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Economic determinants of global mobile telephony growth

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Abstract

This study examines the substitution effect between fixed-line and mobile telephony while controlling for the consumption externality associated with telephone networks. A dynamic demand model is estimated using a global telecommunications panel dataset comprised of 56 countries from 1995–2000. Estimation results show the presence of a substantial substitution effect. Additionally income and own-price elasticities are reported. Analysis of impulse responses for price, income and network size indicate substantial mobile telephone growth is yet to be realised. However, price ceilings imposed in the fixed-line network can retard the growth of the mobile network.

1. Introduction

Accurately measuring the interaction between fixed-line and mobile telephone subscription demand is a subject of recent interest. Ahn and Lee (1999), e.g., find that fixed-line penetration has a positive impact on mobile telephone subscription, while no conclusive price impact is evident. Gruber (2001), for Central and Eastern European countries, concur with Ahn and Lee (1999). Conversely, Gruber and Verboven (2001) find, for the European Union, a negative impact of fixed-line

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network size on mobile telephone subscription, viz., fixed-line and mobile service are substitutes. Further, Cadima and Barros (2000) estimate the diffusion of Portuguese fixed-line and mobile networks, and conclude that mobile telephone adoption slowed fixed-line growth, while fixed-line subscription growth had no impact on mobile subscription growth. Finally, Sung et al. (2001) estimate separate South Korean fixed-line connection and disconnection equations containing mobile price arguments. They indicate fixed-line and mobile service operators compete.

Whether fixed-line and mobile service are substitutes (or complements) has proved difficult to empirically determine as the occurrence of technology improvement and network effects are, more or less, concurrent. Introduction of digital technology led to convergence in the service quality of fixed-line and mobile telephony. Hence, for an increasing number of consumers, the only perceptible service attribute difference is mobility. The mobile subscription trigger is released only when a consumers' perceived value of mobility attribute is greater than the mobile subscription price. Another, and perhaps offsetting, effect is the consumption or network effect that arises from being able to call to an enhanced subscriber base. This network effect is likely to stimulate both fixed-line and mobile network growth, irrespective of the original cause of growth. Should the network effect dominate then the observed correlation is positive. Hence, obtaining an accurate measure of the impact of a change in relative subscription prices requires controlling for this network effect.

Understanding the underlying dynamics of fixed-line and mobile network interaction is important. By measuring the value of mobility to consumers more accurately, suppliers, such as wireless LAN operators, can better determine optimal prices so as to obtain maximal returns. Moreover, determining the extent to which fixed-line and mobile services are substitutes (or complements) inform competing carriers as to the impact of, say, a change in fixed-line subscription price has on mobile services demand. The direction and magnitude of this impact will determine whether or how mobile service providers compete with fixed-line operators. The purpose of this study is to analyse the relative importance of the economic drivers of market growth, viz., price, income and network externalities. The approach adopted here, rather than modelling the diffusion process per se, analyses optimising economic agent behaviour. This approach permits estimation of the impact of the substitution effect between fixed-line and mobile telephony, while controlling for the network effect from both networks. The paper is organized as follows. Section 2 develops the theoretical model of demand for mobile telephony subscription. Data and variables used in estimation are presented and described in Section 3. The empirical modelling strategy is explained in Section 4, and estimates are reported. Concluding remarks and policy implications are provided in Section 5.

2. Theoretical model

The approach adopted here follows Madden and Coble-Neal (2001) who model optimising economic agent behaviour directly. [1] Let the instantaneous utility of

[1] An impediment to using diffusion models is the reliance on long time-series for cogent estimation.

subscribing to the telephone network for an individual with income Y and a network of size N be given by $u(Y, N_F, N_M)$, where the number of fixed-line and mobile telephone network subscribers are denoted N_F and N_M, respectively. [2] Assuming network connection yields an infinite stream of future utility, given an expected future time path of network size $N^e(t) = f(N_F, N_M)$, the present value of the benefits from network subscription for a consumer with income Y is,

$$V(Y, t, N^e(t)) = \int_t^\infty e^{-\rho s} u(Y, N^e(s)) ds, \tag{1}$$

where ρ is the discount rate. Suppose subscription is offered at time t at fixed-line price ($P_F(t)$) and mobile price ($P_M(t)$). When subscribed at t, the corresponding present value of the access price is

$$q(t) = e^{-\rho t} \ (P_F(t) + P_M(t)). \tag{2}$$

Consumers choose to subscribe at t^* so as to maximize

$$V(Y, t, N^e(t)) - q(t). \tag{3}$$

Assuming (3) is concave over the relevant range, t^* is characterized by

$$u(Y, N^e(t^*)) = \rho P(t^*) - \frac{\partial P(t^*)}{\partial t} \equiv \lambda(t^*), \tag{4}$$

where $\lambda(t^*)$ is the opportunity cost of subscription. With utility specified Cobb–Douglas, (4) translates to

$$u(Y_t, N_t^e) = A Y_t^\kappa N_{F,t}^\omega N_{M,t}^\chi = \lambda_t, \tag{5}$$

and implies an equilibrium mobile telephony network size of

$$\ln N_{M,t}^e = \mu + \alpha \ln \lambda_t + \beta \ln Y_t + \delta \ln N_{F,t}, \tag{6}$$

where

$$\mu = -\omega^{-1} \ln A,$$

$$\alpha \ln \lambda_t = \omega^{-1} \ln \lambda_t,$$

$$\beta \ln Y_t = -\omega^{-1} \kappa \ln Y_t,$$

and

$$\delta \ln N_{F,t} = -\omega^{-1} \kappa \ln N_{F,t}.$$

Further, assume the mobile telephone carriers do not instantaneously adjust to satisfy their long-run demands. Then, growth in the size of the mobile network responds to deviations between the equilibrium network and the actual network size in the preceding period,

[2] Due to the compatibility of the fixed and mobile telephone networks, it is important to account for externalities flowing between both networks. We are thankful to an anonymous referee for pointing this out.

$$\ln N_{\mathrm{M},t} - \ln N_{\mathrm{M},t-1} = \gamma_{\mathrm{M}}(\ln N^{\mathrm{e}}_{\mathrm{M},t} - \ln N_{\mathrm{M},t-1}), \tag{7}$$

where the partial adjustment coefficient is $0 < \gamma_{\mathrm{M}} < 1$. Substitution of (6) and (7) yields the network equilibrium correction model for estimation:

$$\ln N_{\mathrm{M},t} - \ln N_{\mathrm{M},t-1} = \gamma_{\mathrm{M}}(\mu + \alpha \ln \lambda_t + \beta \ln Y_t + \delta \ln N_{\mathrm{F},t} - \ln N_{\mathrm{M},t-1}), \tag{8}$$

which after rearrangement becomes

$$\Delta \ln N_{\mathrm{M},t} = \alpha_0 + \alpha_1 \ln \lambda_t + \alpha_2 \ln Y_t + \alpha_3 \ln N_{\mathrm{F},t} + \alpha_4 \ln N_{\mathrm{M},t-1}, \tag{9}$$

where $\Delta \ln N_{\mathrm{M},t} = \ln N_{\mathrm{M},t} - \ln N_{\mathrm{M},t-1}$, $\alpha_0 = \gamma_{\mathrm{M}}\mu$, $\alpha_1 = \gamma_{\mathrm{M}}\alpha$, $\alpha_2 = \gamma_{\mathrm{M}}\beta$, $\alpha_3 = \gamma_{\mathrm{M}}\delta$ and $\alpha_4 = -\gamma_{\mathrm{M}}$. Finally, for estimation purposes, the monthly fixed-line subscription price ($P_{\mathrm{F}t}$) and the monthly cellular (mobile) subscription price ($P_{\mathrm{M}t}$) are proxies for λ_t, the opportunity cost of subscription. Hence (10) is written

$$\Delta \ln N_{\mathrm{M},t} = \alpha_0 + \alpha_{1\mathrm{F}} \ln P_{\mathrm{Ft}} + \alpha_{1\mathrm{M}} \ln P_{\mathrm{M},t} + \alpha_2 \ln Y_t + \alpha_3 \ln N_{\mathrm{F},t} + \alpha_4 \ln N_{\mathrm{M},t-1}. \tag{10}$$

3. Data and variables

Annual data are required to estimate (10) and are collected for 58 countries for 1995–2000 from the ITU (2002) *World Telecommunications Indicators Database*. [3] These data are comprised of GDP, mobile telephone subscription, monthly mobile telephone subscription charge and population. Countries represented include 10 Low, 11 Lower-Middle, 9 Upper-Middle and 28 High income nations from Africa, Asia, Europe, the Middle East and the Western Hemisphere. [4]

GDP is denominated in Special Drawing Rights (SDR) to offset the rapid appreciation in the USD during the mid- to late-1990s and deflated by the consumer price index (CPI) (1995 = 100). CPI is obtained from the World Bank (2002) *World Development Indicators Database*. Deflated GDP series are divided by population to provide per capita Income series. Cellular mobile telephone subscribers per 100 inhabitants (Mobile Subscriber) comprise analogue and digital users (CDMA, DAMPS, GSM, PCS and PHS systems). [5] Fixed-line telephone subscribers (Fixed Subscriber) are the number of telephone mainlines per 100 inhabitants. Fixed Price and Mobile Price are constructed using the fixed-line and cellular monthly subscription denominated in SDR and deflated by the CPI index. Missing data for OECD member countries is sourced from the OECD *Communication Outlook* (1997, 1999, 2001). The remaining missing observation for the US (1997) is obtained from

[3] Choice of data is determined by the time period that provides the largest number of countries.

[4] Countries are classified according to World Bank 1997 criteria. Low-income countries have GNP per capita of USD 785 or less, Lower-Middle income countries more than USD 786 and less than USD 3125, Upper-Middle income countries with GNP per capita of more than USD 3126 and less than USD 9655, and High income countries with GNP per capita more than USD 9656.

[5] Acronyms are defined as follows. GSM is Global Systems Mobile, CDMA is Code Division Multiple Access, DAMPS is Digital Advanced Mobile Phone System, PCS is Personal Communications Service, PHS is Personal Handyphone System. For precise descriptions of each technology, see Huurdeman (1997).

the Cellular Telecommunications and Internet Association's Semi Annual Mobile Telephone Survey(2000). Other data are detailed in Appendix A. Finally, the change in subscriber numbers (ΔMobile Subscriber) is obtained by taking the first-difference of the Mobile Subscriber series.

Tables 1–4 present descriptive statistics for Income, Fixed Price, Mobile Price, Fixed Subscriber and Mobile Subscriber by income group for 1995–2000. Average Income growth across the sample is 2.2% for the period (and range from −8.4% to 8.7%). Inspection reveals underlying trend growth, while annual variations decline with higher Income. Among Low income countries, growth ranges from −0.2% (Cambodia) to 7% (Viet Nam), with an average growth of 2.5% per annum. Costa Rica recorded the lowest Income growth (−8.4%) for Lower-Middle nations, while China (4.9%) has the highest growth. Average sample growth for Lower-Middle and Upper-Middle income countries is 0.4% and 2.2%, respectively. Growth in Upper-Middle countries, range from 0.4% (Czech Republic) to 3.4% (Poland). Among High income countries, Income growth range from 0.1% (Hong Kong) to 8.7% (Ireland) with a sample average of 2.7%.

Inspection of Fixed Price indicates that growth, on average, is 1%, and has range from −31.8% (the Republic of The Sudan) to 22.9% (Pakistan). Comparison of Fixed Price across countries reveal considerable variation in subscription price, with highest price country (the Republic of The Sudan) reporting a price magnitude 26 times the price of the lowest price country (Sri Lanka). Across income groups, Lower-Middle income countries have the least Fixed Price, representing a third of the corresponding average High income country price. Both Low and Lower-Middle countries exhibit price deflation of −3.7% and −2.0%, respectively. By contrast, Mobile Price exhibits substantial price deflation (average −9.6%), which is greatest in High income countries (−10.9%). In price levels, Lower-Middle income countries have the lowest price on average. These prices are 35% less than those of the most expensive income category (Low income). Moreover, on a per capita basis, cellular subscription represents a substantial proportion of the annual income in Low income countries (13.6%), which contrasts with only 0.1% for the High income category.

In general, Fixed Subscriber numbers exhibit steady growth, average 5.8% for the period, but considerable variation across countries (zero to 28.1%). Fixed Subscriber penetration levels reveal substantial variation, and range from 0.2 per 100 inhabitants (Cambodia) to 71.2 (Sweden). By income group, subscriber penetration and growth appear inversely related, so those countries with lower penetration are recording higher growth rates. Similarly, Mobile Subscriber numbers suggest some convergence across income group. In terms of penetration, subscription range from zero (the Republic of The Sudan) to 47.0 (Finland) per 100 inhabitants. Low income countries report an average growth of 187.4%, while Upper-Middle countries report 75.9% growth.

Figs. 1–4 illustrate the relationship between Mobile Subscriber against Income, Fixed Price, Mobile Price and Fixed Subscriber. Pair-wise correlations reveal the expected underlying economic relationships between Mobile Subscriber and the identified variables. Also evident is the high degree of country variation, particularly

Table 1
Low-income national statistics, 1995–2000

Country	Income		Fixed Price		Mobile Price		Fixed Subscriber		Mobile Subscriber	
	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR
Benin	282.6	3.0	3.1	−3.4	7.2	8.9	0.7	8.9	0.2	90.3
Burkina Faso	158.1	0.8	3.3	14.8	20.2	−17.2	0.4	8.2	0.0	425.3
Cambodia	164.5	−0.2	11.8	−17.8	14.9	6.3	0.2	20.1	0.5	39.1
Central African Rep.	233.2	1.4	5.0	5.1	20.0	−0.7	0.3	0.7	0.1	117.5
Kenya	210.0	3.1	2.5	−5.5	14.1	4.3	1.0	3.8	0.1	95.7
Nicaragua	290.7	1.2	4.5	−2.2	18.4	1.6	2.8	5.9	0.6	61.3
Pakistan	303.3	1.2	2.2	22.9	13.3	−13.9	2.0	4.5	0.1	39.6
Sudan	225.9	3.2	31.3	−31.8	180.2	−26.1	0.6	28.1	0.0	337.4
Togo	226.6	4.3	2.1	−2.5	14.1	−19.6	0.7	10.0	0.3	590.1
Viet Nam	234.9	7.0	3.3	−16.8	14.9	−12.1	2.1	20.3	0.3	77.3

Source: ITU (2002).

Note: CAGR is compound annual growth rate. n.a. indicate data are not available for the full period. Income is per capita USD GDP, Price is in constant 1995 SDR and Subscriber is per 100 inhabitants.

Table 2
Lower-middle income national statistics, 1995–2000

Country	Income		Fixed Price		Mobile Price		Fixed Subscriber		Mobile Subscriber	
	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR
Belize	1800.9	1.1	2.6	−1.0	13.3	−5.0	14.1	1.8	2.4	46.2
China	447.7	4.9	1.9	−3.6	3.7	−1.5	6.7	22.6	2.3	67.8
Colombia	1398.8	−1.9	1.9	−5.4	13.3	−24.2	14.6	7.5	3.3	37.7
Costa Rica	847.8	−8.4	2.6	−3.5	9.5	−5.2	18.5	7.6	2.5	44.4
Fiji	1713.9	−1.3	2.2	−10.8	19.1	−2.5	9.5	3.9	2.0	69.4
Indonesia	737.4	2.3	4.4	−11.1	11.4	−8.9	2.5	11.0	0.7	58.7
Morocco	892.0	1.0	4.5	2.0	14.3	−12.3	4.8	2.5	1.8	105.1
Philippines	747.6	1.7	8.1	8.9	4.0	23.5	3.1	11.8	3.1	50.7
Sri Lanka	486.8	2.6	1.2	8.4	4.5	−20.2	2.5	23.8	1.0	40.6
Thailand	1837.0	−1.4	2.4	−3.4	11.4	−3.4	7.9	7.9	3.5	14.9
Tunisia	1523.9	3.9	1.7	−2.6	16.4	−9.0	7.7	9.4	0.4	80.8

Source: ITU (2002).

Note: CAGR is compound annual growth rate. n.a. indicate data are not available for the full period. Income is per capita USD GDP, PRICE is in constant 1995 SDR and Subscriber is per 100 inhabitants.

Table 3
Upper-middle income national statistics, 1995–2000

Country	Income		Fixed Price		Mobile Price		Fixed Subscriber		Mobile Subscriber	
	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR
Czech Republic	3440.6	0.4	2.2	10.3	17.9	−14.9	32.3	8.0	13.0	111.4
Hungary	2819.4	2.8	4.3	7.6	11.2	−4.9	31.0	10.3	11.9	51.1
Malaysia	3123.8	2.4	4.9	−2.5	14.6	−2.5	19.0	3.1	11.1	27.4
Malta	6249.9	2.3	3.6	−2.0	30.3	−14.8	49.5	2.2	9.3	47.1
Mexico	1841.4	2.6	5.3	4.7	12.1	−8.9	10.4	4.9	4.9	63.9
Poland	2434.5	3.4	2.9	7.8	13.6	−5.1	21.4	11.4	5.9	111.6
Saudi Arabia	4839.6	2.5	5.4	0.2	21.8	−27.8	11.0	6.5	2.7	104.3
Slovak Republic	2451.3	2.3	1.7	9.2	34.4	−38.4	26.7	7.1	7.7	111.5
South Africa	2609.8	0.7	8.0	1.1	24.9	−1.9	11.3	1.9	7.5	55.3

Source: ITU (2002).

Note: CAGR is compound annual growth rate. n.a. indicate data are not available for the full period. Income is per capita USD GDP, Price is in constant 1995 SDR and Subscriber is per 100 inhabitants.

Table 4
High-income national statistics, 1995–2000

Country	Income		Fixed Price		Mobile Price		Fixed Subscriber		Mobile Subscriber	
	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR	Mean	CAGR
Australia	14,575.8	2.0	5.8	1.3	15.0	−18.8	50.9	1.1	27.2	23.8
Austria	20,535.0	1.6	11.0	2.6	15.6	−8.8	48.1	0.0	30.6	59.0
Belgium	19,281.0	1.9	14.0	1.4	27.1	−20.4	48.8	1.3	19.6	68.2
Canada	14,263.8	2.3	8.5	8.3	14.4	−10.9	63.4	1.9	17.2	21.6
Cyprus	9528.8	2.3	2.3	13.3	14.4	−5.6	59.3	3.4	17.3	29.5
Denmark	24,860.3	2.1	11.3	2.6	8.7	1.0	65.5	2.7	36.2	26.0
Finland	19,179.8	4.4	7.7	5.7	6.4	−2.0	55.1	0.2	47.0	23.7
France	19,129.0	1.5	8.7	9.2	16.4	−9.8	57.4	0.5	20.3	67.3
Germany	20,504.4	1.1	10.4	−3.4	24.8	−15.7	56.1	2.9	20.9	53.1
Hong Kong	15,070.0	0.1	6.0	4.4	15.1	−20.5	56.0	1.5	43.6	35.7
Iceland	19,623.1	3.5	5.3	11.6	5.8	−4.6	62.6	3.5	38.2	37.1
Ireland	16,193.1	8.7	12.9	0.1	23.5	1.4	41.3	2.4	27.1	57.1
Israel	10,535.0	1.9	5.1	5.1	9.9	−17.2	45.5	2.4	34.6	43.8
Japan	25,638.1	0.9	11.3	−0.2	33.2	−6.9	53.4	2.8	32.7	33.4
Korea (Rep. of)	7516.2	1.2	2.5	4.7	15.6	−11.3	43.7	2.0	27.1	58.0
Kuwait	10,790.9	2.8	5.4	−1.5	10.5	−12.2	23.4	1.3	13.6	23.6
Luxembourg	34,039.6	4.9	9.4	12.4	25.8	−23.5	66.8	4.6	30.1	47.9
Netherlands	18,736.4	3.1	12.1	3.8	17.1	−17.9	57.4	2.8	25.3	63.8
New Zealand	11,268.7	1.1	15.3	−0.4	18.6	−23.9	47.7	0.1	25.4	33.3
Norway	25,504.6	4.7	13.2	2.0	15.6	−1.9	64.7	4.5	45.5	22.3
Portugal	7995.4	3.9	8.4	1.2	19.0	−18.4	40.3	2.7	28.2	63.9
Qatar	11,496.1	6.1	5.6	−2.3	9.3	−5.2	25.0	3.1	10.3	34.9
Singapore	16,763.8	2.0	3.9	−0.7	18.9	−2.7	45.0	2.7	30.1	40.7
Spain	10,845.6	3.7	8.0	−1.0	20.8	−21.5	40.5	1.7	21.9	71.7
Sweden	20,883.3	3.5	11.2	1.5	11.8	−4.5	71.2	1.5	43.9	21.1
Switzerland	30,661.2	1.0	14.4	−0.5	32.5	−7.5	67.7	2.3	26.9	47.2
United Kingdom	13,555.1	2.0	8.7	1.0	20.3	−3.3	54.7	2.7	30.1	39.7
United States	20,016.4	2.5	12.7	−1.4	24.5	−12.0	65.2	2.4	24.5	20.7

Source: ITU (2002).

Note: CAGR is compound annual growth rate. n.a. indicate data are not available for the full period. Income is per capita USD GDP, Price is in constant 1995 SDR and Subscriber is per 100 inhabitants.

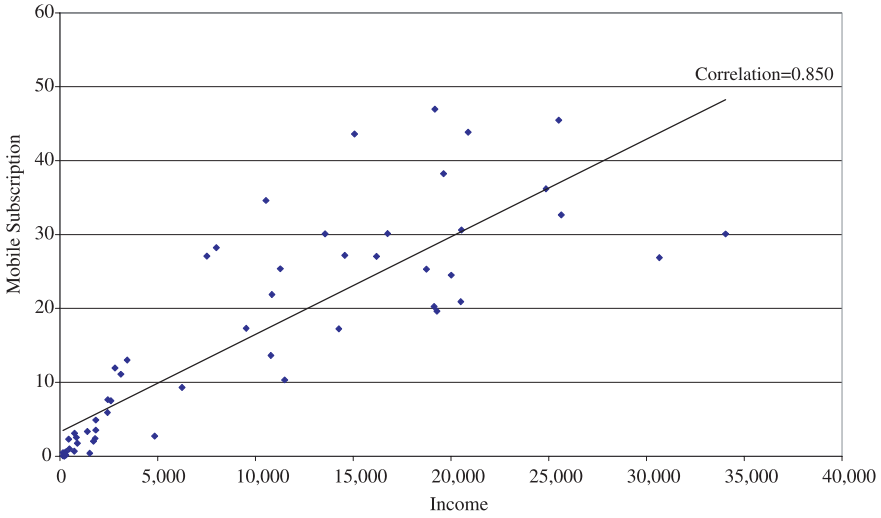

Fig. 1. Mobile Subscribers and Income, 1995–2000. *Note*: Observations are six year averages for each country.

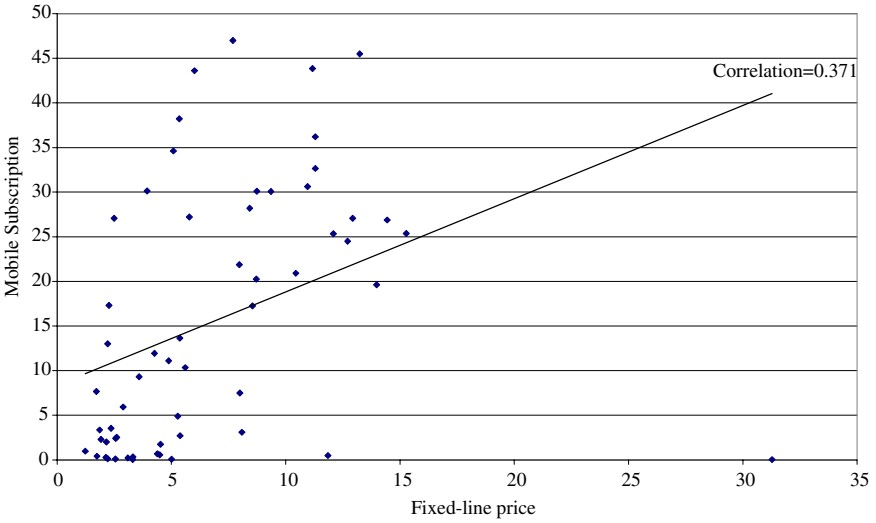

Fig. 2. Mobile Subscribers and Fixed-Line Price, 1995–2000. *Note*: Observations are six year averages for each country.

for Fixed Price and Mobile Price. Cursory examination of Fig. 1 suggests variation in Mobile Subscriber increases with Income, suggesting a potential source of heteroscedasticity.

An outlier for both Figs. 2 and 3 is from the Republic of The Sudan. Removing the Republic of The Sudan from the sample reduces the correlation slightly in Figs. 1

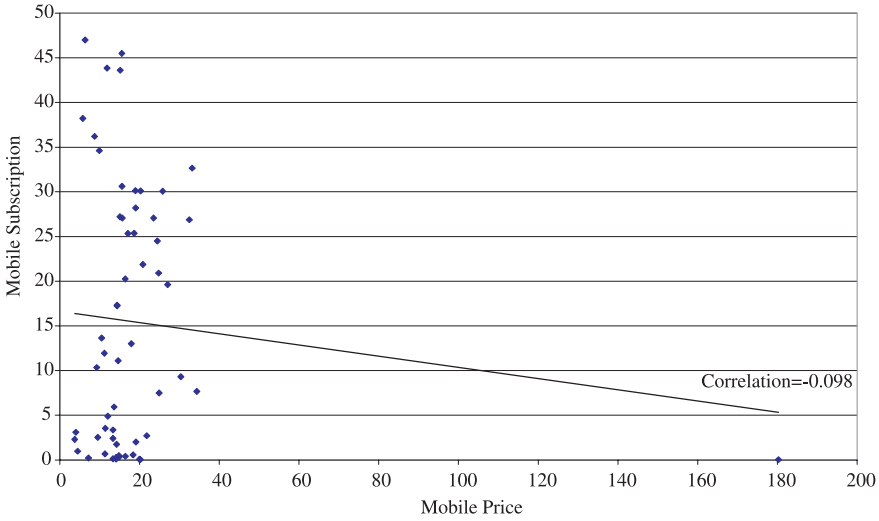

Fig. 3. Mobile Subscribers and Mobile Price, 1995–2000. *Note*: Observations are six year averages for each country.

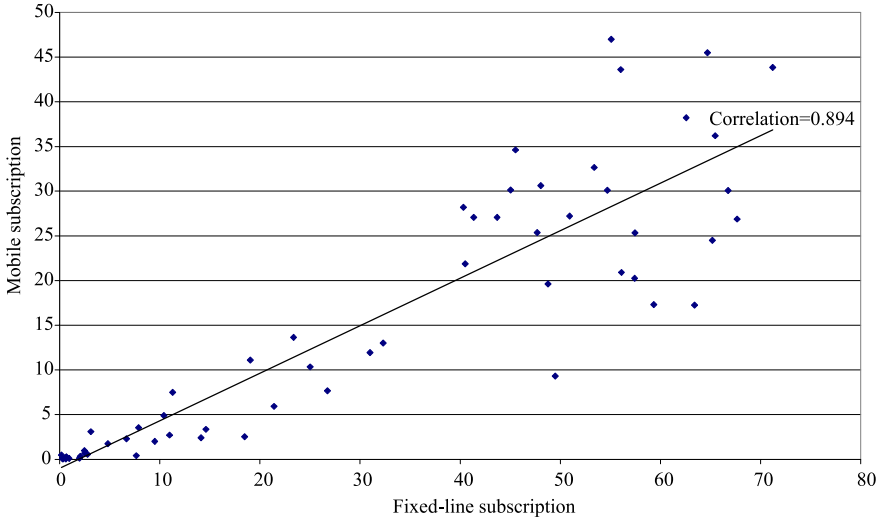

Fig. 4. Mobile and Fixed-line Subscribers, 1995–2000. *Note*: Observations are six year averages for each country.

and 4, 0.849 and 0.892, respectively. The correlation in Fig. 2 increases substantially to 0.605. For Fig. 3, the correlation increases to 0.120, indicating a change from negative to positive correlation. Calculated correlations by country income classifications yield: −0.052 for Low income, −0.167 for Lower-Middle, −0.121 for Upper-Middle and −0.217 for High income.

4. Model estimation

Two key issues relevant in the estimation of consistent and unbiased parameters for dynamic panel models are the unbiasedness of parameter estimates in the presence of lagged dependent variables, and parameter heterogeneity across country (Baltagi, 2001). The presence of lagged dependent variables is generally resolved through instrumental variable estimation (IV). Further, when country-specific parameters are homogenous the dynamic random effects estimator, suggested by Arellano and Bover (1995), provides consistent parameter estimates for (10). Accordingly, model estimation is conducted in two steps.

In step one, parameter homogeneity is checked by estimating (10) using IV. Since there are only five annual observations per country, groups of three countries are pooled and regressed. After adjusting for heteroscedasticity, a likelihood ratio test indicates whether pooling progressively larger groups of countries is valid. [6] In step two, the modified version of (10) is estimated using the Arellano and Bover dynamic random effects estimation (available in LIMDEP 8.0). This estimator utilises a larger set of instruments than the procedure employed in step one, and leads to substantial efficiency gains.

Final estimation results are reported in Table 5. Results of the likelihood ratio test support the pooling of countries contained in the sample, except the Republic of The Sudan and Togo. Consequently, the reported results include the remaining 56 countries utilising the period 1996–2000, with only the lagged value of Fixed Subscriber designated as uncorrelated with the error term. Resulting Z-statistics indicate all argument parameters are statistically significant. [7]

Table 5 reports coefficient estimates for Income, Fixed Price and Mobile Price are correctly signed and have plausible magnitudes. The estimated Income coefficient indicates that a small increase in current per capita income results in a 0.03% increase in the growth of mobile telephony subscription next year. The positive sign for Fixed Price suggests mobile and fixed-line telephone subscription are substitutes, with a higher Fixed Price yielding a 0.12% mobile subscription growth increase. By contrast, the own-price estimate suggests a small decline in Mobile Price has an immediate 0.05% increase in subscription growth. Similarly, the sign for Mobile Subscriber an increase in current year subscription growth yields a further 0.80% increase in growth, with a corresponding long-run increase of 5% in subscriber numbers. By contrast, the Fixed Subscriber coefficient estimate suggests a growth of 0.13% in the short run with a corresponding long-run value of 1.15%.

The results indicate that mobile network size has the greater long-run impact in enhancing network subscription, followed by mobile price reduction. Fixed-line price increases induce further subscription with income least important. Calculated im-

[6] See Greene (2002), for more information on panel likelihood ratio tests.

[7] During estimation, it was found that next period's fixed-line and mobile prices and income per capita had substantially more explanatory power than the current period. A possible explanation is systematic variation in final reporting by the ITU between variables. Thus, the price and income variables are perhaps properly interpreted as beginning period values.

Table 5
Coefficient estimates

Variable	Coefficient	*Z*-statistic
Constant	0.02	0.20
Income	0.03	1.93
Fixed Price	0.12	4.90
Mobile Price	−0.05	−2.73
Fixed Subscriber	0.13	6.10
Mobile Subscriber	0.80	56.81
Countries	56	
Likelihood ratio test (330 d.f.)	239.26	
Critical value (LR test)	373.36	

pulse response functions, used to consider the time-paths of disturbances to model arguments, show a percent increase in mobile subscription yields an additional 2.9% subscription increase within three years. When stimulus is initiated by a percent reduction in the mobile telephone price, the direct price effect together with the network effect yields a total 3.09% increase in subscription within the same time frame. Further, when the mobile price shock is accompanied by a percent increase in monthly fixed-line subscription, the cumulative effect is a 3.48% increase in subscription within three years. [8] Finally, the small Income elasticity suggests mobile subscription is largely unaffected by marginal income fluctuations. Thus, the greatest effect of government intervention is likely from direct influences, such as stimulating price competition. Moreover, the results suggest the imposition of local loop price controls may slow mobile network growth.

5. Conclusion

The impact of the fixed-line network on mobile telephone subscription is the subject of recent empirical debate. While early results suggest complementarity, subsequent research reports a substitution effect. However, in these studies the network effect had not been explicitly controlled for. Network effects induce simultaneous growth in both the fixed-line and mobile networks. To address the issue, this study develops an economic model for mobile telephone subscription demand that incorporates a network effect. Estimation reveals a significant substitution effect.

Additionally, model results indicate increases in mobile telephone market size provide the greater impact on subscription, followed by reductions in mobile subscription rates. The cumulative impact of a percent mobile subscription price

[8] Summation of the impulse response estimates provides approximate standard elasticity estimates. It is possible to generate scenarios for all sampled countries, e.g., when average growth rates (presented in Table 4) are indicative of future growth, say, the United States could experience a 65% cumulative increase in mobile telephone subscription within three years.

decrease and a percent fixed-line subscription rates increase yields a 3.48% subscription growth within three years. Further, the high mobile subscriber base elasticity suggests that welfare benefits from enhancing mobile subscription are substantial. Finally, since the mobile subscription elasticity with respect to mobile subscription price is inelastic, price competition results in higher industry revenues, raising prospects for enhanced employment. Therefore study results are suggestive the policy recommended by Hausman (2002), viz., policy designed to stimulate competitive pressure through the introduction of mobile communications service providers stimulates improved prospects for both consumers and the telecommunications industry.

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Appendix A

The primary data source is the International Telecommunication Union World Telecommunication Indicators, 2002 database. Missing data are sourced as follows.

A.1. Consumer price index

Central African Republic (2000) is sourced from the World Bank web site (http://www.worldbank.org/data/). Values for China (1996–2000) are from the International Monetary Fund (2000) *International Financial Statistics Yearbook* 2001, page 355. Nicaragua (2000) is available from the Internal Monetary Fund Statistical Appendix (http://www.imf.org/). Sudan (2000) is sourced from the Republic of The Sudan Ministry of Foreign Affairs (http://www.sudmer.com).

A.2. Cellular monthly subscription price

OECD mobile telecommunications data used is the annual fixed price component converted to monthly. These data correspond to Canada, (1996), Denmark and France (2000), Italy (1996, 1998, 2000), Netherlands (2000), Spain (1998, 2000), Sweden (1998, 2000), United States (1996, 1998 and 2000). Interpolated data points

are Belgium Canada, Italy and the United States (1997). The data for Colombia (2000) was located at http://www.asocel.org.co/. Initial (1995) PRICE data for Burkina Faso, the Sudan and Togo are missing because there were zero mobile subscribers. In order to calculate meaningful PRICE points to correspond to zero subscribers, the intercept price was calculated from a linear extrapolation from the line of best fit, in effect creating a virtual price. Interpolated data points are Cambodia (1998), Nicaragua (2000), Pakistan (1996, 1998), Viet Nam (1997, 1998), Tunisia (2000). Data for Hungary (2000) was located at http://www.westel900.net/dijcsomagok/alapszolgaltatas_e.html. PRICE is a simple average of market leader Westel's Eurofon I, Eurofon II, Eurofon III and MobilMester packages as at 29 February 2000. Missing data point for Israel (2000) is kindly provided in index form by the Central Bureau of Statistics. Annual index numbers converted to growth rates and the growth factor for 1999–2000 is multiplied by the 1999 ITU price to yield a currency based measure. An average monthly mobile subscription price for Nicaragua at 2000 was interpolated from the 2002 value. This 2002 value was sourced from the National Nicaraguan Telecommunications Regulatory website at http://www.telcor.gob.ni/. This average value for 2002 was $417.97 (local currency unit) and did not include the 'extra' plans. Poland (1997, 1998 and 1999) sourced from Teligen. Monthly rental is the arithmetic average of subscription rates for pricing plans: Halo, White, Simply, Blue, Navy-Blue and VIP.

A.3. Gross domestic product

Values corresponding to Cambodia, Central African Republic, Fiji, Japan and Kenya (2000) are sourced from the *World Development Indicators 2002* World Bank. Values for Sudan (1998, 1999, 2000) are from *World Development Indictors 2002*, World Bank.

A.4. Residential monthly telephone subscription price

Ireland, Netherlands, Sweden (2000), is sourced *Communications Outlook 2001*, OECD from Table 7.18, page 204. Canada and Sweden (1998) are sourced from *Communications Outlook 1999*, OECD, Table 7.22, page 190. Missing observations for China (1995, 1996) sourced directly from staff at ChinaNex.com. Columbia (2000) was sourced from Colciencias, Colombian Institute for the Development of Science and Technology. The year 2000 residential monthly fixed line subscription price was taken directly from the National Nicaraguan Telecommunications Regulatory website at http://www.telcor.gob.ni/. It is defined there as the basic residential subscription price and is quoted in local currency unit. Further, it states on this website that this tariff maintains its value in relation to the US dollar as of the 10th of June 2000.

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