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# An Assessment of Telecommunications Reform in Developing Countries

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## Abstract

Fink, Mattoo, and Rathindran analyze the effect of policy reform in basic telecommunications on sectoral performance using a new panel data set for 86 developing countries across Africa, Asia, the Middle East, and Latin America and the Caribbean over the period 1985 to 1999. The authors address three questions:

- What impact do specific policy changes—relating to ownership and competition—have on sectoral performance?
- How is the impact of change in any one policy affected by the implementation of the other, and by the overall regulatory framework?
- Does the sequence in which reforms are implemented affect performance?

The authors find that both privatization and competition lead to significant improvements in performance. But a comprehensive reform program, involving both policies and the support of an independent regulator, produced the largest gains—an 8 percent higher level of mainlines and a 21 percent higher level of productivity compared to years of partial and no reform. Interestingly, the sequence of reform matters: mainline penetration is lower if competition is introduced after privatization, rather than at the same time. The authors also find that autonomous factors, such as technological progress, have a strong influence on telecommunications performance, accounting for an increase of 5 percent a year in teledensity and 9 percent in productivity over the period 1985 to 1999.


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# An Assessment of Telecommunications Reform in Developing Countries

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## I. Introduction

The dynamism of global telecommunications markets is widely attributed to rapid technological development and an increasingly liberal policy environment. Over the past decade, a large number of developing economies have embarked on reform paths, and witnessed significant expansion of their telecommunications networks and striking improvements in productivity.[1] Over the period 1985-1999, mainline penetration and productivity in developing countries more than tripled. But neither performance nor policy was uniform within or across regions. For example, while mainline penetration in Sri Lanka increased more than five-fold, Malawi saw a more modest 40% increase. It is not obvious where the improved performance is because of specific policy choices rather than in spite of them, and where more could have been achieved had policy been different.

Telecommunications liberalization is a complex and relatively new process for developing countries. Choices have to be made regarding the privatization of state-owned telecommunications operators, the introduction of competition, the opening of markets to foreign investment and the establishment of pro-competitive regulations. While there is growing consensus that each of these elements is desirable, it is a rare country that has immediately gone all the way on all fronts. In general, governments have differed in their willingness to concede control to the market, and most have a penchant for gradualism. Competition has been introduced, but the number of firms has been fixed by policy; privatization is often partial and there are limits on foreign participation; "autonomous" regulators have been created but are rarely fully independent.[2]

This paper has a dual purpose. First, to introduce a new data set for 86 developing countries on telecommunications policy (described in Appendix 1).[3] Second, to analyze the impact of telecom policy on telecom sector performance. We address three questions. First, what impact do specific policy changes – relating to ownership, competition and regulation - have on sectoral performance? Second, how is the impact of any one policy change affected by the implementation of complementary reforms? Third, does the sequence in which reforms are implemented affect performance?

There are several recent cross-country econometric studies examining the effect of telecommunications reform on sector performance.[4] Wallsten (2001), Ros (1999), Li and Xu

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[1] Substantial reform has also taken place in Eastern Europe. However, this study focuses on developing countries where network development was much more limited.

[2] Noll (2000) sets forth the problems of telecommunications policy reform and analyzes the same within the historical, economic and political context of developing countries.

[3] The "newness" of our data refers to the fact that we have information on competition in the local fixed line segment, the analogue mobile segment, and the digital mobile segment for 86 countries until 1999. Further, we also have data on strategic foreign equity in the incumbent fixed-line operator.

[4] There have also been studies that examine the link between telephone density (or teledensity) and economic development. For example, Jipp (1963) first brought to light the strong correlation between teledensity and the level of GDP per-capita. Further, there are recent studies that look at the relationship between telecom liberalization and macroeconomic performance. See, for example, Roller and Waverman (2001) & Mattoo et. al. (2001).

(2001) explore the effects of reforms such as privatization, competition and regulation on several performance indicators, using panel data. While the results broadly indicate that liberalization of the sector improves performance, different country samples and estimation techniques lead to differing conclusions about the effects of specific policies.

Our empirical investigation improves upon existing studies in several ways. First, we explore not only individual and interactive effects of policy choices, but also whether the *sequencing* of privatization and competition affects performance. This latter dimension of telecommunications reform has not been analyzed before. Second, we explicitly allow for the fact that, aside from policy reforms, autonomous technological advances drove improvements in telecommunications performance in recent years. We quantify the relative importance of autonomous and policy-induced improvements in sector performance. Third, we use more comprehensive data on policy and regulation than previous studies. Our panel spans the years 1985-1999 and thus captures a large number of reform initiatives in developing countries that occurred in the second half of the 1990s. Fourth, our competition variable directly reflects competition in the local market segment, which we believe is the most relevant influence on teledensity and telecommunications productivity. Furthermore, we are also able to distinguish competition in the fixed line sector from mobile competition and control for the endogenous effect of the competing network while explaining sectoral performance. Finally, our estimates control for the problems of serial correlation and panel-level heteroscedasticity, which were not addressed by previous studies.[5]

The rest of the paper is organized as follows. Section II describes the pattern of both telecommunications policy and performance in the developing world. Section III presents a conceptual framework to analyze the impact of reforms on performance building upon the existing literature on the subject. The estimation methodology and results are presented in section IV. Concluding remarks are presented in Section V.

## II. Telecommunications performance and policy in developing countries

Over the 1985-1999 period, mainline penetration in all developing countries tripled from 2.4 telephone mainlines per 100 people to 7.27 mainlines per 100 (Figure 1a).[6] Productivity showed an even more impressive trend, rising from 27.2 mainlines per worker in 1985 to 91.2 mainlines per worker in 1999 (Figure 1b).

[5] See Wallsten (2001) and Ros (1999).

[6] From here on, we use the terms "teledensity", "fixed-line teledensity", "mainlines per 100", and "mainline penetration" interchangeably.

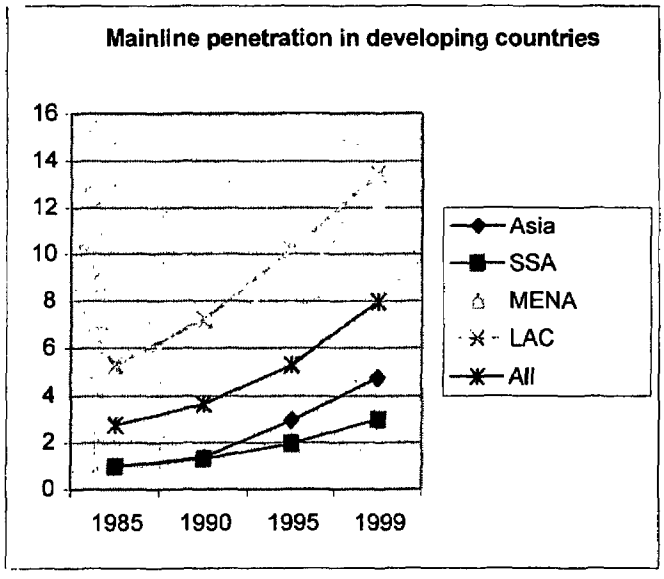


*Figure 1.a*

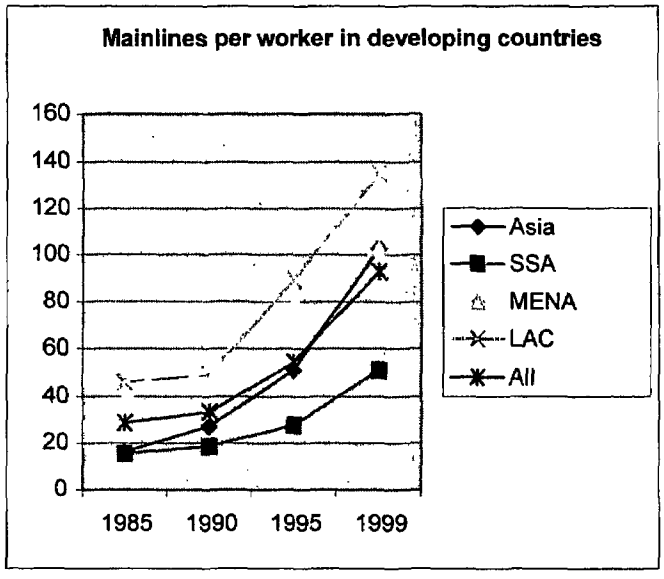


*Figure 1.b*

There is, however, considerable variation in performance across regions. Sub-Saharan Africa (SSA) and Asia had comparable levels of teledensity in 1985 (around 1 mainline per 100), but by 1999, Asia witnessed nearly a five-fold increase while SSA only experienced a three-fold increase. Similarly, Latin American and Caribbean (LAC), and the Middle Eastern and North African (MENA) countries started from comparable levels of around 5 mainlines per 100 in 1985, but while mainline penetration nearly trebled in the LAC region, the MENA region witnessed only around a two-fold increase. The comparative performance of Asia and the LAC region in terms of telecommunications productivity was even more impressive.

The pattern of policy reform adoption is equally diverse. In 1985, privatization was rare in the developing world. However, by 1999, one-quarter of SSA countries, about half of the Asian countries, and two-thirds of the LAC countries in our sample had at least partially privatized their incumbent phone operators (Figure 2a). The United Arab Emirates was the sole country among the MENA countries in our sample to have private ownership of the incumbent over the 1985-1999 period. Asian and MENA countries have been the most reluctant to allow foreign equity participation in their incumbent phone operators, but many SSA and LAC countries have been more permissive in this respect (Figure 2b).

In 1990, no country in our sample had licensed a second operator in competition with the incumbent local services provider. By 1999, two-fifths of Asian and LAC countries had introduced some form of competition in local services, while less than one-fifth of SSA countries had done so (Figure 2c). None of the MENA states had licensed a second local fixed line operator over our sample period of 1985 to 1999. In 1985, independent regulators were rare, whereas by 1999, half of the Asian and SSA countries, one-third of MENA countries and three-quarters of the LAC countries had independent regulators (Figure 2d).

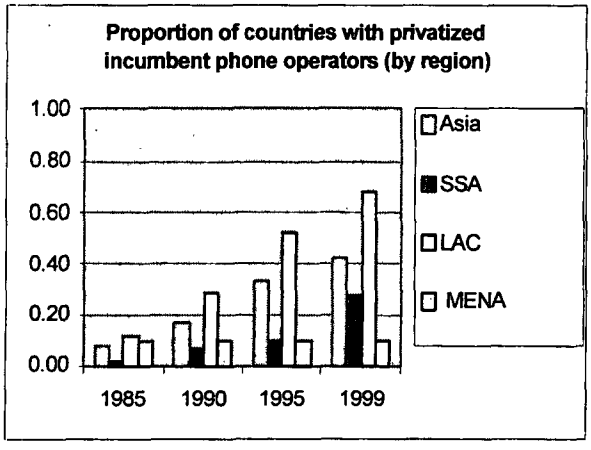


*Figure 2.a*

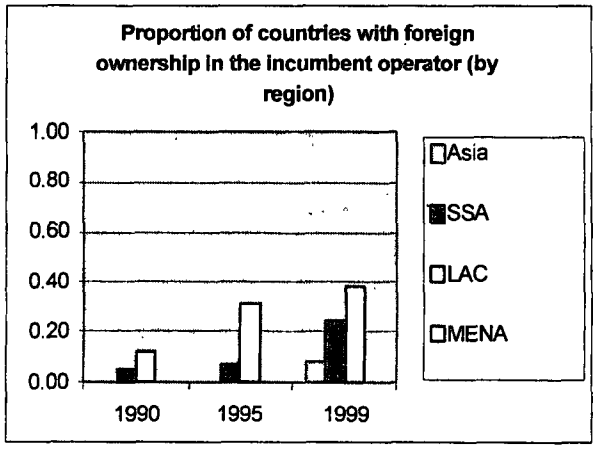


*Figure 2.b*

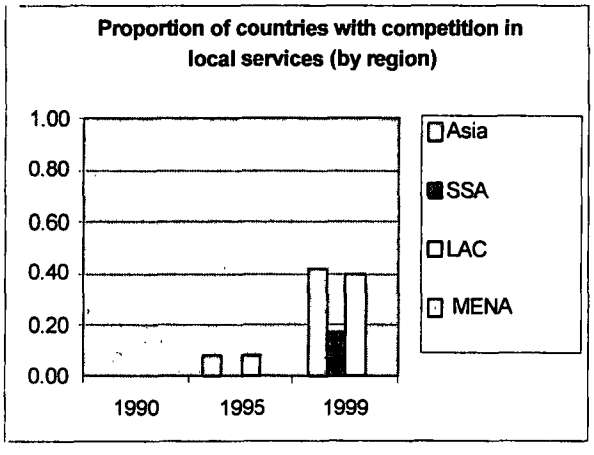


*Figure 2.c*

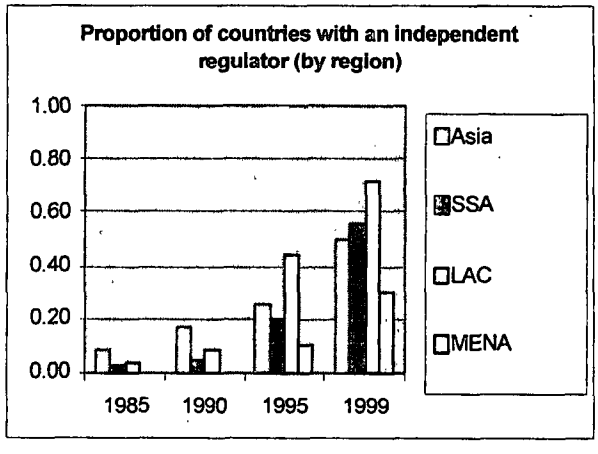


*Figure 2.d*

*Mobile telecommunications in developing countries*

A truly remarkable feature of telecommunications performance in developing countries over the 1990s has been the widespread diffusion of mobile telephony. In 1985, most developing countries had virtually no mobile telephony. By 1999, a number of countries, e.g. Cambodia, Cote d'Ivoire, Paraguay, Uganda and Venezuela, had more mobile subscribers than fixed-line subscribers (I.T.U., 2000). Interestingly, the MENA region leads the developing world in mobile penetration (at 6.8 mobile subscribers per 100 people), followed by LAC (6.3), Asia (2.4) and SSA (1.7).

Unlike fixed-line services, the mobile telephony segment was often subject to competition in its infancy. By 1999, more than 90% of the Asian economies in our sample had more than one cellular operator. The MENA countries have been the most reluctant to introduce mobile competition, with only 30% having done so by the end of 1999. About half the SSA and LAC countries in our sample had licensed a second mobile operator by 1999.

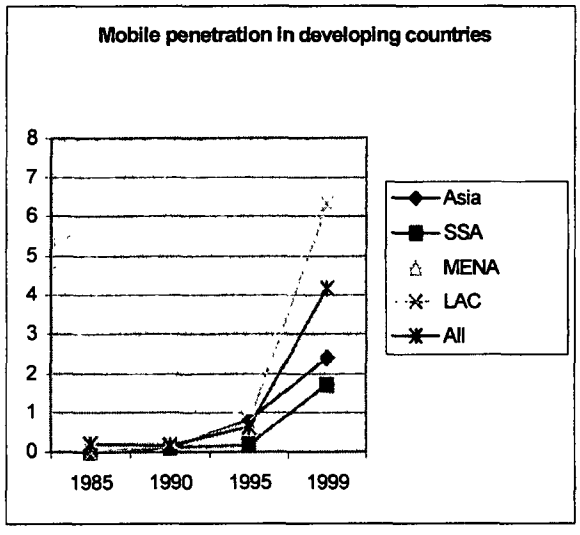


*Figure 3.a*

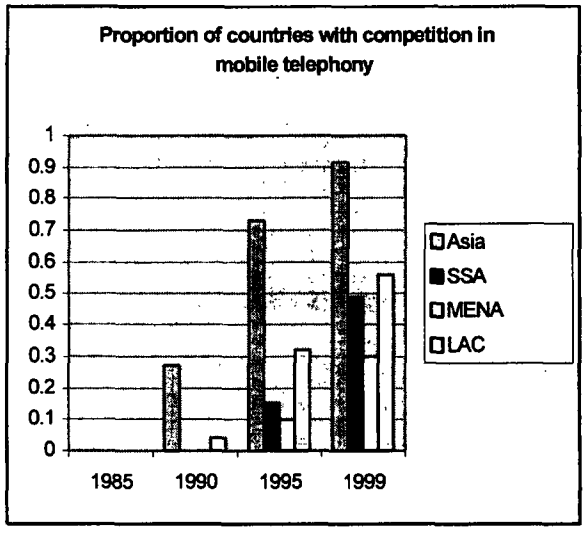


*Figure 3.b*

## III. Conceptual framework

Our objective is to find a relationship, if any, between these diverse patterns of policy and performance. Three dimensions of policy are relevant: a change of ownership, introduction of competition, and strengthened regulation. Performance itself is generally seen as having two dimensions: internal efficiency within firms and allocative efficiency in the market. In order to generate testable hypotheses, we link the conceptual discussion in this section to two proxy variables. Our proxy for internal efficiency is labor productivity – measured by the number of mainlines per employee. Since we do not have the data to measure price-cost wedges, we use the aggregate output – measured by the number of main lines – as a crude proxy for allocative efficiency. We are aware that each of these proxies is imperfect. For instance, internal efficiency is better measured by total factor productivity, and output may be a deceptive measure of allocative efficiency because, for example, there could be an excessive expansion of the network. Nevertheless, these two measures are the ones that can be computed most easily with available data and with the smallest measurement error.

Privatization involves the transfer from public to private hands of the ownership of productive assets, the right to take allocative decisions and the entitlement to the residual profit flows. Earlier analyses emphasized the impact of the resulting change in objectives: from the maximization of social welfare to the maximization of profit.[7] The implication was that with a concentrated market structure, public ownership was more likely to promote allocative efficiency than private ownership – where the temptation would be to restrict output to maximize profits.

[7] For a discussion of these issues, see Shapiro and Willig (1990).

More recent analyses of the impact of a change of ownership have focused on the change in the incentives for the firm's management.[8] Changes in performance are attributed to changes in the principal-agent relationship between the firm's management (the agent) and either private shareholders or the government or ultimately the general public (the alternative principals). Private ownership is likely to lead to greater internal efficiency for a variety of reasons, ranging from lower costs of monitoring, more precise and measurable targets and greater flexibility to devise incentive contracts.

In some ways, the traditional and more recent analyses are complementary. The general prediction would be that a change of ownership from public to private (or foreign) hands would improve internal efficiency.[9] The presumption of a positive impact on the chosen proxy, labor productivity, is even greater because public enterprises may seek to meet social or political objectives by creating excessive employment. The impact on the measure of allocative efficiency, the number of mainlines, is less obvious. Increased internal efficiency due to privatization would favor an expansion, but the greater emphasis on private profitability may dampen the effect.[10] However, the impact may still be positive if the public provider is resource-constrained in a way that the private (or foreign) provider is not – e.g. because the latter has better access to the capital market. Therefore, we have:

> *Hypothesis* 1: Privatization leads to an increase in labor productivity. There is a weaker presumption that it will lead to an increase in the number of mainlines.

The results of increased competition would seem to be relatively straightforward, as it promotes both allocative efficiency and internal efficiency. [11] Firms, private or public, must produce efficiently in order to survive, and there is less scope for monopolistic restraint on output.[12] There is, however, a twist. In some cases, public monopolies have sought to expand networks through a system of cross-subsidization – using revenues from segments like urban areas or international calls, to extend services to poorer areas or consumers. The introduction of competition may threaten these arrangements. This possibility introduces an element of ambiguity to the relationship between increased competition and the expansion in the number of mainlines. On balance we have:

> *Hypothesis* 2: The introduction of local fixed-line competition will lead to an increase in productivity. There is a weaker presumption that it will lead to an increase in the number of mainlines.

The impact of individual policy changes may be modified when they are implemented in conjunction with other policy changes. Consider first the interaction between privatization and competition. If a public monopoly is privatized, the introduction of competition helps eliminate

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[8] See, e.g. Levy and Spiller (1996).

[9] Foreign ownership may also be associated with the transfer of improved technology.

[10] The latter negative effect may in turn be diluted by the existence of positive network externalities.

[11] Vickers and Yarrow (1988).

[12] Competition also makes it easier to monitor managerial performance – e.g., by diluting the management's monopoly of information.

the remaining scope for managerial slack and the monopolistic incentive to restrict output.[13] At the same time, privatization of a public monopoly renders the introduction of competition more credible and less distorted by eliminating the government's incentive to favor the public provider.[14] We would therefore expect the interaction of privatization and competition to have a positive impact on both internal and allocative efficiency, subject to the qualifications noted above. Furthermore, in so far as mobile telephony is a substitute for fixed line telephony, mobile competition could serve as a surrogate for fixed line competition. So we test:

> *Hypothesis* 3: The interaction of privatization and fixed-line competition will lead to an increase in productivity and the number of mainlines. The interaction of privatization and mobile competition may also have the same effect.

The most critical complementary policy change is in the regulatory framework. In the case of basic telecommunications, regulation can play at least two roles.[15] First, if for any reason the market structure is not competitive, then regulation of behavior in the output market (e.g. by fixing consumer prices) can help simulate a more competitive outcome. In this sense, regulation can function as an imperfect substitute for competition when a public monopoly is privatized. Second, since the incumbent operator invariably controls access to essential facilities, i.e. the network, regulation of the terms of access to the network for entrants is necessary to deliver competition. Effective interconnection regulation must, therefore, be seen as a precondition for the emergence of meaningful competition. For these reasons, we would expect the interaction of effective regulation with both privatization and the introduction of competition to have a positive effect on performance.

There is, however, one qualification. There is invariably a conflict between the regulatory objectives of ensuring competitive outcomes and access at any one point of time, and creating adequate incentives for cost-reduction and network expansion over time. Consider a simple example. A regulatory mechanism that sets prices equal to, say, average costs at every point of time encourages allocative efficiency but eliminates the firm's incentives to reduce costs. Conversely, a regulatory mechanism that sets prices for a certain length of time allows firms to reap the benefits of, and hence provides incentives for, cost-reductions, but at the expense of allocative efficiency. Therefore, the relationship between regulation and performance is more complex, and requires a more detailed analysis of the nature of regulation than available data permits. Nevertheless, assuming that existing regulatory arrangements generally strike an appropriate balance between the two objectives, we would suggest:

> *Hypothesis* 4: The interaction of regulation with privatization and competition leads to an increase in labor productivity and the number of mainlines.

Finally, consider the implications of alternative sequences of reform involving, in particular, privatization and competition. There are several reasons why it may matter if privatization

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[13] Armstrong, Cowan and Vickers (1994).

[14] See e.g. Fershtman (1989). De Fraja (1991) arrives at an opposite conclusion. In a theoretical model of Cournot oligopoly, it is shown that the continued presence of a welfare-maximizing public firm can impose added competitive pressure on private firms.

[15] See e.g. Laffont, Rey, Tirole (1998).

precedes the introduction of competition, essentially because conditions of "competition" may be affected. First of all, the importance of location-specific sunk costs in basic telecommunications, suggests that allowing one provider privileged access may have durable consequences.[16] Sunk costs matter because they have commitment value and can be used strategically by those who are allowed to enter the market first. The commitment value is stronger the more slowly capital depreciates and the more specific it is to the firm. In general, if one firm is allowed to enter the market early, then this incumbent may accumulate a quantity of "capital" sufficient to limit, or modify the conditions of, entry of other firms.[17]

Because of the importance of sunk costs, sequential entry can produce very different results from simultaneous entry. A market outcome where one firm enters first is not necessarily worse than one where all firms enter at the same time, but it may well be for several reasons. First, if entry is costly, then the incumbent may be able to completely deter entry so that the outcome is a much more concentrated market structure.[18] Second, the first-mover advantage may be conferred on an inferior (national) supplier who may nevertheless use it to establish a position of market dominance. How durable such a position is depends on the degree of cost or quality advantage more efficient firms have.[19]

A second reason that sequences matter has to do with political economy. Allowing privileged access creates vested interests that may then resist further reform or seek to dilute its impact. The South African experience provides an example.[20] Private shareholders in the incumbent (national and foreign) successfully lobbied to reduce the number of entrants that the government was planning to allow from two to one.[21]

Finally, sequences matter because of the implied changes in the regulatory environment. Consider the prospects of new entry in two alternative situations that arise depending on whether privatization follows or precedes the introduction of competition. In the former case, the

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[16] See Bos and Nett (1990).

[17] Capital need not necessarily take a physical form. A firm may be able to develop a clientele though advertising and promotional campaigns that pre-empt demand. The more imperfect the consumers information and the more important the costs of switching suppliers, the greater the clientele effect. Consumers are often reluctant to switch telecommunications suppliers even when new entrants offer better terms. Each of these forms of "capital accumulation" enhances the first-mover advantages and allows the established firms to restrict or prevent competition.

[18] In situations of network externalities, entry deterrence could also be through the choice of a standard that is incompatible with that of potential entrants.

[19] Two qualifications to this argument are important. First, entry by the more efficient firm could take place through acquisition circumventing some of the problems of first-mover advantage. But this would require no asymmetry of information about the value of assets and no direct costs of transferring assets. Secondly, incumbents could learn by doing: the experience acquired by the established firms during the previous period reduces their current costs, enhancing their competitiveness and discourages others from entering. This form of entry deterrence may well promote welfare.

[20] Lamont (2001).

[21] While we are emphasizing the political economic implications of sequencing, there are also important strategic considerations. For instance, Perotti (1995) argues that one reason we observe partial privatizations is because of the government's inability to credibly commit to non-interference after the transfer of ownership takes place.

incumbent is a relative inefficient public operator and the regulator is well informed about the cost structure. In the latter case, the incumbent is a relatively efficient private operator and the regulator is less well informed about the cost structure. It could be argued that new entry is easier to accomplish in the former situation.

While there are good reasons to believe that the sequence matters, it is not easy to predict the impact of alternative sequences. First, any differences in internal efficiency may not persist once each of the sequences is complete. Thus, delaying the introduction of competition would allow the privatized monopoly a period of slack, but once competition is introduced, the incumbent would be forced to improve performance rapidly and so there is no reason to presume continued differences in levels of productivity. As far as allocative efficiency (or its present proxy, mainlines) is concerned, allowing entry sequentially rather than simultaneously could lead to an inferior outcome. This could happen if sunk costs are so high that new entry is blocked with the monopolist incumbent producing an output lower than the output produced by, say, two firms that enter simultaneously. But this is not necessarily the case, because in some cases strategic behavior by the incumbent could lead to a large expansion of output.[22] The implications of alternative sequences is therefore an interesting empirical question. We test:

> *Hypothesis* 5: Alternative sequences of reform do not have any impact on internal efficiency but matter for allocative efficiency. In particular, the number of mainlines created will be lower if privatization takes place before the introduction of competition, rather than after or at the same time.

While our main hypothesis pertains to the introduction of competition in fixed line services, we consider also the implications of sequences where mobile competition is introduced prior to fixed competition.

## IV. Econometric investigation

In this section, we econometrically test the above hypotheses using the data described in Appendix 1 on 86 developing economies in Sub-Saharan Africa, Asia, MENA and LAC for the period 1985-1999.

A limitation of an econometric investigation is that available measures of policy do not capture the multiple dimensions of a complex reform process. For example, the mere issuing of additional licenses in a particular service segment is an imperfect indicator of effective competition—let alone the contestability of markets. Similarly, while the existence of a separate regulatory agency indicates that a government is willing to commit to pro-competitive regulatory principles, a regulator can be ineffective if key regulatory responsibilities (e.g., interconnection) fall outside its mandate. Moreover, the overall credibility of a government's reform program is not adequately captured by our policy proxies, but is likely to exert an important influence on investment decisions by domestic and foreign firms. These reservations notwithstanding, an

[22] For instance, the aggregate output in a Stackelberg oligopoly equilibrium, where one firm has a first-mover advantage, need not be lower than in a Cournot equilibrium, where all firms make output decisions simultaneously (Tirole, 1988).

econometric investigation is attractive because it enables a rigorous analysis of the implications of specific policies and their interaction, controlling for other country-specific influences.

*Previous literature*

Before presenting our model, we briefly describe some existing econometric work analyzing the link between telecommunications policy and performance.[23] Wallsten (2001) explores the effects of privatization, competition and regulation on several performance indicators, using a panel dataset for 30 African and Latin American countries from 1984-1997. While competition is generally found to have a positive effect on performance, the impact of privatization is mixed. A weakness of Wallsten's study is that it approximates the degree of competition in fixed-line telecommunications by the number of mobile operators not owned by the incumbent operator. In our view, this is inadequate because many countries have introduced competition in mobile services while maintaining a monopoly in fixed-line services.

The study by Ros (1999) examines the effects of privatization and competition on network expansion and efficiency on the basis of data for 110 countries from 1986-1995. Using fixed effects estimation, he finds that countries that allowed majority private ownership in their incumbent telecom operator had significantly higher teledensity (mainline penetration) and a higher growth rate in teledensity.[24] Allowing a majority private stake in the incumbent was also found to improve efficiency (telephone mainlines per employee). By contrast, competition in at least one fixed line market segment (local, long distance, international) did not significantly affect mainline penetration, but impacted positively on efficiency.[25] Ros however, interprets the telecom regime to be competitive as long as any one of the basic services segments (local, long distance, or international) is competitive. This is misleading as the most direct influence on mainline penetration is exerted by local competition. Furthermore, the sample period misses out on several episodes of telecommunications reforms during the late 90s.

Li and Xu (2001) look at the impact of liberalization on telecommunications sector performance using a sample of 160 countries for the analysis of the effects of privatization, and a smaller sample of 40 countries for the analysis of the effects of competition. They find that privatization significantly increases teledensity and telecom productivity. Their competition variable is an index measuring the extent of competition in both the fixed and mobile sectors, which is not significantly correlated with higher mainline penetration. They find that once fixed line and mobile competition is controlled for, privatization no longer has a significant impact on mainline

[23] Refer appendix 2 for an overview of the empirical literature on fixed line telephony.

[24] Ros finds the contribution of privatization to the growth in teledensity to be statistically insignificant for countries with a per-capita GDP below $10,000.

[25] Boylaud and Nicoletti (2000) provide additional econometric evidence of the impact of entry liberalization and privatization on productivity, prices, and quality of long distance and mobile services, focusing on the 23 OECD countries over the 1991-1997 period. Their findings suggest a generally favorable impact of policy reforms on productivity, quality, and prices in the trunk (domestic long distance), international, and mobile segments. It is not clear, however, to what degree these results apply to developing countries, most of which have had to implement reforms in situations where telecommunications networks are poorly developed.

penetration, mobile penetration and productivity, but the interaction of privatization and competition is associated with higher penetration and productivity. However, a drawback of using a hybrid index of competition is that one cannot disentangle the direct effect that competition in each segment has on performance in that segment.

*The model*

We assume the following specification for our model:

$$y_{i,t} = \alpha + \mu_i + \delta\, year + C_{i,t}.\gamma + X_{i,t}.\beta + \rho \hat{M}_{i,t} + \varepsilon_{i,t}, \qquad i = 1,2,....,N; t = 1,2,....T,$$

where $y_{i,t}$ is the natural logarithm of our performance indicator, which is either teledensity or mainlines per employee in country "i" at time "t". The coefficient α is the constant term, while $\mu_i$ is a country-specific dummy variable that is intended to capture time-invariant country fixed effects. The parameter δ is the coefficient on a time-trend, which captures the effect of autonomous factors, including technological progress. The matrix of control variables is $C_{i,t}$ and includes the GDP per capita and population (both in natural logs). Our telecom policy variables are represented by $X_{i,t}$ and include dummy variables for privatization, competition, and the existence of an independent regulator, with $\beta$ being the corresponding vector of coefficients.[26] The number of countries is N (86, in our case), and the number of time series observations, T (15, in our case) per country.

We need to take into account the interplay between fixed and mobile networks.[27] In particular, we must allow for the fact that fixed-line teledensity could be influenced by the spread of mobile telephony.[28] However, we cannot simply include the mobile penetration rate as an independent variable because this variable could be endogenous – i.e. mobile penetration could in turn depend on fixed penetration. We correct for this by using a two-stage estimation procedure. The vector $\hat{M}_{i,t}$ is the fitted value from a first stage regression of the natural log of (1 + mobile subscribers per 100 people) on a time trend, country fixed effects, natural logs of per capita GDP and population, and a dummy variable representing competition in the mobile segment.

[26] The partial correlation matrix for different policy reforms is presented in appendix 3.

[27] See appendix 6 for a simultaneous equation approach to the determination of fixed-line and mobile penetration. Also see Jha and Majumdar (1999).

[28] Positive network externalities imply an increased incentive to acquire a fixed telephone when there is an additional mobile user. But for any one consumer, the negative substitution effect implies a reduced incentive to acquire a fixed telephone when he already has a mobile line. The net effect depends on the relative strengths of these two effects.

In contrast to the previous literature referred to above, we allow for country-wise heteroscedasticity, i.e. – that the variance of the error term differs across countries.[29] In addition, we also account for the existence of first-order autoregressive serial correlation in the errors, but assume a common autocorrelation parameter across panels. The latter assumption is justified by the fact that the $\beta$'s themselves do not vary across countries.[30] The heteroscedasticity and autocorrelation corrections make the estimation far more efficient than an ordinary fixed effects panel estimation. We choose to estimate our model using Kmenta's cross-sectionally heteroscedastic and time-wise autocorrelated (CHTA) approach.[31] For more on our choice of estimation technique, refer appendix 4.

*Effects of individual reforms on performance*

Table 1 presents the results of our first investigation on the effect of individual reforms on mainline penetration and productivity. The dependent variables are the number of mainlines per 100 inhabitants and the number of mainlines per worker (both in natural logs). As control variables, we use GDP per capita and population (both in natural logs), and a linear time trend to capture reductions in switching and network costs due to technological progress. We expect mainline penetration to be higher in developing countries with higher per-capita GDP, and lower in developing countries with higher populations.

In the first model specification, our policy proxies are a dummy variable that takes the value 1 if an incumbent has been partially or wholly privatized and zero otherwise and a dummy variable that equals 1 if there is competition for local services and zero if local services are provided by a monopoly.[32]

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[29] We did a preliminary examination for group-wise heteroscedasticity using the likelihood ratio test. We first estimated the model with only heteroscedasticity and no autocorrelation using iterated GLS, then the same model with neither heteroscedasticity, nor autocorrelation, and compared the likelihoods in both cases. In models without autocorrelation, GLS estimates are equivalent to maximum likelihood estimates. A likelihood ratio test of the variances in the two models turned out a $\chi^2(74)$ statistic of 848.71, which strongly rejected the null hypothesis of no group-wise heteroscedasticity. Economically, the reason for the presence of heteroscedasticity is somewhat unclear. Why should the variance of shocks to mainlines differ across countries? It could be because of differing government initiatives on mainline expansion under different regimes, so that countries with a more volatile political environment, or unstable and frequently changing governments have a higher variance in the level of mainlines per capita than others arising from differing government initiatives on mainline expansion. Another hypothesis is that the richer developing countries can more easily overcome natural and geographical obstacles (for example terrain) in laying down the network than poorer countries can. Countries also differ in their impact to adapt to technology shocks and this could be an additional source for different variances across countries.

[30] As Beck and Katz (1995) admit, the assumption of a common autocorrelation parameter across panels is unlikely to cause FGLS estimates to estimate variability inaccurately, as it necessitates the calculation of only one additional unknown parameter (the autocorrelation coefficient).

[31] We cannot assume contemporaneous correlations across panels as the estimation technique would require as many time series observations as there are panels to satisfy matrix invertibility conditions during estimation. In our case, we have only 15 time-series observations per country for 86 countries. Since we also abstain from modeling country-specific correlation, we are immune from the criticism by Beck and Katz (1995) regarding the inaccurate computation of standard errors.

[32] We also ran regressions with a dummy variable for corporatization of the incumbent. The coefficient on this variable was consistently insignificant.

In Section III, we argued that privatization and the introduction of competition are likely to lead to an increase in labor productivity, and (less strongly) an increase in the number of mainlines (Hypotheses 1 and 2). Our empirical estimates in column 1 of Table 1 suggest that both privatization and competition significantly increase mainline penetration.[33] The coefficients on the privatization and competition dummy variables are positively significant at 1% and 5% levels, respectively. The time trend and the natural log of GDP have the expected signs and are statistically significant at the 1 percent level. The mobile penetration rate is a positive and significant determinant of mainline penetration. One explanation for this positive relationship may be that positive network externalities work to increase the benefits of belonging to the fixed network given the size of the mobile network.[34] Our results with regard to labor productivity (column 2 of Table 1) suggest that both privatization and competition significantly boost productivity, with all controls and the time trend working as expected.[35]

We also tested whether the effects of privatization and competition differ in the presence of an independent regulator (Hypothesis 4). Accordingly, we interacted both dummy variables for privatization and competition with a dummy variable that equals 1 if a separate regulatory agency exists and zero otherwise. As mentioned before, this is a crude measure of the quality of regulation and the results should therefore be interpreted with due caution. Table 2 (columns 1 and 4) presents our estimated coefficient on the interaction terms. As above, we find both privatization and competition – confined to observations that exhibit a good regulatory framework – to impact positively on teledensity and productivity.

*Does the interaction of privatization and competition matter?*

To capture the interdependence between privatization and competition, we estimate another model that also includes a two-way interaction term. As explained in Section III, we expect the

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[33] We also estimated a similar model replacing our privatization measure with a dummy variable that takes the value one if foreign equity participation was observed and zero otherwise. The results are similar, which is not surprising given that most privatizations take place through the sale of strategic equity to foreign investors. Indeed, the partial correlation between the privatization and foreign equity dummy variables exceeds 0.8.

[34] Li and Xu (2001) account for the mobile sector by including an aggregate measure of competition (that includes both fixed and mobile competition) in the fixed line equation. It should be pointed out that all of our results about fixed line performance are qualitatively robust to estimation without accounting for the presence of the mobile network.

[35] Our findings for labor productivity are similar to the results of Ros (1999). By contrast, Ros finds that only privatization exerts a significant impact on mainline penetration. We ran a similar fixed effects OLS regression using our data, but confining ourselves to the years 1986-1995, as in Ros' specification. We still found a significantly positive impact of both competition and privatization. The most plausible explanation for this result is that our estimation sample only consists of developing countries, where initial network conditions were weaker and subsequent growth faster. By contrast, most countries that introduced competition in Ros' estimation samples are developed countries that already had a well-developed telecommunications network. Moreover, the different findings may also be due to different control variables and different specifications of our policy proxies.

Jha and Majumdar (1999) find that cellular diffusion positively influences the productive efficiency of the telecommunications sector through pecuniary and technical network externalities. In the light of this finding, we also carried out estimations that account for mobile penetration in the fixed-line productivity regressions. We find a similar result (not reported) that mobile penetration has a positive impact on fixed-line productivity.

interaction of these two policy choices to impact positively on both mainline penetration and labor productivity (Hypothesis 3). Our findings with regard to teledensity (Table 2, column 2) confirm this hypothesis: the coefficients on privatization and the interaction of privatization and competition are both positive and statistically significant at the 1 and 5 percent levels respectively. Interestingly, competition is not statistically significant in this model. This result suggests that the beneficial effect of competition primarily occurs through its interaction with privatization. The same holds for labor productivity (Table 2, column 5): privatization and the interaction of privatization and competition are statistically significant, whereas competition is not statistically significant.

We also tested for the effects of the interaction of privatization with mobile competition. The results are presented in column 3 of table2. Here, we found that the dummy variables for privatization and fixed-line competition were positive and statistically significant at the 5% level. The interaction of privatization with mobile competition was also positive and significant, albeit at the 10% level. This result seems to suggest that mobile competition may well be a surrogate for fixed-line competition. See appendix 6 for an empirical analysis of the mobile sector as well as the interplay between the fixed and mobile sectors.

*How large are the effects of policy reform relative to autonomous increases?*

In order to quantify the effects of "complete" liberalization – defined as the introduction of competition, privatization of the incumbent and the establishment of a separate regulator – we estimated a model whereby our only policy variable is a dummy variable that equals 1 if all three policies are in place and zero otherwise (i.e., the three way interaction term).[36] We find this variable to be highly significant for both mainline penetration and productivity (Table 3). The estimated coefficients suggest that mainline penetration is 8 percent higher and productivity is 21 percent higher in years of complete reform compared to years of no or partial reform.

It is revealing to compare these magnitudes to the implied growth in teledensity and productivity due to autonomous factors, including technological progress. Our estimated coefficients on the linear time trend, suggest autonomous increases of approximately 5 percent per annum in mainline penetration and over 9 percent per annum in productivity. Hence, our empirical investigation suggests that the effect of the policy reforms studied here was outweighed by the improvements attributable to autonomous factors, like technological progress. It should be kept in mind, however, that the time trend captures an average effect across all countries and we do not consider how policy reforms influence the diffusion of telecommunications technology. The latter is beyond the scope of this study and would require explicit data on the international diffusion of telecommunications technology.

*Does the sequence of reform matter?*

Having found evidence of the beneficial effects of privatization and competition and the interaction of the two on performance, we investigate the effects of the order in which the two

[36] In fact, since all countries that have fully liberalized fixed telephony have also liberalized their mobile segments, the interaction term captures full liberalization of both segments.

are introduced.[37] In other words, while we know that the interaction of privatization and competition results in a significantly higher mainline penetration, are the effects any different if privatization takes place before the introduction of competition, or vice-versa? As argued in Section III, we expect mainline penetration to be higher if competition and privatization are introduced at the same time, than if privation precedes the introduction of competition (Hypothesis 5). For labor productivity, we expect little difference in the effects of alternative sequences of policy reforms.

We define simultaneous introduction of policies as those reforms where privatization and competition were introduced within a one-year time period. Since no country in our sample introduced competition more than one year before privatizing the public operators, we, therefore, do not observe a possible third sequence, where competition clearly precedes privatization.[38] (However, we do observe countries that have introduced competition for local services, but as of 1999, had not privatized their state-owned operator.)

In order to test the effects of different sequences, we constructed 4 dummy variables. First, the "simultaneous sequence" (hereafter, SEQSIM) is represented by a variable that takes the value 1 for the year in which both privatization and competition were simultaneously introduced as well as all subsequent years, and zero otherwise. Second the "privatization before competition sequence" (hereafter, SEQPC) is represented by a variable that takes the value 1 for the year in which competition was introduced *after* privatization as well as all subsequent years, and zero otherwise.[39] Third, the "competition only"(hereafter, SEQC) variable takes the value 1 for all years in which only competition is observed, and zero otherwise. Finally, the "privatization only" (hereafter, SEQP) variable takes the value 1 for all years in which only privatization is observed, and zero otherwise.

Our estimation results on sequencing are presented in Table 4. As the first column shows, the coefficient on SEQP (which represents years where only privatization is observed) is significant, whereas the coefficient on SEQC (which represents years where only competition is observed) is not. Hence, it would seem that years where privatization takes place without local competition witness higher mainline penetration, whereas we do not observe higher mainline penetration in years where local competition is introduced without privatization of the incumbent firm. However, on looking at the completed sequences, we find that the coefficients on both SEQPC and SEQSIM are positive and statistically significant at the 1 percent level (column 1). Interestingly, the two coefficients are significantly different from each other, with that on SEQSIM being greater than the one on SEQPC.[40] This implies that mainline penetration in years

[37] Wallsten (2002) considers the impact of the sequencing of privatization and regulation. He finds that countries that established an independent regulator prior to privatization experienced better performance in the telecommunications sector.

[38] As an alternative, we created a variable that represented a "competition before privatization" sequence, allowing for situations in which competition was introduced before privatization, even if the gap between the two was only a few months. The estimation results were similar to the ones presented here. We chose the "simultaneous sequence" characterization, however, since it is unlikely that there are significant sequencing effects from policies that are introduced within a short time period of each other.

[39] Refer Appendix 5 for a more detailed illustration of the construction of SEQSIM and SEQPC.

[40] $H_0$: SEQSIM (.22) = SEQPC (.12); $\chi^2(1) = 3.70$; Prob > $\chi^2$ = .0544.

following the simultaneous introduction of competition and privatization is significantly higher than mainline penetration in years following the "privatization before competition" sequence (Hypothesis 5). See Figure 4 for an illustration of the effects of the two different sequences.

In order to better understand the impact of exclusivity periods that are often granted to newly privatized incumbents, we re-estimated the above equation by introducing the interaction of SEQP (privatization only) with mobile competition as an additional explanatory variable (table 4, column 2). Interestingly, we found that SEQP, which was formerly significant, was not significant anymore, while the interaction of SEQP with a dummy variable for mobile competition was positive and significant. As noted above, this result indicates that the presence of mobile competition may serve as a surrogate for fixed line competition and mitigate any negative effects that exclusivity periods may have on mainline penetration.[41] Further, the result explained in the previous paragraph still holds in this estimation, with the coefficient on SEQSIM (simultaneous introduction of both privatization and competition) being significantly greater than that on SEQPC (privatization before competition).

In Table 4 (Column 3), we estimated the effects of alternative sequences of privatization and competition, given the prior existence of an autonomous regulator.[42] The estimated coefficients and significance levels are qualitatively similar to the results obtained earlier (Column 1), but an important difference in this case is that the dummy variable capturing years in which only competition is observed (SEQC) is now also statistically significant (in addition to SEQP), suggesting a 'pro-competitive' effect of independent regulation. The other difference here is that the magnitudes of the coefficients on SEQSIM and SEQPC is now greater, lending more credence to hypothesis 5.[43]

Finally, we also tested for the effect of different sequences on productivity (Table 4, Column 4). The effect of each sequence was found to be positive and statistically significant at the 1 percent level, but the coefficients on the dummy variables representing the two sequences were not significantly different from each other.[44] It can be seen though, that productivity is significantly higher in years where only privatization is observed, whereas the effect of competition (without privatization) is not statistically different from zero. As above, interacting all policy variables with our regulation dummy does not fundamentally change this result (Table 4, Column 5).

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[41] Wallsten (2000) finds that each year of exclusivity can reduce fixed network growth by as much as 0.4 percentage points. However, in the presence of a competing network (i.e., mobile), we find that the effects of exclusivity are not as drastic.

[42] We took care to exclude those observations where autonomous regulation was introduced only after privatization and competition. This led to the exclusion of the Bahamas, Chile, the Dominican Republic, and Surinam from the regression sample. Had observations on these countries been included, it would have had the effect of the regulatory variable disrupting a previously chosen sequence, and making it start afresh.

[43] $H_0$: SEQSIM (.24) = SEQPC (.07); $\chi^2(1) = 9.41$; Prob > $\chi^2$ = .0022

[44] $H_0$: SEQSIM (.39) = SEQPC (.29); $\chi^2(1) = 1.95$; Prob > $\chi^2$ = .163

## V. Conclusion

This paper has analyzed the impact of policy reform in basic telecommunications on sectoral performance in 86 developing countries in Africa, Asia, the Middle East, Latin America, and the Caribbean over the period 1985 to 1999. While, most countries experienced substantial increases in teledensity and sectoral productivity – in part driven by fast technological progress in telecommunications – the approach to policy reform has differed markedly across regions and countries. Most governments have been unwilling to commit to complete liberalization immediately, preferring instead a gradual reform process, encompassing the privatization of state-owned operators, the introduction of competition, and the establishment of independent regulation.

The econometric evidence presented in this study may provide some guidance on possible priorities for telecommunications reform. First, we find that complete liberalization pays off. Ceteris paribus, teldensity is 8 percent higher and labor productivity 21 percent higher in years that saw privatized incumbents, additional competitors, and separate regulators, compared to years with no or only partial reform. Second, both privatization and competition improve performance and the latter reinforces the former. Third, sequences matter. Introducing competition after privatizing incumbent operators leads to fewer mainlines per population compared to a simultaneous introduction of the two policies. This result suggests that delays in the introduction of competition – for example due to market exclusivity guarantees granted to newly privatized entities – may adversely affect performance even after competition is eventually introduced. Furthermore, mobile competition can serve as a surrogate for fixed-line competition in achieving higher mainline penetration and can thereby mitigate the harmful effects of exclusivity periods.

An interesting supplemental finding of the paper is that the impact of policy reforms have in the past fifteen years been outweighed by the improvements in telecommunications performance not directly attributable to the policy variables considered here. According to our crude quantification, autonomous developments accounted for increases of 5 and 9 percent per annum in teledensity and productivity respectively. One possible explanation is the rapid pace of technological progress in telecommunications. Another is the increased public investment in this sector. A richer exploration of these issues was beyond the scope of this paper, but is a priority for future research. Two questions seem particularly important. What kind of policies support technological diffusion? What role does foreign investment play in transferring modern telecommunications technology to developing countries?

More research is also necessary to verify and refine the other findings presented in this study. Improved data would make it possible to analyze several issues that have not been addressed here. How much is to be gained from eliminating all barriers to entry when some competition has already been allowed? How great are the gains from eliminating all barriers to foreign investment when some is already permitted? How significant are the benefits of making commitments under regional and multilateral trade agreements with regard to present and future policy? It will become possible to respond to these questions when more detailed data become available and more observations are available after the point in time when policy changes were implemented and multilateral commitments took effect.

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**Table 1. Effects of individual reforms on mainline penetration and productivity**

| *Dependent variable* | *Natural log of mainlines per 100 people (1)* | *Natural log of mainlines per employee (2)* |
|---|---|---|
| *Time trend* | .045*** (4.12) | .094*** (19.82) |
| *Natural log of per-capita GDP* | .314*** (8.85) | .189*** (4.07) |
| *Natural log of population* | -.132 (-0.45) | -.594*** (3.61) |
| ***Dummy variable for privatization*** | **.073*** (4.42)** | **.176*** (7.68)** |
| ***Dummy variable for competition in basic services*** | **.046** (2.52)** | **.091*** (3.24)** |
| *Natural log of (1+ mobile penetration)* | .449*** (4.30) | |
| *Wald Chi-squared (k-1)* | 61,076 | 15,385.82 |
| *AR(1) coefficient* | .67 | .54 |
| *Number of Observations* | 1,200 | 1,085 |

*Note:* All specifications estimated by feasible generalized least squares. "*", "**" and "***" indicate statistical significance at the 10%, the 5%, and the 1% levels respectively. The bracketed figures are GLS corrected z-statistics. Country fixed effects and the intercept are not reported.

**Table 2. Effects of combinations of reforms on mainline penetration and productivity**

| *Dependent variable* | *Natural log of mainlines per 100 people* | | | *Natural log of mainlines per employee* | |
|---|---|---|---|---|---|
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* |
| *Time trend* | .05*** (4.46) | .046*** (4.17) | .051*** (4.42) | .10*** (20.33) | .09*** (19.99) |
| *Natural log of per-capita GDP* | .319*** (8.90) | .308*** (8.59) | .312*** (8.79) | .21*** (4.46) | .18*** (3.97) |
| *Natural log of population* | -.253 (-0.84) | -.152 (-0.51) | -.271 (-0.88) | -.66*** (4.01) | -.60*** (3.66) |
| ***Dummy variable for privatization*** | | **.062*** (3.59)** | **.047** (2.07)** | | **.16*** (6.86)** |
| ***Dummy variable for competition in basic services*** | | **.003 (0.12)** | **.045** (2.45)** | | **.00004 (0.00)** |
| ***Privatization*competition*** | | **.076** (2.40)** | | | **.15*** (2.99)** |
| ***Privatization*mobile competition*** | | | **.042* (1.72)** | | |
| ***Competition*regulation*** | **.056*** (2.71)** | | | **.12*** (3.83)** | |
| ***Privatization*regulation*** | **.061*** (3.43)** | | | **.12*** (5.02)** | |
| *Natural log of (1+ mobile penetration)* | .412*** (3.88) | .445*** (4.24) | .394*** (3.60) | | |
| *Wald Chi-squared(k-1)* | 61,259.29 | 61,959.38 | 61,628.89 | 15,225.99 | 15,528.57 |
| *AR(1) coefficient* | .66 | .66 | .66 | .54 | .54 |
| *Number of Observations* | 1,200 | 1,200 | 1,200 | 1,085 | 1,085 |

*Note:* All specifications estimated by feasible generalized least squares. "*", "**" and "***" indicate statistical significance at the 10%, the 5%, and the 1% levels respectively. The bracketed figures are the GLS corrected z-statistics. Country fixed effects and the intercept are not reported.

**Table 3. Effects of Full reform (vis-à-vis partial or no reform) on mainline penetration and productivity**

| *Dependent variable* | *Natural log of mainlines per 100 people (1)* | *Natural log of mainlines per employee (2)* |
|---|---|---|
| Time trend | .043*** (3.91) | .10*** (21.03) |
| Natural log of per-capita GDP | .32*** (8.86) | .21*** (4.44) |
| Natural log of population | -.072 (-0.24) | -.67*** (4.10) |
| ***Dummy variable for privatization, competition and regulation – full liberalization*** | **.075*** (3.25)** | **.19*** (5.58)** |
| *Natural log of (1+ mobile penetration)* | .50*** (4.78) | |
| Wald Chi-squared(k-1) | 59,851.18 | 15,270.15 |
| AR(1) coefficient | .67 | .54 |
| Number of Observations | 1,200 | 1,085 |

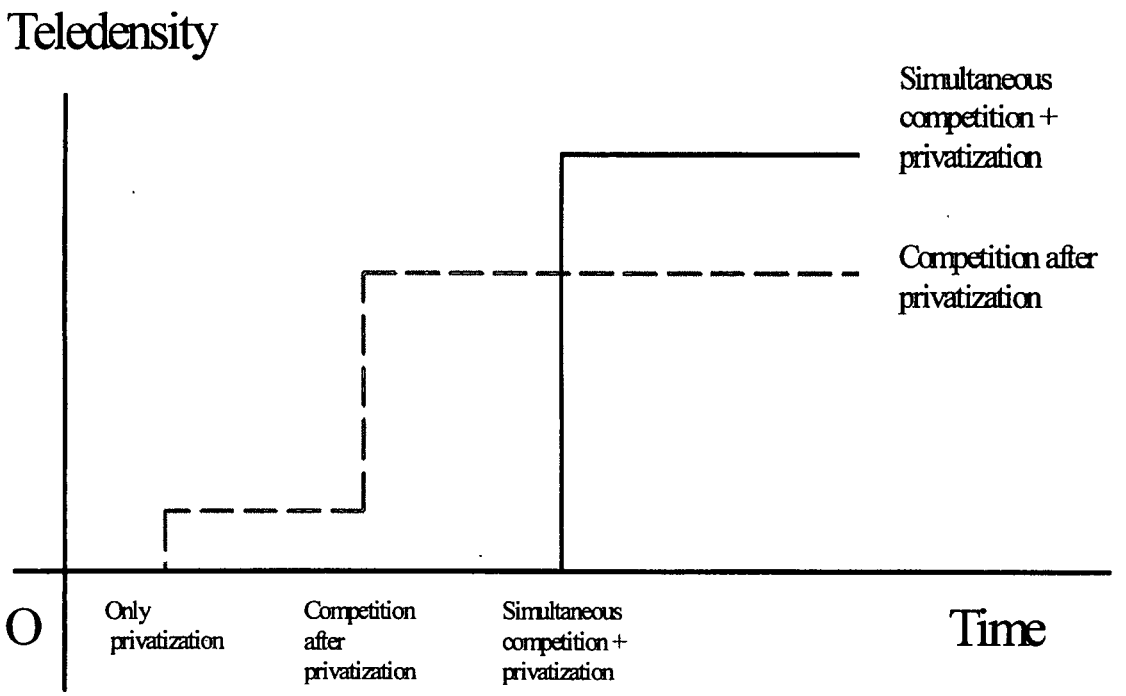
*Note:* All specifications estimated by feasible generalized least squares. "*", "**" and "***" indicate statistical significance at the 10%, the 5%, and the 1% levels respectively. The bracketed figures are GLS corrected z-statistics. Country fixed effects and the intercept are not reported.

**Table 4. Effects of sequencing of reform on mainline penetration and productivity**

| *Dependent variable* | *Natural log of mainlines per 100 people* | | | *Natural log of mainlines per worker* | |
|---|---|---|---|---|---|
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* |
| *Time trend* | .047*** (4.28) | .052*** (4.62) | .051*** (4.60) | .09*** (19.89) | .10*** (20.51) |
| *Natural log of per-capita GDP* | .311*** (8.64) | .31*** (8.61) | .329*** (9.27) | .19*** (4.04) | .20*** (4.36) |
| *Natural log of population* | -.182 (-0.61) | -.328 (-1.07) | -.282 (-0.95) | -.59*** (3.55) | -.64*** (3.94) |
| ***Dummy variable for privatization only (SEQP)*** | **.057*** (3.21)** | **.031 (1.37)** | | **.14*** (5.82)** | |
| ***SEQP* mobile competition*** | | **.046* (1.90)** | | | |
| ***Dummy variable for competition only (SEQC)*** | **.045 (1.50)** | **.048 (1.59)** | | **-.007 (.11)** | |
| ***Simultaneous introduction of competition & privatization (SEQSIM))*** | **.221*** (4.31)** | **.227*** (4.43)** | | **.39*** (6.17)** | |
| ***Privatization before competition sequence (SEQPC)*** | **.125*** (4.27)** | **.138*** (4.59)** | | **.29*** (7.10)** | |
| ***SEQP (in the presence of an independent regulator)*** | | | **.044** (2.38)** | | **.10*** (4.12)** |
| ***SEQC (in the presence of an independent regulator)*** | | | **.084** (2.54)** | | **.01 (.15)** |
| ***SEQSIM (in the presence of an independent regulator)*** | | | **.241*** (5.05)** | | **.38*** (6.08)** |
| ***SEQPC (in the presence of an independent regulator)*** | | | **.075*** (2.61)** | | **.25*** (6.09)** |
| *Natural log of (1+ mobile penetration)* | .423*** (4.01) | .364*** (3.31) | .398*** (3.77) | | |
| *Wald Chi-squared(k-1)* | 61,424.43 | 61,925.59 | 62,459.88 | 15574.19 | 15583.57 |
| *AR(1) coefficient* | .66 | .66 | .66 | .54 | .54 |
| *Number of Observations* | 1,200 | 1,200 | 1,200 | 1,085 | 1,085 |

*Note:* All specifications estimated by feasible generalized least squares. "*", "**" and "***" indicate statistical significance at the 10%, the 5%, and the 1% levels respectively. The bracketed figures are the GLS corrected z-statistics. Country fixed effects and the intercept are not reported.

**Figure 4: An example of alternative policy sequences and their effects**[45]




[45] Note that the coefficients on the dummy variables representing different sequences (SEQSIM & SEPC) do not measure instantaneous "jumps" in the lines. Rather, they measure the extent to which mainline penetration is higher in years following the completion of the respective sequences, compared to years where no reform had taken place. The figure is too simple to reflect the actual dynamics of teledensity in response to policy changes.

## Appendix 1: The ITU-World Bank Database on Telecommunications Policy

The telecommunications reform process is now old enough to have produced the data needed to analyze the implications of alternative policy choices. While the International Telecommunications Union (I.T.U.) has a comprehensive database on performance indicators, there did not exist until now any worldwide database containing detailed time-series information about telecommunications policy. The ITU and the World Bank have recently created a database on telecommunications policy and regulation. The database spans 86 developing countries in Africa, Asia and Latin America. [46]

The policy data are drawn from a variety of sources, including responses by governments to an ITU questionnaire, information from World Bank programs in various developing countries, World Bank Aid Memoirs, the Tradeport and International Trade Administration databases of the U.S. Department of Commerce, www.cellular.co.za , country reports of the Economist Intelligence Unit (E.I.U.), and direct queries to national regulators and telecom operators across the world. The data cover various aspects of policy and market structure in fixed line and mobile telecommunications including inter alia, information about corporatization of the incumbent public telephone operator, the share of private equity, the share of foreign equity, the market structure in local, domestic long distance, and international services, mobile operators, and the year an independent regulator was instituted.[47]

*Assumptions made in the creation of the database and sample selection*

1. *Observed policy changes*

Data on variables like private equity, competition, are recorded based on observed private equity shares, or observed entry and commencement of services. There usually exists a substantial time lag between the announcement of a policy and an observed result. For example, suppose a government would like to introduce competition. First, it has to pass a new law, which has to be ratified by its parliament. Decisions also need to be made on how many operators to admit, in what regions, and so on. The auctioning of licenses, the bidding process for which takes time to settle, follows this. Even after licenses are awarded, there still is a time lag before the licensee(s) enter the market and effectively commence service provision. We thought it best to consider a market competitive at the point at which a second operator begins providing basic services since this is the least ambiguous criterion. For instance, using the date of issue of licenses as an indicator of when competition began can be misleading as licenses are sometimes withdrawn or revoked with a change of government. Similar considerations arise in the privatization of a state-owned network operator, with a long time lag (at least 1-2 years) between the government's announcement of its desire to privatize, and the completion of the sale of equity.

2. *Timing of policy changes*

[46] Liberia, Seychelles and Cuba had to be omitted for lack of GDP data. We also omitted some small island nations, for example, Vanuatu and Western Samoa, where country size is a constraint on having more than one operator.

[47] We obtained part of the information on cellular operators and mobile competition in Latin America from the Stanford-World Bank Database. We have supplemented this data to reflect the market structure in both analogue and digital mobile segments, and to cover years until 1999. For Africa, detailed information on cellular operators was obtained from the African Telecommunications Research Project at the World Bank.

The panel data is on an annual basis but is sometimes difficult to assign a particular policy to a particular year. For example, if the second operator in Nigeria only commenced services in November of 1996, then we took the starting year of effective competition as 1997, and not 1996. As a rule, any entry relatively late in a given year was taken as effective from the following year. This approach seemed appropriate because our main concern was to link policy changes in a particular year to the performance variables compiled by the ITU. Similarly, if the sale of a public enterprise was completed relatively late in the year, we record the privatization as effective from the following calendar year.

3. *Entry and geographical market segmentation*
Sometimes, a country has more than one telephone operator, but each has a monopoly in its respective regions. For example, Bangladesh has two basic network operators – the incumbent Bangladesh Telephone and Telegraph Board (BTTB), which provides services in the urban areas, and the Bangladesh Rural Telephone Authority (BRTA), licensed in 1990, which provides basic services in rural areas. Similarly, in Argentina, ENTel was separated into two companies in 1990, Telecom Argentina, which provides services in the north, and Telefonica de Argentina in the south. Since the markets are geographically segmented, we deemed it appropriate to consider each country as having a monopoly in basic services.

4. *Privatization in limited segments*
In some cases, the domestic long distance or the international long distance segment is separated from the local services segment and then privatized. In this study, only privatization of local service providers was taken into account.

*Country coverage*

| *Region* | *No. of countries* | *List of countries* |
|---|---|---|
| Asia | 12 | Bangladesh, China, Indonesia, India, Cambodia, Sri Lanka, Malaysia, Nepal, Pakistan, Philippines, Thailand and Vietnam |
| Sub–Saharan Africa (SSA) | 39 | Angola, Burundi, Benin, Burkina Faso, Botswana, C.A.R., Cote d'Ivoire, Cameroon, Congo, Rep., Cape Verde, Ethiopia, Gabon, Ghana, Guinea, Rep., Gambia, Equatorial Guinea, Kenya, Liberia, Lesotho, Madagascar, Mali, Mozambique, Mauritius, Malawi, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Swaziland, Seychelles, Chad, Togo, Tanzania, Uganda, South Africa, Zaire, Zambia and Zimbabwe |
| Middle East and North Africa (MENA) | 10 | Algeria, Egypt, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Syria, Tunisia and U.A.E. |
| Latin America and the Caribbean (LAC) | 25 | Argentina, Bahamas, Belize, Bolivia, Brazil, Barbados, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Guyana, Honduras, Haití, Jamaica, Nicaragua, Panama, Peru, Paraguay, El Salvador, Suriname, Uruguay and Venezuela |

## Appendix 2. Review of empirical literature on fixed-line telecommunications policy and performance

| Study | Objective | Time period, regional focus and sample | Estimation technique | Results | Strengths | Problems with analysis |
|---|---|---|---|---|---|---|
| Wallsten (1999) | To explore the effects of privatization, competition and regulation on mainline penetration, payphone penetration, connection capacity and local call prices. | 30 African and Latin American countries from 1984-'97. | Ordinary fixed effects panel estimation. | 1. Competition significantly correlated with increased mainline penetration, connection capacity, payphone penetration, and a decrease in local calling prices.<br><br>2. Privatizing an incumbent negatively correlated with mainline penetration and connection capacity.<br><br>3. Interaction of privatization and regulation positively correlated with connection capacity and mitigates negative effect of privatization on mainline penetration. | 1. Analyzes the costs associated with granting a privatized incumbent an exclusivity period. | 1. Weak measure of competition – i.e., the use of the number of mobile operators not owned by the incumbent, captures spurious correlation.<br><br>2. No correction for complications in the panel error structure. |
| Ros (1999) | To examine the effects of privatization and competition on network expansion and efficiency. | 110 countries (including developed countries), 1986-'95. | Ordinary fixed effects, and fixed effects with Instrumental variable correction. | 1. Countries with majority privatized PTO have higher mainline penetration, and to a lesser degree, a higher growth in mainline penetration.<br><br>2. No evidence of privatization leading to higher growth of mainline penetration in countries with annual per-capita income below $10,000. | 1. Use instrumental variables to correct for endogeneity.<br><br>2. Large sample makes fixed effects appropriate. | 1. Sample period does not include developing country liberalization of the late 1990s.<br><br>2. Competition measure includes long distance and international competition<br><br>3. Ignores the effect of an independent regulator.<br><br>4. No corrections for complications in panel error structure. |
| Boylaud | To investigate the effects | 23 O.E.C.D | Fixed effects, | 1. The prospect of competition | 1. Exhaustive study | 1. No analysis of |

| | | | | | | |
|---|---|---|---|---|---|---|
| and Nicoletti (2000) | of entry liberalization and privatization on productivity, prices and quality of service in long-distance (domestic and international) and mobile services. | countries from 1991-'97. | robust regressions and random effects. | (measured by time remaining until liberalization) has a strong positive effect on productivity, quality of services and a strong negative effect on prices. | of OECD. countries regulatory system and reform agendas.<br><br>2. Use various techniques to check robustness of estimations. | developing countries.<br><br>2. Do not correct for complications in panel error structure. |
| Fink et. al. (2001) | To ascertain the impact of privatization, competition and regulation on mainline penetration, network quality, and productivity. | 12 East and South Asian economies from 1985-'99. | Ordinary fixed effects panel estimation. | 1. Interaction of privatization and competition significantly increases mainline penetration.<br><br>2. Countries that privatize, introduce competition and establish and independent regulator see much higher levels of mainline penetration, network digitalization and productivity than others. | 1. Useful evidence that policy interactions matter, rather than individual policy effects. | 1. Sample too small to make inferences about other developing countries.<br><br>2. No corrections for complications in panel error structure. |
| Wei et. al. (2001) | To explore the relationship between privatization, competition, regulatory autonomy, and interconnection policies on fixed and mobile capacity, profitability, and local calling prices. | 160 Countries on privatization & 40 Countries on competition over the 1990s | Ordinary fixed effects | 1. In a no interactions model, privatization is significantly positively associated with mainline penetration.<br><br>2. In model with interactions, only the interaction of privatization and competition has a significant influence on mainline penetration.<br><br>3. Autonomous regulator has a negative impact, and competition no impact on mainline penetration. The interaction of competition and interconnection has a strongly negative impact on mainline penetration. | 1. Explores the effects of policy reforms on a wide variety of performance indicators. | 1. Use of information on mobile competition in measuring fixed-line competition makes it hard to disentangle the effects of each on performance.<br><br>2. No corrections for complications in panel error structure. |

**Appendix 3. Partial correlations between various reforms**

| Variable | P | C | R | P*C | C*R | P*R | P*$C_m$ | P*C*R |
|---|---|---|---|---|---|---|---|---|
| P | 1.00 | | | | | | | |
| C | 0.29 (.00) | 1.00 | | | | | | |
| R | 0.28 (.00) | 0.22 (.00) | 1.00 | | | | | |
| P*C | 0.36 (.00) | 0.86 (.00) | 0.18 (.00) | 1.00 | | | | |
| C*R | 0.24 (.00) | 0.74 (.00) | 0.31 (.00) | 0.69 (.00) | 1.00 | | | |
| P*R | 0.60 (.00) | 0.27 (.00) | 0.62 (.00) | 0.33 (.00) | 0.39 (.00) | 1.00 | | |
| P*$C_m$ | 0.60 (.00) | 0.44 (.00) | 0.41 (.00) | 0.52 (.00) | 0.41 (.00) | 0.70 (.00) | 1.00 | |
| P*C*R[48] | 0.28 (.00) | 0.67 (.00) | 0.28 (.00) | 0.78 (.00) | 0.90 (.00) | 0.45 (.00) | 0.47 (.00) | 1.00 |

Note: Numbers in brackets indicate p-values

KEY: P = privatization of fixed line incumbent,
C = competition in local services,
R = independent regulator,
$C_m$ = competition in mobile services.

[48] Since in our sample, every country that had fully liberalized the fixed line sector had also introduced mobile competition, P*C*R is equivalent to P*C*R*$C_m$, i.e., full liberalization of both fixed line and mobile segments.

## Appendix 4: Our choice of estimation technique

Estimating a model containing time-series cross-section (TSCS) data typically implies a complicated regression error structure that involves serial and/or contemporaneous correlation, and heteroscedasticity.[49] Models that feature these kinds of non-spherical disturbances are usually estimated by feasible generalized least squares (FGLS).[50] A model that involves contemporaneous error correlations, serial error correlation, and group-level heteroscedasticity, is estimated by researchers using Park's FGLS method. It is worth noting the criticism of Beck and Katz (1995) on panel data estimation by the Park's FGLS method. Beck and Katz propose using OLS panel corrected standard errors (PCSE) estimation, rather than GLS. Based on Monte Carlo simulations, they infer that GLS estimates that correct for contemporaneous correlation and panel-specific serial correlation produce standard errors that lead to extreme over-confidence, often underestimating variability by 50% or more. [51,52]

A second genre of TSCS models features errors that are serially correlated, and group-wise heteroscedastic, but not contemporaneously correlated. These models are typically estimated using Kmenta's cross-sectionally heteroscedastic and time-wise autocorrelated (CHTA) technique, which is also an FGLS procedure. CHTA first transforms the data to eliminate serial correlation in the errors, and then transforms the transformed data to correct for group-wise heteroscedasticity using panel weighted least squares (PWLS). Using Monte Carlo evidence, Beck and Katz (1996) critique this approach saying that, although CHTA does not produce dramatically incorrect estimates or standard errors, its PWLS component is no more efficient than OLS, and further, that it is better to model dynamics using a lagged dependent variable, rather than an autoregressive process for the error.

We choose to estimate our model using Kmenta's CHTA approach assuming a common autocorrelation parameter across countries. Since we assume neither contemporaneous correlations, nor country-specific serial correlation, we are immune from criticisms regarding the

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[49] The term "time-series cross-section data" is used differently from "panel data". The latter typically has a few repeated observations on a large number of sampled units. We use the terms "panel", "group", and "country" interchangeably. For a good exposition on panel data analysis, refer Hsiao (1986) & Baltagi (1995).

[50] Essentially, a feasible generalized least squares procedure first estimates the model by ordinary least squares (OLS), and uses the OLS residuals to estimate serial correlations, if any, in the error. These estimated serial correlations are then used to transform the model into one with serially independent errors. The transformed model is then estimated by OLS, and the residuals from this are used to estimate the error variance-covariance matrix that contains the estimated contemporaneous correlations. The estimated contemporaneous error correlations and variances are then used to transform the model yet again into one with no contemporaneous correlations and no heteroscedasticity, which can be easily and accurately estimated by OLS.

[51] If group specific autocorrelation (modeled by a first order autoregressive process (AR1)) processes are assumed, then the necessary computation of N extra autocorrelation coefficients (one for each of the N groups), based on only T time series observations per group, is likely to cause more serious underestimations of variability. It is widely accepted that autoregressive parameters estimated in samples of 30 or less time-series observations are inaccurate and downward biased. See, for example, Nickell (1981).

[52] Suppose there are T time-series observations in each of the N panels/groups. Each element of the matrix of contemporaneous covariances is estimated, on average, using 2T/N observations. If the ratio of T/N is close to 1, then contemporaneous covariances are calculated using about 2 observations, which is problematic as their accuracy would be highly questionable.

inaccurate computation of standard errors mentioned earlier.[53] While we could have used a lagged dependent variable, which Beck and Katz suggest is a better way to capture dynamics, its estimation typically requires the use of instruments, if there is serial correlation in the error. Kiviet (1995) has shown that estimation of dynamic panel data models using instrumental variables leads to poor finite sample efficiency. Moreover, it is hard to find good instruments.[54]

[53] We do not assume contemporaneous correlations across panels as the estimation technique would require as many time series observations as there are panels to satisfy matrix invertibility conditions during estimation. In our case, we have only 15 time–series observations per country for 86 countries.

[54] Another interesting estimation technique that we could potentially have used is the Arellano-Bond (1991) procedure for dynamic panel data estimation (or panel estimation with a lagged dependent variable) as it could help account for any endogeneity in the explanatory variables. This technique uses a Generalized Method of Moments estimation procedure and features variables in first differences with lagged values of explanatory variables acting as instruments. However, lagged values make good instruments only if there is no second-order serial correlation in the error term of the first differenced regression.

## Appendix 5. Construction of sequencing dummy variables

Below is an illustration of the construction of the sequencing dummies for Malaysia and Sri Lanka. Malaysia privatized its incumbent Telkom Malaysia in 1990. Competition in basic services was only introduced in 1996, so that Malaysia followed the "privatization before competition" sequence. On the other hand, Sri Lanka introduced competition in 1996, but privatized only in 1997, so that Sri Lanka followed the "simultaneous" sequence.

| Country | Year | Only competition observed (SEQC)[55] | Only privatization observed (SEQP) | Simultaneous sequence (SEQSIM) | Privatization before competition sequence (SEQPC) |
|---|---|---|---|---|---|
| Malaysia | 1985 | 0 | 0 | 0 | 0 |
| Malaysia | 1986 | 0 | 0 | 0 | 0 |
| Malaysia | 1987 | 0 | 0 | 0 | 0 |
| Malaysia | 1988 | 0 | 0 | 0 | 0 |
| Malaysia | 1989 | 0 | 0 | 0 | 0 |
| Malaysia | 1990 | 0 | 1 | 0 | 0 |
| Malaysia | 1991 | 0 | 1 | 0 | 0 |
| Malaysia | 1992 | 0 | 1 | 0 | 0 |
| Malaysia | 1993 | 0 | 1 | 0 | 0 |
| Malaysia | 1994 | 0 | 1 | 0 | 0 |
| Malaysia | 1995 | 0 | 1 | 0 | 0 |
| Malaysia | 1996 | 0 | 0 | 0 | 1 |
| Malaysia | 1997 | 0 | 0 | 0 | 1 |
| Malaysia | 1998 | 0 | 0 | 0 | 1 |
| Malaysia | 1999 | 0 | 0 | 0 | 1 |
| | | | | | |
| Sri Lanka | 1985 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1986 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1987 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1988 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1989 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1990 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1991 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1992 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1993 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1994 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1995 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1996 | 0 | 0 | 0 | 0 |
| Sri Lanka | 1997 | 0 | 0 | 1 | 0 |
| Sri Lanka | 1998 | 0 | 0 | 1 | 0 |
| Sri Lanka | 1999 | 0 | 0 | 1 | 0 |

[55] Note that SEQC (years where only competition is observed) does not take the value 1 for Sri Lanka in the year 1996. This is due to the fact that we have taken the introduction of competition and privatization to be simultaneous (as the two were introduced only a year apart). The variable SEQC takes the value 1 only for those countries who have only introduced competition without privatizing the incumbent.

## Appendix 6: Effect of policy reforms in the mobile sector

We estimated another set of equations for the mobile segment with the mobile penetration rate, measured by the number of mobile subscribers per 100 of the population, as the dependent variable. We used controls and explanatory variables along the lines of Gruber & Verboven (2001 a & b), Barros and Cadima (2000), Xu & Li (2001), and Gebrebab (2002). Using a similar model and estimation technique as the one introduced earlier for fixed line penetration (fixed effects, autonomous time trend and country controls estimated by FGLS), we find that mobile competition is a positive and highly significant determinant of mobile penetration.[56] This result is in line with the findings of the aforementioned authors. The effect of mobile competition has been to drastically reduce the price of handsets and mobile calling prices thereby contributing to a large increase in subscribers.

On running separate regressions for the analogue and digital segments, we find that analogue and digital mobile competition are positive and significant determinants of analogue and digital mobile penetration respectively. Not surprisingly, the introduction of digital technology, which substantially increased spectrum capacity, seems to have reduced the analogue mobile phone penetration rate. These results are presented in table 5 below. Surprisingly, there is no robust relationship between mobile penetration and the log of GDP, which is in line with the findings of Gebrebab (2002) and Barros and Cadima (2000).[57]

**Table 5: Effects of policy reforms on mobile penetration**

| *Dependent variable* | *Ln(mobile Subscribers per 100 people)* | *Ln(Analogue mobile subscribers per 100 people)* | *Ln(Digital mobile subscribers per 100 people)* |
|---|---|---|---|
| Time trend | .026*** (2.86) | .25* (1.83) | .238* (1.77) |
| Natural log of per-capita GDP | -.859** (-2.31) | 2.15*** (3.98) | .945 (1.14) |
| Natural log of population | -.30 (-0.21) | -2.81 (-1.33) | 1.468 (0.47) |
| ***Dummy variable for mobile competition*** | .537*** (8.78) | | |
| ***Dummy variable for competition in the analogue segment*** | | .65*** (5.95) | |
| ***Dummy variable for competition in the digital mobile segment*** | | | .576*** (6.90) |
| *Dummy variable for the introduction of digital technology* | .058 (0.87) | -.138* (-1.66) | |
| *Natural log of mainline penetration* | 3.62*** (3.87) | 1.045 (0.72) | 5.835*** (4.84) |
| AR(1) coefficient | .35 | .41 | -.03 |
| Number of Observations | 531 | 408 | 195 |

[56] The results for the mobile segment are robust to using a variety of estimation techniques such as ordinary fixed effects, random effects, and OLS with panel corrected standard errors.

[57] We attribute the insignificance of per capita GDP to its high degree of correlation with the fixed line teledensity of almost 0.9. When the fixed line teledensity is excluded, the natural log of per capita GDP is significant.

In all the mobile regressions, the fixed line penetration rate exerts a positive and statistically significant influence on the mobile penetration rate. Gebrebab (2002) and Gruber & Verboven (2001a) find the same result without correcting for the endogeneity of the fixed network. The latter interpret this finding to mean that mobile and fixed phones are complements for one another (also see Jha and Majumdar (1999) for a conceptual discussion). We address this issue empirically in the next sub section.

*Interdependence between fixed and mobile segments*

An interesting question has to do with the impact that higher penetration in the fixed (mobile) sector has on penetration in the mobile (fixed) sector. The interdependence between the fixed line and mobile sectors is best studied by using a simultaneous equation approach. We find that there exists a positive relationship between fixed and mobile penetration in levels.[58] This seems to suggest that network externalities seem to enhance the benefits of belonging to either network given the size of the other. This result is in line with Gruber and Verboven (2001a), but differs from the finding of Barros and Cadima (2000). The latter find that a unit increase in mobile penetration leads to a 10% decline in the fixed line teledensity of Portugal. Our result is robust to estimation by 3SLS, or the Baltagi-Chang instrumental variables method and is presented in column 1 below.

**Table 6: Interdependence between fixed and mobile segments**

| ***Fixed line equation*** | *(1) Levels on levels* | *(2) Growth Rate on levels* |
|---|---|---|
| *Natural log of per-capita GDP* | .345*** | .076*** |
| | (9.76) | (4.50) |
| *Natural log of population* | -.114 | .041 |
| | (-0.40) | (1.44) |
| *Dummy variable for privatization* | .067*** | .037*** |
| | (4.05) | (4.40) |
| *Dummy variable for competition in basic services* | .037** | -.036*** |
| | (2.00) | (-3.21) |
| *Natural log of mobile subscribers per 100* | .474*** | -.007 |
| | (4.57) | (-0.44) |
| ***Mobile penetration equation*** | | |
| *Natural log of per-capita GDP* | -.975*** | .062 |
| | (-2.65) | (0.35) |
| *Natural log of population* | -.495 | .519*** |
| | (-0.35) | (2.39) |
| *Dummy variable for mobile competition* | .648*** | .137** |
| | (19.87) | (2.44) |
| *Dummy variable for the introduction of digital technology* | .047 | .07 |
| | (0.72) | (1.41) |
| *Natural log of mainlines per 100* | 3.428*** | -.655*** |
| | (3.66) | (-4.52) |

[58] The estimated coefficients (elasticities) suggest that a 1% increase in mobile penetration is associated with a .47% increase in fixed-line penetration, while a 1% increase in the latter corresponds to a 3.4% increase in mobile penetration. We do not report the time trend, the constant and the country fixed effects.

Column 2 of table 6 presents estimates from equations where growth rates are regressed on levels. When we regress the first difference of the natural log of mainlines (which is equivalent to the growth rate) on the level of mobile penetration, we find that the latter does not exert a significant influence on the former. Interestingly, when we regress the first difference of the natural log of mobile subscribers (which is equivalent to the growth rate of mobile subscribers) on the level of mainline penetration, we find that mobile growth is lower in countries with a higher fixed line penetration. This is similar to the finding of Gruber and Verboven (2001b) that a higher fixed network has a negative impact on the speed of mobile diffusion.

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