FINAL REPORT

The Diffusion of Mobile Telephony in Latin America

Successes and Regulatory Challenges

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Executive summary

This report sets out an economic analysis of the diffusion of mobile telephony in Latin America. Mobile network operators have proved remarkably effective in extending the communications networks to large territories, including rural and remote areas. From 1991 to 2003 the number of cellular subscribers worldwide increased from 16 million to more than 1.3 billion. The penetration of mobile telephony in developing countries is higher than that achieved by fixed line networks. What is significant about those facts is that mobile phones have only been in existence for a comparatively short period of time relative to fixed line networks.

In Latin America the number of cellular subscribers leapt nearly 25-fold, from 4 million in 1995 to 100 million in 2002. Even if the penetration rates are still low (and sometimes very low), the diffusion of mobile telecommunications so far has been strikingly far-reaching. Further, the absolute number of mobile subscribers in Latin America is continuing to increase steeply. Current and forecasted growth of market penetrations of fixed lines and mobile telephony for Latin American countries reveals three important facts. First, fixed line penetration is generally not expected to significantly increase between now and 2008. Second, growth in mobile telephony has continued despite an economic slump in the region. Third, the growth in mobile subscription is driven by growth of prepaid subscribers.

One factor contributing to the speed of expansion of mobile telephony in Latin America compared to fixed line telephones has been the much lower average sunk costs involved in adding a subscriber to the network. Even if that subscriber ultimately proves unprofitable either because she is uncreditworthy or subscribes to very low usage, the loss to the mobile operator is low. As a result, mobile operators have been more willing to sign up customers who fixed line operators would not accept, and even more so under pre-paid plans. This has allowed mobile telephony to bring particular benefits to low-income users.

In developed countries, fixed line and mobile phones tend to be complements in the sense that a large proportion of the population subscribe concurrently to both fixed and mobile networks. In these countries the benefit from mobile telephony is essentially an *incremental gain* from a situation where telecommunications services were already otherwise largely accessible.

In contrast in developing countries, including throughout Latin America, state-owned fixed line operators have traditionally failed to develop adequate infrastructure, a problem that recent privatisation and deregulation has not always alleviated. The introduction of mobile telephony in developing countries has in many instances provided people, in particular low-income and rural groups, with their first opportunity to access telephony. Further, since mobile telecommunications networks represent a competitive alternative to fixed line operators, the latter are facing a competitive constraint that would otherwise be absent. The competitive pressure has the potential to reduce the regulatory burden involved in the control of fixed monopolists and in any event is likely to force those monopolists to increase their efficiency, yielding additional social gains.

Central to the diffusion of mobile telephony has been a general policy of relatively "light handed" regulation as compared to that which applies to fixed line services. Instead competition for customers has encouraged innovation, increased efficiency, and provided consumers with choice, reduced prices and increased quality of service.

Despite success in expanding mobile telephony, the relatively high charges imposed by mobile phone operators on fixed line networks to accept calls – 'mobile termination charges' – have led to recent calls for regulatory intervention. A central question therefore is whether lower mobile termination charges would generally benefit Latin American societies.

This report analyses the relationship between mobile telephone penetration rates and termination charges; penetration rates are then linked to a measure of social welfare. An increased termination rate has two effects on social welfare: a negative direct effect and a positive indirect effect. The direct effect will be to increase fixed-to-mobile call prices resulting in a lower number of fixed-to-mobile calls, which, other things being equal, is socially costly. A second, indirect effect results from the increase in termination profits obtained from every subscriber. If the market for mobile services is workably competitive, as is the case in many Latin American countries, mobile operators will choose – or be forced by competition – to pass termination revenues through to their existing consumers. These revenues may be passed on in a number of forms, including through subsidised handsets, low monthly rentals fees, lower call costs and low minimal monthly plans. Furthermore, higher termination costs will create incentives for mobile operators to compete aggressively to increase their customer base in order to save on termination payments to other mobile networks as well as to attract the largest possible revenue from termination fees.

When the market penetration of mobile telephony is low, it is likely that the benefits associated with the indirect effect of increasing termination fees (that is, the promotion of greater mobile penetration and usage) will substantially outweigh any costs associated with the direct effect (that is, the reduced welfare due to higher fixed to mobile call charges). To test for this hypothesis, we have developed a model of competition between mobile operators and calibrated this formal model to reflect country-specific conditions.

The primary objective of this model is to estimate both the consumer benefits associated with different levels of fixed-to-mobile termination charges and the diffusion of mobile telephony likely to correspond to these different charges.

The general conclusion from these simulated results is that decreasing fixed-to-mobile termination charge would have adverse consequences on the mobile penetration and ultimately on the welfare derived from mobile telephony networks. Furthermore, a relatively high termination charge benefits not only cellular subscribers but also fixed-line subscribers, who are being able to call new mobile subscribers. In other words, the first direct effect is outweighed by the second indirect effect. The simulated results show that, in the neighbourhood of current levels, higher retail fixed-to-mobile prices are more than compensated by the higher number of mobile subscribers – so that the total fixed-to-mobile traffic increases; an effect that also benefits fixed line operators.

It is sometimes argued that the growth of mobile telephony has come at the expense of fixed networks. While this issue merits separate consideration, there are a number of factors that seem relevant. Thus, there can be little doubt that the growth in mobile penetration has resulted in substantial growth in fixed network calling. Given the fixed nature of the cost structure, the increased fixed-to-mobile traffic translates into significant benefits for fixed line operators. At the same time, the value of fixed networks has been enhanced by the spectacular growth in the number of people that, thanks to the diffusion of mobile telephony, can be reached. This too will be reflected in higher subscriber numbers and greater traffic volumes. As a result, the evidence does not point to any detriment to fixed network operators from mobile telephony's continued expansion.

Introduction and outline of report

The growth of mobile telephony in Latin America over the last decade has been spectacular, achieving diffusion levels that fixed networks had not achieved in a century. Between 1995 and 2002 the number of cellular subscribers leapt from 4 million to 100 million.[1] Mobile phones are now the principal means of voice communication in Latin America, and will increasingly be used in the future to deliver a range of data and multimedia services, including access to the Internet.[2]

One factor contributing to the speed of expansion of mobile telephony in Latin America compared to fixed line telephones has been the much lower average sunk costs involved in adding a subscriber to the network. Even if that subscriber ultimately proves unprofitable either because she is uncreditworthy or subscribes to very low usage, the loss to the mobile operator is low. As a result, mobile operators have been more willing to sign up customers who fixed line operators would not accept, and even more so under pre-paid plans. This has allowed mobile telephony to bring particular benefits to low-income users.

Also central to diffusion has been a general policy of relatively light regulation as compared to that which applies to fixed line services. Instead competition for customers has encouraged innovation, increased efficiency, and provided consumers with choice, reduced prices and increased quality of service. Mobile telephones compare favourably to fixed line networks on all these criteria.[3]

The relatively high charges imposed by mobile phone operators on operators of rival mobile and fixed line networks to accept calls – 'mobile termination charges'**-** have led to recent calls for regulatory intervention. Despite the success of current pricing structures in expanding mobile telephony, there is a concern that the cost of termination charges may be harmful. A central question therefore is whether lower mobile termination charges would generally benefit Latin American society.

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1 ITU, *ICT statistics*, available at http://www.itu.int/ITU-D/ict/statistics/ (accessed May 2004)

2 O'Connor, P. J. 2003, '¡Viva la Revolucion! The Resurrection of Telecommunications in Latin America', *Journal of Internet Law*, vol. 6, no. 8, pp. 6-7.

3 Lapuerta, Carlos, Juan Benavides and Sonia Jorge, '*Regulation And Competition In Mobile Telephony In Latin America*' Prepared for the First Meeting of the Latin American Competition Forum Paris: 7-8 April, 2003, available at http://www.iadb.org/res/publications/pubfiles/pubS-168.pdf (accessed May 2004)

This report analyses the relationship between mobile telephone penetration rates and termination charges.[4] We demonstrate that in Latin America termination payments have been used to provide an incentive to competing operators to rapidly acquire a large customer base, and have generally benefited fixed line users by increasing the overall size of the network and also by increasing competition in telephony. The results of the model should assuage regulatory concerns about the current level of mobile termination rates.

This report is structured as follows:

- Section 2 describes the mobile termination service and explains how mobile termination charges are usually determined;
- Section 3 presents data on the diffusion of mobile telephony both globally and in Latin America. This section also sets out the patterns of usage in Latin America, indicating that growth is increasingly driven by social groups who were previously not served by any form of telephony;
- Section 4 considers the substantial contribution of mobile telephony to Latin America, focusing on the benefits to lower income groups and rural communities for whom the introduction of mobile telephony has often provided a first opportunity to access telephony;
- Section 5 discusses the effect of different pricing regimes on diffusion rates, pointing out that current termination rates will often promote network growth and - where network size is still small - may benefit all users;
- Section 6 presents the results of a formal model of competition between mobile network operators. This model estimates the benefits derived from the diffusion of mobile telephony, as well as the impact on fixed line users of different levels of termination charges.

The report concludes by noting that the Latin America mobile telephony sector offers further potential for growth, however, policy settings will be key in ensuring this is not stymied. The results of our model should caution against undue regulatory intervention in an area where market forces have created unambiguous gains for society.

[4] It is generally accepted that theses two variables are likely to be highly interrelated. See: Wright, J. 2004, ‘One-sided Logic in Two-sided Markets’, *Review of Network Economics*, vol. 3, pp. 44-63; Rochet, J-C and J. Tirole 2003, ‘Platform Competition in Two-Sided Markets’, *Journal of the European Economics Association*, vol. 1, pp. 990-1029; Evans, D. 2003, ‘Some Empirical Aspects of Multi-sided Platform Industries’, *Review of Network Economics*, vol. 2, pp. 1-20; Wright J. 2000, ‘Competition and Termination in Cellular Networks’, University of Auckland, available at http://www.crnec.auckland.ac.nz/crnec/research/papers/cellular-new.pdf (accessed May 2004)

2 Mobile termination costs

2.1 What is the mobile termination service

When a mobile call is made between consumers, it will involve two elements – origination and termination. Origination refers to the carriage of a call from the consumer who originates the call over the network to which she is connected. Termination refers to the carriage of the call to the person receiving the call over the network on which he is connected. Where the person making the call and the person receiving the call are on different networks, a point of interconnection between these two networks is established. This service is referred to as the 'mobile termination service'.[5]

The mobile termination service is an essential input into the provision of calls where the person originating and receiving the call are on different networks. Without this service it would not be possible for customers on one network to call either mobile or fixed line subscribers who were connected to other networks.

Under the so-called 'calling party pays' pricing model (CPP), which predominates throughout Latin America, the network owner from which the call is originated purchases the termination service from the network owner that receives the call. The originating network owner will recover the termination fees through the retail price it charges the calling consumer for providing the call. Hence under the CPP model the person initiating the call pays the entire cost of the call.

In contrast under the 'receiving party pays' pricing model (RPP), which exists in North America and China, the termination fee is paid by the network owner who receives the call, and ultimately borne by the receiving customer.

2.2 How is the mobile termination fee determined

Regulatory practice around the world generally favours that the terms of interconnection agreements - including termination charges - between operators be decided by commercial negotiation.

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5 This explanation is based on Australian Competition and Consumer Commission, 'Mobile Services Review Mobile Terminating Access Service - Draft Decision' March 2004, i-ii.

A deregulated market generally provides efficient incentives for parties having a mutual interest in cooperating – in this case, in interconnecting – to agree on terms.[6] These commercial negotiations are driven by largely complementary incentives: each operator wishes the customers on its network to be able to make and receive calls to and from the widest possible group of people. This increases the utility of the service the operator provides and hence its revenue earning potential.

The incentives to reach agreement on a purely commercial basis can, however, be attenuated by a regulator who decides that mobile network operators should be prevented from refusing interconnection and obliged to offer (low) cost-based termination rates. Regulators may intervene in this manner either because they hold conventional views of the desirability of marginal cost pricing, which are not appropriate for network goods (discussed below in sub-section 5.2), or because they lack independence from incumbent fixed line operators who stand to lose profits from higher fixed-to-mobile termination fees.[7]

The fast rate of change and complex nature of the telecommunications industry means that there is a real risk of regulatory error. This is particularly likely to be the case in Latin America where independent regulators have not yet accumulated the technical expertise of their North American and European counterparts. It is therefore generally undesirable for regulators to seek to determine termination rates or intervene other than in exceptional circumstances.

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6 This is discussed in detail in Baumol, W. J. and J. G. Sidak 1994, 'The Pricing of Inputs Sold to Competitors', *Yale Journal on Regulation*, vol. 11, no. 171, p. 176.

7 For example, Mexico' telco regulatory, Cofetel, is seen to be unwilling to enforce regulatory rules because of intense pressure from the principal fixed line telco, Telmex, and from nationalist legislators: Mark A. Jamison, *Strategies for Latin America in the Global E-economy*, March 10, 2000, pp. 5-6. available at http://bear.cba.ufl.edu/centers/ciber/workingpapers/mjlatin1.pdf (accessed May 2004)

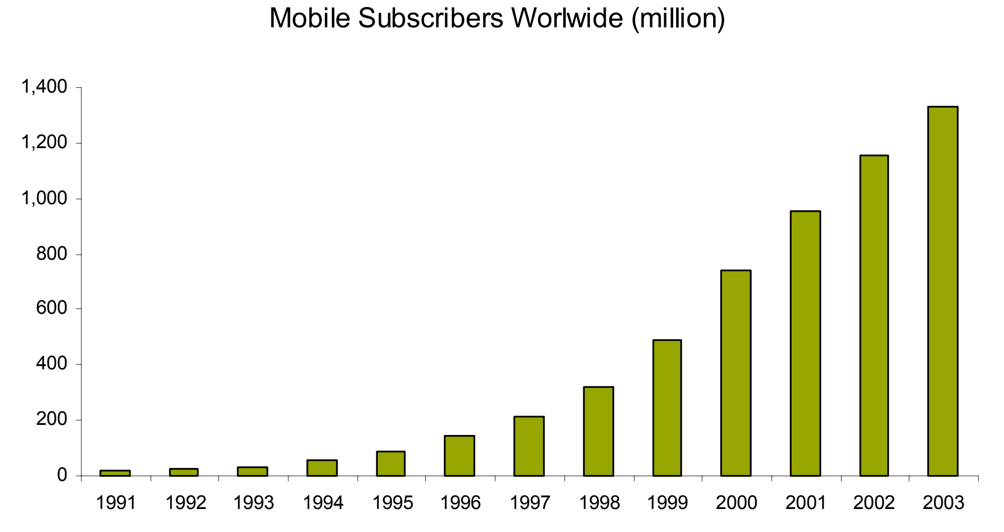
3 Diffusion of mobile telephony

This section first considers some global trends in telephony, and second examines the situation in Latin America.

3.1 Global trends

Originally limited to business people and the wealthy few, cellular telephony has spread rapidly around the world in the 1990s. From 1991 to 2003 the number of cellular subscribers worldwide increased from 16 million to more than 1.3 billion. The following chart illustrates this impressive growth.

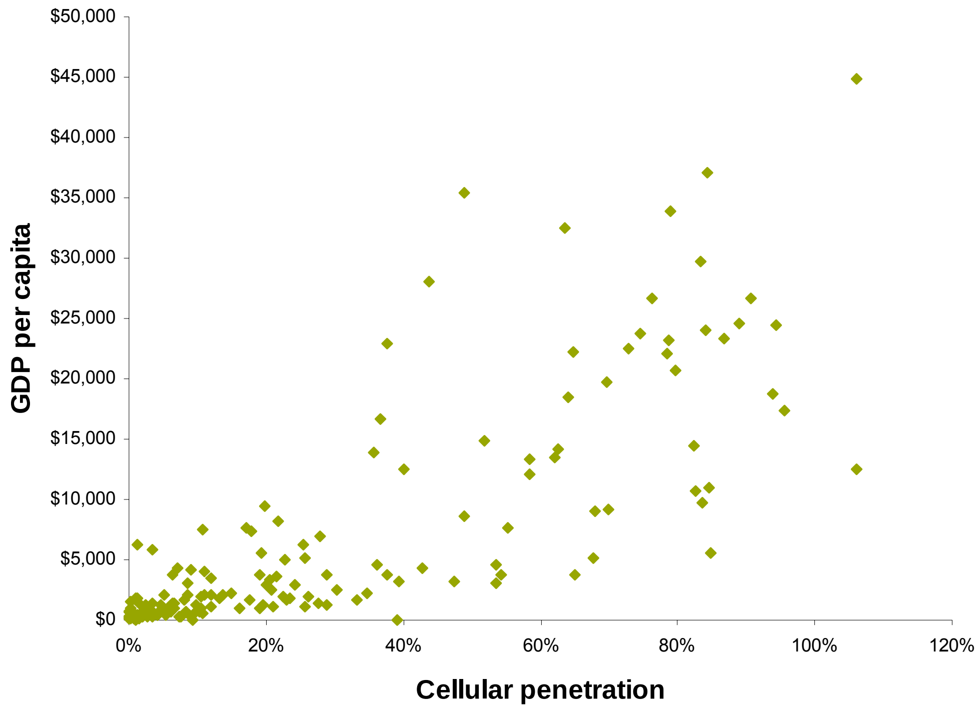
Chart 1: **Global diffusion of mobile telephony**



Data source: International Telecommunications Union (ITU)

However, large disparities in mobile penetration remain between rich and poor countries. As illustrated in the following graph, the penetration of cellular phones is strongly and positively correlated with per capita GDP.

Chart 2 **Worldwide penetration of cellular telephony by GDP per capita**



Note: The coefficient of correlation between the GDP per capita and the cellular penetration equals 80.8 per cent
Data source: ITU

The majority of countries, including most Latin American countries whose average annual per capita GDP is below US$5,000, have relatively low mobile penetration rates.[8] That said, the take up of mobile telephony across relatively poor countries varies significantly. Moreover, some relatively poor countries have take-up rates that exceed those of much richer countries. This suggests that factors other than income influence take-up.

Furthermore, the absolute number of subscriptions shows that poor countries are attaining increased take-up of mobile telephony.[9] The following graph illustrates the growth in the absolute number of mobile subscribers in rich and poor countries.

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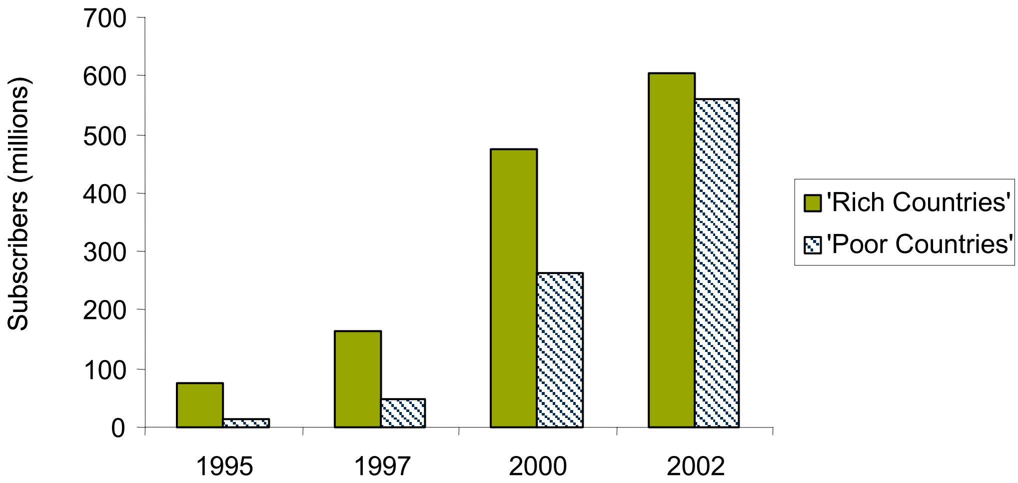
8 Average per capita income in Latin America is only US$3,280 while it is US$20,230 and U$35,060 in Europe and the United States respectively. Latin America also has a significant proportion of the population living in extreme poverty; 16% and 32% of the population live on under US$1 and US$2 US a day respectively: World Bank Group 2003, *World Development Indicators*, Washington, DC; and United Nations Development Programme 2003, *Human Development Report*, available at http://hdr.undp.org/reports/global/2003/pdf/hdr03_HDI.pdf. (accessed May 2004)

9 In contrast the growth of mobile telephony may have reached saturation levels in developed countries. For example, 2002 was the first year where the number of British persons aged 15 and over who own or use a mobile phone did not increase. This indicates that a threshold has been reached beyond which growth will not be explosive, at least in a 2G world. See Oftel, *Key*

Chart 3 **Diffusion of mobile telephony by country's GDP per capita**



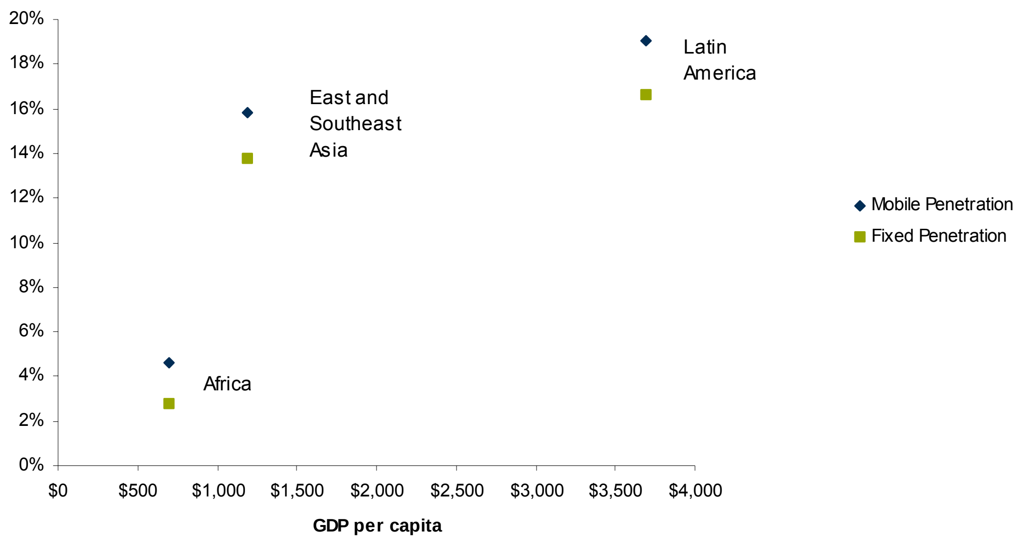
Note: 'Rich countries' are defined as those with a GDP per capita higher than US$10,000 in 2001; other countries are considered as poor

Data source: ITU

Importantly, the diffusion of mobile telephony in developing countries is higher than that achieved by fixed line networks. What is significant about this fact is that mobile phones have only been in existence for a comparatively short period of time relative to fixed line networks. The following graph compares the penetration rates of mobile and fixed line telephony in Latin America, East and Southeast Asia and Africa.

trends in fixed and mobile telephony, and Internet – residential consumers, 17 June 2002, available at http://www.ofcom.org.uk/static/archive/oftel/publications/research/2002/trenr0602.htm (accessed May 2004)

Chart 4: **Tele-density in developing continents**



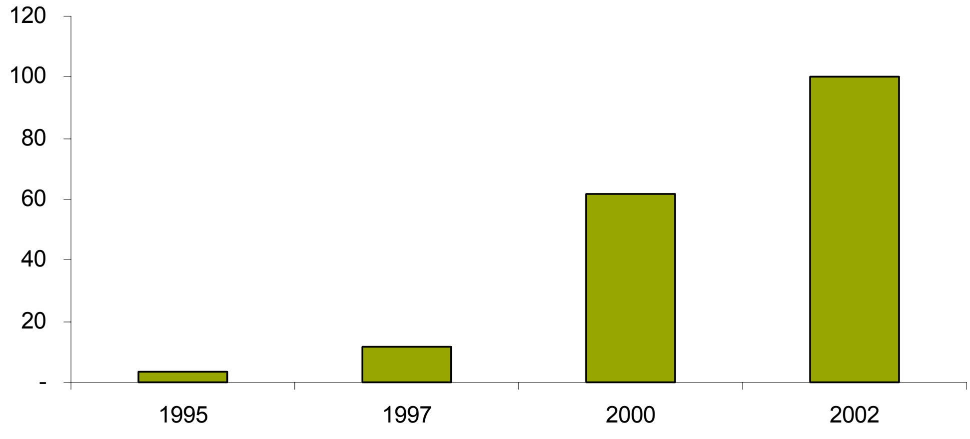
Note: Japan, Singapore and Hong Kong are excluded from East and Southeast Asia.
Data source: ITU

These results show that while overall take-up rates in developing countries, including in Latin America, are much lower than those in richer countries, the growth in mobile telephony is increasing. Furthermore the rate of take-up amongst countries with the same take-up levels varies significantly. Finally, mobile telephony has now overtaken fixed line telephony as the principal means of communication in all developing countries.

3.2 Latin America

In Latin America the number of cellular subscribers leapt nearly 25-fold, from 4 million in 1995 to 100 million in 2002.

Chart 5: **Mobile subscribers in Latin America – (millions)**



Data source: ITU

Further, the absolute number of mobile subscribers in Latin America is continuing to increase steeply. Current and forecasted growth of market penetrations of fixed lines and mobile telephony for seven Latin American countries is presented in Annexure B.[10] This data reveals three important facts. First, fixed line penetration is generally not expected to significantly increase between now and 2008. Second, growth in mobile telephony has continued despite an economic slump in the region. Third, the growth in mobile subscription is driven by growth of prepaid subscribers.

Importantly, Annexure B also reveals that the mobile tele-density of Latin American countries varies significantly. For example, in 2001 Chile had a cellular penetration of approximately 34 per cent while Peru's cellular penetration was only 5.9 per cent, one of the lowest rates in Latin America.[11] Curiously the penetration rates of Argentina, Chile and Venezuela vary considerably despite these countries all having approximately similar income levels, and all having deregulated their telecommunications sectors. This indicates that factors other than income influence take-up rates in Latin America. One important influence on take-up, the choice of pricing systems, is examined further in section 5.

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10 These countries are Argentina, Chile, Columbia, Ecuador, Peru, Uruguay and Venezuela. This is a relatively representative sample of Latin America. Argentina, Chile and Venezuela are amongst the most important telecommunications markets in Latin America, both in terms of overall size and take-up rates, whereas other countries in the group, in particular Peru, are relatively small markets.

11 These statistics are consistent with information provided by the US government: http://www.osec.doc.gov/latinamericatrademission/telecom%20pc.htm (accessed May 2004)

4 The contribution of mobile telephony to social welfare

In developed countries fixed line and mobile phones tend to be complements in the sense that a large proportion of the population subscribe concurrently to both fixed and mobile networks. In these countries the benefit from mobile telephony is essentially an *incremental gain* from a situation where telecommunications services were already otherwise largely accessible.

In contrast in developing countries, including throughout Latin America, state-owned fixed line telcos have traditionally failed to develop adequate infrastructure, a problem that recent privatisation and deregulation has not always alleviated. The introduction of mobile telephony in developing countries has in many instances provided people, in particular low-income and rural groups, with their first opportunity to access telephony.[12]

Thus while it is sometimes suggested that the rise of mobile telephony (and information and communication technology (ICT) generally) is increasing the development gap between advanced and developing countries, it appears that mobile telephony has the potential to give new impetus to economic growth, reduce the rate of rural-urban migration, facilitate the provision of public services in urban areas and decrease social exclusion.[13]

4.1 Take-up of mobile telephony amongst low income groups

As well as the significant differences in mobile diffusion between developed and developing countries examined above, it is frequently observed that there is a ‘digital divide’ *within* countries – where typically younger, urban, high income groups have relatively high take-up rates compared to, for example, low income and rural groups.[14]

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[12] Whether mobiles and fixed line phones are substitutes or complements is a question that has been examined frequently in the context of developed nations. See for example, European Commission 1999, *Consumer Demand for Telecommunications Services and the Implications of the Convergence of Fixed and Mobile Networks for the Regulatory Framework for a Liberalised EU Market*, Discussion Document prepared by Squire, Sanders & Dempsey and Analysys, available at http://europa.eu.int/ISPO/infosoc/telecompolicy/en/fmc.pdf (accessed May 2004)

[13] Alaedini, Pooya and Peter J. Marcotullio, UNU/IAS Working Paper No. 99, Urban Implications of Information Technology/New Electronics for Developing Countries, February 2003, available at http://www.ias.unu.edu/binaries/IASWorkingPaper99.pdf (accessed May 2004)

[14] For example, in December 1984, the Independent Commission for World-Wide Telecommunications Development released the Maitland Report, which highlighted the inequalities in telecommunications resources between nations: Maitland Commission, 1984, *The*

This issue has particular significance in developing countries which, as well as being poor, are characterised by significant income inequalities. Table 1 below, which sets out the percentage of national consumption of the poorest and richest segments of the populations of various Latin American countries, illustrates the much greater income inequalities in Latin America compared to those which exist in Europe and North America.

Table 1: **Percentage of national consumption**

Country	10% Poorest	10% Richest
Uruguay	1.6	33.8
Chile	1.1	45.4
Mexico	1.2	41.6
Colombia	1.1	46.1
Brazil	0.7	48
Venezuela	0.6	36.3
Peru	1.6	35.4
Ecuador	2.2	33.8
Latin America (average)	1.2	40.1
Europe (average)	3	24.6
North America (average)	2.2	27.2

Source: Human Development Report 2003

Another measure that economists use to analyse income inequalities is the 'Gini index'. This index assigns a value of zero to those countries with perfect equality, and 100 to those where there is perfect inequality. The United Nations Development Programme assigned values of 29 and 36 to Europe and North America respectively, while Latin America scored 51.[15]

A preliminary issue is whether the diffusion of mobile telephony in Latin America extends to low-income groups. There are relatively few studies of mobile telephony take-up by low-income groups. One such study was undertaken by Fernández-Maldonado in 2001, who analysed the diffusion of ICTs among different social groups in Lima, Peru.[16] Noting that mobile telephony is becoming the most widespread ICT, she reported the following statistics on the penetration of mobile telephony in Lima:

missing link, available at http://www.itu.int/osg/spu/sfo/missinglink/The_Missing_Ling_A4-E.pdf (accessed May 2004)

15 Human Development Indicators 2003, available at http://www.undp.org/hdr2003/indicator/indic_126_1_1.html

16 Fernández-Maldonado, A. M. 2001, 'Diffusion and use of new information and communication technologies in Lima', *Journal of Urban Technology*, vol. 8, no. 3, pp. 21-43.

Table 2: **Mobile penetration by income range in Lima**

	High-Income	Middle-Income	Low-Income	Very-Low Income	Extreme Poverty
Distribution of Population	3%	13%	34%	37%	12%
Pre-paid Mobile	27%	32%	17%	10%	7%
Post-paid Mobile	63%	27%	6%	1%	0%
Total Mobile	**78%**	**53%**	**22%**	**10%**	**7%**

Table 2 demonstrates that whilst the penetration of mobile telephony is obviously higher for high-income groups, even low-income, very-low income and extreme poverty groups have significant take-up of mobile services. This indicates that mobile telephony is not simply a luxury good. Further, Table 2 shows that mobile subscription amongst these groups – as opposed to the higher income groups - is overwhelmingly accounted for by prepaid subscription.

The take-up of mobile telephony among low-income groups can be explained by a number of reasons.

First, unlike fixed networks, mobile operators incur low sunk costs in connecting an additional subscriber.[17] Instead of having predominantly high fixed costs (as is the case with wired technology), establishing mobile networks involves relatively high variable costs. Thus, whereas a fixed line operator generally loses the bulk of the cost of installing a fixed connection (because connection charges are lower than initial costs) when terminating a customer, the mobile operator incurs relatively low costs.

This is particularly so under pre-paid plans which eliminate the risk of operators failing to collect revenue, obviating the need for stringent income or credit history checks. The option to pre-pay means that low-income groups are not automatically disqualified from using the service because of dubious credit worthiness. Thus even if that subscriber ultimately either proves uncreditworthy or chooses of her own volition to terminate the service, the loss to the mobile operator is low. As a result, mobile operators are more willing to sign up customers that they would otherwise refuse.[18]

Second, the pre-paid alternative allows individuals to tightly manage their telephone expenses, avoiding the exposure that results from post-paid options. Especially for new

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[17] The discussion in section 4.2 provides more information on why the cost structures of mobile and fixed networks mean that it is generally more efficient for low-traffic customers to subscribe to mobile networks.

[18] See Estache A., A. Gomez-Lobo and D. Leipziger 2001, 'Utilities Privatization and the Poor: Lessons and Evidence from Latin America', *World Development, vol.* 29, no. 7, pp. 1179-1198.

customers who are unfamiliar with call costs, prepaid services offer predictability, and prevent unpleasant surprises when invoices are received.

Third, access to mobile telephony increases the probability of low-income earners obtaining employment because they are more likely to obtain information about job opportunities. Low income workers (in particular young people originally from rural areas) are more likely to be itinerant either because of their employment in seasonal work or because they are homeless, not well integrated into cities and isolated from traditional ties.[19] Such workers are more likely to obtain employment if they are contactable by telephone.

Similarly many poor urban families live in homes to which they do not have clear legal title. For example, it is reported that approximately 85% of the Venezuelan population live in shanty towns.[20] In these circumstances, fixed line operators are frequently unwilling to connect these people to their networks.[21] Obtaining a mobile telephone may create opportunities for improved access to educational and health services, which may redress poverty. In this way the lack of connectivity which may have previously inhibited the ability of an individual or group to gain access to the tools they need for economic and political success may be redressed.

Fourth, for low-volume users, mobile telephony is often cheaper than a fixed-line subscription. For example, based on a minimal package for the marginal user with few outgoing calls, Oestmann found that mobile service provided more affordable access to telecom services than fixed line services.[22] Oestmann compared:

1) the start-up cost of obtaining access for the first time to telephone services (i.e. handset and SIM card activation or fixed-line connection costs); and
2) the recurring monthly costs of staying connected (i.e. monthly rental or minimum monthly usage), including the costs of making a minimum number of calls.

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19 In the last 20 years there have been large population movements throughout Latin America, in particular away from rural areas to urban areas: See *A Decade of Light and Shadows*, The Brookings Institution, 2003, p. 321 available at http://www.un.org/esa/usg_ocampo/books/pdf/lcg2205i_cap9.pdf (accessed May 2004)

20 http://news.bbc.co.uk/1/hi/world/americas/country_profiles/1229345.stm

21 See Melo J. R. 2000, 'Telecommunications and the Poor', *World Bank Conference Infrastructure for Development: Private Solutions and the Poor*, 31 May - 2 June, London, available at http://www.ppiaf.org/conference/section3-paper1.pdf (accessed May 2004)

22 The monthly costs for fixed service comprise line rental and fifteen minutes of outgoing local calls. The monthly costs of mobile service, are based on the minimum usage required for a customer to stay connected plus fifteen mobile-to-mobile call minutes. See Oestmann S. 2003, *Mobile Operators: their Contribution to Universal Service and Public Access*, Intelecon Research and Consultancy, Vancouver, available at http://rru.worldbank.org/Documents/PapersLinks/Mobile_operators.pdf, (accessed May 2004)

Table 3: **Costs incurred by low users of telephony in Latin America**

	Start up costs		Monthly cost	
	Fixed	Prepaid Mobile	Fixed	Prepaid Mobile
Argentina	$150.00	$50.00	$13.65	$7.95
Brazil	$27.00	$40.00	$7.90	$4.50
Chile	$43.00	$67.10	$11.40	$8.10
Colombia	$168.00	$49.25	$3.70	$4.20
Mexico	$119.00	$46.20	$16.25	$6.90
Peru	$131.00	$60.40	$13.95	$4.50
Venezuela	$102.00	$54.00	$11.60	$6.15

Source: Oestmann 2003

Mobile telephony service was found to be more affordable both in terms of start-up costs as well as in monthly recurring costs. Specifically:

- the start-up cost of a mobile telephone was found to be on average 50% lower; and
- monthly mobile costs, including a minimum number of calls, were on average 46% lower.

While mobile services were only found to be cheaper when a low number of calls were made, this minimal usage benchmark is the relevant measure to compare the relative costs of access. Annexure C presents data for the average minutes of use for prepaid and post-paid contract respectively, as they are expected to evolve through time in a number of Latin American countries. This indicates that the average minutes of usage of each prepaid mobile phone call is expected to fall in all the surveyed Latin American countries. Together with the data presented in Annexure B, this material indicates that most of the growth in mobile telephony in the foreseeable future will be driven by large numbers of persons using mobile phones for relatively short and/or infrequent calls. This suggests that many people value a telephone in order to be accessible for important calls, rather than for recreational purposes.[23] A recent study of telephone usage in Bangladesh found that the primary purpose of most calls made by low income groups was 'economic', relating to either employment, business or land/commodity transactions. Relatively few calls were

[23] Even if a subscriber to a telecommunications network rarely makes calls from her phone, she may still value owning the phone. Telephone access in such cases is an option good since subscribers purchase the subscription so that they have the ability to use the phone. Certainly the mobile phone has this role, particularly in respect of pre-paid contracts. See Hisrich, R. and M. Peters 1974, 'Selecting the Superior Segmentation Correlate', *Journal of Marketing*, vol. 38, pp. 60-63.

made for social/family purposes.[24] This indicates that low income groups are frequently using mobile telephony in order to improve their economic condition.

4.2 Take-up of mobile telephony amongst rural communities

As the majority of Latin America's rural population is relatively poor, many of the factors which impede low-income groups' usage of fixed line telephony services also apply to them. However, the challenge of offering telephony to rural communities has traditionally been even greater because their geographical isolation, low population densities and the difficult terrain in which they live has made these groups traditionally very expensive to serve.[25] This explains the even lower fixed line penetration rates amongst Latin American rural communities.[26]

That said, people *everywhere* are willing to spend part of their income on telecommunications services. Empirical studies show that affordability and willingness to pay are not such large barriers as one may initially think: residents of rural areas often spend on communications as much as urban communities in terms of percentage of available income. For instance, Kayani and Dymond find that rural communities's spending, relative to their income, is between 60 and 125 per cent of the national average.[27] Similarly, Wellenius found that across a wide range of developing and industrial countries telecommunications services typically account for one to three per cent of GDP, while the worldwide average is 2.2 per cent. This share is not much smaller in rural areas, even in poor countries. In 1996, villages in Botswana generated telephone revenues equivalent to about 1.3 per cent of GDP, compared with 1.6 per cent countrywide. Similarly, villages in Peru spend a larger share of GDP – 1.5 per cent – for telephone services than the country as a whole – 1.2 per cent.[28]

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24 Bayes, A., J. von Braun and R. Akhter 1999, 'Village Pay Phones and Poverty Reduction: Insights from a Grameen Bank, Initiative in Bangladesh', ZEF – Discussion Papers On Development Policy No. 8, Center for Development Research, Bonn, June 1999, pp. 47, available at http://www.zef.de/download/zef_dp/zef_dp8-99.pdf, (accessed May 2004)

25 Navas-Sabater J., A. Dymond and N. Juntunen 2002, 'Telecommunications and Information Services for the Poor: Toward a Strategy for Universal Access', *World Bank Discussion Papers*, 432, Washington, D.C.

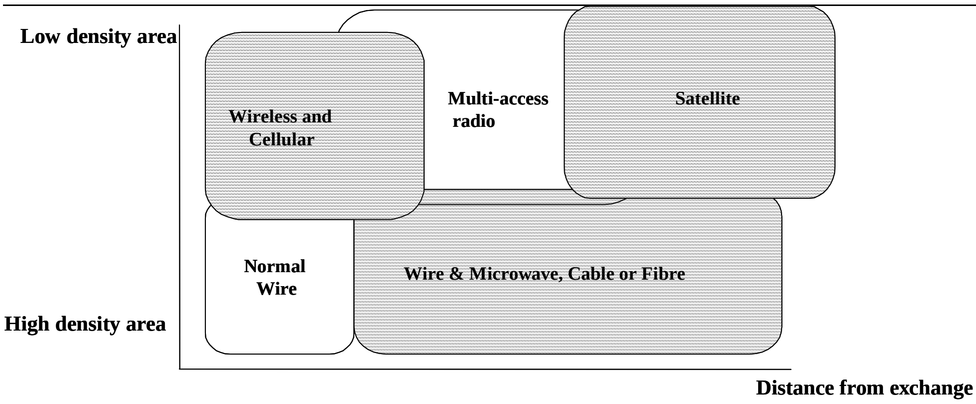
26 See for example: Torero, M. 'The Access and Welfare Impacts of Telecommunications Technology in Peru', ZEF – Discussion Papers On Development Policy No. 27, Center for Development Research, Bonn, June 2000, available at http://www.zef.de/download/zef_dp/zef_dp27-00.pdf (accessed May 2004)

27 Kayani, R. and A. Dymond 1997, 'Options for Rural Telecommunications Development', *World Bank Technical Paper* No. 359, Washington D.C.

28 Wellenius B. 2000, 'Extending Telecommunications beyond the Market', *Public Policy for the Private Sector*, Note 206, World Bank Group.

As predicted in 2002 by the World Telecommunication Development Report[29] the cost structure of wireless networks means that they often provide more efficient telephony services to geographically dispersed, low-usage, rural communities than fixed line networks. Navas-Sabater, Dymond and Juntunen[30] discuss how the costs of serving a particular region vary depending on its distance from an existing telephone exchange and subscriber densities. They illustrate that the typical cost structures of different technologies, showing the most efficient technology to be used in each situation.

Chart 6: **Typical market niches for various technologies**



Source: Navas-Sabater J, Dymond A and Juntunen N, 2002, *op. cit*.

The authors explain that wireless networks are particularly well suited to connecting remote communities, even if they are relatively small. This is because mobile networks are characterised by:

- the speed and ease of deployment of equipments; and
- avoiding the complex process of laying cables.

As explained by Caspary and O'Connor[31], this compares favourably to the last mile of a fixed telecommunications network, which is often the weakest link, and the least well managed in the whole telecommunications infrastructure.[32]

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29 ITU, 2002, 'World Telecommunication Development Report: Reinventing Telecoms', 6th edition.

30 Navas-Sabater J., A. Dymond and N. Juntunen 2002, 'Telecommunications and Information Services for the Poor: Toward a Strategy for Universal Access' *World Bank Discussion Papers*, 432, Washington, D.C.

31 Caspary G. and D. O'Connor 2003, 'Providing Low-Cost Information Technology Access to Rural Communities in Developing Countries: What Works? What Pays?', Webdoc series, OECD, available at http://www.developmentgateway.org/download/192492/Rural_ICT_Access.pdf, (accessed May 2004)

More generally, one of the main differences between fixed and mobile networks is that:

- fixed networks generally face higher costs to increase the number of subscribers, but low costs to expand traffic; and
- mobile networks generally face low costs to expand the number of subscribers, but high costs to expand traffic.

Summing up, the difference in cost structures explains why investment in mobile networks is a cost-efficient solution to the access issues in rural areas previously underserved.

[32] Such a comparative advantage translates into the provision of telecommunications services to areas previously not connected to any network. For example, in the case of El Salvador, nine fixed and four mobile operators serve the population of 6.5 million. Still, as the National Regulatory Authority, SIGET, explained, some rural areas of El Salvador are exclusively served by wireless operators.

5 The effect of pricing structures on diffusion rates of mobile telephony

This section examines the effect of mobile pricing on diffusion rates. This section first reviews the evidence on the impact of CPP regimes on diffusion. It then examines how the CPP pricing model, together with the high termination charges that tend to accompany it, is one of the factors explaining the take-up of mobile telephony. Finally the section considers the effect on social welfare of increased termination charges.

5.1 Diffusion of mobile telephony under a CPP regime

When the mobile communications industry commenced it was largely focused on providing services to business users. Business users did not prefer CPP over RPP pricing as the cost of their calls were paid by large organisations who could predict that the vast majority of calls would be work related.

However, as the mobile sector expanded to cover personal communications, users became more reluctant to subscribe to mobiles under RPP pricing because they did not want exposure to costs over which they had limited control. Table 4 shows the mobile penetration rates of a group of developed countries. It indicates that countries with CPP have achieved significantly higher mobile penetration rates than countries with RPP. Indeed, some countries with lower average incomes but with CPP regimes have achieved higher penetrations than wealthier countries with RPP regimes.[33]

[33] OECD 2000, Cellular mobile pricing structures and trends, DSTI/ICCP/TISP(99)11/Final, available at http://www.oecd.org/dataoecd/54/42/2538118.pdf (accessed May 2004)

Table 4: **Mobile penetration rates in selected developed countries**

Country	Penetration (% of Population)
CPP countries	
Finland	85
Germany	63
Italy	72
Japan	93
South Korea	62
United Kingdom	68
RPP countries	
Canada	37
United States	49

Source: Crandall and Sidak, 2004.[34]

There is strong evidence that after moving from a RPP to a CPP regime, Latin American countries have experienced very rapid subscriber and network traffic growth. The International Telecommunications Union, an international organization within the United Nations System, considered that:

> Nations that have abolished this system in favour of the traditional calling party paying, such as Argentina and Peru, have witnessed large increases in subscribers and usage. The launching of the calling party pays system in April 1997 in Argentina led to its highest annual growth ever in mobile cellular subscribers. In Peru, mobile cellular calls increased over two hundred per cent following the introduction of calling party pays.[35]

The ITU illustrates this point in a case study on Mexico.[36] Mexico introduced CPP in April 1999. Telmex, the country's principal fixed line telco, opposed this change, which it considered would decrease fixed-to-mobile traffic as a result of higher fixed-to-mobile termination charges. Instead, there was a significant increase – almost 30% – in traffic terminating on the mobile network, despite the fact that the price for fixed-to-mobile calls increased from US$0.115 to US$0.403 per minute. Moreover, the total number of minutes per mobile subscriber increased from 162 to 177. In Peru, the number of subscribers increased by 150% after CPP was adopted in May 1996.[37] These figures indicate that even

34 Crandall and Sidak, 2004, 'Should Regulators Set Rates to Terminate Calls on Mobile Networks?', *Yale Journal on Regulation*, Forthcoming

35 ITU 1998, 'World Telecommunication Development Report: Universal Access', Geneva.

36 ITU 2000, 'Fixed-Mobile Interconnection: The Case of Mexico', prepared by Arturo Briceño.

37 Lapuerta, C., J. Benavides and S. Jorge, op.cit. 7.

with higher rates, the introduction of CPP does not deter mobile network usage and may indeed have the opposite effect. This is partly explained by the strong incentives CPP provides mobile operators to increase their subscriber base, an issue which is considered in further detail in the following section.

Other pricing innovations, such as the introduction of prepaid calling cards have further increased network expansion. For example the OECD[38] found, using the ratio of mobile subscribers to fixed access lines[39], that the advent of pre-paid cards strongly correlated with countries with CPP overtaking the growth rates for those with RPP. In 1996, countries with RPP had 25 mobile subscribers for every 100 fixed lines compared to 20 mobile subscribers for every 100 fixed lines for countries with CPP. By 1999, countries with CPP had 61 mobile subscribers per 100 fixed lines compared to 42 mobile subscribers per 100 fixed lines for countries with RPP.

5.2 Efficient pricing in two-sided networks

The positive relationship between high termination charges and mobile penetration rates can be analysed by what is known as the *economics of two-sided networks*. In two-sided markets there are two distinct types of users who wish to make use of a common platform, each of which obtains benefits that depend on the number of users of the opposite type.[40] Mobile telephony networks conform to this model because they involve the participation of fixed and mobile consumers each of whom derive value from being able to contact users who are connected to networks other than their own service provider.

The decision to purchase a mobile network subscription is subject to a 'public good' or externality characteristic[41] associated with network connection: the connecting party

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38 OECD 2000, *Cellular mobile pricing structures and trends*, DSTI/ICCP/TISP(99)11/Final, available at http://www.oecd.org/dataoecd/54/42/2538118.pdf (accessed May 2004)

39 Using ratios in this manner controls for the effect of other factors affecting use, in particular GDP per capita.

40 Wright, 2002, op. cit. Wright lists many other examples of two-sided networks including academic journals which cater to readers and authors; airports which cater to airlines and passengers; auctions; trading posts which cater to buyers and sellers; dating agencies which cater to men and women; conferences which cater to speakers and to audiences; debit and credit card payment schemes which cater to cardholders and merchants; directory services such as Yellow Pages which cater to potential buyers and sellers; employment agencies which cater to employees and employers; real estate agencies which cater to home buyers and sellers, as well as to tenants and landlords; search engines which cater to searchers and websites and stock markets which cater to companies wishing to list and to investors/traders (through brokers).

41 Public goods are defined by two features: they are non-rivalrous and non-excludable in their consumption. A product that is non-rivalrous is one that does not diminish when someone makes use of it. A product is non-excludable if it is not possible to exclude others from using it once it exists. The classic examples of public goods are street lighting and public defence.

confers benefits onto all the subscribers to telecommunications networks - both fixed and mobile - because the latter are able to contact the connecting subscriber. This connection benefit is non-rivalrous in consumption, which means that existing subscribers to interconnected telephony networks **all** benefit from a person's decision to subscribe to a mobile service.

However, mobile subscription does not necessarily have the second characteristic of a 'pure' public good, that being non-price excludability. The benefits calling parties obtain from being able to contact mobile subscribers can be priced in a competitive market according to the willingness of such callers to pay for their calls to mobile subscribers.

In two-sided networks, efficient prices should not necessarily just reflect costs. To internalise the benefits fixed network users obtain from high mobile penetration, it may be efficient to set the termination charges above cost. In this way both fixed-line and existing cellular callers to mobile phones will contribute towards the fixed costs of establishing mobile phone networks. In other words, prices should be set so that costs are allocated between both sides of the networks to attract and retain a mix of fixed and mobile customers.

Hence, whilst low usage in Latin America creates a challenge for wireless operators in terms of profitability, if termination rates are relatively high, a CPP regime allows them to generate substantial revenues from termination services. Therefore, if universal service is a policy objective, it may be appropriate for regulatory regimes to tolerate high termination rates, particularly in countries where overall network size is still relatively low.

5.3 The effects of increased termination charges

When a mobile carrier increases its termination charge, there will be two effects on social welfare: a negative direct effect and a positive indirect effect.

First, the direct effect will be to increase fixed-to-mobile call prices resulting in a lower number of fixed-to-mobile calls. Other things being equal, such a price increase is socially costly: the mark-up results in users foregoing minutes of fixed-to-mobile calls or, in the language of economists, losses associated with allocative inefficiency. The higher termination fee may create two other interrelated detriments:

An externality exists whenever one individual's actions affect another individual's well-being in ways that need not be paid for. A 'positive externality' results when part of the benefit of consuming a product accrues to a person other than the person who produces or purchases it. Public goods are extreme examples of good with externalities as the entire benefit of acquiring the good goes to any other person.

- it lessens the ability of service providers who only provide fixed-line calls to compete, as they face increased costs at least some of which must be passed on to their subscribers, without receiving any additional revenue; and

- it may lead to under-investment in the infrastructure required to deliver fixed-to-mobile calls.

Second, the indirect effect of the higher termination charge will be to increase the termination profit obtained from every subscriber. The termination service is not a stand-alone service – it includes the provision of handsets, connection and/or access fees, and call charges - and a mark-up on the cost of fixed-to-mobile termination does not necessarily imply a monopoly rent. If the market for mobile services is workably competitive as is the case in many Latin American countries, mobile operators will choose – or be required – to pass termination revenues through to their existing consumers. These revenues may be passed on in a number of forms, including through subsidised handsets, low monthly rentals fees, lower call costs and low minimal monthly plans.

Furthermore, higher termination costs will create incentives for mobile operators to compete aggressively to increase their customer base. As mobile networks will incur termination charges when their own subscribers make calls to other mobile networks, higher termination charges will induce carriers to increase their customer base in order to save on termination payments to other mobile networks as well as to attract the largest possible revenue from termination fees. Competition for customers will in turn reduce carriers' profits and (if it takes the form of offering lower outgoing call prices or access fees) may actually reduce the prices of mobile telecommunications services. All of these measures will increase mobile subscription – particularly amongst low users of mobiles- and hence continue to increase network size.

When the market penetration of mobile telephony is low, it is likely that the benefits associated with the indirect effect of increasing termination fees will outweigh the costs associated with the direct effect.

The welfare estimates of the diffusion of mobile telephony in section 6 takes into account these two effects. These imply that when overall network size is low, the high termination charges that have characterised CPP networks allow a better alignment between the objectives of mobile phone operators and the wider social interest.

5.4 Effects of higher termination charges on fixed-line users

It is sometimes suggested that high fixed-to-mobile termination charges are unjustified subsidies to mobile users from fixed-line users, which serve ultimately to harm the latter group. However, in two-sided networks it is conceptually incorrect to conclude that the mere presence of a mark-up on the cost of providing termination services means that fixed-line users are worse off. Rather the key issue is whether this group would be better off with a different pricing structure, in particular if fixed-to-mobile termination rates were reduced.

In order for fixed line users to benefit directly from such a reduction fixed line operators would have to decrease fixed-to-mobile retail prices. The low degree of competitive constraint on most fixed line operators in Latin America means that it is doubtful that this would occur. Even if fixed-line operators were required by regulation to pass on some of the benefit, the imperfect nature of regulation would make it highly unlikely that the full cost saving would be passed through. Further, regulation of fixed operators typically involves some constraints on **basket** of services, as against a price regulation on each individual service provided by the fixed line operators. When this is the case, the rate of pass through would typically be lower than 100% because fixed operators would re-optimise their pricing structure.

Even if end users were offered a lower fixed-to-mobile retail price, the lower termination rate could still ultimately make them worse off.[42] This is essentially because a lower termination charge may reduce take up of mobile telephony, reducing the number of callers that fixed-line users could call. In many Latin American countries it is unlikely that mobile users could switch to fixed lines (the factors impeding fixed-line growth have been discussed above) and therefore it is likely that overall network size would decrease.

Further, as mobile networks are the only close demand-side substitute to fixed networks the competitive pressure exerted by mobile operators forces fixed-line operators to improve their performance. Some evidence suggests that this in fact has occurred in Latin America.[43]

Finally, increased mobile penetration and high termination charges also benefit fixed-line operators in terms of revenues raised by fixed-to-mobile calls. Increased penetration creates some traffic to and from fixed networks, which then incur only low marginal costs of incoming and outgoing usage. Increased traffic is secured without incurring the investment costs in new infrastructures. In other words, the 'fixed line externality' coupled with the cost structure of fixed networks (low marginal costs and high fixed cost) explains the gains derived by fixed lines operators from the success of mobile telephony.

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[42] We note that the demand for fixed-to-mobile services is typically less price-sensitive than the demand for outgoing mobile calls. This means that the increase of welfare associated with lower prices is typically small. We do not use this point here since the analysis is of fixed line users themselves and not compared to mobile users.

[43] Gutierrez, L., and S. Berg 2000, 'Telecommunications Liberalization and Regulatory Governance: Lessons from Latin America', *Telecommunications Policy,* vol. 24 , pp. 865-884, 879.

Having mobile terminating charges that are above costs has not been a ‘zero sum game’ between fixed and mobile networks – both can benefit from them. In other words, the *two sides of the network* are jointly benefiting from high termination charges. These conclusions are demonstrated more rigorously in section 6.

6 Model simulations and welfare estimations

In this section, we first discuss the concepts of efficiency and welfare. We then estimate the benefits derived from the diffusion of mobile telephony in some Latin American countries based on traditional welfare analysis.[44] We then present the results of a formal model, fitted to reflect country-specific conditions. The primary objective of this model is to estimate both the consumer benefits associated with different levels of fixed-to-mobile termination charges and the diffusion of mobile telephony likely to correspond to these different charges.[45] The modelling results are then translated into dollar values.

6.1 Definitions of welfare and efficiency

Cost-benefit analysis is a quantitative procedure that requires identification of all effects, categorisation of these effects as benefits or costs, quantitative estimation (in a common measure) of each benefit and cost, and eventually discounting of future costs and benefits into the terms of a given year.

At the core of the cost-benefit analysis lies the concept of 'efficiency'. Simply defined, a pricing structure is efficient if it maximises welfare. Politicians, lawmakers, economists and society generally agree that an efficient outcome is more desirable than an inefficient one. To develop criteria for judging economic efficiency economists often treat utility as if it were a measurable scale of consumer satisfaction so as to assess changes (for example, a change in relative prices) in terms of their increasing or decreasing economic welfare[46].

Consumer surplus is defined as the benefit (or utility) a consumer gains from consuming a particular good less the amount paid for the good. If a given consumer buys a good for exactly what it is (subjectively) worth, then they will be indifferent as to whether or not to make the transaction. Since different consumers may have different valuations, it is usually the case that some will buy goods and services that are worth more than their price[47]. Therefore by measuring the additional amount that consumers would be willing

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[44] Sensitivity tests are provided in the Appendix 3.

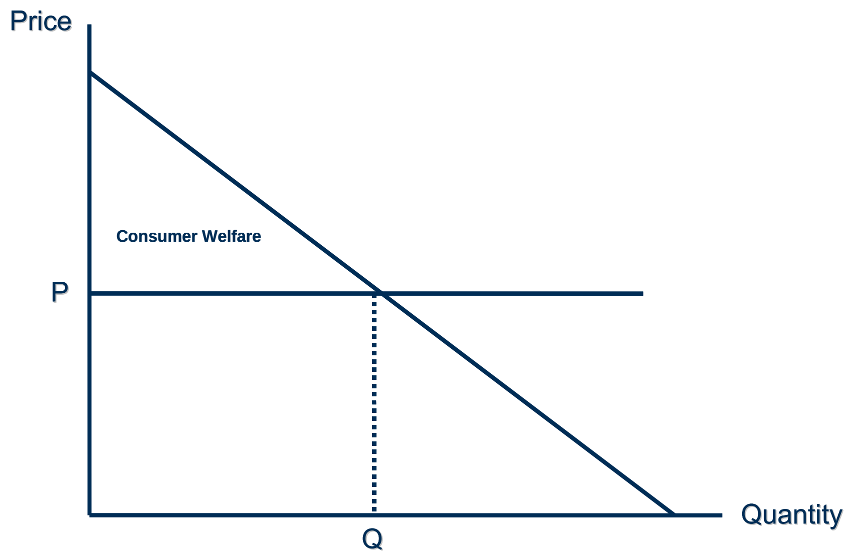
[45] The model and the calibration methodology are presented in the Appendix.

[46] Economists generally use the so-called Kaldor-Hicks criterion, under which any economic change or reorganisation should be considered beneficial if, after the change, gainers could hypothetically compensate the losers and still be better off. Utilising this criterion does not enable us to escape from making interpersonal comparisons, but merely makes the implicit assumptions that a dollar gained or lost should be valued the same regardless of who gains or loses it.

[47] This is because, by definition, the marginal consumer pays her willingness to pay.

pay for a good we can determine how much was gained from the transaction. The demand curve for an individual reflects exactly this: the marginal willingness to pay, or the maximum amount a consumer will spend for an extra unit. Consumer surplus measures the extra well-being derived from a transaction in dollars. Consumer surplus is thus the area bounded above by the demand curve and below by the market price (see Chart 7). Defining the market demand curve as the aggregation of each individual's demand curve therefore leads to the definition of the market consumer surplus.

Chart 7: **Consumer welfare**



6.2 Estimation of consumer surplus

Given the preceding discussion, to compute a value for consumer surplus we need information on the market price and the location of the demand curve. The location of the demand curve can be determined by specifying a functional form and price elasticity at a given price P

These quantities are obtained for each of the countries in this report from the following data:

Table 5: **Prices and quantity data**

	ARPS ($ per month)	***MOU (per month)***	***Mobile Subscribers (million)***
ARGENTINA	11.82	89.42	6.96
CHILE	13.72	106.49	7.13
COLOMBIA	12.81	66.92	8.66
ECUADOR	13.89	68.71	2.42
MEXICO	17.27	67.70	33.42
PERU	16.61	67.13	3.84
URUGUAY	16.66	52.24	0.54
VENEZUELA	16.69	80.82	7.03

Note: ARPS: Average Revenue per Subscriber; MOU: Minutes of Use (average per subscriber)

Source: Pyramid

To compute the consumer welfare, we first define a compound 'price' as the average spending per minute of use (MOU)[48]. This methodology is standard as a direct estimation of consumer welfare[49] and is used to compute the benchmark consumer welfares. Note that by doing this we do not distinguish between the different services bought by mobile users (in contrast to the case in the competition model used in the next section).

Given this price, we then assume that the demand curve is linear with price elasticity equal to –1.5 at the computed price. This enables the consumer surplus in Chart 7 to be fully identified.

Base case results derived using this methodology are provided in Table 6.

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48 For example, in Argentina we have that average revenue per subscriber is $11.82 per month and the average usage per month is 89.42 minutes, so the average price is 11.82/89.42 = $0.13 per MOU.

49 See Robert W. Crandall, Charles L. Jackson and Hal J. Singer, 2003, "The Effect of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy", available at http://www.criterioneconomics.com/docs/ubiquitous_broadband_adoption.pdf and also Jerry A. Hausman, 1997, Valuation and the Effect of Regulation on New Services in Telecommunications", Brookings Papers on Economic Activity, available at http://econ-www.mit.edu/faculty/download_pdf.php?id=470

Table 6: **Baseline consumer surplus**

	Consumer Surplus ($ million per year)
ARGENTINA	329
CHILE	391
COLOMBIA	444
ECUADOR	134
MEXICO	2,309
PERU	255
URUGUAY	36
VENEZUELA	469

Source: NECG Calculations

6.3 Model of competition and impact of F2M termination charge

In this section, we simulate the impact of different levels of F2M termination charges on the consumer surplus estimated above. The simulation is based on the following steps:

- Derivation of a model of competition;
- Fitting the model to reflect country-specific conditions;
- Estimation of the consumer surplus and mobile penetration under different pricing structures; and
- Translation of simulated (index) values into dollar values.

The first step (derivation of a model of competition) is an extension of the model suggested by Julian Wright[50] and is thoroughly described in the Appendix 1.

The methodology used to fit the model to the data (known as 'model calibration') is also described in the Appendix 2. Essentially, the calibration procedure involves choosing the parameters of the model to ensure that when the model is simulated it generates outcomes that are consistent with those actually observed in each country. The outcomes we require the model to attain are the observed mobile penetration rates in each country and the number of subscribers to each network within each country (see Table 7).

50 Wright J. 2000, 'Competition and Termination in Cellular Networks', University of Auckland, available at http://www.crnec.auckland.ac.nz/crnec/research/papers/cellular-new.pdf (accessed May 2004)

Table 7: **Targeted values**

	Argentina	*Chile*	*Colombia*	*Ecuador*	*Mexico*	*Peru*	*Uruguay*	*Venezuela*
Mobile penetration	18.0%	44.3%	19.1%	18.8%	31.9%	13.9%	15.7%	27.0%
Number of firm 1 subscribers per 100 inhabitants	6.7[a]	12.5[a]	2.1[a]	1.2[a]	24.3[a]	7.5[a]	10.3	10.5[a]
Number of firm 2 subscribers per 100 inhabitants	4.5	16.4	12.8	10.5	3.5	3.3	5.5	11.2
Number of firm 3 subscribers per 100 inhabitants	3.8	8.2	2.1	7.1	2.3	3.0	0	4.5
Number of firm 4 subscribers per 100 inhabitants	3.0	7.2	0	0	1.7	0	0	0.7
Number of firm 5 subscribers per 100 inhabitants	0	0	0	0	0	0	0	0.2

a: integrated fixed and mobile operations

Source: Pyramid

We also use the data provided by Pyramid to calibrate the model to country-specific price and demand conditions and we assume an elasticity of –1.5 and –0.5 for outgoing mobile calls and incoming fixed-to-mobile calls, respectively.

The calibrated model is then used to simulate what would happen under different pricing structures and in particular if the F2M termination charges were changed by, say, regulatory intervention.

In the graphs below we plot results from simulation exercises for each country showing the relation between the level of termination charge and:

- the mobile penetration (expressed as a percentage of mobile subscribers to the total population); and
- the consumer surplus obtained by mobile users (expressed as a index, base 100 for the current level of termination charges[51].

Based on these numerical simulations, we then provide a table summarising the welfare losses (in dollar terms) to users of mobile telephony from a decrease of the termination charge by US 2.5 cents and US 5 cents.

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[51] In the appendix, we also report the simulated F2M traffic data for different levels of F2M termination charge, expressed as a index, base 100 for the current level of termination charges.

Argentina

Chart 8: **Mobile Penetration**

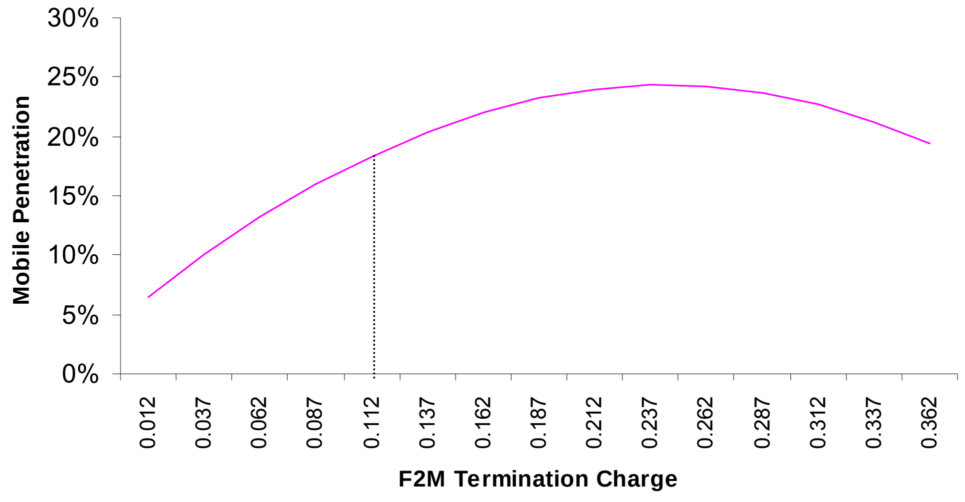
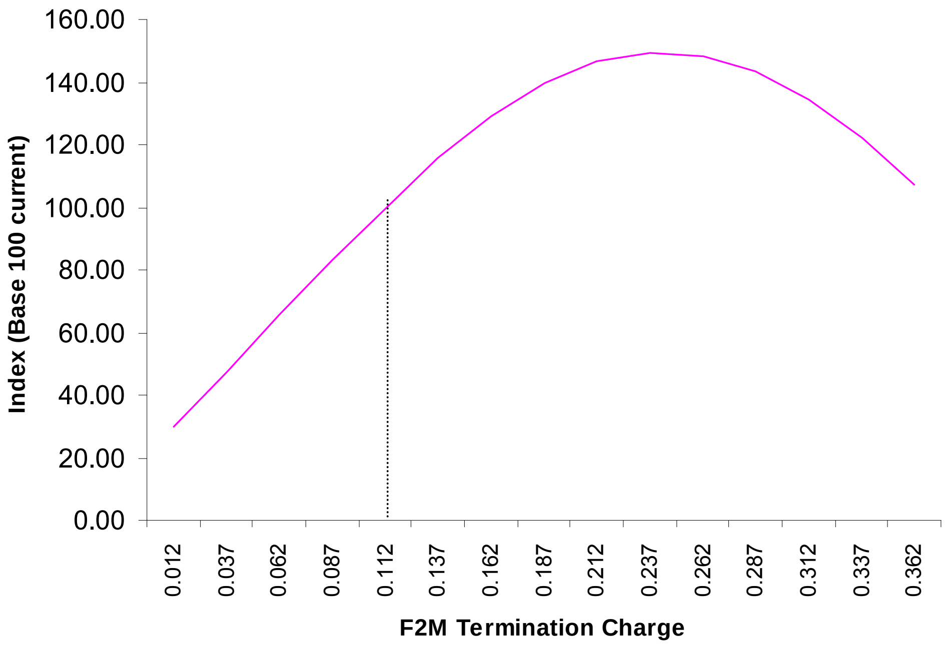


Chart 9: **Cellular Consumer Surplus (Index)**



Chile

Chart 10: **Mobile Penetration**

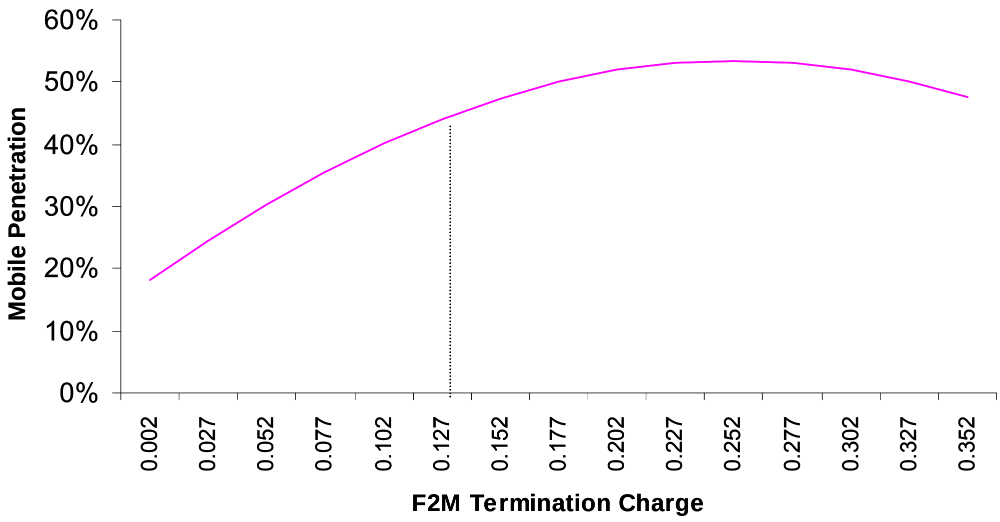
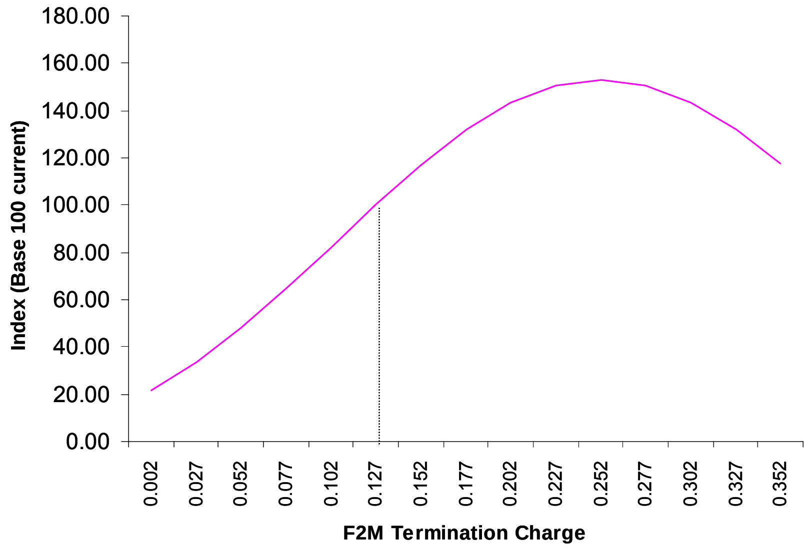


Chart 11: **Cellular Consumer Surplus (Index)**



Columbia

Chart 12: **Mobile Penetration**

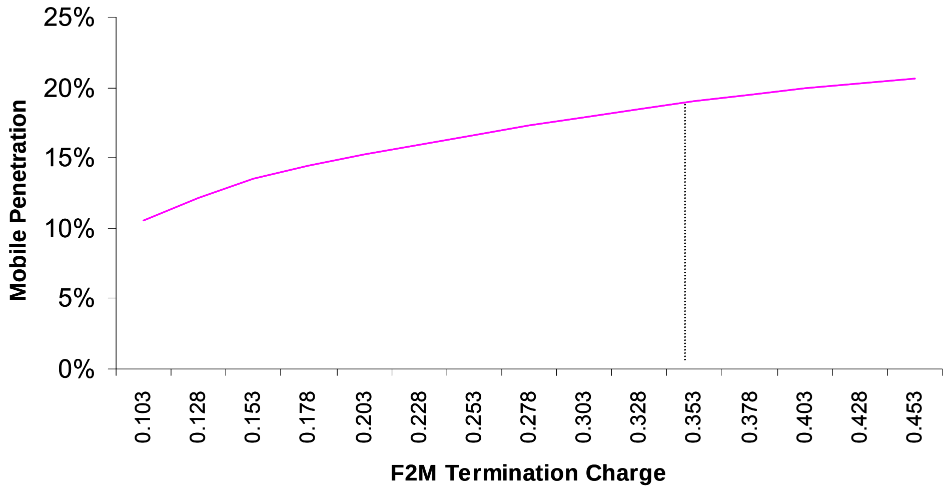
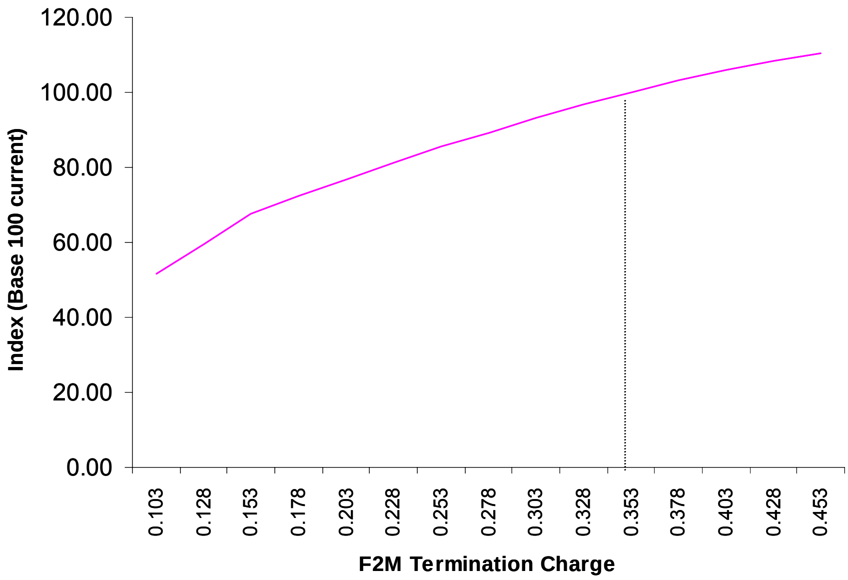


Chart 13: **Cellular Consumer Surplus (Index)**



Ecuador

Chart 14: **Mobile Penetration**

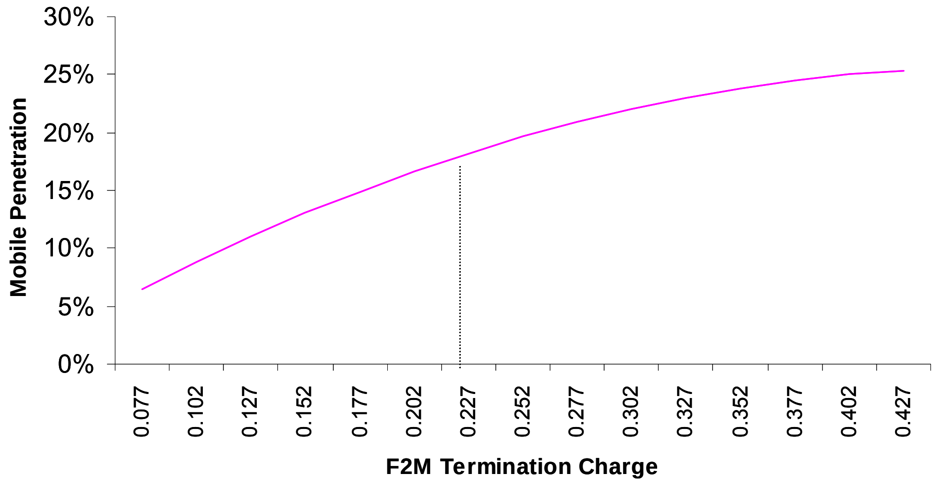
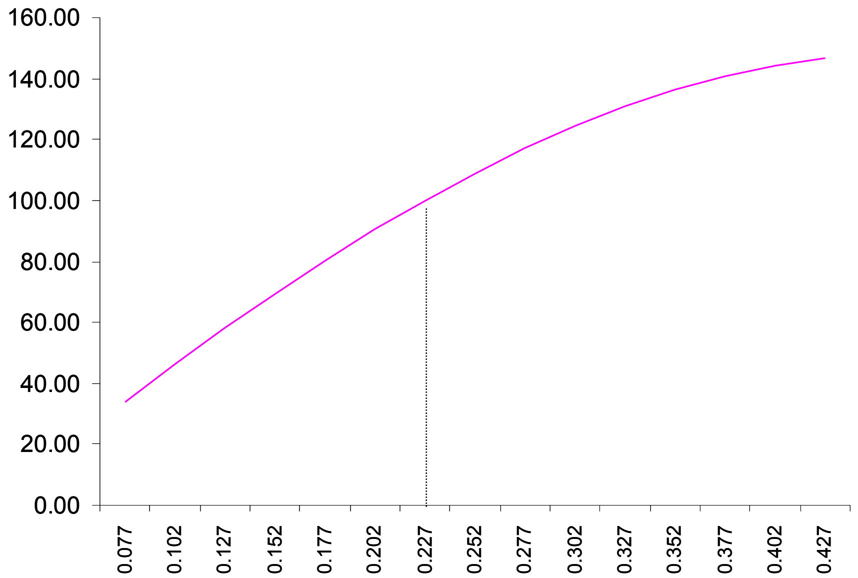


Chart 15: **Cellular Consumer Surplus (Index)**



Mexico

Chart 16: **Mobile Penetration**

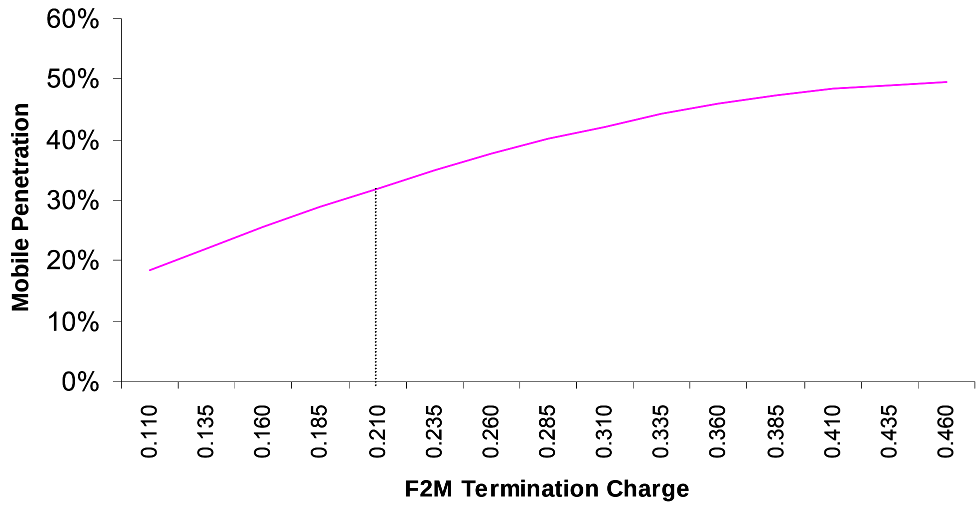
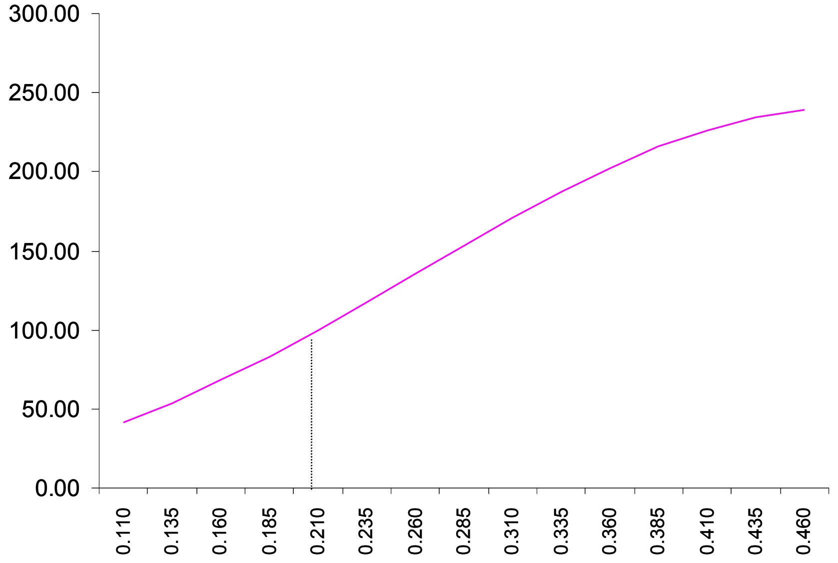


Chart 17: **Cellular Consumer Surplus (Index)**



Peru

Chart 18: **Mobile Penetration**

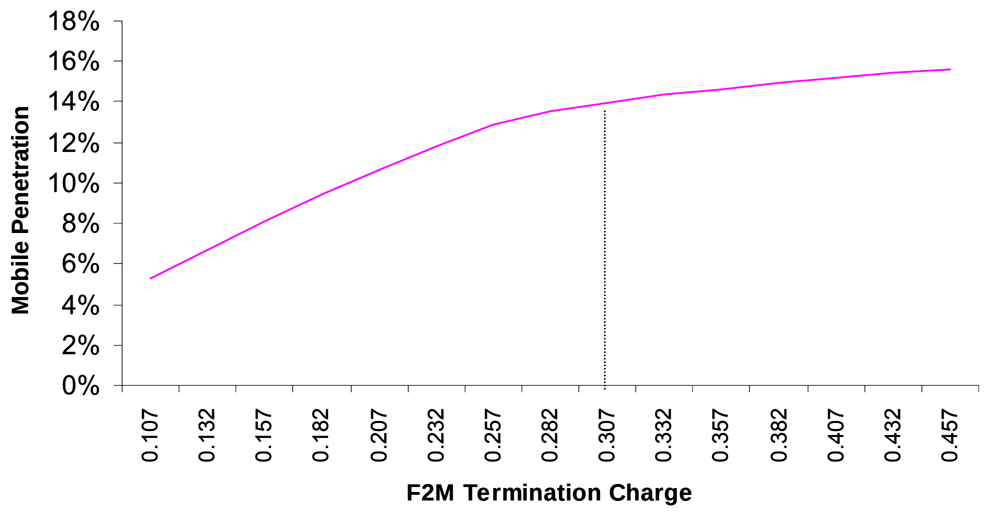
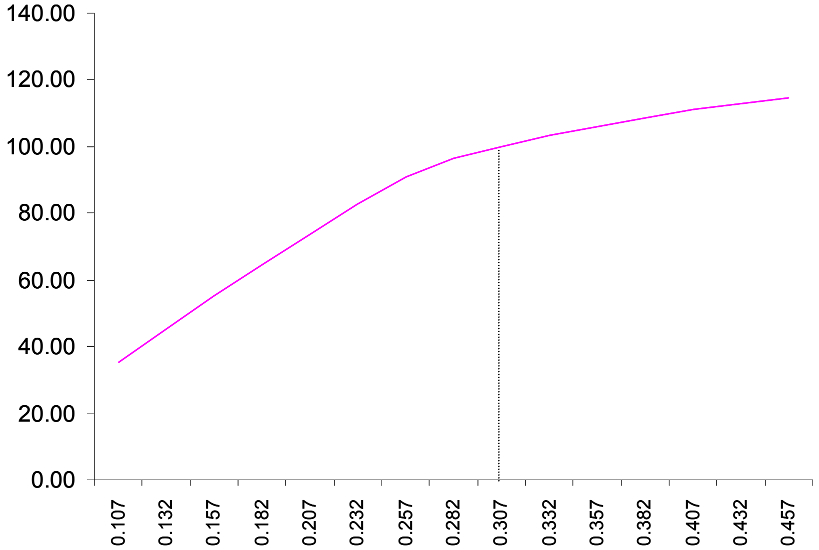


Chart 19: **Cellular Consumer Surplus (Index)**



Uruguay

Chart 20: **Mobile Penetration**

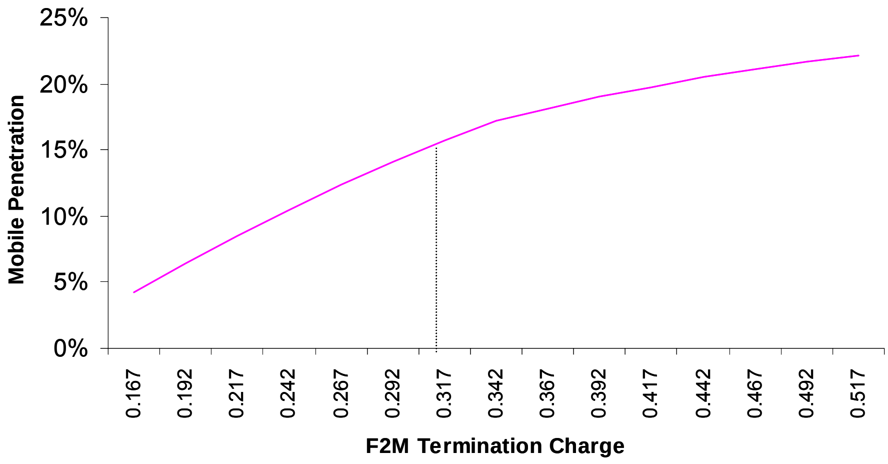
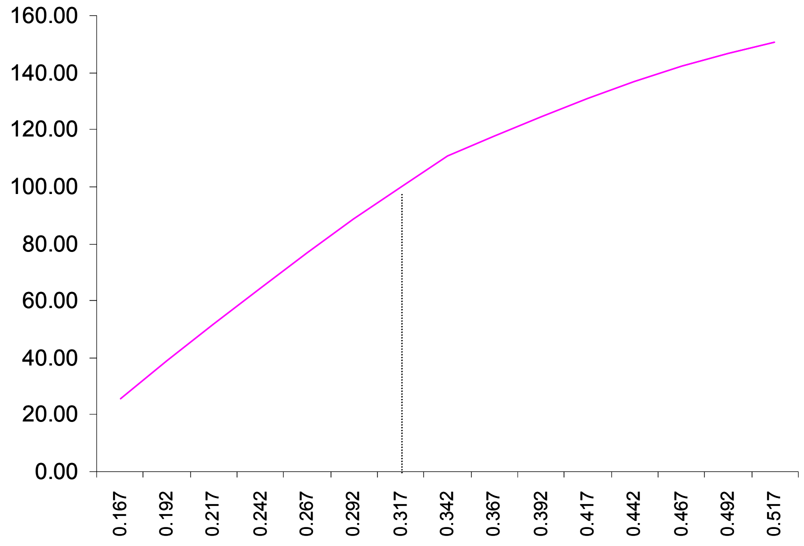


Chart 21: **Cellular Consumer Surplus (Index)**



Venezuela

Chart 22: **Mobile Penetration**

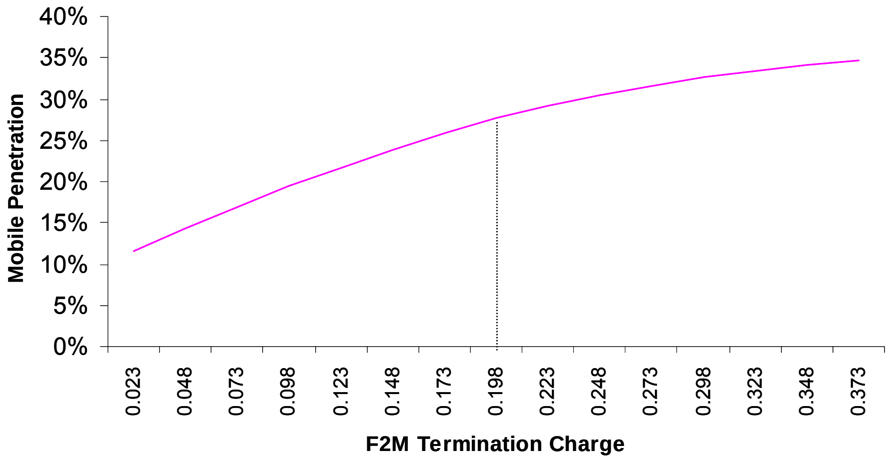
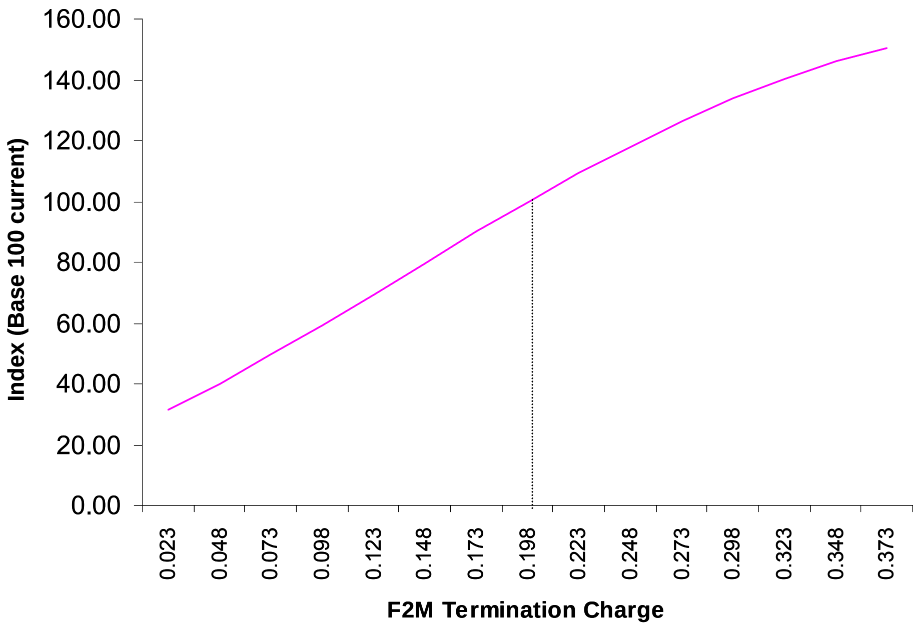


Chart 23: **Cellular Consumer Surplus (Index)**



Summary of welfare effects

The final step is the estimation (in dollar terms) of the change in the consumer welfare resulting from a change of the level of F2M termination charge. These estimations are provided in Table 8 below for decreases equal to US 2.5 cents and US 5 cents of the F2M termination charges, relative to their current levels[52].

Table 8: **Consumer Losses (US$ million per year)**

	US 2.5 cents	*US 5 cents*
ARGENTINA	55 (17%)	113 (34%)
CHILE	70 (18%)	139 (35%)
COLOMBIA	14 (3%)	30 (7%)
ECUADOR	12 (10%)	26 (20%)
MEXICO	382 (17%)	739 (32%)
PERU	9 (3%)	23 (9%)
URUGUAY	4 (12%)	8 (23%)
VENEZUELA	47 (10%)	96 (21%)

Source: NECG Calculation

The general conclusion from these simulated results is that, as explained in section 5, decreasing fixed-to-mobile termination charge is likely to have adverse consequences on the mobile penetration and ultimately on the welfare derived from mobile telephony networks. Furthermore, a relatively high termination charge benefits not only cellular subscribers but also fixed-line subscribers, who are being able to call new mobile subscribers. The results presented in Appendix 4 show that, in the neighbourhood of current levels, higher retail fixed-to-mobile prices are more than compensated by the higher number of mobile subscribers – so that the total fixed-to-mobile traffic increases; an effect that also benefits fixed line operators.

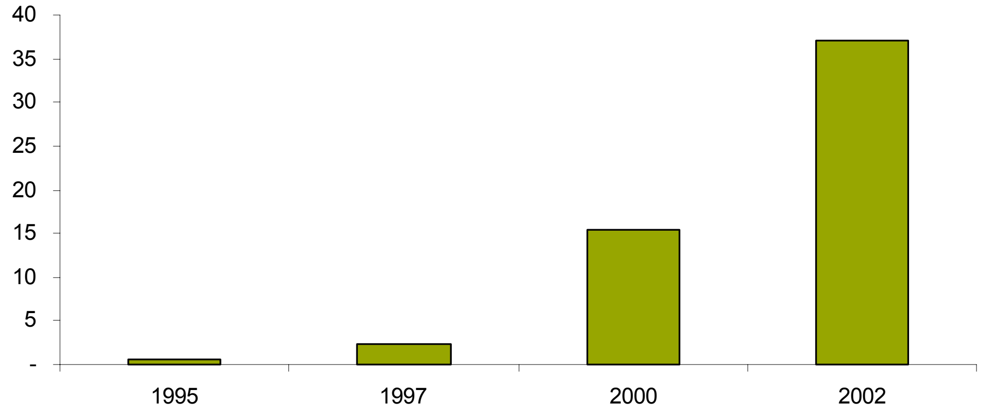
52 These dollar values are computed based on (1) the Base Case results provided in Table 2 and (2) the indices simulated above.

Annexure A - Diffusion of mobile telephony in developing regions

This annexure illustrates the diffusion of mobile telephony in Latin America, East and Southeast Asia and Africa.

In Africa, the poorest of these continents, the number of cellular subscribers has increased from approximately 600,000 in 1995 to 15.5 million in 2000 to in excess of 37 million in 2002. Even excluding South Africa, Africa's richest country, the growth remains impressive – 110,000 subscribers in 1995 had increased to 23 million in 2002.

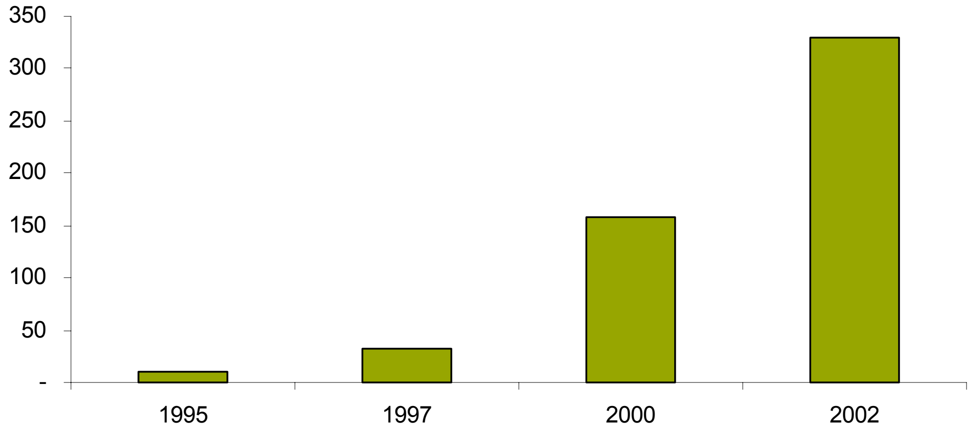
Chart 24: **Mobile subscribers in Africa (millions)**



Data source: ITU

East and Southeast Asia (excluding Japan) has experienced even larger growth. The number of subscribers grew from 10 million in 1995 to 329 million in 2002. China accounts for a massive share of this increase, from fewer than 3 million subscribers in 1995 to more than 200 million in 2002. Even excluding China, the region still saw cellular-subscriber numbers jump from 7 million to 122 million over that same period, an increase in excess of 1600 per cent – that is, a compound annual growth rate of more than fifty per cent.

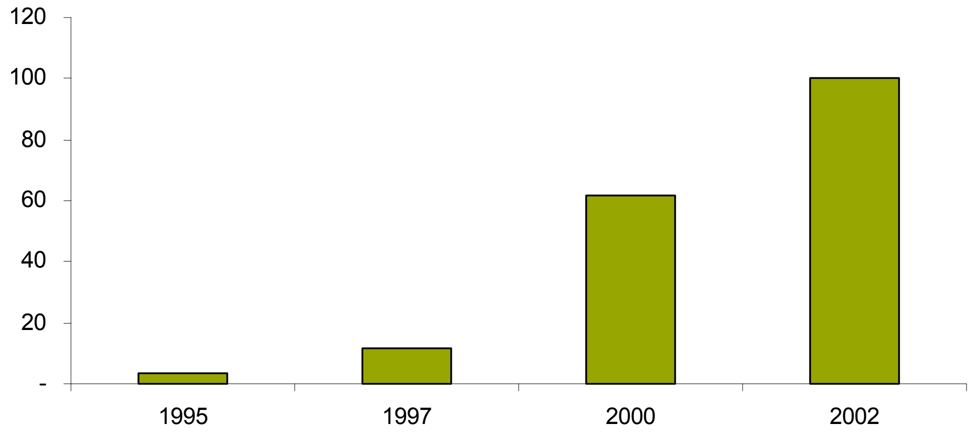
Chart 25: **Mobile subscribers in East and Southeast Asia (ex. Japan) – (millions)**



Data source: ITU

Slightly lower rates of growth were evident in Latin America, where the number of cellular subscribers increased nearly 25-fold, from 4 million in 1995 to 100 million in 2002.

Chart 26: **Mobile subscribers in Latin America – (millions)**

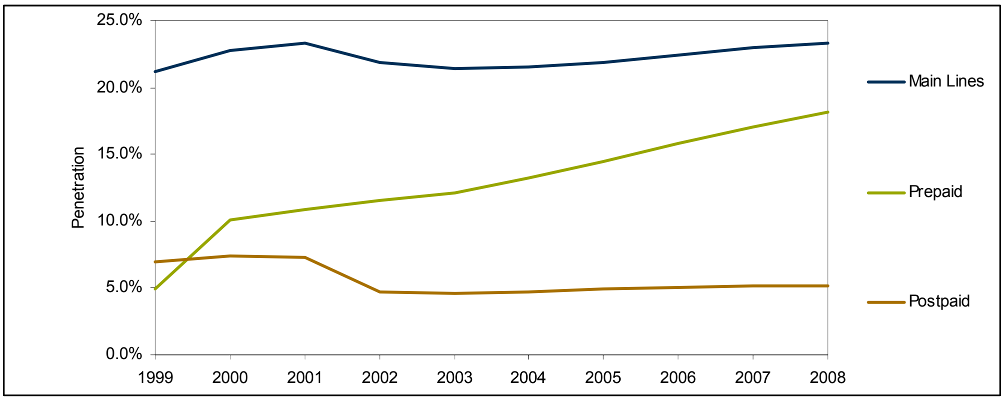


Data source: ITU

Annexure B - Penetration of telephony in Latin America

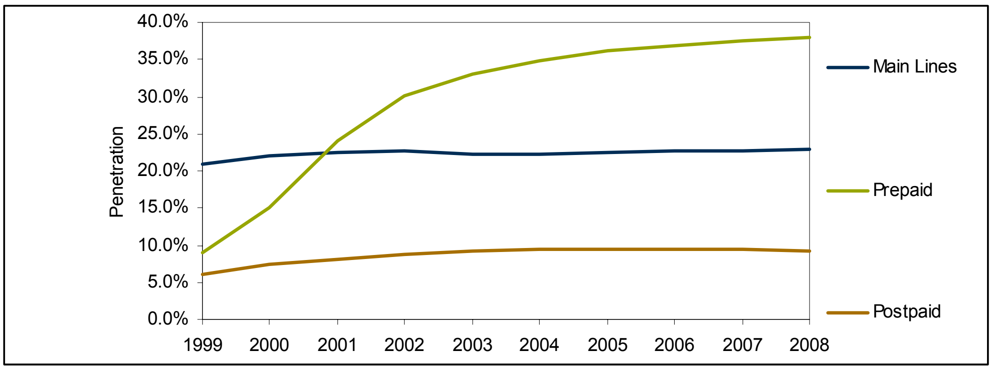
This annexure presents the growth of prepaid and postpaid mobile telephony as they are expected to evolve through time in several Latin American countries.

Chart 27: **Market Penetration – Argentina**



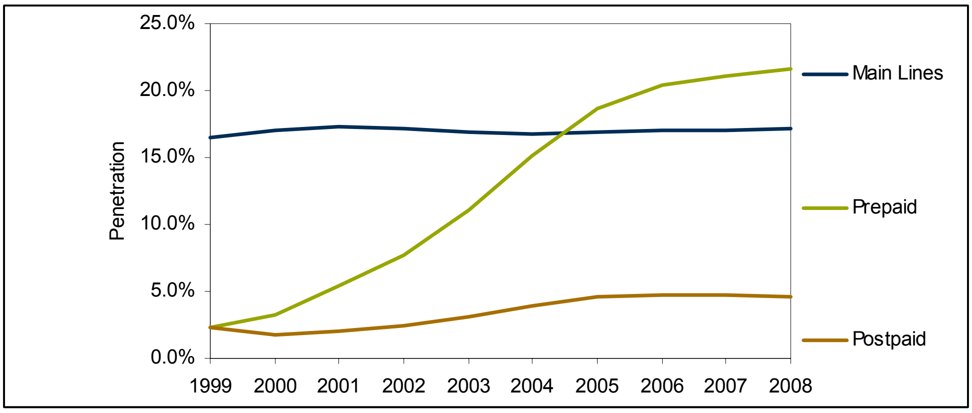
Data source: Pyramid Research

Chart 28: **Market Penetration – Chile**



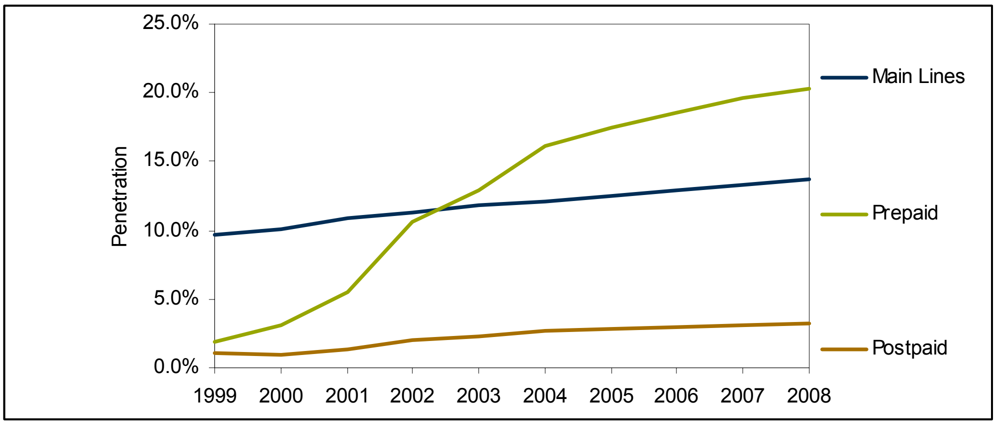
Data source: Pyramid Research

Chart 29: **Market Penetration – Colombia**



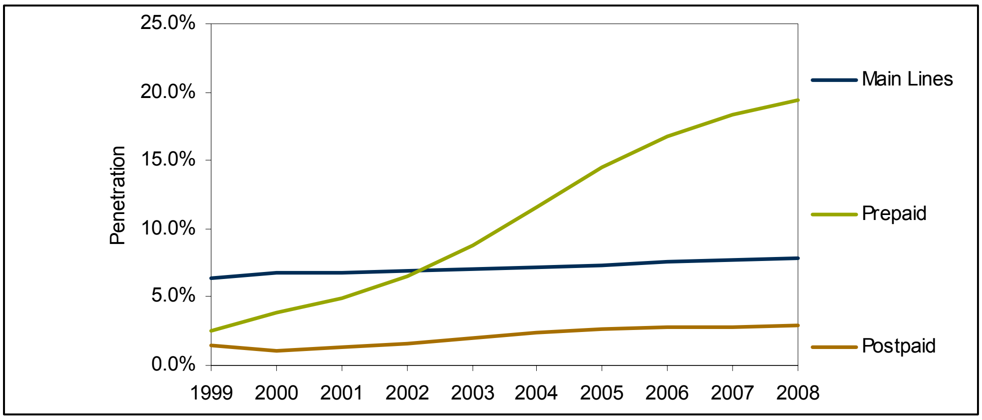
Data source: Pyramid Research

Chart 30: **Market Penetration – Ecuador**



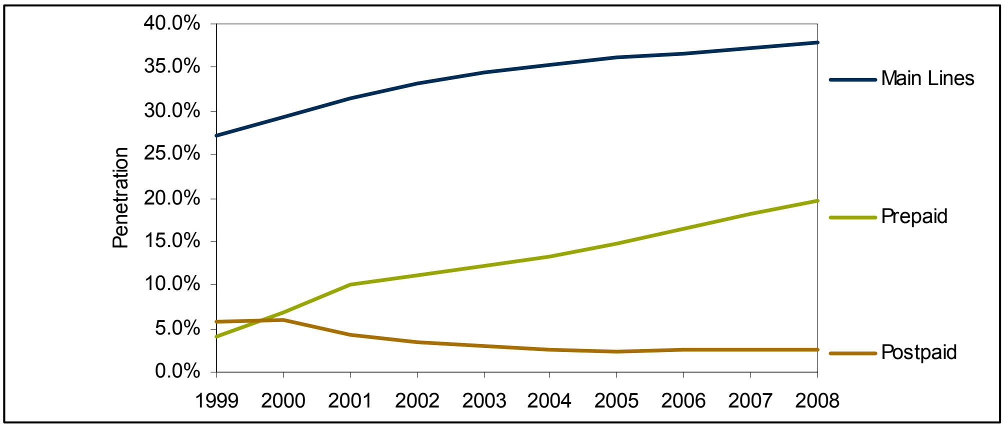
Data source: Pyramid Research

Chart 31: **Market Penetration – Peru**



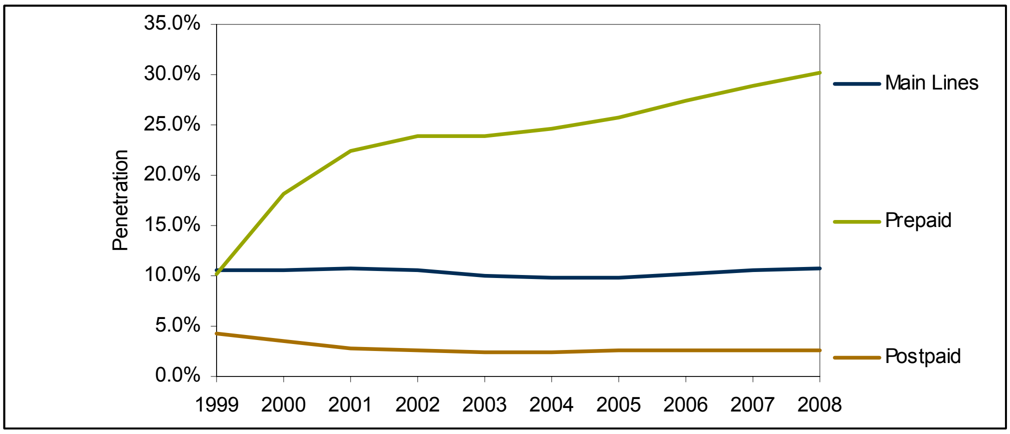
Data source: Pyramid Research

Chart 32: **Market Penetration – Uruguay**



Data source: Pyramid Research

Chart 33: **Market Penetration – Venezuela**

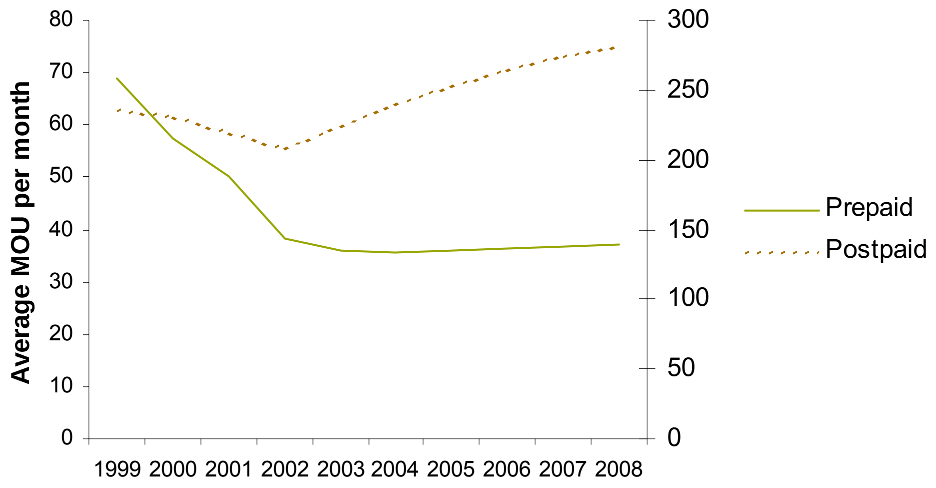


Data source: Pyramid Research

Annexure C - Minutes of use in Latin America

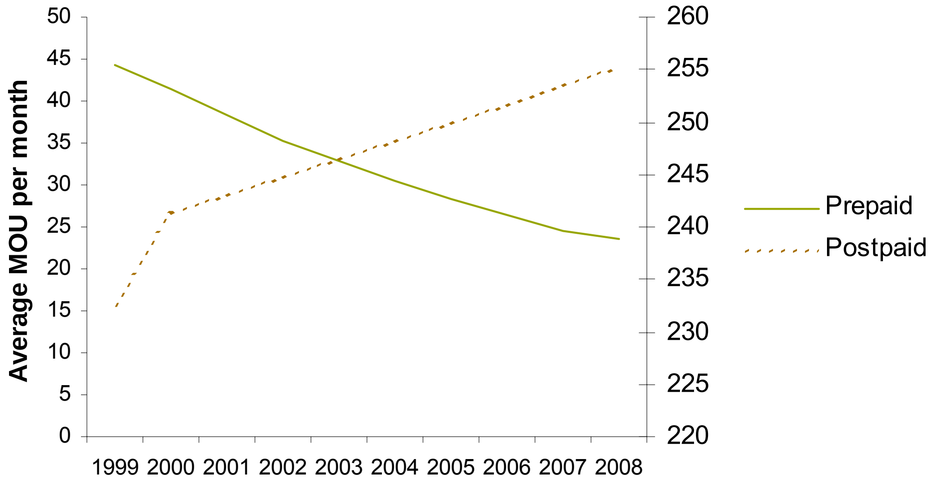
This annexure presents the average minutes of mobile telephone use for prepaid and post-paid contracts respectively, as they are expected to evolve through time in several Latin American countries.

Chart 34: **Minutes of Use (MOU) Argentina**



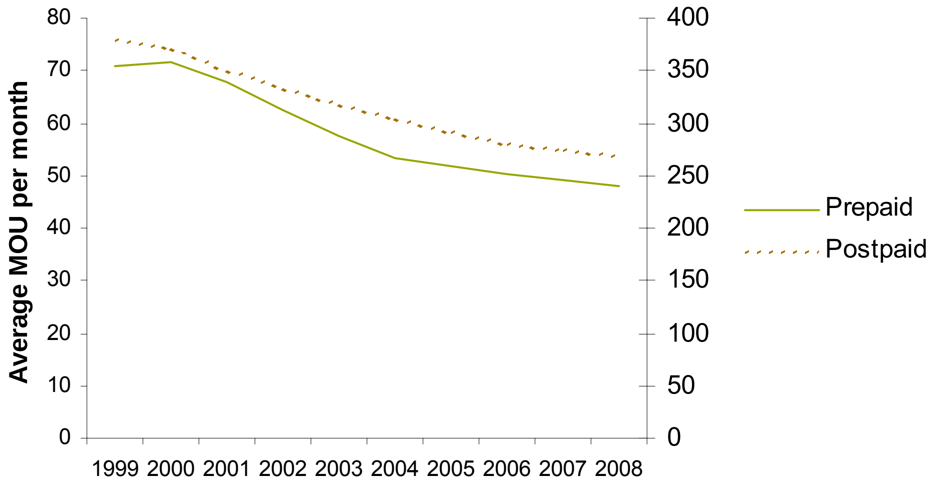
Data source: Pyramid Research

Chart 35: **MOU - Bolivia**



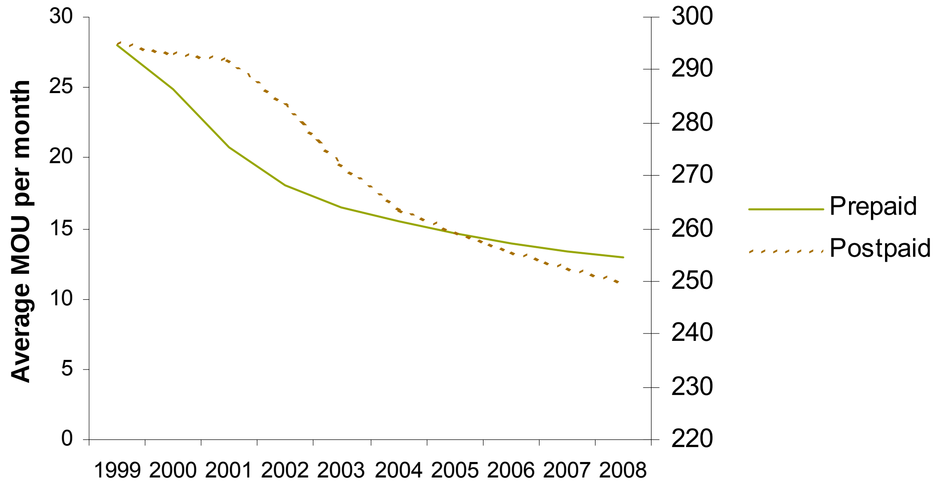
Data source: Pyramid Research

Chart 36: **MOU - Chile**



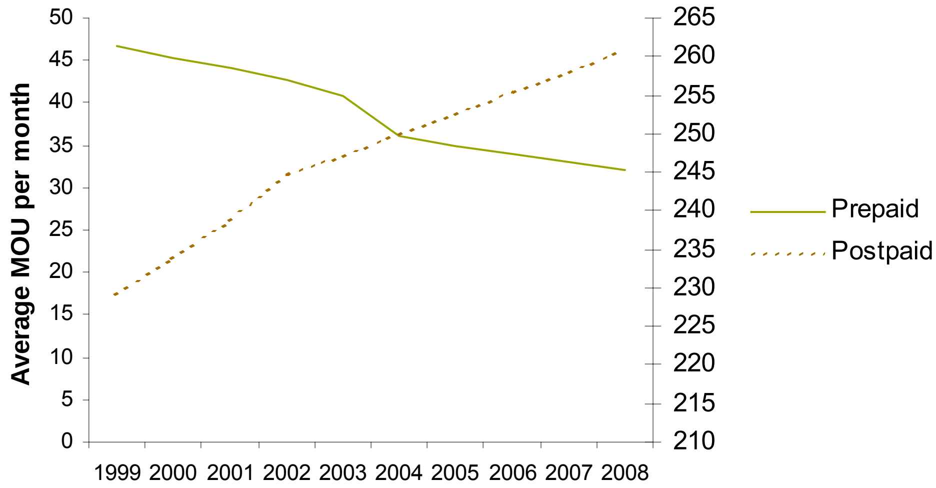
Data source: Pyramid Research

Chart 37: **MOU - Colombia**



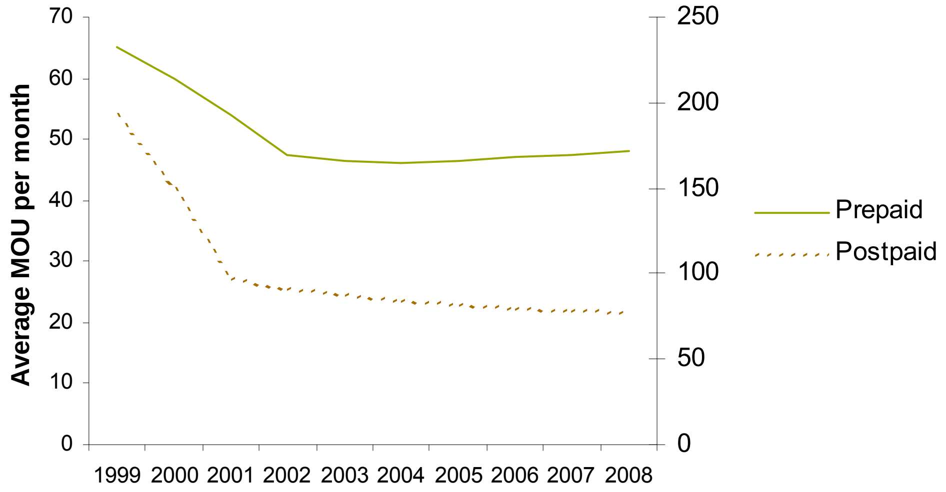
Data source: Pyramid Research

Chart 38: **MOU - Ecuador**



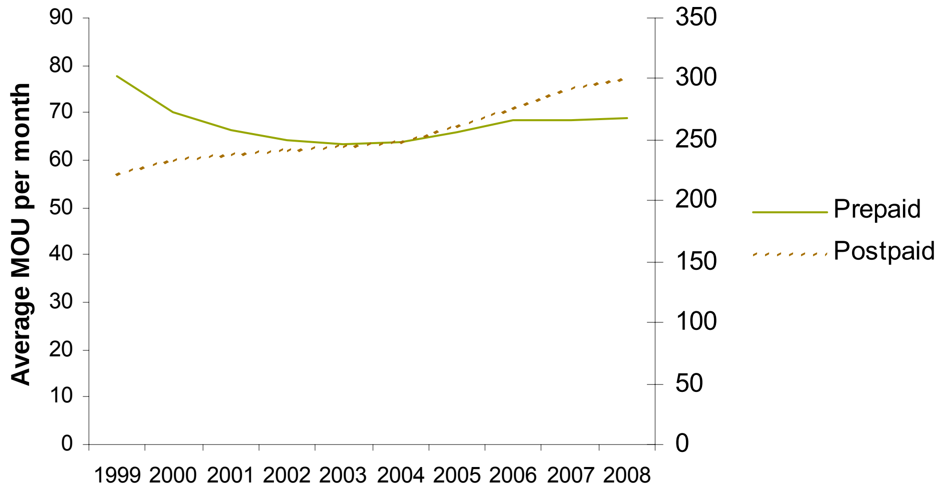
Data source: Pyramid Research

Chart 39: **MOU - Uruguay**



Data source: Pyramid Research

Chart 40: **MOU - Venezuela**



Data source: Pyramid Research

Appendix 1 - Analytical Model

We have developed a model of competition to generalise the results reported in Wright's cellular termination model.[53] This appendix documents the derivation of the model. The algorithm used to compute the numerical solution and the method used to fit the model to the data are described in Appendix 2.

A.1 Market structure

We start by assuming that there is some number *N* of interconnected cellular operators that sell the following services to a fixed set of potential consumers:

- mobile-to-mobile calls;
- mobile-to-fixed calls; and
- fixed-to-mobile terminating services.

A single fixed-to-mobile operator provides the fixed-to-mobile retail service. The fixed-line provider may be a monopoly provider or integrated with a cellular provider.

The cellular firms offer similar services but may have different market shares even if they set the same prices. The extent to which one firm may attract (and retain) a larger number of subscribers could depend on the particular services offered to its subscribers, and/or the particular brand preferences on the part of consumers. These additional factors that differentiate cellular firms are described when consumer utility is introduced.

A.2 Termination services

The fixed-to-mobile and mobile-to-mobile terminating charges are parameters used to estimate the welfare consequences of different price levels of this service. As parameters they are not endogenously determined – rather, they are set at different levels to test the efficiency of the implied price structure by comparing the estimated welfares.

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[53] Wright J. 2000, 'Competition and Termination in Cellular Networks', University of Auckland, available at http://www.crnec.auckland.ac.nz/crnec/research/papers/cellular-new.pdf (accessed May 2004)

A.3 Population

The fixed set of potential consumers of mobile services comprises the entire population. The population could be defined as the total number of residents in a given country or alternatively as any other measure that could describe more realistically the population of potential mobile subscribers. For example, one may exclude very young children. The potential set of subscribers is, however, different from the actual number of mobile subscribers. That is to say, market penetration is determined endogenously.

A.4 Willingness to pay and demand for telecommunications services

The demand for each type of call (including from fixed subscribers to mobile subscribers) is characterised by demand functions. These demand functions are the result of optimising behaviour: each subscriber maximises his or her consumer surplus.

In terms of willingness to pay for access, the heterogeneity among the members of a particular group has two components:

- the preference for a particular cellular operator; and
- the preference for having access to the cellular network in general.

The latter preference reflects the valuation of a potential subscriber for simply having access to mobile services in general. This valuation is assumed to be independent from the amount of usage of mobile services, which are modelled separately. Potential consumers with high valuation for access (i.e. a high willingness to pay) are more likely to join one of the cellular networks.

The preference for a particular cellular operator reflects the fact that the operators will differ in some respects. For example, although not explicitly modelled, cellular operators may have a difference in geographic coverage, may appeal to different groups of the population, or may have different brand awareness. This differentiation has two features.

- It can be asymmetric in the sense that a firm may be seen as providing a higher quality or, simply enjoy a higher brand loyalty.[54]
- Even without qualitative asymmetries, there will be some non-price differentiation between cellular firms, which means a small unilateral price cut will not lead all consumers to switch operators.[55]

In summary, each potential mobile subscriber is characterised by a willingness to pay for:

- mobile-to-mobile call-minutes;

---

[54] Economists define this as vertical product differentiation

[55] This differentiation is called horizontal product differentiation.

- mobile-to-fixed call-minutes;
- access to any of the mobile operators; and
- access to a specific mobile operator.

A representative consumer's utility from subscribing to cellular network *i* for one year can then be written as

(1) $U_i = w_i + \theta_i + v_i \ , \ i = 1,\ldots,N$

where w_i is the net benefit from call-related services, θ_i is the operator-specific benefit and $v_i \in [\underline{v}, \bar{v}]$ is a benefit from subscription to any cellular operator.

In addition, fixed-line subscribers have a willingness to pay for calling mobile subscribers.

A.5 Model derivation

A.5.1 Call-related services

To model the utility from call services w_i let

p_i = Per-minute price of M2M

p_i^f = Per-minute price of M2F

r_i = Fixed charge for mobile subscription

q_i = Quantity of minutes of M2M purchased over one year

q_i^f = Quantity of minutes of M2F purchased over one year

ρ = Penetration rate (defined below)

Then the optimal benefit from one year of call-related services is given by[56]

(2) $w_i = \rho \ v(p_i) + v(p_i^f) - r_i$

where

(3) $v(p_i) = \max_{q_i} \{ u \ (q_i) - p_i \, q_i \}$

and

[56] Since cellular market penetration is less than 100%, the surplus arising from M2M calls has to be multiplied by the penetration rate ρ to account for the fact it is not possible to make M2M calls to all other people.

(4) $v(p_i^f) = \max_{q_i^f} \{ u^f(q_i^f) - p_i^f q_i^f \}$

Thus for example if the consumer's utility function from making q_i calls is $u(q_i) = (m_0 - m_1 q_i) q_i$, $m_0, m_1 > 0$, we would have the optimisations

(5) $\max_{q_i} \{ (m_0 - m_1 q_i) q_i - p_i q_i \}$

which implies demand functions of the form

(6) $q_i = \dfrac{1}{2m_1}(m_0 - p_i)$

and maximised utility given prices can be obtained by substituting (6) into (3), and likewise for (4).

A.5.2 Operator-specific benefits

To model operator-specific benefits θ_i we assume consumers are arranged around the edges of a *N*-dimensional simplex. This means all firms are the same distance from one another and each firm competes with every other firm. Normalising the total distance along the edges of the simplex to 1, and noting that there are *N*(*N*-1)/2 such intervals, we have that the length $L = |i - j|$ of any single interval (*i*,*j*) is

(7) $L = 2 / N(N-1)$

If we then specify $x_{i \to j} \in [0, L]$ as the position index on the simplex measuring the distance from firm *i* in the direction of firm *j*, we can write the firm-specific benefit as

(8) $\theta_i = \beta_i - t x_{i \to j}$

where β_i is the maximum benefit to a consumer of subscribing to firm *i* (it can be used to capture brand loyalty towards particular operators), and $t > 0$ is a parameter determining the rate at which this benefit declines as the consumer moves away from point *i* (it indexes the inverse degree of competition, since a higher value of *t* implies a lower degree of substitution between firms for a given change in relative prices).

A.5.3 Market shares

From above we have that the total benefit a consumer located between firm *i* and firm *j* obtains from subscribing to firm *i* is given by

(9) $U_i = w_i + (\beta_i - t x_{i \to j}) + v_0$

and, similarly, the net benefit the consumer obtains from subscribing to firm $j \neq i$ is given by

(10) $U_j = w_j + (\beta_j - tx_{j \to i}) + v_0$.

Thus the marginal consumer located on the interval between firm i and j will equate (9) and (10)[57], so that

(11) $w_i + \beta_i - tx_{i \to j} = w_j + \beta_j - tx_{j \to i}$

and since $x_{j \to i} = L - x_{i \to j}$ we can solve to obtain the market share (assuming full market participation) of firm i of consumers located between i and j as

(12) $s_{i \to j} \equiv x^*_{i \to j} = \dfrac{L}{2} + \dfrac{1}{2t}\left[(w_i - w_j) + (\beta_i - \beta_j)\right]$

A.5.4 Market participation

In the model we assume consumers are endowed with characteristics indexed by $(x_{i \to j}, v_0)$. That is, any consumer will be located between just two firms, denoted here i and j, so the first characteristic x defines the distance from i in the direction of j, while the second characteristic is the value v_0 the consumer obtains from having access to the cellular network in general. This defines a region $[\overline{v} \; - \underline{v}\;] \times [0, L] \times N(N-1)/2$ with total measure $(\overline{v} - \underline{v})$. Assuming the consumers are uniformly distributed over this region we can define the penetration rate as the proportion of the region for which $U_i > 0$, $i = 1,\ldots,N$, which is given by

(13) $\rho = \dfrac{1}{(\overline{v} - \underline{v})} \sum_{i=1}^{N} n_i$

where n_i is the measure of consumers subscribing to operator i.

To obtain this measure for a given firm i we note that the marginal consumer will join a firm at the point

(14) $U_i = 0$ for any $i = 1,\ldots,N$

and will switch between firms i and j at the point

(15) $U_i = U_j$,

57 Note that if v_0 is sufficiently low it is possible that the marginal consumer has negative utility, in which case in an incomplete market-penetration model they would opt out altogether. This issue is addressed in the next Section.

It follows from this that the measure of firm *i* in the direction of firm *j* is given by the area of the region in the $(x_{i\to j}, v_0)$ plane in which both $U_i > 0$ and $U_i > U_j$. This region is bounded by the curves (12) and[58]

(16) $$x_{i\to j} = t^{-1}(w_i + \beta_i + v_0)$$

Since the equations are linear the measure can be computed simply as[59]

(17) $$n_{i\to j} = \left[\bar{v} - \frac{1}{2}(v_{i\to j} + v_i)\right] \times s_{i\to j}$$

where $s_{i\to j}$ is as in (12) and

(18) $$v_i = -(w_i + \beta_i)$$

(19) $$v_{i\to j} = \frac{tL}{2} - \frac{1}{2}\left[(w_i + w_j) + (\beta_i + \beta_j)\right]$$

Substituting (18) and (19) into (17) gives:

(20) $$n_{i\to j} = \left[\bar{v} - \frac{1}{4}\left[tL - 3(w_i + \beta_i) - (w_j + \beta_j)\right]\right] \times s_{i\to j}$$

and the consumer measure for each firm *i* is obtained by summing across all $j \neq i$

(21) $$n_i = \sum_{j\neq i} n_{i\to j}, \qquad i = 1,\ldots,N$$

from which ρ can be obtained.

A.5.5 Profits

The profit functions depend on whether or not the fixed-line service provider is also a supplier of cellular service.

Integrated fixed-line case

Let firm $i = 1$ be the integrated fixed-line service provider and cellular provider and let firms $i = 2,\ldots,N$ be the remaining cellular-only providers. The profit of cellular firm *i* is generated from three sources: calls originating on its network, calls terminating on its network, and rentals. Let

---

58 Equation (16) is the curve $U_i = 0$.

59 Note that this derivation assumes that $(w_i + \beta_i) < 0$, which needs to be checked and imposed a s a constraint in simulations.

c = Per-minute cost to cellular firm i of originating and terminating calls to/from all points

C = Per-minute cost to fixed-line network of originating and terminating calls to/from all points

f = Fixed cost per subscriber to firm i of providing cellular service (per year)

Q = Quantity of minutes called by fixed-line consumers to each mobile subscriber over one year

a = Per-minute F2M termination charge levied by cellular service providers

P = Per-minute price levied by fixed line network of calling from fixed to cellular

Then we have that the integrated firm's total profit is given by the sum of profit from cellular services and fixed line services[60]

$$\begin{aligned}\pi_1 &= n_1\left[(p_1^f - c - C)q_1^f + \rho(p_1 - 2c)q_1 + (r_1 - f)\right] \\ &+ \left[\left(\sum_{i=1}^{N} n_1\right)(P - C) - n_1 c - \sum_{i=2}^{N} n_i a\right]Q\end{aligned} \tag{22}$$

and for cellular firms $i = 2,\ldots,N$

$$\pi_i = n_i\begin{bmatrix}(p_i^f - c - C)q_i^f + \rho(p_i - 2c)q_i + \\ (a - c)Q + (r_i - f)\end{bmatrix} \tag{23}$$

In both cases the demand functions are given by (6) and

$$Q = B_0 - B_1 P \tag{24}$$

Non-integrated fixed-line case

In the non-integrated case the cellular firm derives profit only from the provision of cellular service. Thus we have that cellular firm 1 total profit is given by

$$\pi_1 = n_1\begin{bmatrix}(p_1^f - c - C)q_1^f + \rho(p_1 - 2c)q_1 + \\ (a - c)Q + (r_1 - f)\end{bmatrix} \tag{25}$$

and the demand functions are given by (6).

---

60 We have assumed that cellular providers are charged a termination charge by the fixed-line provider for M2F calls equal to cost so there is no term in the integrated firm's profit function corresponding to this term. Likewise, we have assumed M2M calls are terminated at cost. Thus, we focus only on the effects of F2M termination charges which may differ from cost.

In this case, the profit (loss) of the fixed-line supplier is generated from originating calls to the cellular networks.[61] Thus:

$$(26) \quad \Pi = \left(\sum_{i=1}^{N} n_i \, (P - C - a) \right) \times Q$$

where Q is the demand curve as specified in (24).

A.6 Equilibrium and theoretical model solution

The equilibrium in retail prices is taken as the Nash equilibrium with respect to all prices, which is obtained by the simultaneous solution of the maximised profit functions with respect to each firm's decision variables.

The decision variables are (r_1 , p_1 , p_1^f).[62] The first-order conditions are

$$(27) \quad \frac{\partial \pi_i}{\partial p_i} = 0 \qquad i = 1,\ldots,N$$

$$(28) \quad \frac{\partial \pi_i}{\partial p_i^f} = 0 \qquad i = 1,\ldots,N$$

$$(29) \quad \frac{\partial \pi_i}{\partial r_i} = 0 \qquad i = 1,\ldots,N$$

Solving (27) and (28) yields:

$$(30) \quad p_i = 2c$$

$$(31) \quad p_i^f = c + C$$

The solution to (29) has no analytical solution (see Wright, 2000) and is obtained numerically.

A.7 Measuring consumer welfare

We define total consumer surplus as the sum of the surplus from cellular and fixed-line usage. The surplus from outgoing cellular usage is equal to the volume of the region

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61 It also depends on variables such as service/rental charges, but these are exogenous to the system we are considering and can be ignored.

62 We assume that the F2M retail price is exogenous. It is equal to the F2M termination charge, *a*, plus the marginal cost of fixed origination *C*, plus a mark-up, *xa*. For an extension to the optimised F2M retail price, see Julian Wright, 2000, opt. cit.

under the utility function in which $U_i > 0$, summed across all firms and consumer groups. The area of this region was computed earlier as the consumer measure $n_{i\to j}$ in (21). To obtain the volume of this region we integrate $x_{i\to j}$ and v_0 from (9). The fixed-line surplus is equal to the area under the fixed-line demand curve above the market price. Putting these two terms together we get the following expression for consumer surplus.

(32) $$CS = \sum_{i=1}^{N} \sum_{j \neq i} CS_{i\to j}$$

where $CS_{i\to j}$ is the consumer surplus in the region of firm *i* in the direction of firm *j*, which is given by

(33) $$\begin{aligned} CS_{i\to j} &= \int_{v_i}^{v_{i\to j}} \int_0^{x_{i\to j}} U_i \, dx dv_0 + \int_{v_{i\to j}}^{\bar{v}} \int_0^{s_{i\to j}} U_i \, dx dv_0 \\ &= \int_{v_i}^{v_{i\to j}} \int_0^{\frac{1}{t}(w_i + \beta_i + v_0)} \left[w_i + (\beta_i - x_{i\to j} t) + v_0 \right] dx_{i\to j} dv_0 \\ &\quad + \int_{v_{i\to j}}^{\bar{v}} \int_0^{s_{i\to j}} \left[w_i + (\beta_i - x_{i\to j} t) + v_0 \right] dx_{i\to j} dv_0 \\ &= \frac{1}{2t} \int_{v_i}^{v_{i\to j}} (w_i + \beta_i + v_0)^2 dv_0 \\ &\quad + \int_{v_{i\to j}}^{\bar{v}} [(w_i + \beta_i + v_0 - s_{i\to j} t / 2) s_{i\to j}] dv_0 \\ &= \frac{1}{6t} \left[(w_i + \beta_i + v_{i\to j})^3 - (w_i + \beta_i + v_i)^3 \right] \\ &\quad + (w_i + \beta_i - \tfrac{1}{2} t\, s_{i\to j}) s_{i\to j} (\bar{v} - v_{i\to j}) + \tfrac{1}{2} s_{i\to j} [(\bar{v})^2 - (v_{i\to j})^2] \end{aligned}$$

and since $v_i = -(w_i + \beta_i)$, we can solve to obtain

(34) $$\begin{aligned} CS_{i\to j} &= \tfrac{1}{6t} (w_i + \beta_i + v_{i\to j})^3 + \{ (w_i + \beta_i - \tfrac{1}{2} t\, s_{i\to j})(\bar{v} - v_{i\to j}) \\ &\quad + \tfrac{1}{2} [(\bar{v})^2 - (v_{i\to j})^2] \} s_{i\to j} \end{aligned}$$

Summing across all firms *j≠i* we have the consumer surplus associated with firm *i*

(35) $$CS_i = \sum_{j \neq i} CS_{i\to j}$$

and it follows that the total consumer surplus is obtained by summing across the N firms, and adding the consumer surplus from fixed-to-mobile calls:

$$(36) \quad CS = \sum_{i=1}^{N} CS_i + \left(\sum_{i=1}^{N} n_i \right) \int_{P}^{B_0 / B_1} Q$$

$$= \sum_{i=1}^{N} CS_i + \left(\sum_{i=1}^{N} n_i \right) \frac{1}{2B_1} [Q]^2$$

Appendix 2 - Computation of model and parameter estimation

A.8 Model Solution

To obtain the equilibrium of the system, we allow each firm, in turn, to maximise its profits by choice of its decision variables, subject to the prices and rentals of the other firms. Equilibrium is reached when no firm is able to alter prices and rentals to increase its own profits.

Formally, let Ω represent the set of exogenous variables and parameters in the system and let $H_i^{[m]} = (r_i \ , p_i \ , p_i^f)$ be the set of decision variables for firm *i* at iteration *m*. Denote $H_{\backslash i}^{[m]}$ as the set of decision variables for all firms other than firm *i* at iteration *m*. Then given an arbitrary set of starting values $(H_1^{[0]},...,H_N^{[0]})$, the Nash equilibrium is taken to be the set of values $(H_1^{[M]},...,H_N^{[M]})$ for which

$$\sum_{i=1}^{N} | \pi_i^{[m]} - \pi_i^{[m-1]} |^2 < \text{TOL} \quad \forall m > M$$

where

$$\pi_1^{[m]} = \max_{[H_1]} \left\{ \pi_1 \mid H_{\backslash 1}^{[m]}, \Omega \right\}$$

$$\pi_2^{[m]} = \max_{[H_2]} \left\{ \pi_2 \mid H_1^{[m+1]}, H_3^{[m]},..., H_N^{[m]}, \Omega \right\}$$

…

$$\pi_N^{[m]} = \max_{[H_N]} \left\{ \pi_N \mid H_{\backslash N}^{[m+1]}, \Omega \right\}$$

and TOL is the tolerance level (set to 0.3 in simulations). Since analytic solutions are available for profit-maximising prices in (30)-(31), the maximisations only have to be performed numerically with respect to r_i. That is, if we let $\Omega^* = \{\Omega, p_i \ = 2c, p_i^f \ = c + C, P = c + a + ax\}$, the sequence of optimisations reduces to

$$\pi_1^{[m]} = \max_{\{r_1\}} \left\{ \pi_1 \mid r_{\backslash 1}^{[m]}, \Omega^* \right\}$$

$$\pi_2^{[m]} = \max_{\{r_2\}} \left\{ \pi_2 \mid r_1^{[m+1]}, r_3^{[m]},..., r_N^{[m]}, \Omega^* \right\}$$

…

$$\pi_N^{[m]} = \max_{\{r_N\}} \left\{ \pi_N \mid r_1^{[m+1]}, \ldots, r_{N-1}^{[m+1]}, \Omega^* \right\}$$

Since the profit functions (22), (23), (25) and (26) depend on the participation rate ρ and the consumer measures n_i, these also have to be obtained at each iteration of r_i. Writing the equations for these variables in their general form

$$w_i = g_1(\rho \mid p_i, p_i^f, r_i)$$

$$n_i = g_2(w_i \mid \bar{v}, \sigma, L, \beta_i)$$

$$\rho = g_3(n_i \mid \bar{v}, \underline{v})$$

we can see that the system is simultaneous in (ρ, n_i, w_i). Therefore to obtain the participation rate and consumer measures at each iteration of r_i, we obtain ρ and n_i by finding the fixed point of the above system. Since it is non-linear this is done numerically by iterating on ρ. The fixed-point iteration minimises the objective criterion

$$(\rho - g_3(n_i \mid \bar{v}, \underline{v}))^2 \Big| \{r_i^{[m]}\}_{i=1}^N, \Omega^*$$

subject to

$$n_i = g_2(w_i \mid \bar{v}, \sigma, L, \beta_i)$$

$$w_i = g_1(\rho \mid p_i, p_i^f, r_i)$$

All computations are performed using the MATLAB (Version 6) programming language. Baseline simulations with the fixed point solved to 3 decimal places take approximately 15 seconds on a 1200 MHz Pentium(R).

A.9 Fitting the Model to the Data

The procedure described above obtains the model solution conditional on Ω, the set of exogenous variables and parameters in the system. The next step is therefore to estimate the values of some elements of this set so ensure that the simulated model variables match country-specific conditions.

To do this we choose a set of observed variables that we wish the model to be matched to then we iterate on the model parameters until an exact match is obtained between the observed values and the simulated model values. The observed values we target are the market penetration rate and the number of subscribers that each firm obtains. For example, in the 3-firm case,

Table 9: **System identification and calibration**

Targets	Definition	Calibrated parameters	Normalisation
ρ	Mobile penetration	$\overline{v}$	$\beta_1 = 0$
n_1	Number of subscriber firm 1 per 100 inhabitants	t	Total Population = 100
n_2	Number of subscriber firm 2 per 100 inhabitants	β_2	$\underline{v} = 0$
n_3	Number of subscriber firm 3 per 100 inhabitants	β_3	

A.10 Simulations of the impact of termination charges

Once the model has been calibrated to country-specific conditions (i.e. once the numerical values of set Ω have been found) the next step is to solve the model for different level of F2M termination charges. In other words, the model is solved while keeping Ω constant except for the variable *a*, which takes a range of values.

These simulations are used to compute the impact of different levels of F2M termination charge on:

- Mobile penetration;
- Surplus obtained by mobile users (index value); and
- Total F2M traffic (index value).

Appendix 3 – Traditional welfare estimation

In addition to the base case results, we provide in the following box the different estimated values of consumer surplus under:

- different functional forms (linear vs. constant elasticity); and
- different price elasticities.

The formulas used in the estimations are described in the following table:

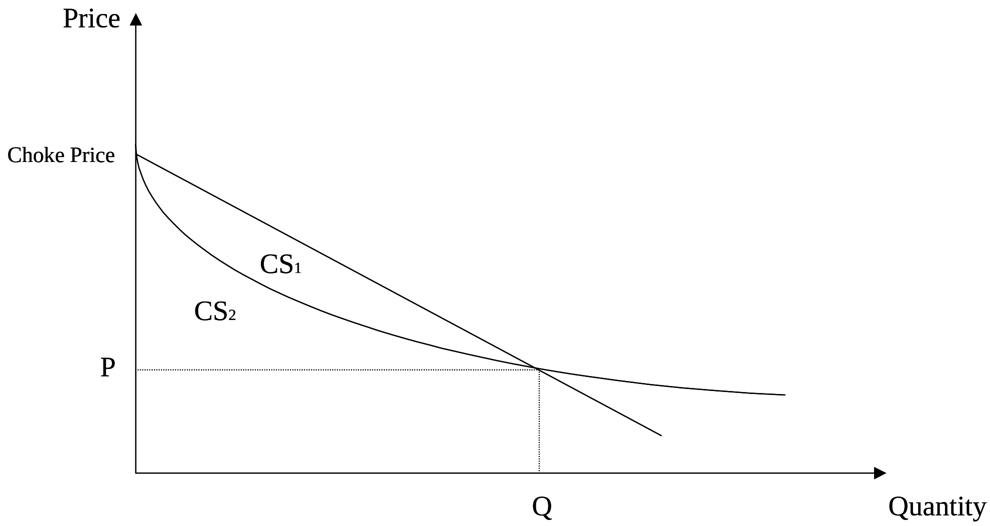
Table 10: **Welfare computation**

	Linear demand	Constant price elasticity
Demand function	Q=A+BP	$P=(A/B).Q^{1/\gamma}$
Price elasticity	$\varepsilon < 0$	$\gamma < 0$
Consumer surplus	$-P.Q/\ 2\varepsilon$	$-P.Q/\ (1+\gamma)$

Note: Q quantity; P Price, A, B: demand parameters, (A/B) is the choke price, i.e. the price above which no one would subscribe. This price is determined by P, Q, ε under the linear demand assumption.

In the following chart, the consumer surplus under the linear demand assumption is CS_1+CS_2, while the consumer surplus under the constant price elasticity demand assumption is CS_2.

Chart 41: **Consumer surplus under linear demand vs. constant price elasticity demand**



Note: See Robert W. Crandall, Charles L. Jackson and Hal J. Singer, 2003, opt.cit.

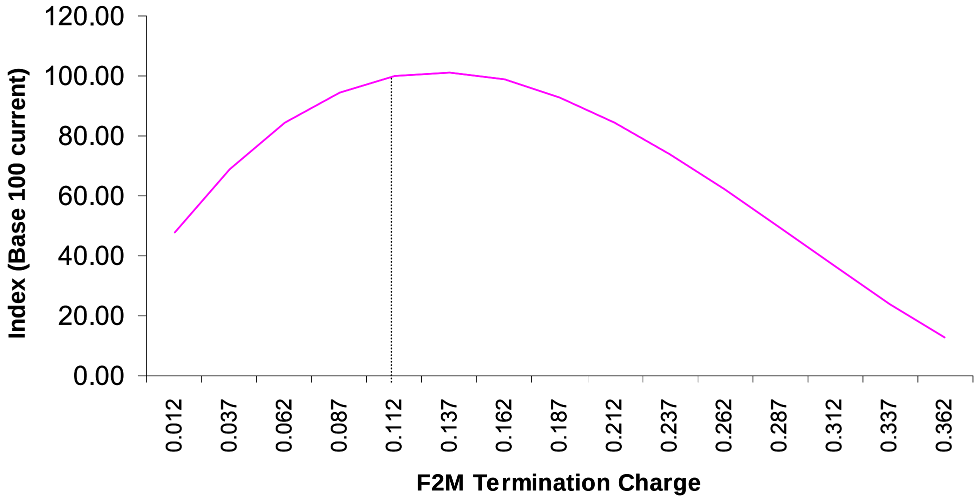
Box 1 Consumer surplus (US$ million)

Country	Consumer Surplus		Price Elasticity of Linear Demand		
			1.50	1.00	2.00
ARGENTINA	Demand Function	linear	329	494	247
		log-linear	127	180	98
CHILE	Demand Function	linear	391	586	293
		log-linear	144	205	112
COLOMBIA	Demand Function	linear	444	666	333
		log-linear	184	263	142
ECUADOR	Demand Function	linear	134	201	101
		log-linear	55	79	43
MEXICO	Demand Function	linear	2,309	3,464	1,732
		log-linear	955	1,364	737
PERU	Demand Function	linear	255	383	191
		log-linear	106	151	82
URUGUAY	Demand Function	linear	36	54	27
		log-linear	16	23	12
VENEZUELA	Demand Function	linear	469	704	352
		log-linear	185	264	143

Appendix 4 – F2M Traffic

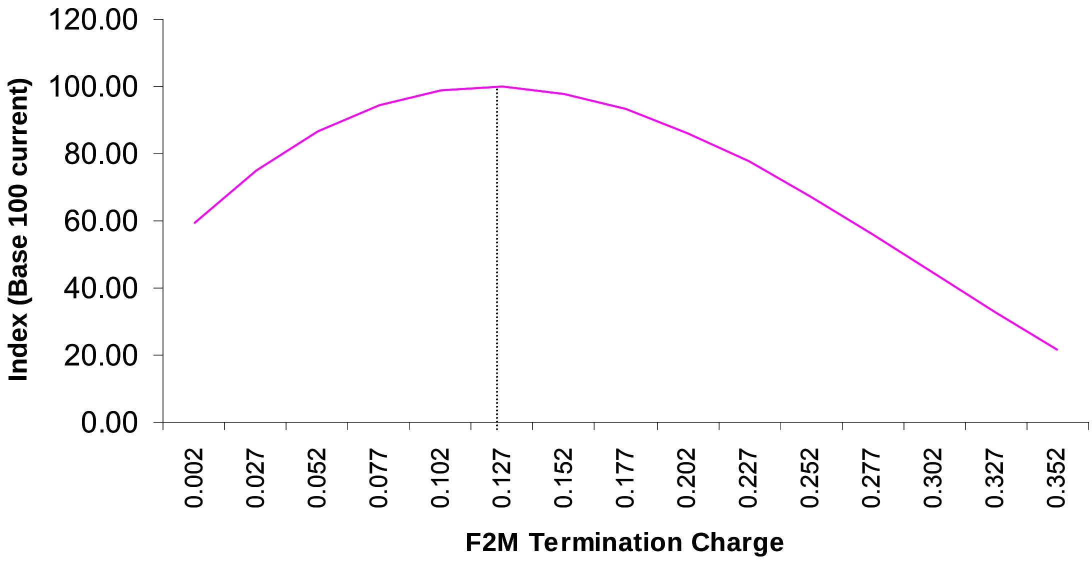
Argentina

Chart 42 **F2M Traffic (Index)**



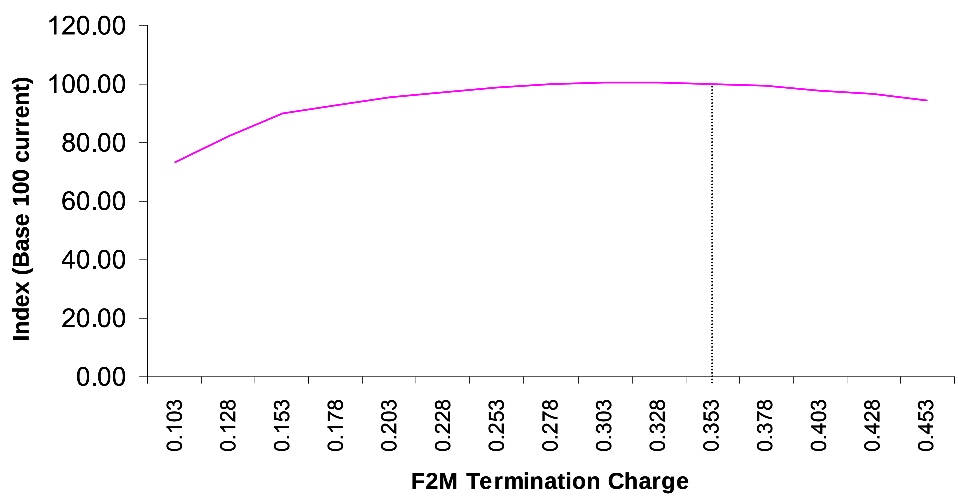
Chile

Chart 43 **F2M Traffic (Index)**



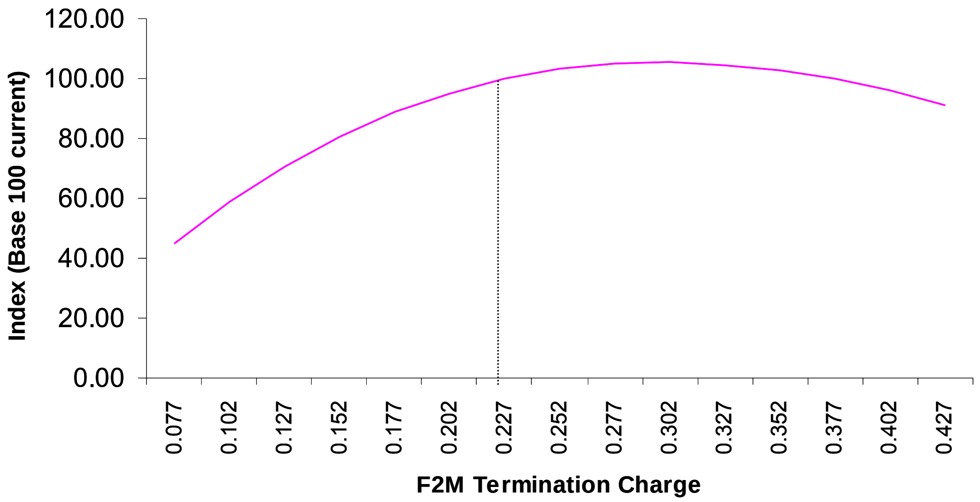
Colombia

Chart 44 **F2M Traffic (Index)**



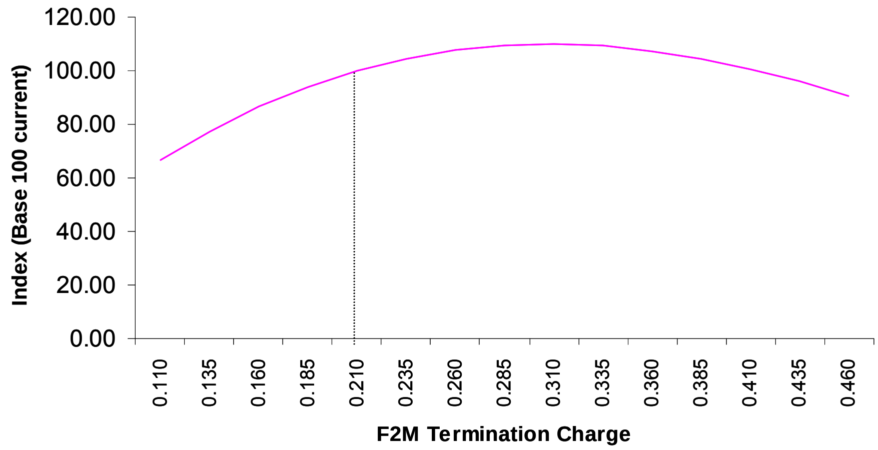
Ecuador

Chart 45 **F2M Traffic (Index)**



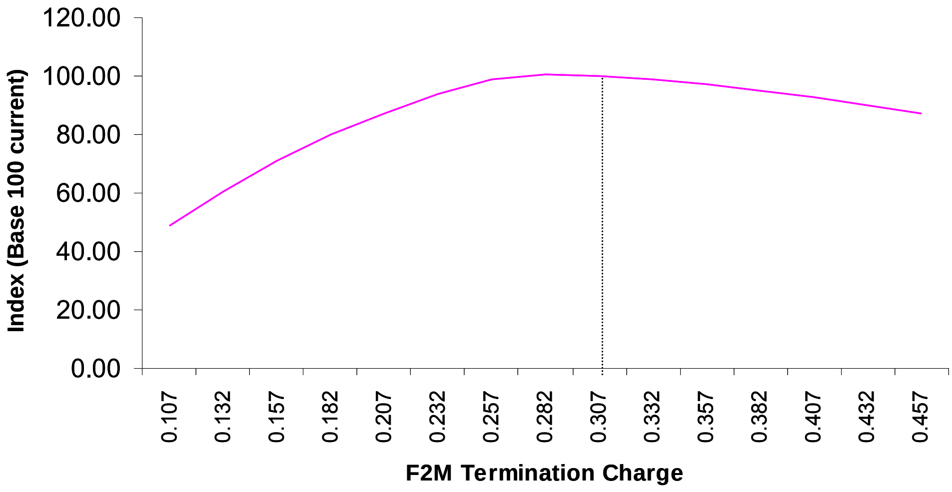
Mexico

Chart 46 **F2M Traffic (Index)**



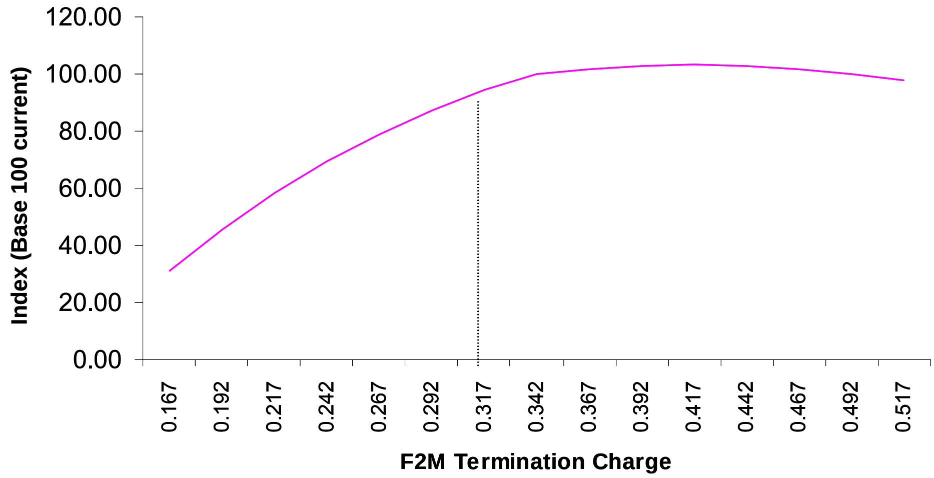
Peru

Chart 47 **F2M Traffic (Index)**



Uruguay

Chart 48 **F2M Traffic (Index)**



Venezuela

Chart 49 **F2M Traffic (Index)**