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Empirical Evidence of Network Externality of Thailand's Telephone System

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1. Introduction

Telecommunications infrastructure is a crucial element for economic development, especially for developing countries. However, telephone service in developing countries is typically characterized by a supply that does not meet demand. This means that the telephone service may not be available in some areas, or that there may be delays in getting a telephone. In terms of telephone usage, it means that telephone calls may not go through during peak hours because of congestion. As the Maitland Commission (1984) noted, telecommunication is a missing link in much of the developing world.[1]

During 1980's, the problem of telephone shortage in developing countries had been modestly reduced because of changes in telecommunications technology and policy. Hudson (1995) found that the average growth of the telephone line capacity per 100 population in developing countries between 1980-1990 was many times higher than the average growth of their per capita GNP. However, the average level of telephone line capacity per 100 population for the low-income and the lower middle-income economies was relatively low, i.e., 0.5 lines per 100 population and 5 lines per 100 population respectively. Thus, there is still a significant gap in the access to telecommunications between the industrialized and the developing countries.

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1 A commission created by the International Telecommunications Union (ITU) in 1984.

In the case of Thailand, the provision of domestic telephone service was undertaken by a state-owned monopoly—the Telephone Organization of Thailand (henceforth, TOT). The enterprise failed to cope with the soaring demand for telephones during the 1980's. The requests for telephone service took many years to fill, and the service was available only in densely populated areas. The government took many measures through a number of National Economic and Social Development Plans (NESDP) to alleviate the telephone shortage problem. During the 5th plan (1982-1986), meeting the market demand for telephone was already a national policy goal. The level of investment budgeted for network facilities increased four fold. During the 6th plan (1987-1991), the export boom in the late 1980's and the early 1990's pushed the telephone demand up to an unprecedented level. It was apparent that the telephone supply became a bottleneck of economic growth. The National Economic and Social Development Board (1987) proposed that the role of the private sector in national development should be enhanced both in production and in provision of infrastructure of services hitherto provided by the government and that the state should encourage private sector participation in investing and operating public communications services. For example, joint investments, leasing and partial or total takeovers will be allowed. Therefore, during the 7th plan (1992-1996) the government allowed the private sector to participate in telecommunications development through a number of build-transfer-operate (BTO) projects.[2]

The change in Thailand's telecommunications policy from totally relying upon a state operator to embracing the use of private operators has a significant impact. The land-line telephone network has been expanded rapidly. In 1997, the national basic telephone line capacity reached 6.9 million lines or 11.4 lines per 100 population. About 52 percent is operated by the TOT while the rest is

[2] Under the BTO scheme, private operator is given a right to invest and construct a network facility. Upon the completion of the construction, the ownership of the facility is transferred to the government. The private operator manages the facility and recoups the investment costs plus profits through the revenue sharing with the government. The length of contract may last between 10 and 20 years, depending upon the size of initial investment.

operated by two private operators, Telecom Asia and Thai Telephone & Telecommunications (Plengmaneepun, 1997). Structurally, the telecommunications sector turned from having been a purely public-supplied system to a mixed system with public and private sectors coexisting under centralized network planning. In addition, the network expansion benefits from technological progress. The newly-constructed telephone exchanges are equipped with modern technology. The Bangkok metropolitan land-line network is wired by 160,000 kilometers of fiber optic (Hengkietisak, 1997). A variety of value-added telecommunications services is introduced into the markets. These services include cellular telephones, paging service, ISDN, leased lines, public card phones, and satellite communication services.

Unlike other services and commodities, telephone service is known to have externalities (Squire, 1973; Sharkey, 1982; Katz and Shapiro, 1985). The externalities are created every time a telephone is used because the recipient of the call obtains a benefit for which he or she does not pay, i.e., a *call externality*. Similarly, a new subscriber confers a benefit on the existing subscribers because they are able to call and to be called by the new subscriber, i.e., a *network externality*. Thus, the value of a telephone is larger with the presence of externalities than what it would be in their absence (Taylor, 1994).

The role of externalities in the analysis of network development and technological change is crucial. Antonelli (1992) pointed out that externalities not only apply to investment decisions in a theory of industrialization of underdeveloped countries but to all cases of technological change and industrial expansion in interdependent systems where the introduction and diffusion of innovations in one point of the system affects radically the profits and behavior of other points as well as the chances of introduction of other innovations. Brock (1994) stated two important aspects of network externalities. First, an individual piece of telephone equipment or a separate communication system is either of no value or limited value without interconnection to the public network. Second, the social value of subscribing to a telephone is greater than the private value. As a result, economic efficiency requires that the availability of telephone service be made available to the people for whom the social value is greater than the cost, even though the private value of the service may be less than the cost. Similarly, Baumol and Sidak (1994) argued that since the individual demand for use increases with the number of other users on the network, the increasing supply of access even to a competitor can conceivably stimulate demand for a local exchange carrier's final product.

Despite the significance of network externality in theory, its actual magnitude has not been determined (Taylor, 1994). There are a number of empirical studies that assessed the network effect in telephone service. Mostly, they are cases where the telephone markets are well developed, and their focus was on demand for access. Perl (1983), for instance, examined the value of residential telephone access in the United States using a logit model. The result suggested that in 1980 the value of telephone service will increase 8 percent if the network size is doubled from 25,000 to 50,000 subscribers, and the incremental value of the telephone will increase by 2 percent (down from 8 percent) if the network of subscribers increases to 100,000 subscribers.[3] In a separate study, Taylor and Kridel (1990) used the data of the same year (1980) that included only the states served by the Southwestern Bell, and employed probit model. The authors found that 10 percent increase in the number of subscribers will lead to 0.027 percent increase in the probability that a household would demand telephone access. In both cases, the impact of network externalities was apparently small and did not justify the administrative burdens associated with subsidizing access (Perl, 1983). Bodnar et al. (1988) examined the residential demand for access in Canada using a logit model. The results showed that the probability of telephone subscription increases with the size of the urban center. Moreover, the analysis of network

[3] The magnitude of network externalities should be interpreted with caution. It depends on a number of factors, primarily the level of telephone penetration rate and demand elasticity.

externality was extended to non-telephone markets. For example, Economides and Himmelberg (1995) examined the impact of network externalities in the U.S. facsimile market for the period between 1979-1992. The authors found that the rapid growth of the facsimile market during the late 1980's was influenced by network externalities. Cabral and Leite (1992) examined network externality in the Portuguese telex service for the period between 1962-1987. The result suggested that the optimal reduction for the price of access was between 2.5 and 16 percent below the marginal cost due to externalities.

In the case of Thailand, the recent large scale expansion of the modern network and the proliferation of value-added telecommunications services imply that network externality is an underlying factor that not only stimulates the growth of demand for telecommunications services but also accelerates the diffusion of modern telecommunications technologies. However, there has not been any serious economic research that documents or assesses network externality of the enlarged telephone network. This study contends that network externality is an important issue for long run economic and network development policies, and it needs to be carefully investigated. Generally speaking, a strong presence of network externality indicates that not only the benefits of telephone are understated by the standard analysis but also certain public policy measures should be undertaken if allocative efficiency is a goal. Thus, the empirical analysis of network externalities provides an indispensable basis for optimal network development planning and pricing.

2. Objective, Significance, and Methodology

The objective of this study is to measure and analyze network externality associated with the expansion of Thailand's telephone system, specifically the Bangkok metropolitan's basic and cellular telephone markets for the period between 1978-1995. The scope and depth of the study are limited due to regional income and telephone data paucities. However, the results of the study are not affected by the segmentation because the market demarcation between the

Bangkok metropolitan areas (BMA) and the rest of the country is clear. That is, the Bangkok economy is larger than the economies of the rest of the nation combined. Its share of network capacity has been about 60 percent of the national network capacity while the balance of capacity is apportioned among 76 provinces. Therefore, each market faces a different set of problems and requires a separate study.

The present study is unique in many respects. First, this study is the first attempt to assess network externality in Thailand's telephone system, and it offers a developing country case study to the telephone demand literature. While the empirical evidences of network externality in the telephone system with high telephone penetration rate appear minimal or insignificant, it is unclear *a priori* if the opposite will be true for the telephone system with low telephone penetration. Second, unlike the previous empirical studies that identified network externality with demand for access, the present study assesses the network externality based upon demand for use. The approach is influenced by Thailand's initial market conditions and network characteristics, and it is consistent with the current state of telephone demand theory. These points can be elaborated as follow.

It is commonly known that there is a theoretical distinction between demand for telephone usage, i.e.,

$$Q = Q(P_c, P_x, r, Y, N) \qquad (1)$$

where Q is the number of outgoing calls, P_c is the price of use, P_x is the price of a composite goods, r is the price of access, Y is the income, and N is the number of subscribers; and demand for telephone access, i.e.,

$$N/POP = \Phi(P_c, P_x, r, Y, N) \qquad (2)$$

where $\Phi(\cdot)$ is a composite function, N/POP is the proportion of population that subscribes to the telephone system (Taylor, 1980, 1994). The current state of telephone demand theory established a recursive relation between these two demand equations (Alleman, 1977; Mitchell, 1978). In principle, network externality, i.e., the external benefit of a network enlargement, can be expressed as "the benefit to existing subscribers *of making [phone] calls* to the new subscriber and the benefit to existing subscribers to *receiving [phone] calls* from the new subscriber" (Squire, 1973: 520). In other words, the assessment of network externality is based on demand for telephone usage, and the network effect is represented by the *consumer surplus* associated with demand for use. However, the previous empirical studies emphasized demand for access because the telephone demands in the United States and Canada are subject to a flat rate system. As Mitchell and Vogelsang (1991: 55) pointed out, "[t]he network externality can therefore be assumed to equal the sums of consumer surplus changes of other subscribers who call and who are called by the new customer. Both of these changes are reflected in the change in the (derive) demand for access by all other customers; that is, by the shift in the market demand function for access." In the case of Thailand, since the quantity demand for access is supply-limited, this quantity is a *predetermined* variable. Hence, the demand for use equation is *not* part of a simultaneous system and can be estimated independently by using appropriate estimation procedure (Pyndick and Rubinfeld, 1991).

Third, the assessment of network effects is based on the *conceptual* demand for use but not on the *observed* demand for use. The reason is that the demand for use is conditional on the number of subscribers. Therefore, the *observed* demand for use delineates a single point on the *conceptual* demand for use. It follows that the empirical analysis has to estimate the observed demand for use and uses the estimated parameters to derive the conceptual demand for use, which is the valid basis for the assessment of the network effect. Fourth, due to a substantial presence of demand for cellular telephone service in the 1990's, the study has to include the effect of this market. This represents a major adjustment of this study to accommodate the innovation in telecommunications technology that has blurred the traditional market boundaries. In a proper sense, the basic and cellular telephone services are two separate demands and should be treated individually, i.e., the same way as the business and residential telephone demand. However, since the cellular telephone service is available only in recent years, one practical way is to treat the demand for cellular telephone as if it were the demand for basic telephone. Other modes of telecommunications, such as internet usage, corporate leased-line service, ISDN, etc., that might contribute to the network externality are not included due to data limitations and their small shares of local telecommunications traffic.

The empirical analysis involves three sequential processes: the model development, the estimation, and the assessment of network effects. Following Taylor (1994), the study precedes the empirical analysis by developing a theoretical framework of demand for telephone service. Next, the study constructs an econometric demand for telephone usage model that meets the theoretical and statistical requirements and applies it to the local basic and cellular telephone traffic of the Bangkok metropolitan telephone market. Following Squire (1973), the estimated parameters of the observed demand for use are used to derive the slope of the conceptual demand curve, which is the valid basis for the assessment of the network effects. The network externality is analyzed in terms of the estimated consumer surplus.

3. Theoretical Framework

Following Taylor (1994), let the utility of the i^{th} individual be a function of telephone service Q, i.e., the number of outgoing calls, composite good X, and number of subscribers N:

$$U_i = U_i(Q_i, X_i, N) \qquad (1)$$

where $i = 1, \ldots, N$ and $\partial U_i/\partial N \geq 0$, which implies that a large network system is desirable.

Since the tariff structure for the local calling service in Thailand is two-part tariff: a fixed fee and a charge per call, let r be the price of access and P_c be the price of use. The price of composite good is denoted by P_x. Thus, the consumer budget constraint is given by

$$(r + P_c \cdot Q_i) + P_x \cdot X_i \quad = \quad M_i \tag{2}$$

where M_i represents individual income.

Following Rohlfs (1974), the rational decision making to own a telephone can be represented by the two-stage utility maximization process. In the first stage, suppose the potential subscriber already has a telephone. He maximizes his utility such that

$$\text{Max} \;\; U_i(Q_i, X_i, N) \tag{3}$$

$$\text{s.t.} \;\; (r + P_c \cdot Q_i) + P_x \cdot X_i \quad = \quad M_i. \tag{4}$$

The Lagrangian function is given by

$$L \quad = \quad U_i(Q_i, X_i, N) \; - \; \lambda \cdot (P_c \cdot Q_i + P_x \cdot X_i - M_i + r). \tag{5}$$

The first order conditions yield:

$$U_{iQ} \; - \; \lambda \cdot P_c \quad = \quad 0 \tag{6}$$

$$U_{ix} \; - \; \lambda \cdot P_x \quad = \quad 0 \tag{7}$$

$$P_c \cdot Q_i \; + \; P_x \cdot X_i \quad = \quad M_i \; - \; r \tag{8}$$

where $(M_i - r)$ represents net income.[4] Equation (8) implies that the consumer has to purchase an access to the network before he can use the telephone. It follows that if the consumer can make his own choice and the supplies of telephone service and other goods are available, the market state will be in equilibrium. The marginal rate of substitution between telephone service and composite good will equal the price ratio: $U_{iQ}/U_{ix} \; = \; P_c/P_x$. Thus, the individual demand for use can be written as

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[4] The present study treats the TOT's price of access as a taxation on income since the demand for access is a predetermined variable. However, James H. Alleman pointed out that it has an effect of confining the price of access.

$$Q_i = g_i[P_c, P_x, (M_i - r), N]. \qquad (9)$$

In the second stage, the potential subscriber evaluates the consumer surplus associated with the number of outgoing calls he plans to make and the number of incoming calls he expects to receive in the first stage. For the purpose of this study, the number of incoming calls is assumed to be exogenous and does not enter the utility function. Let the inverse demand function be

$$P_c = h_i[Q_i, P_x, (M_i - r), N]. \qquad (10)$$

Thus, the consumer surplus associated with the demand for use is given by

$$s_i = \int_0^{Q_i^*} h_i[z, P_x, (M_i - r), N]\, \partial z - P_c \cdot Q_i^*. \qquad (11)$$

He maximizes his utility such that

$$\text{Max } (s_i, r) \qquad (12)$$

if $s_i \geq r$, he will subscribe for a telephone service. If $s_i < r$, he will do the otherwise.[5] Equation (12) ensures that any equilibrium user set includes only those whose $s_i \geq r$. Thus, the aggregate demand for use can be written as

$$Q^N = \Sigma^N Q_i = G[P_c, P_x, (Y - r \cdot N), N] \qquad (13)$$

where $(Y - r \cdot N)$ represents the aggregate *net* income, which equals gross income subtracted by the price of access times the number of subscribers. Thus, the inverse aggregate demand for use is

$$P_c = H[Q^N, P_x, (Y - r \cdot N), N] \qquad (14)$$

[5] Had it been the case, his utility maximization process becomes one-stage: Max $U_i (X_i)$ subject to $\pi \cdot X_i = M_i$.

and the corresponding consumer surplus is given by

$$S^N = \Sigma^N s_i = {}_0\int^{Q^{N*}} H_N[z, P_x, (Y - r\cdot N), N] \, \partial z - P_c \cdot Q^{N*} \qquad (15)$$

Note that the individual and aggregate demand for use equations (9, 10, 13, and 14) are conditional demand. They depend not only on the price and net income variables but also on the number of subscribers *N*. As Squire (1973) pointed out, these *conceptual* demands may not be observed directly. In other words, the *observed* demand curve delineates a single point on each conceptual demand curve and appears more elastic than the conceptual demand curve. Following Willig (1979b), the change of consumer surplus from $Q^*(p, Y, N)$ to $Q^*(p, Y, N + \Delta N)$ that results from an increase in the number of subscribers from *N* to $N + \Delta N$, holding the price and income constant, represents the magnitude of network externality. By differentiating equation (15) with respect to *N*, the effect of network expansion is

$$\partial S^N / \partial N = \partial [{}_0\int^{Q^{N*}} H_N\{z, P_x, (Y - r\cdot N), N\} \, \partial z - P_c \cdot Q^{N*}] / \partial N. \qquad (16)$$

4. Data Selection

The required data were obtained from many official sources. Their quality and availability greatly influence the scope and depth of the study. The study augments the telephone traffic and network data with the income data. The variables that will be used in the estimation process are chosen based on a set of selection criteria. Some of them are constructed based on specific assumption to ensure that the variables are coherent and conform to the theoretical requirement. The data pertaining to these variables were obtained from the following sources:

1) Telephone traffic, telephone prices, and network characteristic, e.g., telephone capacity, waiting list, and the number of subscribers, from the TOT's Division of Statistics and Report.

2) Regional income for the period 1984-1994 from the National Account Division, the Office of National Economic and Social Development Board and for the period 1979-1983 from the Statistical Yearbook of Thailand.

3) Population from the Department of Local Administration, Ministry of Interior.

4) Consumer price index from Department of Business Economics, Ministry of Commerce.

There are three criteria for the data selection process. First, equation (12) requires the inclusion of those who actually own a telephone. The TOT classifies its customers into 5 broad categories: business, residential, public, government, and TOT. The residential category accounts for more than 66 percent of the total number of subscribers. The business category is about 28 percent. The last three categories together amount to about 6 percent. The study includes only the business and residential categories because they meet the theoretical requirement and represent the overwhelming majority of the population of the fixed-line subscribers. Second, although there is an economic distinction between the business and residential categories, the study lumped them up together. The reason is that since they face the same price structure, their valuation of telephone service, either in terms of business or social purpose, does not alter the results of the analysis. Third, the study employs the consumer price index for the Bangkok metropolitan areas ($CPI_{BMA,1988} = 100$) to deflate the nominal telephone price and income.

The dependent and independent variables that will be used in the estimation process, as well as their respective assumptions are described as follow.

1.) ***Number of calls*** Q^{BC} refers to the annual quantity of local telephone calls for the Bangkok metropolitan's telephone system. There are two quantities of telephone calls that are combined together, i.e., $Q^{BC} = Q^{B} + Q^{C}$. First, Q^{B} refers to the total number of completed, business and residential calls, reported at the end of the TOT's fiscal period, to any destination within the same service area. Since the Bangkok metropolitan market includes three surrounding towns, there are four local calling zones altogether. Second, Q^C refers the total number of cellular telephone calls within the same service area.[6] Since this quantity is not available, the study divides the air time revenues, excluding the international and long distance, calls by the nominal price of three-minutes call.

2.) ***Price of usage*** P_c^{BC} refers to the real, annual quantity-weighted price per call to any destination within the same service area. Since there are two prices, i.e., P_c^B and P_c^C, associated with two quantities, the quantity-weighted average price is the most appropriate representation that reflects the effective price of use to the subscribers. Basically, the price of use has a behavioral influence on the demand for use; the price is also set by government policy, not the market demand and supply in the usual sense; the price variation over the sample period is contributed not only by the general rise of prices, but also by a significant change in nominal price; and this price does not include the opportunity cost of time spent on using the telephone.

3.) ***Price of access*** refers to the real, annual cost of access to the telephone network. For the real price of access to basic telephone service r^B, it includes the monthly access charge A^B multiplied by twelve, the perpetual value of the initial connection charge $\rho \cdot I^B$, and the opportunity cost of using the deposit $\rho \cdot S^B$:

$$r^B_t = [12 \cdot A^B_t + \rho \cdot (I^B_t + S^B_t)]/CPI_t \quad (17)$$

where the discount rate ρ is 8 percent. Similarly, the real price of access to cellular phone service r^C includes the monthly access charge A^C multiplied by twelve, the perpetual value of initial connection charge $\rho \cdot I^C$, the opportunity cost of using the

[6] It is arguable that there is a simultaneity in demand for cellular telephone service, especially in the early 1990's when the supply of cellular telephone was unconstrained owing to multiple BTO contracts by the TOT and CAT. There are many ways to handle this issue including the use of instrumental variable. However, the present study opts to assume it away in order to avoid the theoretical and econometric complexities.

security deposit fund $\rho{\cdot}S^{C}$, and the perpetual payment for the cellular telephone equipment $\rho{\cdot}T^{C}$:

$$\dot{r}^{C}_{t} \quad = \quad [12{\cdot}A^{C}_{t} + \rho{\cdot}(I^{C}_{t} + S^{C}_{t} + T^{C}_{t})]/CPI_{t} \qquad (18)$$

Except the monthly access charge, the prices of access that include the initial connection charge, the deposit, and the cost of equipment for cellular phone subscribers is sizable. To the extent that the consumers are willing to undertake the acquisition of telephone service, the initial connection charge and the cost of equipment in case of cellular telephone may be viewed as a perpetual payment over the life time of the telephone. In addition, since the security deposit will be refunded when the consumers discontinue the service, the economic cost of this fund is represented by the accrued interest rate gain for each period. Since the real annual price of access, either r^{B} or r^{C}, has no direct influence on the users' immediate decision to make a phone call, it does not enter the demand function explicitly. Rather, their effect occurs through a subtraction from the real income. This reflects that one cannot use a telephone unless he or she purchases an access to the network and that the marginal effect of the price of access on the demand for use is zero.

4.) ***Net income*** refers the real, net annual subscriber's income. The real, net aggregate income $(Y - r^{BC}{\cdot}N^{BC})$ is represented by the real gross regional product (GRP) for the Bangkok metropolitan area from which the aggregate real prices of access are subtracted:

$$[Y - r^{B}{\cdot}N^{B} - r^{C}{\cdot}N^{C}]_{t} \quad = \quad (GRP/CPI)_{t} - r^{B}_{t}{\cdot}N^{B}_{t} - r^{C}_{t}{\cdot}N^{C}_{t}. \qquad (19)$$

5.) ***Number of subscribers*** N^{B} ***and*** N^{C} refer to the total number of business and residential as well as cellular telephone subscribers, corresponding to the quantities of calls described above.

6.) ***Cellular phone penetration*** D^{C} refers to the ratio of cellular phone subscriber to population: $D^{C}_{t} = (N^{C}/POP)_{t}$. This dummy variable serves as a proxy that represents the impact of cellular phone on the demand for use. It takes the value of zero for the periods that the cellular phone service is absence, or otherwise.

5. Model Specification

Since the theoretical framework suggests a set of potential explanatory variables but not a specific functional form, the study justifies the model specification and the estimation procedure based upon the initial market condition and network characteristic that influence the data generating process. First, it is clear that the explanatory variables, e.g., the prices of use, the prices of access, the income, and the number of subscribers, are predetermined variables. That is, (1) the telephone tariffs are influenced by government policy. (2) The income variable is generally determined by the level of economic activities. (3) Since the availability of telephones is supply-limited and the network expansion is subject to resource constraint, thus the observed number of subscribers is also predetermined. Second, data evidence suggests that the marginal effect of the independent variables is unlikely to be constant. The scatter diagram shows that the relationship between the dependent and the independent variables may be nonlinear. This means that the independent variables enter the demand function multiplicatively and that the marginal effect of independent variables depends on the level of development where the change occurs. Taken together, the study proposes the constant elasticity function as an appropriate representation for the demand function:

$$Q = \beta_0 \cdot P_c^{\beta 1} \cdot (Y - r \cdot N)^{\beta 2} \cdot N^{\beta 3}. \qquad (20)$$

While the constant elasticity function includes all explanatory variables as other specifications do, using this functional form has a number of advantages. First, it allows for the marginal effect. Second, it is linear in logarithmic form and can be estimated by the ordinary least squares (OLS) technique. It is apparent that not only is the revealed data generating process consistent with important assumptions of the classical linear regression,[7] but also the OLS estimator is known to be the best linear unbiased estimator (BLUE). Third, the coefficients of the independent variables are elasticities which can be easily interpreted. Finally, since the constant elastic function is homothetic, the use of consumer surplus to analyze the change of consumer surplus is invariant to the sequence of price change. However, there is a minor drawback of this functional form that should be noted. If the data cannot be transformed into logarithmic form, the constant elasticity function will not apply. It follows that the econometric demand model for the aggregate demand for use is specified as

$$\ln Q^{BC}_t = \ln \beta_0 + \beta_1 \cdot \ln P_c{}^{BC}_t + \beta_2 \cdot \ln [Y - r^B \cdot N^B - r^C \cdot N^C]_t + \beta_3 \cdot \ln N^{BC}_t + \beta_4 \cdot D^C_t + \varepsilon_t \qquad (21)$$

where $ln\ Q^{BC}_t$ is the natural log of the total quantity of the basic and cellular phone calls for the fiscal year t,

$ln\ P_c{}^{BC}_t$ is the natural log of the real, quantity-weighted average price per call for year t,

$ln\ [Y - r^B \cdot N^B - r^C \cdot N^C]_t$ is the natural log of the real, net annual aggregate income for year t,

$ln\ N^{BC}_t$ is the natural log of the net total number of the fixed-line and cellular phone subscribers for the fiscal year t,

D^C_t is the cellular subscriber penetration, and

ε_t is error term, which is assumed to be normally distributed and have a zero mean.

Following Box and Cox (1964), a statistical test for discriminating a linear versus a log-linear model is

$$L = n/2 \cdot | \ln RSS_1' / \ln RSS_2' | \quad \in \quad L \sim \chi^2(1) \qquad (22)$$

[7] The underlying assumptions include (i) the relationship between the dependent variable and independent variables has to be linear; (ii) the independent variables have to be nonstochastic; (iii.a) $E(\varepsilon_i) = 0$ and $E(\varepsilon_i^2) = \sigma^2$; (iii.b) $E(\varepsilon_i \varepsilon_j) = 0$ for $i \neq j$; and (iii.c) $\varepsilon \sim N(0, \sigma^2)$. The last assumption is especially necessary for small sample size to use the standard formulas for the t and F distribution to perform statistical tests.

where the RSS_1' is the residual sum of squares obtained when the dependent variable is subject to a transformation: $Q_i' = Q_i/c$ where $c = e^{(\Sigma \ln Q_i)/n}$ and the RSS_2' is the residual sum of squares obtained when the dependent variable is in logarithmic form $\ln Q_i'$. The idea is that the RSS_1' and RSS_2' are invariant with respect to the change in the unit of Q_i regardless of what regressors are included, the comparison of these residual sum of squares is a valid way to discriminate the two models (Doran, 1989). The test result is $L = |-3.248|$, which is less than $\chi^2(1)_{0.05} = 3.84$. The null hypothesis that these two models are equivalent at 5 percent level of significant cannot be rejected. Therefore, the use of the constant elasticity function with this particular sample is indifferent to the linear function on a statistical basis.

6. Estimations

The equation (21) was initially estimated by the ordinary least squares (OLS) technique. However, the null hypothesis that the error terms are uncorrelated was rejected at five percent level. The correlograms of residuals revealed that the autocorrelation process is the first-order, stationary autoregressive (Wei, 1990). Thus, equation (21) was rewritten and estimated by using the nonlinear least squares estimation (NLS) using Marquardt (1963) algorithm. The study also employed the conventional generalized least squares (GLS) using Cochrane-Orcutt (1949) iterative procedure and the full maximum likelihood procedure (FML) for the first-order autocorrelation (Beach and MacKinnon, 1978) for comparison. Table 1 summarizes the estimated elasticities for the aggregate demand for use using all procedures.

7. Assessment of Network Effects

The estimated parameters of the observed demand for use can be used to derive the parameters of the conceptual demand. Following Squire (1973), the relationship between the price elasticities of the observed demand and the conceptual demand is

Table 1

Summary of Estimated Parameters of Demand for Telephone Usage for Bangkok Metropolitan Market, 1978-1995

Estimation procedure	Coefficient	Standard Error	t-statistic
I. Price Elasticity			
NLS using Marquardt procedure	-0.198	0.111	-1.777
GLS using iterative Cochrane-Orcutt	-0.203	0.107	-1.909
Full Maximum Likelihood (FML)	-0.028	0.099	-0.284
II. Income Elasticity			
NLS using Marquardt procedure	0.663	0.190	3.485
GLS using iterative Cochrane-Orcutt	0.682	0.184	3.702
Full Maximum Likelihood (FML)	0.486	0.199	2.444
III. Subscriber Elasticity			
NLS using Marquardt procedure	0.441	0.126	3.489
GLS using iterative Cochrane-Orcutt	0.419	0.114	3.668
Full Maximum Likelihood (FML)	0.460	0.133	3.451
IV. Cellular Phone Penetration Elasticity*			
NLS using Marquardt procedure	0.040	0.015	2.242
GLS using iterative Cochrane-Orcutt	0.044	0.012	3.306
Full Maximum Likelihood (FML)	0.044	0.015	2.412

* The elasticity for a log-linear relation is computed as $\hat{\beta}_4 \cdot \bar{D}^C$ (Johnson el. al. 1987).

$$\partial Q/\partial p \,|_{\bar{N}} = \partial Q/\partial p - \partial N/\partial p \cdot \partial Q/\partial N. \qquad (29)$$

It follows that

$$\hat{\varphi} = \hat{\mu} - \hat{\eta} \cdot \hat{\vartheta} \qquad (30)$$

where $\hat{\varphi}$ is the derived price elasticity of the conceptual demand;

$\hat{\mu}$ is the estimated price elasticity of the observed demand;

$\hat{\eta}$ is the estimated elasticity of subscribers with respect to price; and

$\hat{\vartheta}$ is the estimated elasticity of calls with respect to subscribers.

Since the number of subscribers is unresponsive to the change in price, i.e., $\partial N/\partial P_c = 0$, equation (30) reduces to $\hat{\varphi} = \hat{\mu}$. Thus, the slope of the conceptual demand curve for each successive network size is computed by using the estimated price elasticity of the observed demand. The shape of the conceptual demand curves is assumed to be linear in order to avoid the willingness-to-pay becoming infinite. Therefore, the consumer surplus is represented by the triangle area above the price level (Brown and Sibley 1986).

Table 2 presents the estimated consumer surplus of the demand for basic and cellular telephone usage for the period between 1979-1995. By using equation (16), the external benefit due to network expansion is given by

$$\partial S / \partial N^{BC}\Big|_{N}^{N+\Delta N} = {}_0\int^{\hat{Q}_{N+\Delta N}} H[z, (Y - r^B \cdot N^B - r^C \cdot N^C), N^{BC} + \Delta N^{BC}]\, \partial z - P_c \cdot \hat{Q}^{BC}_{N+\Delta N}$$

$$- {}_0\int^{Q_N} H[z, (Y - r^B \cdot N^B - r^C \cdot N^C), N^{BC}]\, \partial z - P_c \cdot Q^{BC}_{N} . \qquad (31)$$

where N^{BC} is the number of basic and cellular telephone subscribers and $\hat{Q}^{BC}_{N+\Delta N}$ is the induced number of telephone calls if the network size expands from N^{BC} to $N^{BC} + \Delta N^{BC}$. Equation (31) states that the estimated magnitude of network externality is the difference between the estimated consumer surpluses. For example, the estimated network externality due to the network expansion that elevated the subscriber penetration from the level of 3.3 subscribers per 100 population in 1980 to the level of 10.1 subscribers per 100 population in 1990 is about 6.04 billion real bahts. This calculation is based upon the estimated price elasticity of -0.203. The observations are as follow:

1. The estimated consumer surplus, hence the value of telephone, has a positive relation with network size. The larger the network size is, i.e., the higher the level of

Table 2

Estimated Consumer Surplus of Demand for Basic and Cellular Telephone Usage for Bangkok Metropolitan Market, 1979-1995

Year	Subscriber Penetration Rate*	Growth %	Estimated Consumer Surplus (In Million Bahts) Elasticity $\hat{\varphi}_{GLS} = -0.203$	Elasticity $\hat{\varphi}_{NLS} = -0.198$	Elasticity $\hat{\varphi}_{FML} = -0.028$
1979	3.13	-	3,832	3,929	27,784
1980	3.36	7.19	3,239	3,321	23,486
1981	3.45	2.65	3,094	3,172	22,428
1982	3.61	4.82	3,205	3,286	23,236
1983	4.12	14.04	3,307	3,391	23,978
1984	4.25	3.29	3,529	3,618	25,584
1985	4.94	16.04	3,515	3,604	25,484
1986	6.17	25.06	3,946	4,045	28,606
1987	6.79	9.92	6,357	6,518	46,091
1988	7.48	10.26	7,208	7,390	52,261
1989	8.58	14.66	8,046	8,249	58,334
1990	10.13	18.07	9,277	9,511	67,255
1991	12.17	20.14	10,691	10,961	77,512
1992	14.36	17.99	12,802	13,125	92,814
1993	18.55	29.19	15,858	16,259	114,974
1994	24.32	31.11	19,415	19,906	140,762
1995	32.05	31.75	24,908	25,537	180,584

* The number of basic and cellular phone subscribers per 100 BMA population.

subscriber penetration, the greater the value of telephone becomes. It is clear that the estimated consumer surplus increases with the network size. Therefore, the value of telephone service of a large network system is greater than that of a small one. This confirms the *a priori* belief that the demand for telephone service depends not only on price and income, but also on the number of subscribers.

2. The magnitude of network effect, stated in terms of the incremental change of the estimated consumer surplus, is substantial not only because the network system becomes large but also because a large network expands at a fast rate. Consider the upper half of Table 2. It shows that before 1990 the magnitude of network externalities tends to be relatively small due to low rate of network growth, which is less than 20 percent per year (third column). This reflects the fact that the network growth was subject to a resource constraint. The opposite is true for the lower half of the table. In the 1990's, the magnitude of network externalities is relatively large. It reflects a high rate of network growth, which is well above 20 percent per year. In particular, beginning from the period that private operators began to supply the basic and cellular telephone services, the estimated network externality per annum is in the range between 1.4 and 5.5 billion real bahts (see Table 3).

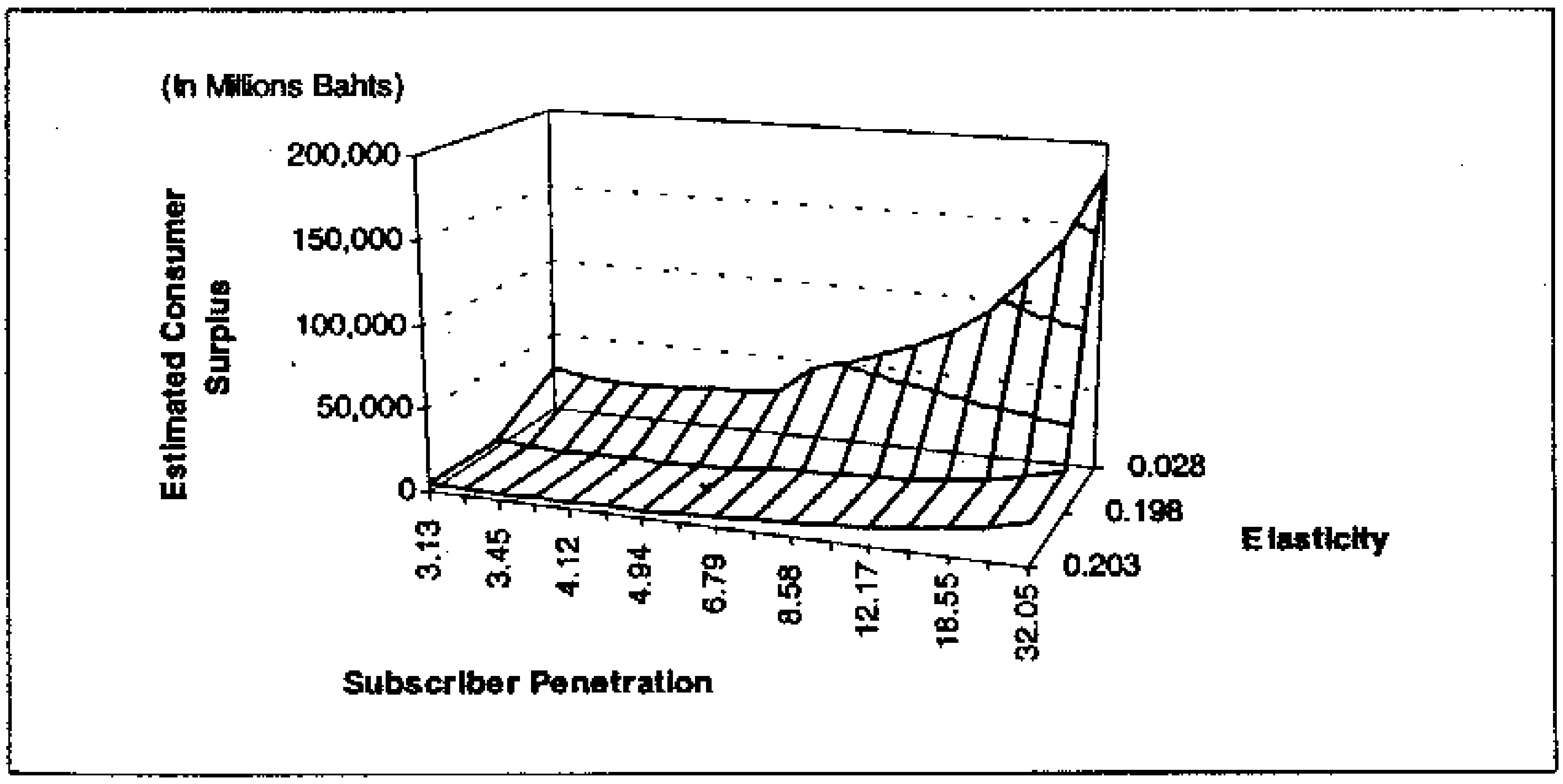

Figure 1 The Estimated Consumer Surplus Depends on Subscriber Penetration and Demand Elasticity

3. The estimated consumer surplus is particularly sensitive to the price elasticity of demand for use. The less elastic the demand for use is, the greater the estimated consumer surplus becomes. Figure 1 shows that as the demand for telephone usage becomes highly inelastic, e.g., from -0.20 to -0.028, the estimated consumer surplus increases dramatically. This should not be a surprise because Thailand's telephone service has been in deficit for more than a decade. Therefore, the willingness to pay for telephone access and usage tends to be high, given subscribers can afford to have a telephone. It also reflects the fact that telephone service becomes an essential part for a normal living and conducting business for people who live in the city. In the context of community of interest, the sheer size of network externality reflects an increasingly growing and overlapping interactions between different segments of economic activities.

Table 3

Relative Magnitude of Estimated Network Externality per Annum Versus TOT's Revenues In Million Bahts

Year	TOT's Real Local Access and Usage Revenues	Estimated Real Usage Revenues	Estimated Real Access Revenues	Estimated Change of Network Externality	N.E. / Est. Access Revenues %
	Estimated Using Full Maximum Likelihood				
1991	8,114	4,341	1,872	10,258	548.0
1992	8,995	5,198	2,360	15,302	648.4
1993	11,419	6,439	3,266	22,159	678.5
1994	12,981	7,883	4,201	25,788	613.9
1995	14,148	10,113	5,444	39,822	731.5
	Estimated Using GLS Conventional Method				
1991	8,114	4,341	1,872	1,415	75.6
1992	8,995	5,198	2,360	2,111	89.4
1993	11,419	6,439	3,266	3,056	93.6
1994	12,981	7,883	4,201	3,557	84.7
1995	14,148	10,113	5,444	5,493	100.9

* Estimated from TOT's actual local access and usage revenues.

** Calculated from observed number of calls times the real price of use.

*** Calculated from observed number of subscribers times the real price of access.

4. During the period of high rate of network growth, the relaive magnitude network externality is between 75 and 100 percent of the TOT's estimated local access revenues. Table 3 shows the breakdown of the TOT's real revenues. These estimates include the income transfers from private operators of both basic and cellular telephone services. The last column shows the ratio of the estimated network externality to the estimated total real access revenue. It reveals that the network effect is almost twice as much the demand for access. Therefore, network externality is a significant factor that has to be included in the telephone demand analysis, as well as in determining optimal network development and pricing policy.

8. Conclusions

The present study contends that part of the problem in the development of Thailand's telephone system is the lack of the identification of telephone benefits. As it was revealed, the estimated external benefit of network expansion is quite large. A strong presence of network externality is important for at least three reasons. First, it means that telephone users gain from having an *increasing opportunity* to use the telephone as the network is expanded and they actually increase their use of telephone by making telephone calls to and receiving telephone calls from *new* network destinations. As Larson et al. (1992) pointed out, it is the information but not the telephone calls per se that increases the utility of individual. Therefore, the enormous size of external benefit implies the volume and the spread of information which is a crucial input for economic transactions.

Second, since telephone users increase their use of telephone as the network is enlarged, the consumer surplus is increased. It follows that the willingness to pay for telephone access also increases. If the telephone supply is available and the telephone network is expanded, this has a feedback effect on the demand for use which in turn increases the demand for access further. Therefore, the demand for telephone is dynamically increasing with the presence of network externality. This partly explains the rapid growth of cellular telephone markets in the early 1990's.

Third, the presence of network externality implies that marginal social benefit of the last telephone line is greater than the private value of acquiring the telephone line. In principle, the price of access has to be set below the marginal cost in order to reflect the externality and hence the optimal telephone system should be enlarged. In the context of Thailand, it is unclear however for the price of access may already have been set below the marginal cost of supplying telephone service. In other words, the TOT's price of access is already optimal by accident. If it was the case, the price of telephone access may have to be raised. In any case, since a large part of Thailand's population still do not have access to telephone service either because of telephone availability or because of insufficient income, it is argurable that an enhanced network subscription by any means is justified on the ground of network externality.

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