization of Petroleum Exporting Countries.

Memberships in all the above groups are provided in the Appendix.

The seventh category is termed "**Geographical Separation**", and includes:

- DIS: great-circle distance between the capitals of countries A and B;
- ♠TIME: time zone difference between countries A and B (hours);
- CONT: =1 if countries A and B share a common border;
- ISLA: =1 if neither country A nor country B is an island.

The DIS variable is a standard one in most trade gravity models, but has been used only by Rietveld and Janssen (1970) and Sandbach (1996). Moreover, Sandbach restricted the relationship to be linear in the inverse of distance. The ♠TIME variable was also used by Sandbach, and in a modified form (number of common working hours between countries A and B) by Lago (1970). The contiguity variable has often been used, but the ISLA variable never. The underlying assumption regarding the island status of a country is that it creates a special barrier to telecommunications, whether outgoing or incoming. There are 62 island countries in the sample, which makes it feasible to test for this effect.

The eighth category is termed "**Continental/Subcontinent Memberships**". The list of continents and subcontinents, and their country memberships, is available in Table A.1 in the Appendix. A dummy variable is defined for each continent and subcontinent, and takes the value of 1 if both countries A and B belong to this continent or subcontinent.

Of course, those subcontinents that have no internal interaction in the sample (Central South America, Eastern South America, Northern North America) are excluded.

The ninth and final category is termed "**Spatial Structure**". The formulation in Equation (2) has been implemented as follows:

- the distance between countries k and m is the great-circle distance;
- three measures of a country size have been considered: The number of main access lines, MTL, the population, POP, and the GDP;
- five definitions of the sets of countries k associated to country m in the summation have been considered: (1) all countries in the world, except country m (SSV1); (2) all countries in the same continent as m (SSV2); (3) all countries in the same subcontinent as m (SSV3); (4) all countries contiguous to m (SSV4); and (5) all countries that share the same main language as m (SSV5) irrespective of their locations.

4.3. Results

The estimated model is linear in the logarithms of the dependent (F) and of the continuous independent variables (MTLA, MTLB, INTHSA, INTHSB, ISDSA, ISDSB, PBMLA, PBMLB, INCA, INCB, EXP, IMP, TOURA, TOURB, DIS), linear in the dummy variables and in the time zone difference variable, and linear in the logarithms of the spatial structure variables. A few missing values were estimated for the variables TOUR, PBML, and ISDS, using regression relations between the number of business lines and the number of ISDN subscribers, on one side, and the number of main access lines, MTL, on the other side (with R^2 of 0.97 and 0.70, respectively). The number of tourists was regressed on the variables MTL and INC, with an R^2 of 0.76. Also, because the variables INTHS, ISDS, EXP, and IMP take a value of zero in several countries (mostly developing or small countries), the Box-Cox transformation, with a parameter α=0.001, was used for these variables in order to approximate their logarithms, with:

$$X(\alpha) = (X^{\alpha} - 1)/\alpha \qquad (4)$$

All regression analyses are performed with OLS. The results are reported in Table 2.

In a first stage, a benchmark model without spatial structure variables (Model 1) was estimated, with $R^2 = 0.863$. Several dummy variables associated with various groups, continent, and subcontinents were deleted because they turned out to be insignificant. Among the "Telecommunication Equipment" variables, the effects of the access lines variables, MTLA and MTLB, are highly significant, very close, and surprisingly similar to those obtained by Sandbach (1996). The coefficients of the Internet variables, INTHSA and INTHSB, are significant (at the 5% level), negative for country A, and positive for country B. The negative sign suggests that electronic mail and WWW browsing (although admittedly in its infancy in 1995) substitute for telephone calls from country A, while the availability of Internet hosts (hence Web sites) in country B stimulates calls from A, possibly as a result of the newly gathered WWW information, and the need for further complementary information. The coefficients of the ISDN variables are both positive, pointing to stimulation effects. Among the "Economic Development" variables, the shares of business lines in both countries, PBMLA and PBMLB, have significant and positive effects, with lines in country A having nevertheless a stronger impact, as expected. The

coefficient of the income-per-capita variable INCA is highly significant and positive, as expected, but the variable INCB turned out to be completely insignificant, and was deleted. The dummy variable ADEC, which characterizes interactions between advanced economies, is significant and positive, pointing to specific telecommunications interactions among these countries. Among the "International Trade" variables, the coefficients of the actual export and import flows, EXP and IMP, are highly significant and positive, but in a 2/1 ratio, suggesting that trade-related calls from A to B pertain more heavily to imports by A from B. Only four trade
group dummy variables turn out to be significant (APEC, ECWAS, LAIA, and MERCOS). As LAIA includes all South-American countries, its negative sign may point to overall lesser telephone interactions on this continent, irrespective of trade, whose effect is primarily taking place among the Southern Cone Common Market countries (MERCOS). Among the "International Tourism" variables, only TOURA has a significant and positive effect, suggesting that visitors in A call home in B, but that no one from A calls the visitors in B (assumedly sailing from A). The "Geographic Separation" variables have all significant effects, with the expected sign. Island status clearly creates a barrier for telecommunications, while contiguity enhances them. Distances and time zone differences appear to have distinct, negative effects. All the "Cultural Relationships" variables have significant and positive effects. Among languages, it appears that French may play a specific and enhanced role, as measured by ACCT. The impact of religion commonality is uncovered here for the first time. Among the "Political and Former Colonial Relationships" variables, only CMWTH, FSU, and FZ have strong and positive effects. Finally, the "Continent Membership" variables are significant for all continents, except Asia. The negative coefficients for America and Europe may reflect a compensation effect, counterbalancing the possibly excessive and positive influences of some other variables, such as income per capita or the level of telecommunication equipment and technology. The "Subcontinent Membership" variables point to networks with positive interactions in the cases of Northern, Western, and Southeastern Europe, Eastern Africa, the Middle East, and Southern Asia. However, the negative coefficient for Northern Africa cannot be easily explained.

As discussed earlier, data on telephone call prices from country A to country B are available for 952 pairs of countries (about 23% of the sample). Model 1 specification was expanded to include the logarithm of this price as an additional independent variable, and was re-estimated with the reduced sample. The coefficient of the price variable turned out to be positive, but insignificant (t=0.87), probably as a result of the correlation between distance and price, and the inability of the regression to disentangle both effects. We therefore retain Model 1 specification over the whole sample, and expand it by considering the "Spatial Structure" variables.

Table 2: Regression Models of International Telephone Flows

Variable	Model 1 Basic	Model 2 Spatial Structure Whole World	Model 3 Spatial Structure Continents	Model 4 Spatial Structure Subcontinents	Model 5 Spatial Structure Adjacent Countries	Model 6 Spatial Structure Language Commonality	Model 7 Combination of Models 2 and 6
Intercept	3.242 (4.08)[1]	5.188 (6.25)	6.051 (2.91)	4.844 (5.08)	2.913 (3.65)	2.954 (3.75)	4.193 (5.25)
In MTLA	0.633 (31.75)	0.609 (30.29)	0.632 (31.66)	0.615 (29.40)	0.633 (31.57)	0.642 (32.50)	0.607 (30.11)
In MTLB	0.685 (45.94)	0.694 (46.59)	0.690 (45.83)	0.681 (45.04)	0.673 (44.38)	0.687 (46.48)	0.689 (47.10)
In INTHSA	-0.00028 (3.71)	-0.00031 (4.10)	-0.00026 (3.44)	-0.00027 (3.61)	-0.00027 (3.63)	-0.00020 (2.67)	-0.00021 (2.79)
In INTHSB	0.00026 (3.80)	0.00028 (4.09)	0.00026 (3.82)	0.00027 (3.91)	0.00026 (3.82)	0.00027 (3.92)	0.00030 (4.36)
In ISDSA	0.00013 (1.89)	0.00010 (1.47)	0.00013 (1.85)	0.00014 (2.07)	0.00015 (2.23)	0.00016 (2.41)	0.00016 (2.32)
In ISDSB	0.00016 (2.63)	0.00018 (3.05)	0.00016 (2.66)	0.00017 (2.80)	0.00018 (3.01)	0.00014 (2.38)	0.00022 (3.67)
In PBMLA	0.996 (12.35)	0.755 (8.66)	1.003 (12.22)	0.945 (11.40)	0.998 (12.38)	0.920 (11.45)	0.674 (7.65)
In PBMLB	0.512 (6.39)	0.490 (6.12)	0.491 (6.11)	0.495 (6.12)	0.517 (6.46)	0.482 (6.06)	0.413 (5.19)
In INCA	0.591 (14.26)	0.627 (15.11)	0.578 (13.54)	0.587 (14.17)	0.584 (13.87)	0.564 (13.59)	0.600 (14.52)
ADEC	0.349 (3.66)	0.413 (4.34)	0.359 (3.76)	0.367 (3.85)	0.330 (3.46)	0.229 (2.40)	0.258 (2.74)
In EXP	0.000372 (4.92)	0.000380 (5.05)	0.000370 (4.89)	0.000361 (4.77)	0.000359 (4.74)	0.000378 (5.05)	0.000392 (5.28)
In IMP	0.000742 (9.65)	0.000717 (9.37)	0.000742 (9.63)	0.000737 (9.58)	0.000727 (9.46)	0.000737 (9.68)	0.000717 (9.51)
APEC	0.814 (7.24)	0.649 (5.68)	0.811 (7.20)	0.832 (7.39)	0.827 (7.36)	0.829 (7.46)	0.656 (5.88)
ECWAS	0.800 (3.97)	0.764 (3.81)	0.787 (3.90)	0.778 (3.86)	0.811 (4.03)	0.760 (3.81)	0.774 (3.91)
LAIA	-0.505 (2.50)	-0.646 (3.20)	-0.506 (2.51)	-0.527 (2.61)	-0.467 (2.31)	-0.418 (2.09)	-0.612 (3.07)
MERCOS	1.124 (2.83)	1.077 (2.73)	1.105 (2.79)	(0.995 (2.50)	1.133 (2.86)	1.049 (2.67)	1.057 (2.72)
TOURA	0.176 (7.38)	0.220 (8.98)	0.176 (7.37)	0.190 (7.79)	0.174 (7.28)	0.152 (6.42)	0.195 (7.98)

[1] *The t-statistics are in parentheses*

Table 2: Regression Models of International Telephone Flows (continued)

Variable	Model 1 Basic	Model 2 Spatial Structure Whole World	Model 3 Spatial Structure Continents	Model 4 Spatial Structure Subcontinents	Model 5 Spatial Structure Adjacent Countries	Model 6 Spatial Structure Language Commonality	Model 7 Combination of Models 2 and 6
ln DIS	-1.059	-1.131	-1.066	-1.080	-1.052	-1.099	-1.173
	(22.70)[1]	(23.91)	(22.38)	(22.94)	(22.58)	(23.70)	(25.13)
ΔTIME	-0.047	-0.046	-0.050	-0.047	-0.043	-0.043	-0.046
	(3.44)	(3.40)	(3.61)	(3.45)	(3.18)	(3.21)	(3.42)
CONT	0.376	0.279	0.368	0.352	0.386	0.377	0.288
	(3.62)	(2.68)	(3.54)	(3.38)	(3.72)	(3.67)	(2.81)
ISLA	0.133	0.220	0.144	0.124	-0.127	0.124	0.227
	(2.45)	(3.97)	(2.65)	(2.27)	(1.55)	(2.31)	(4.17)
LANG	1.470	1.480	1.447	1.492	1.474	1.359	1.350
	(21.36)	(21.65)	(20.81)	(21.59)	(21.46)	(19.66)	(19.71)
ACCT	0.716	0.761	0.735	0.698	0.723	0.664	0.700
	(7.57)	(8.06)	(7.72)	(7.37)	(7.65)	(7.09)	(7.54)
RELIG	0.186	0.157	0.189	0.168	0.169	0.178	0.136
	(3.08)	(2.62)	(3.13)	(2.77)	(2.81)	(2.99)	(2.30)
CMWTH	0.765	0.656	0.762	0.748	0.769	0.762	0.658
	(7.12)	(6.10)	(7.10)	(6.96)	(7.17)	(7.18)	(6.22)
FSU	1.336	1.518	1.336	1.338	1.332	1.706	1.949
	(6.77)	(7.67)	(6.75)	(6.79)	(6.77)	(8.57)	(9.78)
FZ	1.204	1.213	1.211	1.195	1.200	1.311	1.289
	(6.77)	(6.87)	(6.81)	(6.73)	(6.76)	(7.44)	(7.39)
AMERICA	-0.311	-0.418	-0.274	-0.394	-0.317	-0.527	-0.643
	(3.35)	(4.49)	(2.85)	(4.08)	(3.35)	(5.57)	(6.80)
CARIBBEAN	1.637	1.664	1.640	1.647	1.729	1.617	1.688
	(6.39)	(6.54)	(6.41)	(6.44)	(6.73)	(6.39)	(6.73)
EUROPE	-0.706	-0.550	-0.689	-0.712	-0.719	-0.539	-0.408
	(7.47)	(5.72)	(7.15)	(7.54)	(7.61)	(5.66)	(4.29)
NORTHERN EUROPE	0.970	0.893	0.979	0.972	1.032	1.332	1.346
	(2.58)	(2.39)	(2.61)	(2.59)	(2.75)	(3.56)	(3.64)
WESTERN EUROPE	0.608	-0.444	-0.602	-0.600	-0.714	-1.020	-0.955
	(2.10)	(1.54)	(2.08)	(2.07)	(2.46)	(3.53)	(3.33)
SOUTHEAST. EUROPE	1.643	1.590	1.639	1.584	1.650	1.586	1.547
	(6.00)	(5.84)	(5.99)	(5.78)	(6.04)	(5.84)	(5.75)

[1] *The t-statistics are in parentheses*

Table 2: Regression Models of International Telephone Flows (continued)

Variable	Model 1 Basic	Model 2 Spatial Structure Whole World	Model 3 Spatial Structure Continents	Model 4 Spatial Structure Subcontinents	Model 5 Spatial Structure Adjacent Countries	Model 6 Spatial Structure Language Commonality	Model 7 Combination of Models 2 and 6
AFRICA	0.494 (5.10)[1]	0.402 (4.10)	0.328 (2.73)	0.442 (4.48)	0.497 (5.14)	0.389 (4.04)	0.291 (3.01)
NORTHERN AFRICA	-1.543 (5.09)	-1.437 (4.77)	-1.532 (5.05)	-1.497 (4.93)	-1.531 (5.06)	-1.518 (5.06)	-1.487 (5.01)
EASTERN AFRICA	1.221 (2.57)	1.118 (2.37)	1.217 (2.57)	1.200 (2.53)	1.243 (2.63)	1.281 (2.73)	1.103 (2.37)
MIDDLE EAST	0.630 (3.74)	0.578 (3.46)	0.673 (3.96)	0.614 (3.65)	0.594 (3.52)	0.436 (2.60)	0.350 (2.10)
SOUTHERN ASIA	1.728 (3.20)	1.494 (2.78)	1.761 (3.25)	1.706 (3.16)	1.769 (3.27)	1.927 (3.60)	1.729 (3.26)
OCEANIA	2.015 (8.45)	1.594 (6.52)	1.863 (7.41)	1.978 (8.28)	2.341 (9.28)	2.006 (8.50)	1.487 (6.16)
SSV1A	—	-0.1381 (7.18)	—	—	—	—	-0.0831 (7.33)
SSV1B	—	-0.0506 (3.46)	—	—	—	—	-0.0605 (6.50)
SSV2A	—	—	0.0075 (0.29)	—	—	—	—
SSV2B	—	—	-0.0725 (2.76)	—	—	—	—
SSV3A	—	—	—	-0.0132 (2.82)	—	—	—
SSV3B	—	—	—	-0.0117 (1.70)	—	—	—
SSV4A	—	—	—	—	0.0061 (2.35)	—	—
SSV4B	—	—	—	—	0.0099 (4.35)	—	—
SSV5A	—	—	—	—	—	0.0240 (7.73)	0.0303 (8.70)
SSV5B	—	—	—	—	—	0.0149 (5.93)	0.0247 (8.03)
R^2	**0.863**	**0.865**	**0.864**	**0.864**	**0.864**	**0.866**	**0.869**
Optimal Distance Exponent λ	**N.A.**	**2.6**	**0.2**	**0.2**	**0.6**	**3.2**	**3.8**

[1] *The t-statistics are in parentheses*

While considering separately each of the five spatial structure variables (SSV1—SSV5), we have attached each one to both the origin country A (SSV1A—SSV5A) and the destination country B (SSV1B—SSV5B). The results reported in Table 2 involve variables computed while using the access lines variable MTL. Similar results were obtained while using the POP and GDP variables, and are not reported here. Model 2 includes the variables SSV1A and SSV1B, which involve all the countries in the world, except countries A and B, respectively. The coefficients of both variables are negative and highly significant, although they only add marginally to the explanatory power of the model ($R^2 = 0.863$). The results suggest that the intervening opportunity effect is stronger (-0.1381) than the destination effect (-0.0506), which is of a competitive nature, and that large clusters of countries close to A and B tend to reduce the telephone flow from A to B. The results obtained with Models 3 and 4, where the spatial structure variables involve same-continent (SSV2A, SSV2B) and same-subcontinent (SSV3A, SSV3B) countries, are much less persuasive than those of Model 2, involving insignificant (SSV2A, SSV3B) or less precisely-estimated coefficients. The results with Model 5, where the variables SSV4A and SSV4B involve only adjacent countries, are more difficult to interpret. The positive coefficient of SSV4A suggests a reverse IO effect, that is, the more countries around A, the larger the flow from A to B. In contrast, the positive, and highly significant, coefficients of the variables SSV5A and SSV5B, point to the complex and synergistic effect of language commonality, which was already uncovered in benchmark Model 1. These results suggest that having clusters of countries with similar language in proximity encourages the generation of telephone conversation. Finally, we have combined the better specifications - Model 2 and Model 6 - into Model 7. The coefficients of all four variables are precisely estimated, and with the same original signs. Overall, we can conclude that there are spatial structure effects in international telecommunications, of both competitive and agglomerative nature.

5. **CONCLUSIONS**

Spatial interaction models of international telephone flows have been estimated, using a much larger data set than in past studies, as well as explanatory variables hitherto unavailable. The results point to both the stimulation and substitution effects of new technologies (Internet, ISDN), to the importance of trade, political, and cultural group memberships, to the importance of language commonalities, to the complementarity between telephone, trade, and tourism flows, and, of course, to the role of geography, as measured by great-circle distances, time zone differences, island status, and several "Spatial Structure" variables. Further research is contemplated, that will involve new explanatory variables, alternative functional specifications, as well as a multi-period sample of inter-country telephone flows.

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APPENDIX

TRADE, CULTURAL, AND POLITICAL GROUP MEMBERSHIPS

ACCT:	Belgium, Benin, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Rep., Chad, Comoros, Congo, Cote d'Ivoire, Djibouti, Dominica, Egypt, Equatorial Guinea, France, French Polynesia, Gabon, Guadeloupe, Guiana, Guinea, Guinea-Bissau, Haiti, Lao P.D.R., Lebanon, Luxembourg, Madagascar, Mali, Martinique, Mauritania, Mauritius, Mayotte, Moldova, Morocco, New Caledonia, Niger, Reunion, Romania, Rwanda, Saint Lucia, Sao Tome and Principe, Senegal, Seychelles, Switzerland, Togo, Tunisia, Vanuatu, Vietnam
ADEC:	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Korea (Rep. of), Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States
ANDEAN:	Bolivia, Colombia, Ecuador, Panama, Peru, Venezuela
APEC:	Australia, Brunei, Canada, Chili, China, Hong Kong, Indonesia, Japan, Korea (Rep. of), Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, Philippines, Russia, Singapore, Taiwan, Thailand, United States, Vietnam
ASEAN:	Brunei, Indonesia, Lao P.D.R., Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam
CACM:	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama
CAEU:	Egypt, Iraq, Jordan, Kuwait, Libya, Mauritania, Somalia, Sudan, Syria, United Arab Emirates, Yemen
CBSS:	Denmark, Estonia, Finland, Germany, Iceland, Latvia, Lithuania, Norway, Poland, Russia, Sweden
CHWTH:	Antigua and Barbuda, Australia, Bahamas, Bangladesh, Barbados, Belize, Botswana, Brunei, Cameroon, Canada, Cyprus, Dominica, Fiji, Gambia, Ghana, Grenada, Guyana, India, Jamaica, Kenya, Kiribati, Lesotho, Malawi, Malaysia, Maldives, Malta, Mauritius, Mozambique, Namibia, New Zealand, Nigeria, Pakistan, Papua New Guinea, Saint Kitts and Nevis, Saint Lucia, Seychelles, Sierra Leone, Solomon Islands, South Africa, Sri Lanka, St. Vincent and the Grenadines, Swaziland, Tanzania, Tonga, Trinidad and Tobago, Uganda, United Kingdom, Vanuatu, Western Samoa, Zambia, Zimbabwe
ECWAS:	Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo

EFTA:	Iceland, Liechtenstein, Norway, Switzerland
EU:	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
FSU:	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
FZ:	Benin, Burkina Faso, Cameroon, Central African Rep., Chad, Comoros, Congo, Cote d'Ivoire, Equatorial Guinea, France, French Polynesia, Gabon, Guadeloupe, Guinea-Bissau, Mali, Martinique, Mayotte, New Caledonia, Niger, Reunion, Senegal, Togo
LAIA:	Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Ecuador, Mexico, Paraguay, Peru, Uruguay, Venezuela
MERCOSUR:	Argentina, Brazil, Chile, Paraguay, Uruguay
NAFTA:	Canada, Mexico, United States
OPEC:	Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela

Table A.1: Originating and Terminating Links and Flows

Country	Number of Originating Links	Total Originating Flow (minutes)	Number of Terminating Links	Total Terminating Flow (minutes)
AFRICA/CENTRAL AFRICA				
Burundi	69	2427126	14	915286
Central African Republic	70	2312291	16	815589
Chad	75	1623937	14	493621
Rwanda	0	0	12	1004842
Zaire	0	0	15	6168610
AFRICA/EASTERN AFRICA				
Djibouti	40	4022876	22	1564015
Ethiopia	0	0	19	20034937
Kenya	74	22481282	16	25266706
Seychelles	15	1314672	16	754256
Somalia	0	0	10	363460
Tanzania	0	0	10	5431113
Uganda	68	4212132	10	3883633
AFRICA/NORTHERN AFRICA				
Algeria	49	80262165	30	89308439
Egypt	174	98614734	35	327563941
Libya	0	0	28	16554854
Mauritania	0	0	24	1710644
Morocco	29	119518011	31	212834531
Sudan	36	8899272	20	21471201
Tunisia	24	32023652	31	101679214
AFRICA/SOUTHERN AFRICA				
Angola	0	0	18	7827793
Botswana	74	29399438	14	16861820
Comoros	0	0	14	96953
Lesotho	0	0	10	9632656
Madagascar	0	0	16	675267
Malawi	11	103160	11	4574669
Mauritius	29	17980000	13	1310302
Mayotte	0	0	1	1
Mozambique	0	0	14	18379430
Namibia	1	45799510	13	37868907
Reunion	0	0	11	2518578
South Africa	20	249370000	27	230054193
Swaziland	0	0	13	14030458
Zambia	23	3357849	14	7686007
Zimbabwe	68	21543735	16	3390362
AFRICA/WESTERN AFRICA				
Benin	69	5906247	15	2846035
Burkina Faso	0	0	15	1840863
Cameroon	36	6866967	16	9887226
Cape Verde	0	0	14	6177380
Congo	0	0	16	1103789
Cote D'Ivoire	0	0	18	16351817
Equatorial Guinea	0	0	8	224887
Gabon	0	0	18	3261483
Gambia	0	0	14	8415128
Ghana	0	0	15	25033237
Guinea	35	3491188	13	2698657
Guinea-Bissau	0	0	15	2610931
Liberia	0	0	15	4466398
Mali	68	6917628	15	3296902
Niger	0	0	16	1161688
Nigeria	0	0	16	57804277
Sao Tome & Principe	62	505915	14	18782064
Senegal	0	0	21	23682835
Sierra Leone	0	0	13	5709703
Togo	70	8289483	15	5556235

Table A.1: Originating and Terminating Links and Flows (continued)

Country	Number of Originating Links	Total Originating Flow (minutes)	Number of Terminating Links	Total Terminating Flow (minutes)
AMERICA/CARIBBEAN				
Antigua and Barbuda	0	0	12	10974146
Aruba	0	0	11	12202404
Bahamas	0	0	11	57623979
Barbados	0	0	12	32284362
Cuba	0	0	15	111693188
Dominica	0	0	11	7022809
Dominican Republic	0	0	16	437507437
Grenada	0	0	12	12525470
Guadeloupe	0	0	13	6306739
Haiti	45	10667924	11	73431687
Jamaica	0	0	14	216959805
Martinique	0	0	12	362189
Netherlands Antilles	0	0	14	80105127
Puerto Rico	0	0	12	4014764
Saint Kitts and Nevis	0	0	11	7194679
Saint Lucia	0	0	12	9922757
St. Vincent & Grenadines	0	0	12	10248807
Trinidad and Tobago	47	54273904	12	87528612
Virgin Islands (U.S.)	0	0	12	13912441
AMERICA/CENTRAL SOUTH AMERICA				
Bolivia	0	0	14	38760456
Paraguay	0	0	13	27286367
AMERICA/EASTERN SOUTH AMERICA				
Brazil	62	288375868	20	385333867
AMERICA/MIDDLE AMERICA				
Belize	45	5349857	10	14417308
Costa Rica	0	0	15	70264480
El Salvador	0	0	13	140806713
Guatemala	0	0	13	123377420
Honduras	38	33225616	11	80229802
Mexico	20	927700000	18	1975663397
Nicaragua	0	0	12	43974520
Panama	0	0	13	76117412
AMERICA/NORTH AMERICA				
Bermuda	0	0	12	32404187
United States	194	15602904646	98	6209362630
AMERICA/NORTHERN NORTH AMERICA				
Canada	20	2638100000	82	3597770659
Greenland	0	0	7	5239140
AMERICA/NORTHERN SOUTH AMERICA				
Columbia	15	115900000	16	311066447
Guiana	0	0	11	1314864
Guyana	0	0	13	74365390
Suriname	48	5291560	11	18450232
Venezuela	52	124308289	18	164610292
AMERICA/SOUTHERN SOUTH AMERICA				
Argentina	51	153669520	20	277892541
Chile	21	113755665	16	167740385
Uruguay	52	49439414	13	63560931
AMERICA/WESTERN SOUTH AMERICA				
Equador	63	36620404	15	149549213
Peru	0	0	17	150059218
ASIA/CENTRAL ASIA				
Kazakhstan	0	0	7	23157504
Kyrgyzstan	0	0	6	2643732
Tajikistan	37	20211417	4	551045
Turkmenistan	0	0	6	2024185
Uzbekistan	0	0	7	7845013

Table A.1: Originating and Terminating Links and Flows (continued)

Country	Number of Originating Links	Total Originating Flow (minutes)	Number of Terminating Links	Total Terminating Flow (minutes)
ASIA/EASTERN ASIA				
China	48	1237363573	29	1508181313
DPR Korea	0	0	11	2456932
Hong Kong	20	1614892100	54	1517362286
Japan	0	0	82	1222187904
Korea (Rep. Of)	15	475000000	42	444532008
Macau	47	107322657	14	82785203
Taiwan, China	50	570393671	26	581603157
ASIA/MIDDLE EAST				
Bahrain	38	86115000	17	50988016
Cyprus	37	108340673	25	40591906
Iran (Islamic Rep. Of)	55	168784483	19	94699401
Iraq	0	0	10	16228383
Israel	22	217200000	20	288294843
Jordan	18	42798659	20	106644815
Kuwait	33	117906598	18	111858643
Lebanon	0	0	30	83006436
Oman	0	0	16	39581848
Qatar	43	73734418	16	36337523
Saudi Arabia	43	484979904	38	308215520
Syria	24	61343008	18	87016767
United Arab Emirates	46	483323038	21	170606712
Yemen	41	21345565	14	43216976
ASIA/NORTHERN ASIA				
Mongolia	32	1640164	8	1635776
Russia	20	176100000	32	386300379
ASIA/SOUTHEASTERN ASIA				
Brunei Darussalam	35	16231393	13	11646955
Cambodia	0	0	12	5413878
Indonesia	20	192100000	22	220725759
Lao P.D.R.	0	0	11	1336875
Malaysia	20	343700000	20	359899748
Myanmar	0	0	11	7328894
Papua New Guinea	0	0	12	1687690
Philippines	12	161000000	30	508086996
Singapore	16	693000000	25	495009791
Thailand	34	202784701	23	223079827
Viet Nam	0	0	17	113753265
ASIA/SOUTHERN ASIA				
Afghanistan	0	0	2	796
Bangladesh	0	0	18	54818806
Bhutan	0	0	11	75485
India	20	282600000	48	678898720
Maldives	42	2430701	11	197280
Nepal	0	0	14	4287336
Pakistan	0	0	24	306842991
Sri Lanka	0	0	20	30770381
ASIA/SOUTHWESTERN ASIA				
Armenia	0	0	6	9428599
Azerbaijan	0	0	6	6566190
Georgia	0	0	6	2574759
Turkey	46	353720567	35	607572001
EUROPE/CENTRAL EUROPE				
Austria	0	0	41	810220498
Czech Republic	20	163900000	7	104400000
Germany	97	5114019310	97	3996375842
Hungary	36	223249640	27	156404016
Liechtenstein	0	0	1	408465
Poland	19	345230000	32	568561216
Slovak Republic	0	0	2	6700000
Switzerland	21	1575300000	73	1265660447

Table A.1: Originating and Terminating Links and Flows (continued)

Country	Number of Originating Links	Total Originating Flow (minutes)	Number of Terminating Links	Total Terminating Flow (minutes)
EUROPE/EASTERN EUROPE				
Belarus	31	12368850	9	30191575
Estonia	46	52155185	8	27966492
Latvia	36	41726667	7	16998322
Lithuania	47	45987904	7	16484199
Moldova	46	66648573	7	11357447
Ukraine	0	0	17	120011558
EUROPE/NORTHERN EUROPE				
Denmark	20	478300000	56	496043976
Faroe Islands	0	0	2	9000234
Finland	20	290600000	27	253254973
Iceland	0	0	22	16274236
Norway	20	373000000	31	352331527
Sweden	20	780400000	63	716572633
EUROPE/SOUTHEASTERN EUROPE				
Albania	39	22503823	19	1538279
Bosnia and Herzogovina	0	0	2	50300000
Bulgaria	0	0	24	59233778
Croatia	42	202943290	18	219498517
Romania	33	77418800	21	156231710
Slovenia	38	98481756	14	66865951
T.F.Y.R. Macedonia	0	0	4	27500000
Yugoslavia	36	205417766	24	208114271
EUROPE/SOUTHERN EUROPE				
Greece	46	437714936	54	460686203
Italy	47	1770724969	80	1931190552
Malta	29	24329484	19	10816705
EUROPE/SOUTHWESTERN EUROPE				
Andorra	0	0	*2*	447264
Gibraltar	0	0	*4*	770201
Portugal	57	289477352	*53*	495008306
Spain	44	993011276	*68*	1044596707
EUROPE/WESTERN EUROPE				
Belgium	20	1025100000	62	1101559351
France	21	2263700000	93	2795744010
Ireland	13	388000000	28	537873150
Luxembourg	20	223100000	25	126523020
Netherlands	25	1320559000	74	1363589230
United Kingdom	20	3211500000	95	3877539225
OCEANIA				
American Samoa	0	0	10	6117951
Australia	10	673000000	65	758794603
Fiji	43	14532249	12	10005383
French Polynesia	0	0	10	10255514
Guam	0	0	12	28792576
Kiribati	0	0	9	238055
Marshall Islands	0	0	1	1289573
Micronesia (Fed. States)	38	1358146	5	2176976
New Caledonia	41	8194303	10	1020156
New Zealand	20	236000000	19	205765402
Solomon Islands	0	0	11	361121
Tonga	0	0	11	3866683
Vanuatu	0	0	11	584963
Western Samoa	0	0	9	6793020

Table A.2. Frequency Distributions of Dummy Variables

DUMMY VARIABLE	# Cases = 1 (out of 4137)	Percentage
A. Geographic Separation		
Contiguity (CONT)	279	6.74
No Island (ISLA)	2741	66.26
B. Language/Religion		
Main Language (LANG)	814	19.68
Agency for the French Speaking Community (ACCT)	388	9.38
Religion (RELIG)	906	21.90
C. Trade/Cultural Groups		
Advanced Economies (IMF Definition –ADEC)	410	9.91
Asia-Pacific Economic Cooperation (APEC)	195	4.71
Economic Community of West African States (ECWAS)	59	1.43
Latin American Integration Association (LAIA)	78	1.89
Franc Zone (FZ)	92	2.22
Former Soviet Union (FSU)	58	1.40
Commonwealth of Nations (CMWTH)	241	5.83
Southern Cone Common Market MERCOSUR (MERCOS)	16	0.39
European Free Trade Association (EFTA)	2	0.05
Andean Community of Nations (ANDEAN)	14	0.34
Association of Southeast Asian Nations (ASEAN)	30	0.73
Central America Common Market (CACM)	5	0.12
North American Free Trade Association (NAFTA)	6	0.15
Organization of Petroleum Exporting Countries (OPEC)	38	0.92
European Union (EU)	172	4.16
Council of Arab Economic Unity (CAEU)	64	1.55
Council of Baltic Sea States (CBSS)	75	1.81
D. Continents		
America	493	11.92
Europe	677	16.36
Africa	693	16.75
Asia	459	11.09
Oceania	39	0.94

Table A.2. Frequency Distributions of Dummy Variables (Continued)

DUMMY VARIABLE	# Cases = 1 out of 4137	Percentage
E. Subcontinents		
Caribbean	35	0.85
Central South America	0	0
Eastern South America	0	0
Middle America	16	0.39
North America	1	0.02
Northern North America	0	0
Northern South America	9	0.22
Southern South America	6	0.15
Western South America	1	0.02
Northern Europe	15	0.36
Central Europe	23	0.56
Eastern Europe	19	0.46
Southeastern Europe	30	0.73
Southern Europe	6	0.15
Southwestern Europe	3	0.07
Western Europe	27	0.65
Northern Africa	24	0.58
Central Africa	12	0.29
Eastern Africa	9	0.22
Western Africa	99	2.39
Southern Africa	36	0.87
Central Asia	4	0.10
Eastern Asia	27	0.65
Middle East	93	2.25
Northern Asia	1	0.02
Southeastern Asia	33	0.80
Southern Asia	7	0.17
Southwestern Asia	2	0.05