The determinants and impact of telecommunications reforms in developing countries*

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Abstract

This paper has two related objectives. First, it seeks to identify the key determinants of some policies that have been at the heart of the reforms of the telecommunications industry in developing countries, namely, liberalization, privatization, and the (re)structuring of regulation. Second, it attempts to estimate the extent to which these policies have translated into actual deployment of telecommunications infrastructure. This simultaneous investigation is conducted by means of an econometric analysis of a 1985-1999 time-series-cross-sectional database on 86 developing countries. Sectoral as well as institutional and financial factors are found to be important determinants of the actual reforms implemented. We uncover a positive relationship between the decision to introduce competition in the digital cellular segment and the growth of the fixed-line segment, suggesting that these two segments have benefited from each other. We also find that countries facing increasing institutional risk and financial constraints are more likely to introduce competition in the digital cellular segment and to privatize the fixed-line incumbent, these policies being economically attractive to both investors and governments. In turn, these policies are those that enhance the deployment of fixed-line infrastructure. In contrast, competition in the analogue cellular segment and the creation of a separate regulator seem to be relatively less attractive policies as they are found to be less likely to be introduced in countries facing increasing institutional risk and budget constraints. Their impact on fixed network deployment is found to be negative or non significant.

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1 Introduction

The telecommunications sector has been at the forefront of the wave of reforms that has profoundly reshaped infrastructure industries worldwide by allowing new market configurations and institutions to emerge. Both developed and developing countries have been concerned with enhancing industry suppliers' performance. Competition in some segments of the industry has been introduced, sometimes with some level of privatization of state-owned incumbents, and the legal and regulatory framework has been (re)designed with the purpose of enhancing diversification and quality of service, efficiency, and tariffs. One must recognize, however, that policy makers in developing countries faced a far more challenging task than their developed countries counterparts. Poor infrastructures, weak economic conditions, and inadequate institutions inherited from the pre-reforms era are all but some of the significant impediments to the advancement of the reforms they had to overcome. Given the scarcity of resources, the question then is how to efficiently allocate these resources among the many objectives.

In a previous econometric study (Gasmi et al, 2006), we have shown that political accountability is an important determinant of regulatory performance and forcefully argued that policies aimed at enhancing politically accountable systems should be given due attention in development programs. In this paper, we further investigate the relationship between the reforms of the telecommunications sector that have been actually implemented in developing countries and the evolution of this sector. More specifically, we approach this issue by attempting to both evaluate the impact of the sectoral reforms on the deployment of infrastructure and identify the main factors that lead to specific reforms and allowed them to proliferate.

In addition to insufficient deployment of telecommunications technologies and lack of good institutional governance, developing countries are often characterized by poor macroeconomic conditions. The structuration of the reforms in terms of their number, their design, and their timing, as well as their effective impact on the industry performance, are all subject to these constraints. Hence, market outcomes resulting from the telecommunications reforms are not only conditioned by decisions pertaining to the sector itself, but also by the institutional and macroeconomic environment. Factors

such as corruption engrained in the political system and lack of democracy substantially weakens the efficiency of institutional rules whereas high debt service and inefficient taxation worsen the financial situation.

While the question of the impact of telecommunications reforms on the deployment of infrastructure in developing countries has been fairly well addressed from an empirical standpoint, the issue of the determinants of these reforms has been mainly examined at a conceptual level.[2] This paper seeks to fill this void by tackling these two issues within a unified empirical framework. Using data on the telecommunications industry in developing countries, we attempt to evaluate the impact of the reforms on network expansion and, at the same time, investigate the role that infrastructure deployment, institutional risk, and access to public funds have played in the decisions to introduce competition, to privatize the state-owned incumbent operator, and to create a separate regulatory authority. The link between sectoral reforms and infrastructure deployment variables is explored by means of a systematic investigation of two-way causal relationships between these variables.

Our search for a two-way causality between reform and network expansion variables also gives us an indication of the extent to which the econometric estimation of our regressions would need to account for endogeneity of some of the regressors. Indeed, one might expect that reform policies such as the introduction of competition and privatization may be endogenous to infrastructure deployment, particularly in the early stages of the reforms as licences are often granted conditional on the fulfillment of service penetration and quality targets.[3] Moreover, the creation of a separate regulatory entity may also depend on pre-regulatory conditions.

In this paper, we depart from the approach typically followed in the literature to analyze the telecommunications reforms in developing countries by treating separately the analogue and digital segments of the cellular market as far as the introduction of competition is concerned. This allows us therefore to shed some light on the market implications of technology and history.

[2]Fink et al. (2002) provide a comprehensive overview of the empirical stream of the literature. Contributions to the conceptual stream include Auriol and Picard (2004), Emerson (2006), Evans et al. (2005), Laffont (2005), and Warlters (2004).

[3]Often licences are also associated with exclusivity periods.

The plan of the paper is as follows. The next section summarizes some of the main results recently put forward in the empirical literature on the determinants of the telecommunications reforms and their impact on infrastructure deployment as measured by fixed-line service penetration. Section 3 describes the data set used in this paper which contains information on the telecommunications industry in 86 developing countries during the period 1985-1999. Section 4 describes the basic econometric ingredients used in our empirical analysis. The results of our empirical investigation of the determinants of the telecommunications reforms and their impact on infrastructure deployment are discussed in section 5. This section also discusses some (testable) theoretical hypotheses drawn from the literature on the determinants of reforms on which our analysis brings some empirical evidence. Section 6 summarizes our findings, discusses some policy implications, and points to some directions for further research. A detailed description of the data used, their sources, and some complementary material are given in the appendix.

2 Related literature

Thanks to the availability of data on the telecommunications industry accumulated over two decades now, there is a relatively large empirical literature that analyzes the impact of major reforms on infrastructure deployment in this sector. The empirical literature exploring the determinants of these sectoral reforms, however, is at its infancy and mostly deals with political factors. We briefly review some representative studies in each of these two streams of the literature and indicate all along some points of this literature that our paper contributes to.

Most of the studies done so far on the impact of sectoral reforms on infrastructure deployment in developing countries acknowledge the fact that, overall, there exists a robust relationship between variables representing the reforms and variables measuring telecommunications network expansion such as fixed-line service penetration. In particular, the bulk of this literature has come to the conclusion that the introduction of competition has resulted in measurable network deployment and labor efficiency in the fixed-line seg-

ment. Fink et al. (2002) provide an analysis of the impact of competition on fixed-line deployment and labor efficiency in data on 86 developing countries across African, Asian, Middle Eastern, Latin American, and Caribbean countries for the period 1985-1999. Wallsten (2001), Gutierrez (2003), and Ros (2003) use data on a set of African and Latin American countries while Ros (1999) uses data on countries with GDP per capita of less than USD 10,000 and McNary (2001) and Li and Xu (2004) use worldwide data. Though McNary (2001), Fink et al. (2002), and Li and Xu (2004) consider the introduction of competition in the fixed-line and cellular segments, to the best of our knowledge, the analogue and digital segments have yet to be addressed separately. This paper is an attempt to do so.

There is not such a consensus on the impact of the privatization of the fixed-line incumbent on network expansion. Some empirical results indicate that this policy has a positive impact on fixed-line deployment. After controlling for tariff re-balancing, Banerjee and Ros (2000) find that privatization reduces unmet demand by approximately 28% in a data set on 23 Latin American countries for the period 1986-1995. Gutierrez (2003) reports a reduction of unmet demand of the order of 10 to 18% in data on 22 Latin American countries covering the period 1980-1997. Similar results are obtained by Fink et al. (2002), Ros (2003), and Li and Xu (2004) using various data sets.

Other empirical studies using worldwide data sets, in particular, Ros (1999) and McNary (2001), indicate that privatization has no or even a negative impact on fixed-line deployment.[4] Nevertheless, both authors insist on the role played by independent regulators in the privatization process, a feature that neither of them includes in their investigations. The importance of this issue is highlighted by Wallsten (2001) and Gutierrez (2003) who find that privatization coupled with the existence of an independent regulator results in larger gains in terms of network expansion. Fink et al. (2002) and Ros (2003) also find that the impact of privatization and competition reforms is enhanced by the creation of a separate regulator. As to the impact of privatization on efficiency, it is found that it is similarly affected by the

[4]For an analysis of privatization policies across the world see Bortolotti and Siniscalco (2004).

presence of an independent regulator (Wallsten, 2001, Gutierrez, 2003).[5]

There is an emerging yet limited empirical literature focusing on the determinants of sectoral reforms in infrastructure industries and this literature has been so far mainly concerned with political factors. Using telecommunications data for the period 1990-1998 on a panel of countries chosen worldwide, Li and Xu (2002) and Li et al. (2005) explore the political economy of liberalization, privatization, and regulatory reforms.[6] In both studies, countries with stronger pro-reform interest groups, namely, financial actors and urban consumers, are more likely to implement reforms in more democratic environments. Li and Xu (2002) find that less democratic countries are more likely to maintain the public sector monopoly when the fiscal deficit is high. In addition, Li et al. (2005) find that reforms are less likely to be implemented in countries where incumbent operators have already sunk large investments since these operators have strong incentives to oppose the reforms.

Closer to our work, Gual and Trillas (2006) are, to the best of our knowledge, the first to consider both the determinants of the reforms, in particular, to highlight the role of entry and regulatory policies, and the impact of the reforms on network deployment. They use a Two-Stage-Least-Squares estimation technique to fit 1998 cross-sectional data on 37 countries.[7] Though their results are not always robust, these authors find some preliminary evidence that competition policies have a positive impact on network deployment and that regulatory independence has a negative effect on productivity. With regard to the determinants of reforms, they find that countries with in-

[5]Some details of the private transactions are also found to play an important role in network deployment. See Wallsten (2000) and Li and Xu (2004) for the effects of exclusivity periods and Ros (2003) for the effects of the price cap regulatory regime.

[6]Liberalization reforms are measured by an index computed as the average of six indicators describing the market environment (multiple-player environment, pro-competition initiatives, and interconnection policy) in the fixed-line and cellular segments. Privatization concerns the fixed-line incumbent while regulatory reforms account for tariff policies and the degree of autonomy and transparency of regulation in the fixed-line and cellular segments.

[7]Entry policies relate to investment conditions imposed on entrants, average number of mobile providers, number portability, carrier selection, carrier pre-selection, and local loop unbundling availability. Regulatory policies have to do with licensing, interconnection, tariffs, scarce resources, universal service, the funding structure, the appointment process of regulators, the length of the term, the reporting process, the year of establishment of effective operation, and the incumbent capital ownership.

terventionist traditions have fewer liberalization policies and that the larger the size of the incumbent and the lower the protection of investors, the more prone a country is to create an independent regulator.

We extent the work of Gual and Trillas (2006) in two ways. First, we analyze in a more disaggregated manner the role of major policies that have been used to reform the telecommunications sector. More specifically, we attempt to estimate the effect of the level of competition in the digital and analogue cellular segments, and in the local fixed-line segment, the effect of the creation of a separate regulator, and the effect of privatization of the fixed-line incumbent. Second, we provide an interpretation of some of our results as tests of a series of hypotheses derived from the theoretical literature on telecommunications reform. These hypotheses are mostly concerned with the institutional and financial endowments of a country that have been emphasized in the literature as being important drivers of infrastructure industries reforms in developing countries. This approach allows us therefore to evaluate the indirect impact, through the reforms selected by the governments, of these country-specific features on infrastructure deployment.

3 Data and main variables

We have constructed a time-series-cross-sectional (TSCS) data set containing time-varying information on 86 developing countries for the period 1985-1999.[8] These data have been organized in variables regrouped in five categories, namely, "Telecommunications deployment," "Telecommunications reforms," "Institutional environment and risk indices," "Cost of public funds," and "Other variables and instruments." The list of the countries included in the data set, the designation of each of the variables, the data sources, and some standard summary statistics are given in the appendix.

The deployment of telecommunications infrastructure is captured in a

[8]Selectivity bias should not be a concern in our data set. First, our panel includes some countries that have reformed and some that haven't. Second, firms do not appear as having control over the regulatory regime under which they operate. On the one hand, firms with poor performance may be subject to reforms. On the other hand, the government may decide to reform well performing sectors that deliver high license fees. For empirical evidence on such a positive relationship between firms' performance and the introduction of reforms, see, e.g., Ross (1999).

variable that gives the number of telephone lines per 100 inhabitants that connect the subscribers' terminal equipment to the PSTN.[9] Telecommunications reforms are represented by variables that give the number of competitors in the analogue and digital cellular segments, variables that indicate whether competition prevails in the fixed-line local segment and whether a separate telecommunications regulator has been created, and a variable that gives the % of the fixed-line incumbent's assets sold to private investors. The extent of competition in the analogue and digital cellular markets is captured in a four-category variable that specifies the number of licences issued in these segments, that is, no licence, one licence (monopoly), two licences (duopoly), or more (high competition). As to the fixed-line market, we focus on competition in the local segment as this is the one that has historically constituted a bottleneck.[10] Moreover, we do not differentiate between a duopoly situation and a high competition situation in the fixed-line local segment since there are very few countries in our data set that have actually attributed more than two licenses to this segment.

The institutional environment indices indicate how corrupt the government is and how strong its ability to commit to announced policy is. These indices are constructed from variables measuring the degree of corruption, the quality of the institutional framework, and the level of democracy in the country.[11] Corruption includes actual and potential influence of the political system in the form of excessive patronage, nepotism, job reservations, favors for favors, secret party funding, and close ties between politicians and businesses. The quality of the institutional framework is captured by a variable that is calculated as the unweighted sum of variables reflecting government integrity, the efficiency of bureaucracy, the strength of courts and their capacity to enforce decisions, and government commitment credibility, in particular, the extent to which asset expropriation and contract repudiation is used by the government. The level of democracy is captured in a variable whose value is found by subtracting an index of autocracy from an

[9]Public Switched Telephone Network.

[10]Hence, we do not account for competition in the long distance or international segments.

[11]Laffont (2005) evokes the idea of corruption and democracy being negatively correlated.

index of democracy. The risk index is measured by a variable computed as the average of three series corresponding to economic, financial, and institutional risks. Higher values of these institutional environment and risk indices reflect a "better" overall institutional environment and a lower risk.

The cost of public funds is captured in variables measuring the value of debt service and net taxes on products as a proportion of respectively the gross national income (GNI) and the gross domestic product (GDP) and aid per capita, all expressed in 2000 USD.[12] These variables are chosen because of the relationships between them which can be explained as follows. For a given tax system, increases in debt force the government to increase its revenue requirement by borrowing more or by increasing taxation. Hence, one can expect a positive relationship between debt and the cost of public funds.[13] Net taxes on products capture a type of commodity taxation which has been introduced in recent years providing developing countries with a more effective instrument for raising revenues than other indirect taxation mechanisms such as taxes on profits. These relatively efficient taxes and aid perceived by the government may have a direct impact on the government funding requirements and can be expected to be negatively correlated with the cost of public funds.[14] Since it takes time for changes in debt or aid to have an effect on the tax system and for taxes on products to be settled, we use lagged values of these variables in the parameterization of the cost of public funds.

Variables under the heading of "Other variables and instruments" are those that measure other factors that are deemed relevant for our estimation of the determinants and the impact of the reforms. The "variables" part includes the population density, the % of the population that is rural, imports as a proportion of GDP, full time fixed-line and mobile telecommunications staff as a proportion of total population, and the number of checks and

[12]The cost of public funds is commonly viewed as the deadweight loss due to distortionary taxation that the government has to rely on to collect these funds.

[13]We should note that here we are not making inferences about the variables in levels. Indeed, a given level of the cost of public funds results from a complex interaction among multiple tax instruments and as such it may coexist with different debt levels.

[14]This is a different argument than that of aid conditionality. For example, aid conditionality may not be effective when the recipient country does not want to reform (see Ghosh Banerjee and Rondinelli, 2003).

balances in the political system. In addition to being an indicator of the division of power in the political system, in as so far as it is informative of the political stability of the country, the checks and balances variable also captures the level of the (social) discount rate in the country. More specifically, the higher the discount rate, i.e., the higher the valuation of the future by agents, the higher the number of checks and balances indicating a "better" mode of functioning of the political process.

The "instruments" part includes a set of variables reflecting various country specific features that might improve the explanatory power of the estimated models. This set includes variables concerning some aspects related to the origin (English or French) of the legal system, the importance of protestants in the population (% in 1980), the country's latitude (in absolute value), the country's level of literacy (average schooling years in the population over 25 in 1980), and the ethno-linguistic fractionalization of the country. It also includes variables that specify whether the country belongs to Sub-Saharan Africa, the importance of crop and forest land in the country (ratio to total land), whether there are significant political obstacles to policy changes in the country, the quality of the media's legal environment, the degree of tension attributable to race, nationality, or language, and the strength of the legal system and the public observance of the law.

4 Econometric methodology

To investigate the determinants of the telecommunications reforms and the impact of these reforms on network expansion, we run a set of regressions with the dependent variable representing either a reform policy or a measure of infrastructure deployment. In the reform regressions, the explanatory variables have been chosen so as to allow us to test some hypotheses derived from the recent theoretical literature on the determinants of the reforms. These hypotheses, which are discussed in more details in the next section, are concerned with the role played by corruption and the cost of public funds in the decisions to introduce competition and to privatize state-owned incumbents, and with the influence that the government's ability to commit, the return on investment, and the discount factor have on the decision to create a separate

regulator. In the regressions that aim to explain infrastructure deployment, the latter being measured by a variable of fixed-line network expansion, we use, among other explanatory variables, indicators of the telecommunications reforms.

Prior to specifying the regressions to be estimated, we perform some tests for the existence of two-way causal relationships between the variables representing telecommunications reforms and those representing fixed-line network deployment.[15] These tests, of the Granger-causality type developed in Holtz-Eakin et al. (1988), allow us to obtain a set of potential explanatory variables to be used in the specification of the regressions.[16]

For the estimation, we apply two different techniques according to the nature of the dependent variable. For the regressions involving a discrete dependent variable, we use the group duration methodology. This is the case when the dependent variable is an indicator of competition in the analogue or digital cellular segments, in the local fixed-line segment, or of the existence of a separate regulator. For the regressions involving a continuous dependent variable, we use the System Generalized Method of Moments (SYS-GMM). This technique is used when the dependent variable represents the privatization reform policy or the deployment of fixed-line network. Some basic explanations of these two techniques are provided next.

4.1 Regressions with a discrete dependent variable

For the regressions in which the dependent variables that represent telecommunications reforms are discrete, we fit the data by applying a grouped duration methodology developed in Beck et al. (1998) that allows us to explore the presence of temporal dependence.[17] This methodology consists

[15]These tests also shed some light on the issue of endogeneity of reforms to network expansion, an issue that has been raised in the literature. See Ros (1999) and Gutierrez (2003) on the endogeneity of competition in the local, long distance, and international fixed-line service, and of the privatization of the incumbent operator. Endogeneity of regulation is discussed in Gutierrez (2003) and Ros (2003).

[16]The reader is referred to Gasmi et al. (2006) for details on the implementation of these tests.

[17]The presence of temporal dependence in TSCS discrete regressions results in a violation of the assumption of independent observations which leads to an underestimation of their variability. In our context, the number of years elapsed between an event, e.g., the issuing of a licence in the case of competition variables or the creation of the regulatory

in using the complementary log-log (CLOGLOG) estimation technique with the discrete dependent variables capturing the elapsed time until the reform and with d temporal dummies, $temp_d$, $d = 1, 2, \ldots, 14$, capturing the time since the most recent event.[18] Since including the temporal dummies may introduce multicollinearity, we first test if they are needed by means of a likelihood ratio test of the hypothesis that the observations are temporally independent, i.e., that $temp_d = 0$ for all d.

An econometric issue which is particularly relevant in our modeling context is that of the occurrence of multiple events in the series indicating competition in the analogue and digital cellular segments. Omitting to explicitly model multiple events amounts to assuming that first, second, and subsequent events are independently distributed. It is, however, unlikely that an event such as the issuing of a licence is independent of the timing and the number of licenses previously issued in the same segment. To model multiple events, we include in the previous specification a variable, *counter*, that counts at a given year the number of similar events that occurred in the previous years.[19]

The discrete model is then specified as follows:

$$r^*_{it} = \phi + \mathrm{x}'_{it}\varphi + \sum_{d=1}^{T-1} temp_{d,it} + counter_{it} + \omega_{it} \tag{1}$$

$$i = 1, 2, \ldots, N; \quad t = 1, 2, \ldots, T; \quad r_{it} = \begin{cases} 1 & if \quad r^*_{it} \geq 0 \\ 0 & if \quad r^*_{it} < 0 \end{cases}$$

authority in the case of the variable that indicates the existence of a separate regulator, and the start of the sample or the previous event seems likely to influence the results.

[18] The dependent variable takes on the value 1 in year t if one licence or more has been issued sometime in year t, in the case of the competition variables, or if the regulatory agency has been separated from and is not directly controlled by a ministry or a utility sometime in year t, in the case of the variable indicating the existence of a separate regulator, and 0 otherwise. The temporal dummies are created by first constructing a variable marking the length of the sequence of zeros that precede the current observation of the dependent variable.

[19] The *counter* variable takes on the value 0 in year t if no license has been issued in $t-1$ or earlier, 1 if one license has been issued in $t-1$ or earlier, 2 if two licences have been issued in $t-1$ or earlier, and 3 if three or more licenses have been issued in $t-1$ or earlier. In practice, this variable is noted *counter_ana* in the regression concerning competition in the analogue cellular segment and *counter_dig* in the one concerning competition in the digital cellular segment.

where the indices i and t refer to the country and the year respectively, r^*_{it} is the unobserved latent variable, r_{it} is the dichotomous variable representing the reform, ϕ is a scalar parameter, x_{it} is the vector of regressors, φ is the associated vector of parameters, and ω_{it} is a disturbance term. The vector of regressors x_{it} includes the population density, the % of the population that is rural, and some variables introduced for the purpose of testing a series of hypotheses derived from the theoretical literature on the determinants of reforms.[20,21] For the data set used in the analysis $N = 86$, the number of developing countries in the sample, and $T = 15$, the number of years of observation (1985-1999).

Some of the regressors included in x_{it} may in fact be endogenous, hence, correlated with the disturbance term, which would lead to inconsistent estimators.[22] To circumvent this difficulty, we specify an additional equation for each of the endogenous regressors and use the Full Information Maximum Likelihood (FIML) estimation technique.[23] More specifically, FIML is used to estimate the simultaneous system composed of (1) and the equation

$$v_{it} = \vartheta + \mathrm{w}'_{it}\gamma + \mathrm{z}'_{it}\delta + \eta_{it} \tag{2}$$

where v_{it} is a component of the vector v_{it} of (continuous) endogenous regressors in x_{it}, ϑ is a scalar parameter, w_{it} is a vector of exogenous regressors in x_{it}, γ is the associated vector of parameters, z_{it} is a vector of instruments, δ is the associated vector of parameters, and η_{it} is a disturbance term.

[20] These hypotheses are stated in section 5.1.

[21] The vector of regressors x_{it} is set in first differences in order to eliminate sources of unobserved fixed heterogeneity.

[22] Endogeneity might stem from say competition having an effect on how corrupt the government is (see Bliss and Di Tella, 1997, and Laffont and N'Guessan, 1999) or the creation of a separate regulator affecting the level of network expansion and the size of the telecommunications staff.

[23] Although FIML provides an exogeneity test, it becomes computationally unfeasible as the number of regressors included as endogenous grows. We use then the Two Stage Conditional Maximum Likelihood (2SCML) estimator derived by Rivers and Vuong (1988) to perform exogeneity tests since it allows the presence of multiple potentially endogenous regressors. See the appendix for more on 2SCML exogeneity tests.

4.2 Regressions with a continuous dependent variable

We now briefly discuss the econometric methodology that we use to fit the data when the dependent variable is continuous. This is the case when the dependent variable represents the level of privatization of the incumbent or the measure of fixed-line deployment, i.e., the fixed-service penetration rate.

Given the dynamic nature of our data, which has been confirmed by Lagrange multiplier tests, we use the System Generalized Method of Moments (SYS-GMM) developed by Arellano and Bover (1995) for analyzing panel data and applied by Beck and Katz (2004) to TSCS data.[24] However, these authors show that, with a non stationary dependent variable, the dispersion of the value of the coefficient in an autoregressive process of order one found with different asymptotically equivalent methods often exceeds its standard errors. Hence, for these accuracy reasons, we first investigate the stationarity of our dependent variables. We find that these variables are stationary in first differences and hence continue our analysis with these series transformed in first differences.[25]

We specify the following dynamic autoregressive:

$$y_{it} = \alpha_0 + \alpha_1 y_{it-1} + \mathrm{x}'_{it}\beta + \mu_i + \epsilon_{it} \tag{3}$$

where $i = 1, 2, \ldots, N$, $t = 1, 2, \ldots, T$, y_{it} is a one-dimensional variable representing the continuous dependent variable (fixed-line deployment or privatization level), α_0 and α_1 are scalar parameters, x_{it} is a vector of regressors, β is the associated vector of parameters, μ_i is a country-specific fixed factor, and ϵ_{it} is a disturbance term.[26] For the fixed-line deployment regression, the vector of regressors x_{it} includes the institutional and democracy indices, the population density, and the % of the population that is rural. It also contains the indicators of the telecommunications reforms. For the privatization regression, this vector of regressors contains the two population variables

[24] As an instrumental variables (IV) estimation method, SYS-GMM privileges consistency.

[25] Details on the stationarity tests can be found in Gasmi et al. (2006) and the results obtained for this paper are available from the authors upon request.

[26] The standard assumptions $\mathrm{E}(\mu_i) = 0$, $\mathrm{E}(\epsilon_{it}) = 0$, $\mathrm{E}(\epsilon_{it}\mu_i) = 0$, and $\mathrm{E}(y_{i1}\epsilon_{it}) = 0$ are made. The fixed-line deployment series is transformed in logs to minimize heteroskedasticity and influential outliers problems and the vector of regressors x_{it} is taken in first differences to eliminate any sources of unobserved fixed heterogeneity.

above and the variables that are used to test the hypotheses derived from the theoretical literature on the determinants of reforms.

To take care of endogeneity problems which seem likely to arise in the estimation of equation (3), we set a procedure to find appropriate instruments.[27] When exploiting the information in first differences associated with this equation, we follow the standard approach that consists in taking lagged variables in levels as a set of potential instruments and selecting appropriate lag lengths by investigating whether the disturbance term is serially uncorrelated or follows a moving average process of some order q, $MA(q)$. In the case of a serially uncorrelated disturbance term, we have $\mathrm{E}(\epsilon_{it}\epsilon_{is}) = 0$ for $t \neq s$, and the variables y and x lagged two and more periods are valid instruments.[28] If the disturbance term is a $MA(1)$, we have $\mathrm{E}(\epsilon_{it}\epsilon_{it-l}) \neq 0$ for $l \leq 1$ and $\mathrm{E}(\epsilon_{it}\epsilon_{it-l}) = 0$ for $l > 1$, and the variables y and x lagged three and more periods are valid instruments. More generally, if the disturbance term follows a $MA(q)$, the valid instruments are y and x lagged $(2+q)$ and more periods.[29] Following the same approach when exploiting the information in levels related to equation (3), it is possible to use as instruments, the variables $\{\Delta y, \Delta \mathrm{x}\}$ lagged one period when the disturbance is serially uncorrelated, and lagged $(q+1)$ periods when it follows a $MA(q)$.[30]

[27]Endogeneity is indeed an issue in our context. For example, one may argue that privatization might be used to signal commitment towards policy reforms contributing to the reduction of risk ratings. Moreover, privatization of public utilities may open the door to more corruption (see Martimort and Straub, 2006).

[28]Indeed, it can be seen that for $T \geq 3$, $\mathrm{E}(\Delta\epsilon_{it}\log(y_{it-t'})) = 0$ and $\mathrm{E}(\mathrm{x}_{it-t'}\Delta\epsilon_{it}) = 0,\ i = 1, 2, \ldots, N;\ t = 3, \ldots, T,\ t' = 2, \ldots, t-1$.

[29]In practice, we start by using as instruments for the equation in first differences the variables $\log(y)$ and x lagged two and more periods. If the disturbance term in first differences presents no second-order autocorrelation, we are facing a serially uncorrelated disturbance term in levels which therefore says that the instruments used are valid. If the disturbance term in first differences presents a second-order autocorrelation, this indicates that, in levels, this term follows a moving average process and that the dependent variables $\log(y)$ and x lagged two periods are endogenous and hence are not valid instruments. We then repeat the procedure by using, as instruments for the equation in first differences, the variables $\log(y)$ and x lagged n times $(n \geq 3)$ and more until we find no n-order autocorrelation in the disturbance term in first differences.

[30]Indeed, it can be seen that $\mathrm{E}(\Delta\log(y_{it-1-q})(\mu_i+\epsilon_{it})) = 0$ and $\mathrm{E}(\Delta\mathrm{x}_{it-1-q}(\mu_i+\epsilon_{it})) = 0,\ i = 1, 2, \ldots, N;\ t = 3+q, \ldots, T$.

5 Empirical analysis

In this section, we present the results of our analysis of the determinants of the telecommunications reforms and their impact on fixed-line deployment. First, we discuss the theoretical hypotheses on the determinants of the reforms that we will seek to test in our regressions. Second, we present the results of a preliminary inspection of the data the purpose of which is to search for empirical evidence of causal relationships between the telecommunications reforms and fixed-line deployment variables. Third, we move on to presenting the results of our regressions on the determinants of reforms dependent variables of two types, discrete and continuous. Fourth, we synthesize the empirical information contained in the results pertaining to the simultaneous relationship between the reforms and the expansion of the fixed network, one of the major objectives of the reforms. This involves first examining the impact of reforms on the fixed-line segment which we do in this section. Finally, we summarize our findings on the determinant of reforms.

5.1 The determinants of reforms: Some testable theoretical hypotheses

The literature on the factors that influence the decision to reform the telecommunications sector by introducing competition has emphasized the role of corruption in the political system and the cost of public funds. Emerson (2004) develops a model where rent seeking firms agree to pay bribes to policy makers to limit market entry. One of the equilibria obtained is characterized by low (high) levels of corruption combined with high (low) levels of competition. Under the assumption that data reflect this equilibrium, a testable hypothesis is then that

Hypothesis 1: Countries with relatively high corruption will tend to introduce less competition.

Following a normative approach, Auriol and Picard (2004) develop a model where it is optimal to foster competition in infrastructure industries when the cost of public funds is low. In our context, this argument translates into the hypothesis that

Hypothesis 2: Countries with a relatively high cost of public funds will tend to introduce less competition.

Turning to the reform which involves the creation of an independent regulator, the literature has pointed to the role of government commitment, return on investment, and the discount factor. Drawing on a framework developed for analyzing the decision to create independent central banks, Evans et al. (2005) claim that in infrastructure industries government commitment and regulatory independence are substitutes. Moreover, these authors argue that regulatory independence becomes more necessary to alleviate under-investment when the return on investment and the discount factor are high.[31] These arguments translate into the hypothesis that

Hypothesis 3: Countries with relatively low government commitment, large returns on investment, and high discount factors will tend to create an independent regulator.

Among the determinants of the privatization reform in infrastructure sectors discussed in the literature and given the purpose of our study, we have focused on the role of corruption of the political system and the cost of public funds. Laffont (2005) develops a positive theory of privatization where, for sufficiently low levels of corruption, as corruption increases the private gains of politicians from privatization are larger than those obtained with a public firm and dominate the social costs of privatization. However, for very large levels of corruption, it is necessary to leave the control of the firm to private shareholders, and in these circumstances, the private gains of politicians cannot compensate for the rents appropriated by private investors. An implication of this theory is then that within low (high) levels, increasing corruption levels should influence positively (negatively) the decision to privatize. In our context, this implication translates into the hypothesis that

[31] Evans et al. (2005) show how delegating pricing decisions to a sufficiently pro-industry regulator, i.e., whose preferences differ from those of the government, can alleviate the under-investment problem in the absence of regulatory commitment. In addition, if investment in a regulated sector is crucial for the development of a country, it becomes then necessary to provide a mechanism to alleviate under-investment. These authors also find evidence that when agents attach a high value to the future due, for example, to political stability or low interest rates, the welfare enhancing properties of the independent regulator become more evident.

Hypothesis 4: Countries with sufficiently small or high levels of corruption will tend to privatize less.

Returning to the normative approach, Auriol and Picard (2004) find that when the government does not fully capture the expected profit of the privatization transaction, privatization improves social welfare for intermediate values of the cost of public funds, but state ownership is preferred for low or high values. Since developing countries have typically medium to large levels of the cost of public funds, the latter should negatively influence the privatization decision.[32] The implication then is that when public firms in the infrastructure sector are sold at a discount because of a high country risk rating, a government in need for cash should keep the profitable ones. We translate these argument into the hypothesis that

Hypothesis 5: Countries with a relatively high cost of public funds and a high risk will tend to privatize less.

5.2 Causality relationships

Table 1 below summarizes the results of the Holtz-Eakin et al. (1988) causality testing procedure applied to the telecommunications reforms and fixed-line deployment variables. More specifically, these tests allow us to conclude on the existence of a causal relationship of a Granger type between the variables that represent competition in the analogue cellular segment, ac, competition in the digital cellular segment, dc, competition in the fixed-line local segment lc, the creation of a separate regulator, r, and privatization, p, on the other hand, and the variable that proxies the fixed-line deployment, ml, on the other hand.[33]

Table 1
Causal relationships

	ac	dc	lc	r	p
reform → fixed-line deployment	Yes	Yes	No	Yes	Yes
fixed-line deployment → reform	No	Yes	Yes	Yes	No

[32]Using a normative approach, Warlters (2004) also finds that a decrease in the cost of public funds may induce infrastructure privatization in developing countries.

[33]The estimations on which these Granger-causality tests are based are available from the authors upon request.

This table shows that the telecommunications reforms Granger-cause fixed-line deployment except when using the variable of competition in the fixed-line local segment as the reform variable. Examining the reverse causality, we find some evidence of one that runs from the fixed-line deployment variable to the telecommunications reforms variables although weaker. More specifically, the fixed-line deployment variable causes the variable of competition in the digital cellular segment, the variable of competition in the fixed-line local segment, and the variable that indicates the creation of a separate regulator. However, we do not find any empirical evidence that would suggest that the fixed-line deployment variable causes the variable of competition in the analogue cellular segment and the variable of privatization.

In addition to bringing some empirical evidence on the existence of causal relationships between reforms and infrastructure deployment variables, these Granger tests provide us with invaluable information on the dynamics of these relationships when they are found to exist. In the end, these tests allow us to select potential variables, and their precise lag structure, to be included as regressors in the regressions that are used to model the relationship between reforms and network deployment.[34]

5.3 The determinants of reforms: Empirical analysis

We now make use of regression analysis to investigate the determinants of the telecommunications reforms. We first consider the econometric specifications with a discrete reform dependent variable which are used to model the introduction of competition in the cellular (analogue and digital) and fixed-line (local) markets, and the creation of a separate regulator. These models are estimated using CLOGLOG and FIML when exogeneity turns out to be rejected. Then, we consider the specification with a continuous reform dependent variable which is used to model the privatization reform. This model is estimated using SYS-GMM and possible endogeneity of some regressors is accounted for. In both types of specifications, the main regressors are drawn from the set of variables that have "passed" the causality tests discussed in section 5.2 and so as to permit the testing of the hypotheses discussed in section 5.1.

[34]Following Holtz-Eakin et al. (1988), we use variables lagged one, two, and three periods in the Granger causality tests.

5.3.1 Regressions with a discrete reform dependent variable

Tables 2 through 5 below display the estimation results obtained by applying the grouped duration (robust cluster) methodology to the regressions with, respectively, the variable competition in the analogue cellular segment (ac_{it}), competition in the digital cellular segment (dc_{it}), competition in the fixed-line local segment (lc_{it}), and creation of a separate regulator (r_{it}) as the dependent variable.[35,36] When the CLOGLOG technique is applied (see the columns with the heading "CLOGLOG" in the tables), these tables show the parameter estimates corresponding to the indicated explanatory variables without and with temporal dummies, the value of the log of the pseudo-likelihood, "Log-likelihood," a likelihood ratio statistic for testing the validity of the temporal dummies, "Temporal dummies LR," and the number of observations actually used in the estimation, "Obs."[37]

In the cases where endogeneity problems arise, the FIML, or more specifically the 2SCML, estimation methodology is applied. We indicate the instruments that have been excluded in the first-stage, "Instruments," the squared partial correlation coefficient between the excluded instruments and the endogenous variable, "Partial R^2," the value of the F statistic for testing the joint significance of the instruments excluded in the first stage regression, "F," the Sargan statistic for testing the validity of the excluded instruments, "Sargan," the squared correlation coefficient between observed and fitted first-stage values of the dependent variable, "R^2_{OLS}," the estimated correlation coefficient between the disturbances of the first and second stage regressions (ωit and η_{it} from equations (1) and (2)) that signals whether the tested variable is endogenous, "Rho," and the value of the subsequent exogeneity test statistic, "Exogeneity."[38]

[35] Note that this methodology is applied to the explanatory variables in first differences.

[36] A modified Wald test for groupwise heteroskedasticity under the null of homoskedasticity is rejected at the 1% significance level in all the regressions presented in Tables 2-5. Hence, standard errors are adjusted for intragroup correlation. The mean variance inflator factor is also calculated in all the regressions with obtained values that remain always under 3.

[37] In all the tables presented in this paper, we indicate the significance at the 10%, 5%, and 1% confidence level by the subscripts, $*$, $**$, and $***$ respectively.

[38] A value of an F statistic over 10 is typically sufficient for identification in the presence of one endogenous regressor. A R^2_{OLS} of over 10% is also required for identification. As to the Sargan test, we have adapted it to these discrete regressions. The validity of instruments is given by a Wald test of the joint significance of a number of excluded instruments in the first stage, where this number is found by subtracting the number of

Let us first examine the CLOGLOG estimations of the models without and with temporal dummies exhibited in Tables 2-5. Comparing these two types of models, we see from the values of the Temporal dummies LR statistic displayed in these tables that temporal independence is rejected in the models of competition in the digital cellular segment and creation of a separate regulator.[39] We therefore conclude that while the time elapsed between a given reform and the previous one or the beginning of the sample influences the outcome in the case of the introduction of competition in the digital cellular segment and the creation of a separate regulator, it doesn't in the cases of the introduction of competition in the analogue cellular and fixed-line local segments.

Regarding the presence of multiple events in the series describing the introduction of competition in the analogue and digital cellular segments indicated by the variables *counter_ana* and *counter_dig* respectively, we obtain the following results. In Table 2, the regressor *counter_ana* has a significant negative impact on the variable competition in the analogue cellular segment. In Table 3, however, the regressor *counter_dig* does not have a significant impact on the variable competition in the digital cellular segment once temporal dependence is corrected for (see Model E). Hence, the number and frequency of licences previously granted in the analogue cellular segment has a negative impact on the decision to grant a license, that is, second and subsequent licences are not issued independently of the first one.[40] In contrast, the structuration of previous licenses does not appear as having an effect on the decision to grant a license in the digital cellular segment.

Now, since some explanatory variables in these regressions with a discrete dependent variable may potentially be endogenous, we perform an exogeneity test by applying the 2SCML (cluster-robust) technique to the best of the two models, the one without temporal dummies and the one with. In fact, the best model is the one without dummies if temporal dependence is rejected and the one with temporal dummies if it isn't. From Tables 2-5, we see that the final modeling choices for the dependent variables are Model A for *ac*

endogenous regressors from the number of excluded instruments.

[39]This LR statistic is indeed significant in Tables 3 and 5.

[40]This is consistent with the fact that in the period under study many countries maintained a monopoly in the analogue cellular segment with the unique licence often owned by the fixed-line incumbent.

and Model H for lc, both of these models without temporal dependence, and Model E for dc and Model L for r, both with temporal dependence.

Tables A1-A4 given in appendix report the results of these exogeneity tests performed on each of the potentially endogenous variables separately and then jointly. In addition to containing some items already described for Tables 2-5 above, these tables include a Shea's square partial correlation that takes into account the inter-correlation among instruments when more than one variable is being tested at a time, "Shea's partial R^2."[41] Exogeneity is rejected in three cases.[42] In Table A2, the fixed-line deployment variable ($\Delta \log(ml_{it-1})$) is endogenous to the variable of competition in the digital cellular segment according to both the individual test (at the 10% level) and the joint test (at the 5% level). In Table A3, the corruption variable ($\Delta corruption_{it}$) is endogenous to the variable of competition in the fixed-line local segment when tested both separately (at the 10% level) and jointly (at the 1% level). Finally, in Table A4, the institutional index ($\Delta institutional_{it}$) is endogenous to the decision of creating a separate regulator when test both separately (at the 10% level) and jointly (at the 5% level).

For these cases where exogeneity is rejected, the FIML estimation results are also reported in Tables 3-5 and kept for the subsequent regressions in which alternative explanatory variables are added.[43] We observe that the correlation coefficient Rho and the Exogeneity statistic found with the FIML technique confirm the 2SCML results rejecting the exogeneity of the instrumented variables.[44] In the regressions corresponding to the variable of competition in the digital cellular segment (see Table 3), we see that the variable

[41]The Shea's Partial R^2 is more informative than the Partial R^2 in the presence of multiple potentially endogenous regressors. In such a context, a large partial R^2 and a small Shea's partial R^2 are interpreted as indicating that the model is not identified.

[42]The Sargan statistic confirms the validity of instruments. In addition, there is no problem of identification as is shown by an F statistic always superior to 10 in at least one of the proposed testing configurations (separate or joint testing of the endogenous regressors). The Shea Partial R^2 is severely downsized as compared to the Partial R^2 only in the joint exogeneity test performed in Table A4. Nevertheless, this joint test is consistent with the results of the individual tests shown in the same table.

[43]The CLOGLOG model is kept only in the case of competition in the analogue cellular segment where we didn't find evidence of endogeneity. The reported estimates with CLOGLOG and FIML cannot be directly compared as they are subject to different scaling.

[44]The R^2_{OLS} signals sufficient identification with values superior or close to 10%. The negative correlation in Rho in Tables 3 and 5 signals the downward bias in the endogenous variable, which can be seen by comparing Models E and F, and L and M, respectively. Similarly, the positive correlation in Rho in Table 4 signals an upward bias in the endogenous variable (see Models I and J).

of fixed-line deployment (Δml_{it-1}) becomes significant at the 1% level once instrumented in Models F and G.[45] In the regressions of the variable competition in the fixed local segment (see Table 4), the variable of corruption ($\Delta corruption_{it}$) changes from a positive and significant effect in Model H to a negative and significant effect once this variable is instrumented in Model J.[46] Finally, in the regressions that seek to explain the decision to create a separate regulator (see Table 5), the institutional index ($\Delta institutional_{it}$) changes from having a non significant effect in Model L to a positive and significant effect at the 5% level once this variable is instrumented in Model M.[47]

We now turn to the empirical evidence concerning the hypotheses on the determinants of reforms discussed in section 5.1. Hypothesis 1 regarding the role of corruption is only partially confirmed by our estimation results. We do find some empirical support to it since the variable corruption is incorporated in the institutional index ($\Delta institutional_{it}$) and the latter, as can be seen from Table 2, has a positive and significant impact on the decision to introduce competition in the analogue cellular segment (see the results on Models A and C).[48] However, in Tables 3 and 4 explaining the decisions to introduce competition in the digital cellular and the fixed-line segments respectively, the institutional index, the corruption variable ($\Delta corruption_{it}$), and the democracy variable ($\Delta democracy_{it}$) all have a negative and significant impact (see the results on Models F, G, and J).

What about the role of the cost of public funds in the decision to introduce competition? Hypothesis 2 says that a higher cost of public funds should discourage the introduction of competition. Our empirical analysis although supportive of this hypothesis are somewhat mitigated. The results concerning the decision to introduce competition in the analogue cellular and fixed segments support this hypothesis. Indeed, from Table 2 we see that aid

[45] A "hat" above a variable indicates that this variable has been instrumented.

[46] The level of democracy ($\Delta democracy_{it}$) and the total debt service ($\Delta debt_{it-2}$) loose their significance in Model J and the population density ($\Delta density_{it}$) becomes significant at the 5% level.

[47] The checks and balances variable ($\Delta checks_{it}$) looses significance in Model M and the mainline penetration (Δml_{it-2}) and population density ($\Delta density_{it}$) variables become significant at respectively the 10% and 5% levels.

[48] Recall that increasing values of the variable *corruption* indicates lower corruption in the government.

per capita (Δaid_{it-2} in Models A and B) and net taxes on products (Δtax_{it-3} in Model C) have a positive and significant impact on competition.[49] Moreover, from Table 4 we see that net taxes on products (Δtax_{it-2} in Model J) has also a positive and significant impact on the decision to introduce competition in the fixed-line local segment. In contrast, the results concerning the decision to introduce competition in the digital cellular segment contradict Hypothesis 2. We indeed see from Table 3 that the total debt service ($\Delta debt_{it-2}$ in Model F) has a positive and significant impact on this decision and aid per capita (Δaid_{it-3} in Model G) has a negative and significant impact.

We conclude this section by examining the empirical evidence on the role of government commitment, the discount factor, and the returns on investment in the decision to create a separate regulator. Hypothesis 3 states that countries where government commitment is weak, returns on investment are large, and the discount factor is high are likely to establish a separate regulatory authority.[50] Our results do not seem to confirm the whole claim of this hypothesis. First, assuming that government commitment is reasonably well captured in the institutional index, we see from Model M in Table 5 that it has rather a positive and significant impact on the decision to create a separate regulator (see Model M). Second, assuming that the discount factor is reflected in the variable checks and balances ($\Delta checks_{it}$), we see from the same table that it is not significant once endogeneity problems have been alleviated in Model M. Finally, assuming that the return on investment is well proxied by the variable deployment of fixed lines (Δml_{it-2}), we see from the same model M that it has a positive and significant effect on the decision to create a separate regulator, a result that supports the third part of Hypothesis 3.

[49] Recall that the trust is that there exists a positive (negative) relationship between the cost of public funds and the total debt service (net taxes and aid per capita). In practice, we use these related variables lagged two and three periods and report the coefficients of these lagged variables that are actually significant.

[50] We should emphasize here that when we stated Hypothesis 3 (see section 5.1), we abstracted away from the debate of independence vs. autonomy of the regulator, although we believe that the issue has its own importance.

Table 2
Cellular competition (analogue) parameter estimates

	Model A	Model B	Model C
	CLOGLOG	CLOGLOG W/DUMMIES	CLOGLOG
ac_{it}			
$\Delta institutional_{it}$	0.168***	0.126**	0.147***
$\Delta democracy_{it}$	0.182	0.122	0.174
$\Delta debt_{it-2}$	-0.011	-0.010	
Δtax_{it-2}	0.063	0.047	
Δaid_{it-2}	0.009***	0.010***	
$\Delta debt_{it-3}$			0.003
Δtax_{it-3}			0.113**
Δaid_{it-3}			0.001
$\Delta rural_{it}$	0.321	0.345	0.324
$\Delta density_{it}$	-0.026	-0.023	-0.021
$counter\_ana_{it}$	-0.435**	-0.671**	-0.520**
Log-likelihood	-176.86	-169.64	-167.85
Temporal dummies LR		16.43	
Obs	643	643	586

Table 3
Cellular competition (digital) parameter estimates

	Model D	Model E	Model F	Model G
	CLOGLOG	CLOGLOG W/DUMMIES	FIML W/DUMMIES	FIML W/DUMMIES
dc_{it}				
$\Delta institutional_{it}$	-0.292***	-0.323***	-0.173***	-0.117***
$\Delta democracy_{it}$	-0.240**	-0.115	-0.131*	-0.054
$\Delta debt_{it-2}$	0.048***	0.033*	0.026**	
Δtax_{it-2}	-0.017	-0.034	-0.011	
Δaid_{it-2}	-0.006	-0.002	-0.001	
$\Delta debt_{it-3}$				0.005
Δtax_{it-3}				-0.013
Δaid_{it-3}				-0.007*
$\Delta rural_{it}$	-0.087	-0.284	-0.316*	-0.286
$\Delta density_{it}$	0.040*	0.048***	0.021	0.031*
Δml_{it-1}	0.682	0.187		
$\Delta \widehat{ml_{it-1}}$			2.846***	2.643***
$counter\_dig_{it}$	0.369**	0.105	-0.233	-0.398
Log-likelihood	-207.39	-183.38	-87.73	-92.58
Temporal dummies LR		48.02***		
Instruments			$ethnic_{it}$ $polcon_{it}$	$school80_i$ $polcon_{it}$
Partial R^2			0.098	0.075
F			16.62	9.19
Sargan			0.00	0.03
R^2_{OLS}			0.199	0.155
Rho			-0.684	-0.573
Exogeneity			11.77***	6.44**
Obs	667	667	664	466

Table 4
Fixed-line competition (local) parameter estimates

lc_{it}	Model H CLOGLOG	Model I CLOGLOG W/DUMMIES	Model J FIML
$\Delta corruption_{it}$	1.510***	1.641***	
$\Delta \widehat{corruption}_{it}$			-1.867**
$\Delta democracy_{it}$	-0.266*	-0.317**	-0.055
$\Delta debt_{it-2}$	0.043***	0.029*	0.007
Δtax_{it-2}	0.165***	0.138**	0.056*
Δaid_{it-2}	-0.001	-0.001	0.001
$\Delta rural_{it}$	0.245	0.255	0.121
$\Delta density_{it}$	0.076	0.079	0.054**
Δml_{it-1}	11.821***	10.194***	4.882***
Log-likelihood	-63.29	-59.55	-41.80
Temporal dummies LR	7.47		
Instruments			$\Delta rule_{it}$ $africa_i$
Partial R^2			0.064
F			14.69
Sargan			1.11
R^2_{OLS}			0.095
Rho			0.642
Exogeneity			8.75***
Obs	667	667	667

Table 5
Separate regulator parameter estimates

r_{it}	Model K CLOGLOG	Model L CLOGLOG W/DUMMIES	Model M FIML W/DUMMIES
$\Delta institutional_{it}$	-0.106	-0.131	
$\Delta \widehat{institutional}_{it}$			0.296**
$\Delta democracy_{it}$	-0.256	-0.227	-0.061
$\Delta checks_{it}$	0.221*	0.181*	0.048
$\Delta import_{it}$	0.059***	0.072***	0.038***
$\Delta staff_{it}$	-1.890*	-3.047*	0.762
$\Delta rural_{it}$	0.202	0.365	0.083
$\Delta density_{it}$	-0.047	-0.077	-0.063**
Δml_{it-2}	-1.835	-3.615	-2.197*
Log-likelihood	-130.68	-106.31	-1485.61
Temporal dummies LR	47.94***		
Instruments			$protest80_i$ $africa_i$
Partial R^2			0.032
F			12.50
Sargan			1.32
R^2_{OLS}			0.126
Rho			-0.657
Exogeneity			4.24**
Obs	688	633	688

5.3.2 Regression with a continuous reform dependent variable

Tables 6 shows the SYS-GMM (one-step robust) estimation results of the regressions with the variable privatization as the dependent variable and the coefficient shown corresponding to regressors in first-differences. This table also exhibits the first and n-th order autocorrelation coefficients of the residuals in first differences, $m1$ and mn, the value of the J statistic for testing the validity of the instruments, the value of the Dif-Sargan statistic that allows to test the validity of the additional SYS-GMM conditions, the value of the starting lag of the instruments, L, a Wald statistic for testing the joint significance of the temporal dummies, Temporal dummies, the F statistic for testing the joint significance of the explanatory variables, Goodness-of-fit, and the number of observations actually used.[51]

From this table, it appears that in all the estimations but that of Model P, second-order autocorrelation of the residuals in first differences ($m2$) is rejected using as instruments the initial lag of two and more periods for the variables in levels and one period for the variable in first differences. This confirms the validity of these instruments. In the case of Model P, we find empirical evidence that the disturbance term in levels follows a $MA(2)$. The valid instruments then are the variables in levels lagged 4 and more periods for the equation in first differences and the variables in differences lagged 3 periods for the equation in levels. Moreover, the J test never rejects the validity of the instruments.[52] We also see that the Dif-Sargan test accepts the additional moment conditions required to use the SYS-GMM.

Time specific effects and endogeneity of regressors deserve some attention here.[53] The presence of time specific effects is tested and rejected in the

[51] Even if two-step GMM is known to be asymptotically more efficient than one-step GMM, we omit the two-step GMM estimates as we find that their asymptotic standard errors tend to be abnormally small even when we make the finite sample correction proposed by Windmeijer (2000). In fact, Arellano and Bond (1991) show by means of simulations that this apparent gain in precision may reflect a downward finite-sample bias. In addition, in all the SYS-GMM tables in this paper, the Breusch-Pagan and Cook-Weisberg test always rejects the null hypothesis of no heteroskedasticity. Moreover, the mean variance inflator factor remains always under 5.

[52] A rejection with such a J test may turn out to be a consequence of measurement errors (Blundell and Bond, 1999).

[53] That endogeneity is a relevant issue in our context has been already discussed. As to time specific effects, their investigation is justified by the occurrence of some important events during the period under study including the 1995 "Tequila" crisis, the 1997 South-Asian crisis, the 1998-1999 financial breakdown, and the introduction of digital systems.

regression explaining privatization. Hence, time dummies are not included in this regression.[54] Endogeneity of regressors is checked using the goodness-of-fit criterion. In the privatization regression, only the best model (with no endogenous regressors, except for Δp_{it-1}) is reported in Table 6.

Table 6
Privatization parameter estimates

Δp_{it}	Model N SYS-GMM	Model O SYS-GMM W/DUMMIES	Model P SYS-GMM	Model Q SYS-GMM	Model R SYS-GMM
$\widehat{\Delta p_{it-1}}$	0.018	0.006	0.113	0.022	0.014
$\Delta risk_{it}$	0.010***	0.014***	0.002*	0.003**	0.004**
$\Delta institutional_{it}$				-0.013***	-0.014**
$\Delta institutional_{it}^2$				0.001**	0.001*
$\Delta democracy_{it}$	0.188*	0.135	0.032		
$\Delta democracy_{it}^2$	-0.016	-0.013	-0.002		
$\Delta debt_{it-2}$	0.001*	0.002**		0.001	
Δtax_{it-2}	-0.004	-0.004		-0.003*	
Δaid_{it-2}	-0.001**	-0.001		-0.001**	
$\Delta debt_{it-3}$			0.001**		-0.000
Δtax_{it-3}			0.001		0.003
Δaid_{it-3}			-0.001*		0.000
$\Delta rural_{it}$	0.073	0.083	0.004	0.048	0.045
$\Delta density_{it}$	-0.004	-0.001	-0.001	-0.001	-0.001
$m1$	-3.84***	-3.82***	-2.93***	-3.52***	-3.42***
$m2$	0.59	0.03		1.08	1.09
$m4$			-1.73*		
J	5.54	7.85	2.59	10.18	9.15
Dif-Sargan	0.37	1.37	-0.99	0.60	3.82
L	2	2	4	2	2
Temporal dummies		1.38			
Goodness-of-fit	6.88***	3.43***	3.01***	3.86***	5.71***
Obs.	667	667	620	672	613

Note: The starting lag for the instruments is L and $(L-1)$ for the equation in first differences and levels, respectively.

What are the implications of our empirical results as to the validity of Hypothesis 4 which says that countries with little or extreme corruption in the government should privatize less? We find that when corruption is proxied by the democracy index, it has a negative impact on the privatization decision in Model N, which is not consistent with the hypothesis. Interestingly enough though, thinking of Hypothesis 4 as saying that corruption has a decreasing marginal impact on privatization, we see that it is confirmed.

[54]The variable Temporal dummies is not significant in Model O (Table 6). The Goodness-of-fit test also rejects the presence of time specific effects in Table 6.

Indeed, from Table 6, we see that the institutional index which, recall, incorporates the corruption level, has a positive impact on the privatization decision and the square of this index has a negative impact in Models Q and R.

Regarding the hypotheses on the determinants of privatization, Hypothesis 5 says that high costs of public funds and high risks are associated with low privatization. This hypothesis is partially confirmed by our empirical results. The current increase rate of the risk index ($\Delta risk_{it}$) has a significant impact on the privatization decision across all Models in Table 6, which is consistent with the hypothesis.[55] However, the cost of public funds has a positive impact on the decision of privatizing, which is not consistent with the hypothesis. We find that, in growth rates, the lagged (two and three periods) total debt service ($\Delta debt_{it-2}$, $\Delta debt_{it-3}$) has a positive impact on privatization in Models N, O, and P, the lagged (two and three periods) aid per capita (Δaid_{it-2} and Δaid_{it-3}) has a negative impact in Models N, O, and P, and the lagged (two periods) net taxes on products (Δtax_{it-2}) has a negative impact in Model Q.

5.4 The simultaneous relationship between the reforms and the fixed network development

In this section, we discuss the implications of our results as far as the simultaneous relationship between the telecommunications reforms and the deployment of the fixed-line network is concerned. We first put together the empirical elements that will allow us to build this relationship.

Starting with the impact of the development of fixed service on the reforms, we have included, following the results of the causality tests synthesized in Table 1, the variable fixed-line deployment to explain the decisions to introduce competition in the digital cellular and the fixed-line local segments, and the decision to create a separate regulator. The specific effects obtained are as follows. The growth of the lagged (one period) fixed service penetration rate (Δml_{it-1}) affects positively the decision to introduce competition in the digital cellular segment (see Models F and G in Table 3) and in the fixed local segment (see Models H and J in Table 4). As to the

[55] Recall that higher values of the risk index ($risk$) correspond to lower risk.

decision to create a separate regulator, it is found (see Model M in Table 5) to be negatively affected by the growth of lagged (two periods) fixed service penetration rate (Δml_{it-2}).

Let us now consider the impact of the telecommunications reforms on the deployment of fixed lines. Table 7 displays the results of the regression to look at. This table has the same structure as Table 6 presented in the previous section and, as done earlier, we have made the choice of regressors on the basis of the results of the causality tests discussed in section 5.2.[56] We observe that all the reforms variables have been included as regressors except the one used to represent the introduction of competition in the fixed-line local segment.[57] We find that competition in the analogue cellular segment (Δac_{it-1}) has a negative impact on the fixed-line deployment in Models S, T, and U whereas competition in the digital cellular segment (Δdc_{it-1}, Δdc_{it-2}) has a positive impact in Model S and even when endogeneity is controlled for in Model U (Δdc_{it-2}). As to the other reform variables, we see that while the creation of a separate regulator (Δr_{it-2}) has a positive impact in Model S, once endogeneity is taken into account in Model U, the associated coefficient is no longer significant. Finally, privatization ($\Delta priva_{it-1}$, $\Delta priva_{it-2}$) has positive effect on the fixed service segment in Model S and this impact remains significant ($\Delta priva_{it-1}$) when endogeneity of some regressors is taken into account in Model U.

The results discussed so far indicate that there exists a simultaneous relationship between the introduction of competition in the digital cellular segment and the development of the fixed-line segment. More specifically, our data analysis has shown that higher penetration rates in the fixed segment have been an important determinant of the decision to introduce competition in the digital cellular segment and, in turn, competition in this sector has resulted in higher penetration rates. Table 8 below summarizes the quantitative relationships found between the various reform policies considered in this

[56] In this table, we report the best model (with the endogenous regressors) in Model U, and, for the purpose of making comparisons, the second best (with no endogenous regressors) in Model S. In particular, Model S includes as endogenous the regressors when a two-way causal relationship, that is, the variables competition in the digital cellular segment and creation of a separate regulator.

[57] The lack of causality between the introduction of competition and the deployment of service in the fixed service segment is not surprising as it is well known that this market has experiencing heavy business stealing.

paper and fixed-line deployment.[58] In addition to showing the simultaneous relationship between digital cellular competition and fixed service deployment, this table includes the results on the other relationships considered that are worth discussing.

If we examine the role played by fixed-line deployment in the reform decision-making process, we find evidence that the lower the fixed-line penetration rate, the more likely a separate regulator will be created and the less competition is introduced in the digital cellular and fixed local segments. A possible explanation of these results is that poorly performing fixed service sectors have called for the creation of a separate regulator to bring remedies while well performing fixed sectors have resulted in the introduction of competition in the digital cellular and fixed segments since those entail high licence fees. Let us now turn to an examination of the impact of the reforms on the deployment of fixed infrastructure.

Consider first the results concerning the role of competition. As discussed in the beginning of this section, we have found a positive impact of the introduction of competition in the digital cellular segment. In contrast, we have found that the introduction of competition in the analogue cellular segment has a negative impact.[59] These results demand two remarks. First, the fact that we treated separately has indeed proven to be necessary.[60] Second, these results suggest that fixed service and digital cellular service are complements while fixed service and analogue cellular service seem to be complements.[61]

What about the two other important reform policies, namely, privatization and the creation of a separate regulator? Our work sheds some light on the issue of the impact of privatization which is not settled in the literature.

[58] Table 8 is basically Table 1 where the causal relationships found are given the quantitative form resulting from the regression analysis.

[59] As mentioned earlier, competition in the fixed local segment has not been found to have a significant impact on network expansion.

[60] Recall that the usual practice is to unify these two segments by using an aggregate index of competition in the cellular sector and that the empirical findings have been almost systematically a positive impact on the fixed sector (see section 2).

[61] This implication assumes that competition typically fosters service usage. It is consistent with the fact that analogue licences have appeared before digital licences and have been mostly granted to the incumbent, in which case no strong competition between fixed service and analogue cellular service can be expected. Moreover, capacity constraints associated with the analogue technology have typically limited the number of issued licences in the analogue cellular segment.

We find strong evidence in our data set that privatization has a strong positive impact on the fixed service penetration rate. As to the creation of a separate regulator, the data does not seem to show that it has a significant impact on fixed-line deployment.

Table 7
Fixed-line deployment parameter estimates

$\Delta \log(ml_{it})$	Model S SYS-GMM	Model T SYS-GMM W/DUMMIES	Model U SYS-GMM
$\Delta \widehat{\log(ml_{it-1})}$	0.558***	0.491***	0.529***
Δp_{it-1}	0.107**	0.104*	0.099*
Δp_{it-2}	0.067**	0.066*	0.068
Δac_{it-1}	-0.016***	-0.014**	-0.017***
Δdc_{it-1}	0.031**	0.025	
Δdc_{it-2}	0.011**	0.007	
$\widehat{\Delta dc_{it-1}}$			0.001
$\widehat{\Delta dc_{it-2}}$			0.019*
Δr_{it-2}	0.023*	0.024*	
$\widehat{\Delta r_{it-2}}$			0.042
$\Delta institutional_{it}$	0.002**	0.003*	0.002**
$\Delta democracy_{it}$	0.007	0.010	0.004
$\Delta rural_{it}$	-0.006	-0.012	-0.001
$\Delta density_{it}$	-0.006	-0.006	-0.002
$m1$	-4.93***	-4.88***	-4.99***
$m2$	0.40	0.50	0.76
J	55.04	46.88	57.88
Dif-Sargan	-3.33	-2.63	-3.01
L	2	2	2
Temporal dummies		1.48	
Goodness-of-fit	17.71***	17.43***	20.41***
Obs.	775	775	775

Notes: The starting lag for the instruments is L and $(L-1)$ for the equation in first differences and levels, respectively.

Table 8
Summary of results: Relationship between reforms and fixed-line deployment

	ac	*dc*	*lc*	*r*	*p*
reform → fixed-line deployment	-	+	NA	NS	+
fixed-line deployment → reform	NA	+	+	-	NA

Note: NA and NS stand for not applicable and not significant, respectively.

5.5 The determinant of the reforms: Summary

Table 9 below summarizes the results of our econometric analysis of the determinants of the telecommunications reform policies. We can see from this table that the initial performance of the sector, the institutional environment, and the cost of public funds play an important role in the reform decisions. Let us examine the three main reforms, competition, privatization, and creation of a separate regulator, in turn.

Table 9
Summary of results: Determinants of reforms

	ac	*dc*	*lc*	*r*	*p*
RISK INDEX					
risk	NA	NA	NA	NA	+
COST OF PUBLIC FUNDS					
total debt service	NS	+	NS	NA	+
net taxes on products	+	NS	+	NA	-
aid per capita	+	-	NS	NA	-
aggregated	-	+	-	NA	+
INSTITUTIONAL ENVIRONMENT INDICES					
corruption	NS	NS	-	NS	NS
institutional index	+	-	NS	+	-
democracy index	NS	-	NS	NS	+
institutional index (square)	NA	NA	NA	NA	+
democracy index (square)	NA	NA	NA	NA	NS
DISCOUNT FACTOR					
checks and balances	NA	NA	NA	NS	NA
RETURNS ON INVESTMENT					
fixed-line deployment	NA	+	+	-	NA

Note: NA and NS stand for not applicable and not significant respectively.

We have already discussed the positive impact of fixed service penetration rates on the decision to introduce competition in both the digital cellular and fixed local markets. But, besides fixed service penetration rates what else has a significant impact on the introduction of competition in the telecommunications industry? We find that that the weaker the institutional environment, the less likely to find competition in the analogue cellular market and the more likely to find competition in the digital cellular and fixed local markets. The conduct of competition policy is also found to be markedly influenced by a country's financial situation. Our data analysis has shown that the higher the cost of public funds, the more likely to find competition in the digital

cellular market and the less likely to find competition in the analogue cellular and fixed service markets.

As to the privatization of the fixed service incumbent, we find that the likelihood that it takes place is positively affected by a deterioration of the institutional environment and negatively by a higher country risk, and positively affected by a higher cost of public funds.[62] Finally, concerning the decision to create a separate regulatory authority, we find that a well performing fixed service sector (higher penetration rates) affects this decision negatively whereas a better institutional environment affects it positively.

6 Conclusion

This paper has demonstrated the importance of the institutional and macroeconomic features of developing countries in understanding the evolution of their telecommunications industry over the past two decades. To show this point, we have set an empirical strategy seeking to econometrically identify the key determinants of the three main policy initiatives that have been at the heart of the reforms of the telecommunications industry, namely, competition, privatization, and the (re)structuring of regulation. To give more robustness to our argument, from both a technical (taking care of causality and endogeneity issues) and a policy (accounting for the rational of the reforms) viewpoint, we have also investigated the extent to which these policies have translated into actual deployment of telecommunications infrastructure. Our econometric analysis of a 1985-1999 time-series-cross-sectional database on 86 developing countries indeed finds that sectoral but also institutional and financial factors are important determinants of the actual reforms implemented in these countries.

Concerning the sectoral effects, our separate treatment of the analogue and digital cellular technologies allowed us to obtain some more disaggregated results than those obtained in the literature in which these two segments have typically been merged.[63] We have uncovered a positive relationship between

[62] In a country under high risk rating, the government anticipates that the incumbent will be sold at a discounted price and thus decides not to privatize.

[63] Capacity constraints associated with the analogue technology are among the major reasons why digital technology is relatively more appealing for the rapidly increasing cellular market. Indeed, digital technology allows to allocate more users within the same coverage area and more information can be simultaneously sent and received by each

the decision to introduce competition in the digital cellular segment and the growth of the fixed-line segment, whereas a negative relationship was found between the decision to introduce competition in the analogue cellular segment and the growth of the fixed-line segment. These results reveal that the positive effect of competition in the cellular segment on the fixed segment reported in the literature is in fact mainly due to competition in the digital cellular segment. Analogue cellular appears therefore as a substitute to the fixed service whereas digital cellular appears as a complement. The data analysis has indeed shown that the digital cellular and fixed markets have benefited from each other.

As to the institutional and country risk effects, we find that countries facing increasing institutional risk and financial constraints are more likely to introduce competition in the digital cellular segment and to privatize the fixed-line incumbent. In turn, these policies are those that were found to enhance the deployment of fixed-line infrastructure.[64] In contrast, competition in the analogue cellular segment and the creation of a separate regulator are found to be less likely to be introduced in countries facing increasing institutional risk and budget constraints. Their impact on fixed network deployment is found to be negative or non significant.

How should one interpret our results that highlight the importance of the quality of the institutional environment and the state of the government's finances in the determination of the implemented reforms? Developing countries with higher institutional risk and tighter financial constraints are more likely to promote policies, such as allowing entry into the digital cellular segment and privatizing the fixed-line incumbent, that attract a larger number of investors whose rents can be extracted through the licence fees, red tape, or else.[65] By the same token, these countries are less supportive of

phone user. Moreover, while analogue technology does not allow for wireless data services, digital technology includes voice mail, caller identification, call waiting, access to internet, and short message system (SMS). In addition, digital technology is more prone than analogue technology to interference and has better privacy and security attributes. A drawback of the digital technology, however, is that, unlike the analogue technology, there is no unified system and roaming between systems can be expensive.

[64] Our results on the positive impact of privatization on fixed-line deployment is in contrast with the null or negative impact found in the literature. This might be due to the fact that most empirical studies have aggregated data on countries with different levels of development. Separating data according to GDP, Gasmi et al (2006) find a positive impact in data on developing countries and a negative impact in data on developed countries.

[65] One can take the view that governments promote these reforms in order to circum-

those reforms that are likely to provide them with less cash, such as cellular competition in the analogue segment and the creation of a regulator. Except in extreme cases of high corruption, the economically profitable reforms promoted by the governments are those that are likely to be successful, in particular, those that are expected to have a significant positive impact on the telecommunications infrastructure.[66] This argument may partly explain the impressive growth of telecommunications in Sub-Saharan Africa in recent years.

vent institutional and economic country weaknesses. Nevertheless, this would imply that governments can anticipate which policies will deliver better outcomes in terms of service deployment.

[66]In this paper, we have discussed the positive impact of competition in the digital cellular segment and privatization on fixed-line deployment, but we did find evidence of a (standard) positive impact on cellular subscription as well and the results are available from the authors upon request.

Appendix

- **Data**

  The data set constructed for this study contains observations for the period 1985-1999 on the following list of 86 developing countries:

  - Asia and Pacific: Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam.
  - Sub-Saharan Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Democratic Republic of Congo, Republic of Congo, Côte d'Ivoire, Equatorial Guinea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, Seychelles, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.
  - Middle East and North Africa: Algeria, Egypt, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Syria, Tunisia, and United Arab Emirates.
  - Latin America and the Caribbean: Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, and Venezuela.

  We have collected data on variables regrouped in five categories: "Telecommunications deployment," "Telecommunications reforms," "Institutional environment and risk indices," "Cost of public funds," and "Other variables and instruments." The definition of these variables and the data sources are given below.

Telecommunications deployment

Variable	Source(s)
• Fixed-line deployment	ITU

Telecommunications reforms

Variable	Source(s)
COMPETITION	
• Cellular competition (analogue)	-Various authors (Ros, 1999, Bortolotti et al., 2001, McNary, 2001, Fink et al., 2002, Ros, 2003, and Li and Xu, 2004.). -ITU World Telecommunications Regulatory database. -Operators and regulators websites. -Clark et al. (2004). -http://www.gsmworld.com.
• Counter (analogue)	-Idem
• Cellular competition (digital)	-Idem
• Counter (digital)	-Idem
• Fixed-line competition (local)	-Idem
SEPARATE REGULATOR	
• Separate regulator	-Various authors (Bortolotti et al., 2001, Fink et al, 2002, Gutierrez, 2003, and Ros, 2003). -ITU World Telecommunications Regulatory database. -Clark et al. (2004).
PRIVATIZATION OF THE FIXED-LINE INCUMBENT	
• Privatization	-Various authors (Ros, 1999, Bortolotti et al., 2001, McNary, 2001, Fink et al., 2002, Ros, 2003, and Li and Xu, 2004). -ITU World Telecommunications Regulatory database. -Operators and regulators websites. -Clark et al. (2004). -Private Privatization in Infrastructure (PPI) Project World Bank database. -IPANeT Privatization Transactions database (World Bank).

Institutional environment and risk indices

Variable	Source(s)
INSTITUTIONAL ENVIRONMENT INDICES	
• Corruption	-IRIS data set, University of Maryland (1982-1997).
• Institutional index	-Idem
• Democracy index	-Polity IV project: Political Regime Characteristics and Transitions, 1800-2002, Jaggers and Marshall (2002).
RISK INDEX	
• Risk	-International Country Risk Guide (ICRG) annual ratings (1985-1999).

Cost of public funds

Variable	Source(s)
• Total debt service	-World development indicators 2004.
• Net taxes on products	-Idem
• Aid per capita	-Idem

Other variables and instruments

Variable	Source(s)
OTHER VARIABLES	
• Population density	-World development indicators 2004.
• Rural population	-World development indicators 2004.
• Imports	-Idem
• Telecommunications staff	-ITU -World development indicators 2004.
• Checks and balances	-DPI2000 Database of Political Institutions 1975-2000, The World Bank.
INSTRUMENTS	
• English legal origin	-La Porta et al. (1998).
• French legal origin	-Idem
• Share of protestant (1980)	-La Porta et al. (1998).
• Latitude	-Idem
• Average schooling years (1980)	-Barro and Lee (1996).
• Ethnolinguistic fractionalization	-Policy Research Department, The World Bank (Based on Atlas Narodov Mira, 1964, Muller, 1964, Roberts, 1962, Gunnemark, 1991).
• Africa	-World development indicators 2004.
• Crop and forest land	-Idem
• Political constraints	-Polconv 2002, from Henisz (2002).
• Free press	-Freedom House Annual Survey of Press Freedom, rankings 1980-2004.
• Ethnic tensions	-IRIS data set, University of Maryland (1982-1997).
• Law and Order	-Idem

Telecommunications deployment

. Mainline penetration: Number of telephone lines per 100 inhabitants that connect subscribers' terminal equipment to the Public Switched Telephone Network (PSTN).

Telecommunications reforms

- Competition
  - . Cellular competition (analogue): Dichotomous variable that takes on the value 1 in year t if one cellular analogue license or more have been issued sometime in the year t, and 0 otherwise.
  - . Counter (analogue): Variable that takes on the value 0 in year t if no analogue license has been issued in $t-1$ or earlier, 1 in t if one license has been issued in $t-1$ or earlier, 2 in t if two licences have been issued in $t-1$ or earlier, and 3 in t if three or more licenses have been issued in $t-1$ or earlier. Thus, this variable counts the number of previous granted analogue licenses.
  - . Cellular competition (digital): Dichotomous variable that takes on the value 1 in year t if one cellular digital license or more have been issued sometime in the year t, and 0 otherwise.
  - . Counter (digital): Variable that takes on the value 0 in year t if no digital license has been issued in $t-1$ or earlier, 1 in t if one license has been issued in $t-1$ or earlier, 2 in t if two licences have been issued in $t-1$ or earlier, and 3 in t if three or more licenses have been issued in $t-1$ and earlier. Thus, this variable counts the number of previous granted digital licenses.
  - . Fixed-line competition (local): Dichotomous variable that takes on the value 1 in year t if one or more fixed (local) licenses have been issued sometime in the year t, and 0 otherwise.

- Separate regulator

  . Separate regulator: Dichotomous variable that takes on the value 1 in year t if the regulatory agency has been separated from and is not directly controlled by a ministry or a utility sometime in year t, and 0 otherwise.

- Privatization of the fixed-line incumbent

  . Privatization: Variable that gives the % of the incumbent's assets sold to private investors.

Institutional environment and risk indices

- Institutional environment indices

  . Corruption: Variable with values ranging from 0 to 6 and meant to reflect the degree of corruption of the political system. The higher the value of the variable, the less corrupt the political system. The particular concern here is with actual or potential corruption in the form of excessive patronage, nepotism, job reservations, favors for favors, secret party funding, and close ties between politicians and business.

  . Institutional index: Variable whose value is found by summing the values of the five institutionalization variables: the degree of corruption in the political system, the quality of bureaucracy and its capacity to govern without drastic changes in policies or interruption in services, law and order as a measure of the strength of the legal system and of the popular observance of the law, the risk of expropriation of private investments in terms of forced nationalization, and the risk that the government modifies a contract in the form of repudiation, postponement or scaling down. The values of this institutional index are in the range 0-50. Higher values of this index reflect a "better" overall institutional environment.

  . Democracy index: Variable whose value is found by subtracting an index of autocracy from an index of democracy. The values of the variable are ranging from -10 to 10 and meant

to reflect the political regime of a country. Higher values indicate democracies, lower values autocratic regimes.

- Risk index

  . Risk: Variable whose value is the average of the values of three variables: economic, financial and institutional risks. The values of this risk index are in the range 0-100. Higher values of this index reflect low risk.

Cost of public funds

. Total debt service: Sum of principal repayments and interests paid in foreign currency, goods, or services on long-term debt, interests paid on short-term debt, and repayments to the FMI, as a percentage of Gross National Income (GNI).

. Net taxes on products: Variable obtained by subtracting subsidies to product taxes as a percentage of Gross Domestic Product (GDP). Product taxes are those payable by producers that relate to the production, sale, purchase or use of the goods and services. Subsidies are grants made by the government to private and public firms aiming, e.g., at enabling maintenance of prices of goods and services below costs of production.

. Aid per capita: Variable in 2000 USD that includes both official development assistance, i.e., grants and loans made on concessional terms from official agencies and multilateral institutions, and official aid, i.e., aid flows from donors. It is calculated by dividing total aid by the midyear population estimate.

Other variables and instruments

- Other variables

  . Population density: Midyear population, i.e., all residents regardless of legal status or citizenship, divided by the land area in square kilometers.

. Rural population: Variable that indicates the percentage of the total population that resides in rural areas.

. Imports: The value of all goods and other market services received from the rest of the world as a percentage of GDP. It includes the value of merchandize, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, business, personal, and government services.

. Telecommunications staff: Full-time staff employed by telecommunication operators for the provision of public (fixed and mobile) telecommunication services, as a percentage of total population and multiplied by 1000.

. Checks and balances: Variable with values in the range 0-18 meant to give some indication on the division of powers in a country. Higher values of this variable reflect a "more balanced division of power" and hence a "better" mode of functioning of the political process.

- Instruments

. English legal origin: Dichotomous variable that takes on the value 1 if the country has an English common law tradition, and 0 otherwise.

. French legal origin: Dichotomous variable that takes on the value 1 if the country has an French commercial code tradition, and 0 otherwise.

. Share of protestant (1980): Variable that identifies for the year 1980 the percentage of the population that are protestant within a country.

. Latitude: Variable that gives the absolute value of the latitude of the country, scaled to take values between 0-1.

. Average schooling years (1980): Average schooling years in the total population over 25 within a country in 1980.

. Ethnolinguistic fractionalization: Average value of five indices of ethnolinguistic fractionalization, with values ranging from

0 to 1, where higher values denote higher levels of fractionalization.

. Africa: Dichotomous variables that takes on the value 1 if the country belongs to the Sub-Saharan African region and, 0 otherwise.

. Crop and forest land: Variable that indicates the percentage of land that can includes temporary crops, temporary meadows for mowing or for pasture, land under market or kitchen gardens, land temporarily fallow, and land under natural or planted stands of trees, whether productive or not.

. Political constraints: Variable with values between 0 and 1 that measures the extend to which a change in the preferences of any actor may lead to a change in government policy. The higher the value, the less feasible a policy change.

. Free press: Variable with values between 0 and 100 that measures the legal environment for the media, the political pressures that influence reporting, and the economic factors that affect access to information. Higher values imply higher freedom in press.

. Ethnic tensions: Variable with values between 0 and 6 that measures the degree of tension in a country attributable to racial, nationality, or language divisions. Higher ratings are given to countries where tensions are minimal, even though such divisions may exist.

. Law and Order: Variable taking values between 0 and 6. The "Law" part of this variable is used to assess the strength and impartiality of the legal system (e.g., due to the existence of a strong judiciary system). The "Order" part gives an indication of the popular observance of the law (e.g., low crime rate or law not routinely ignored as with illegal strikes without effective sanctions). A higher value of this variable reflects a "better" judiciary system.

- **Descriptive statistics**

Summary statistics

Variable	Designation	Obs.	Median	Std. Dev.	Min.	Max.
TELECOMMUNICATIONS DEPLOYMENT						
ml	Fixed-line deployment	1287	1.62	6.20	0.01	42.36
TELECOMMUNICATIONS REFORMS						
ac	Cellular competition (analogue)	1250	0.00	0.24	0.00	1.00
counter_ana	Counter (analogue)	1260	0.00	0.69	0.00	3.00
dc	Cellular competition (digital)	1290	0.00	0.25	0.00	1.00
counter_dig	Counter (digital)	1290	0.00	0.42	0.00	3.00
lc	Fixed-line competition (local)	1290	0.00	0.12	0.00	1.00
r	Separate regulator	1290	0.03	0.00	0.00	1.00
p	Privatization	1287	0.00	0.28	0.00	1.00
INSTITUTIONAL ENVIRONMENT AND RISK INDICES						
corruption	Corruption	1062	3.00	1.08	0.00	6.00
institutional	Institutional index	1062	27.51	7.37	7.10	43.00
democracy	Democracy index	1182	-1.00	6.77	-10.00	10.00
risk	Risk index	1075	57.00	12.13	13.04	81.94
COST OF PUBLIC FUNDS						
debt	Total debt service	1153	5.19	6.23	0.00	107.36
tax	Net taxes on products	1135	8.00	4.70	-6.63	26.5
aid	Aid per capita	1280	35.95	69.14	-23.02	629.16
OTHER VARIABLES AND INSTRUMENTS						
density	Population density	1281	38.68	135.97	1.34	972.41
rural	Rural population	1290	59.28	20.96	8.64	94.96
import	Imports	1206	32.09	22.25	4.63	173.49
staff	Telecommunications staff	1161	86.00	105.00	3.00	898.00
checks	Checks and balances	1236	2.00	1.65	1.00	18.00
english	English legal origin	1290	0.00	0.47	0.00	1.00
french	French legal origin	1290	1.00	0.48	0.00	1.00
*protest*80	Share of protestant (1980)	1290	2.75	14.43	0.00	64.20
latitude	Latitude	1290	0.17	0.16	0.00	0.38
*school*80	Average schooling years (1980)	780	2.95	1.65	0.39	6.84
ethno	Ethnolinguistic fractionalization	1245	0.43	0.31	0.00	0.89
africa	Africa	1290	0.00	0.45	0.00	1.00
land	Crop and forest land	1290	10.82	14.80	0.00	72.84
polcon	Political constraints	1260	0.00	0.19	0.00	0.65
free_press	Free press	1284	55.50	22.28	7.00	99.00
ethnic	Ethnic tensions	1062	4.00	1.44	0.00	6.00
rule	Law and order	1062	3.00	1.23	0.00	6.00

- **Exogeneity tests for the reforms represented by a discrete variable**

  The procedure used to perform the exogeneity tests with 2SCML is the following. We first estimate equation (2) to construct a vector of residuals for each of the potentially endogenous variables v_{it}. We then estimate equation (1) by including these constructed residuals and keeping the actual values of the potentially endogenous regressors as right-hand-side variables. If the constructed vector of residuals turns out not to be significantly different from zero, this indicates that ω_{it} and η_{it} are not correlated and we conclude that the regressor v_{it} is exogenous.

Table A1
Cellular competition (analogue) exogeneity tests

MODEL A (ac_{it})	Potentially endogenous variables		
	$\underline{\Delta debt_{it-2}}$	$\underline{\Delta aid_{it-2}}$	$\underline{\Delta institutional_{it}}$
Instruments	$rural_i$ $english_i$	$protest80_i$ $land_i$	$french_i$ $ethnic_{it}$
Partial R^2	0.052	0.064	0.327
F	21.86	27.99	123.42
Sargan	0.71	1.23	0.04
Exogeneity	2.44	1.27	0.01
Instruments	$land_i$ $english_i$ $rural_{it}$ $protest80_i$ $ethnic_{it}$		
Partial R^2	0.072	0.067	0.330
F	11.24	10.50	56.01
Shea Partial R^2	0.031	0.027	0.217
Sargan		1.34	
Exogeneity	1.16	0.11	0.21

Table A2
Cellular competition (digital) exogeneity tests

MODEL E (dc_{it})	Potentially endogenous variables			
	$\underline{\Delta debt_{it-2}}$	$\underline{\Delta aid_{it-2}}$	$\underline{\Delta institutional_{it}}$	$\underline{\Delta \log ml_{it-1}}$
Instruments	$checks_{it}$ $protest80_i$	$ethno_i$ $checks_{it}$	$school80_i$ $rural_{it-1}$	$africa_i$ $rural_{it}$
Partial R^2	0.045	0.094	0.085	0.663
F	13.57	31.34	40.59	714.90
Sargan	0.09	0.01	0.15	0.41
Exogeneity	0.12	0.06	0.10	3.23*
Instruments	$english_i$ $rural_{it-1}$ $checks_{it}$ $school80_i$ $free\_press_i$ $ethno_i$			
Partial R^2	0.103	0.150	0.265	0.824
F	3.81	20.90	23.92	558.91
Shea Partial R^2	0.072	0.110	0.112	0.367
Sargan			0.24	
Exogeneity	0.63	0.83	2.24	4.00**

Table A3
Fixed-line competition (local) exogeneity tests

MODEL H (lc_{it})	Potentially endogenous variables			
	$\Delta debt_{it-2}$	Δaid_{it-2}	$\Delta corruption_{it}$	$\Delta \log ml_{it-1}$
Instruments	$rural_{it}$ $protest80_i$	$school80_i$ $protest80_i$	$free\_press_{it}$ $latitude_i$	$school80_i$ $africa_i$
Partial R^2	0.041	0.064	0.075	0.582
F	17.36	28.88	19.55	406.79
Sargan	0.50	0.83	0.12	0.21
Exogeneity	0.00	0.11	2.90*	0.13
Instruments	$protest80_{it}$ $english_i$ $ethnic_{it}$ $ethno_{it}$ $school80_i$ $latitude_i$ $check_{it}$			
Partial R^2	0.147	0.148	0.209	0.769
F	6.44	16.38	12.25	400.26
Shea Partial R^2	0.112	0.094	0.106	0.389
Sargan			3.77	
Exogeneity	1.24	1.11	7.26***	1.85

Table A4
Separate regulator exogeneity tests

MODEL L (r_{it})	Potentially endogenous variables		
	$\Delta staff_{it}$	$\Delta institutional_{it}$	$\Delta \log ml_{it-2}$
Instruments	$latitude_i$ $english_i$	$english_i$ $ethno_{it}$	$africa_i$ $ethno_i$
Partial R^2	0.130	0.077	0.493
F	42.22	32.47	363.23
Sargan	1.31	0.31	0.38
Exogeneity	1.00	3.61*	0.05
Instruments	$ethnic_{it}$ $french_i$ $africa_i$ $latitude_i$		
Partial R^2	0.347	0.237	0.543
F	105.13	283.89	86.62
Shea Partial R^2	0.048	0.072	0.155
Sargan		0.87	
Exogeneity	1.57	3.98**	0.02

References

Arellano, M. and S.R. Bond, 1991, "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations," *Review of Economic Studies*, Vol 58.

——————— and O. Bover, 1995, "Another look at the instrumental variable estimation of error-component models," *Journal of Econometrics*, Vol 68.

Auriol, E. and P. Picard, 2004, "Privatizations in developing countries and the government's budget constraint," Nota di Lavoro 75.2002, Fondazione Eni Enrico Mattei, Corso Magenta 63 - I - 20123 Milano Italy.

Banerjee, A. and A. J. Ros, 2000, "Telecommunications privatization and tariff rebalancing: Evidence from Latin America," *Telecommunications Policy*, Vol 24.

Barro, R. and J.W. Lee, 1996, "International measures of schooling year and schooling quality," *American Economic Review*, Vol 86.

Beck, N., Katz, J. and R. Tucker, 1998, "Taking time seriously in binary: Time-series-cross-section analysis with a binary dependent variable," *American Journal of Political Science*, Vol 42.

———— and J. Katz, 2004, "Time-series-cross-section issues: Dynamics," Paper presented at the 2004 Annual Meeting of the Society for Political Methodology, Stanford University.

Bliss, C. and R. Di Tella, 1997, "Does competition kill corruption?," *Journal of Political Economy*, Vol 5.

Blundell, R. and S. Bond, 1998, "Initial conditions and moment restrictions in dynamic panel data models," *Journal of Econometrics*, Vol 87(1).

Bortolotti, B., DSouza, J., Fantini, M. and W.L. Megginson, 2001, "Sources of performance in privatized firms: A clinical

study of the global telecommunications industry" Nota di Lavoro 26.2001, Fondazione Eni Enrico Mattei, Corso Magenta 63 - I - 20123 Milano Italy.

Bortolotti, B. and D. Siniscalco, 2004, *The challenges of privatization - An international analysis*, Oxford University Press.

Clark, G., Haggarty, L., Kaneshiro, R., Noll, G. R., Shirley, M., Wallsten, S. and L.C. Xu, 2004, "New tools for studying network industry reforms in developing countries: The telecommunications and electricity regulation database," AEI-Brookings Joint Center Related Publication 04-05.

Emerson, P., 2006, "Corruption, competition and democracy," Forthcoming: *Journal of Development Economics*, Vol 81(1).

Evans, J., Levine, P. and F. Trillas, 2005, "Lobbies, delegation and the under-investment problem in regulation," Working paper Universidad Autónoma de Barcelona.

Fink, C., Mattoo, A. and R. Rathindran, 2002, "An assessment of telecommunications reform in developing countries," The World Bank Policy Research Working Paper 2909.

Gasmi, F., Noumba, P., and L. Recuero Virto, 2006, "Political accountability and regulatory performance in infrastructure industries: An empirical analysis," World Bank Policy Research Paper 4101.

Ghosh Banerjee, S. and D.A. Rondinelli, 2003, "Does foreign aid promote privatization? Empirical evidence from developing countries," *World Development* Vol 31.

Gual, J. and F. Trillas, 2006, "Telecommunications policies: Determinants and impact," *Review of Network Economics*, Vol 5(2).

Gutierrez, L. H., 2003, "The effect of the endogenous regulation on telecommunications expansion and efficiency in Latin America," *Journal of Regulatory Economics*, Vol 23.

Henisz, W. J., 2002, "The institutional environment for infrastructure investment," *Industrial and Corporate Change*, Vol 11(2).

Holtz-Eakin, D., Newey, W. and H.S. Rosen, 1988, "Estimating vector autoregressions with panel data," *Econometrica*, Vol 56.

Laffont, J.J., 2005, *Regulation and development*, Cambridge University Press.

——— and T. N'Guessan, 1999, "Competition and corruption in an agency relationship," *Journal of Development Economics*, Vol 60.

La Porta, R., Lopez-de-Salines, F., Shleifer A. and R.W. Vishny, 1998, "Quality of governance," *Journal of Law, Economics and Organization*, Vol 15(1).

Li, W., Qiang, C. and L.C. Xu, 2005, "Regulatory reforms in the telecommunications sector in developing countries: The role of democracy and private interests," *World Development* Vol 33(8).

——— and L.C. Xu, 2002, "The political economy of privatization and competition: Cross-country evidence from the telecommunications sector," *Journal of Comparative Economics*, Vol 30(3).

———————, 2004, "The impact of privatization and competition in the telecommunications sector around the world," *The Journal of Law and Economics*, Vol XLVII.

Martimort, D. and S. Straub, 2006, "Privatization and corruption," Toulouse School of Economics working paper.

McNary, R., 2001, "The network penetration effects of telecommunications privatization and competition," Mimeo Stanford University.

Rivers, D., and H. Vuong, 1988, "Limited information estimators and exogeneity tests for simultaneous probit models," *Journal*

of Econometrics, Vol 39.

Ros, A.J., 1999, "Does network and competition matter? The effects of telecommunications reform on network expansion and efficiency," *The Journal of Regulatory Economics*, Vol 15.

————-, 2003, "The impact of the regulatory process and price cap regulation in Latin American telecommunications markets," *Review of Network Economics*, Vol 2(3).

Wallsten, S. J., 2000, "Telecommunications privatization in developing countries: The real effects of exclusivity periods," Stanford Institute for Economic Policy Research Paper 99-21.

————————, 2001, "An econometric analysis of competition, privatization, and regulation in Africa and Latin America," *The Journal of Industrial Economics*, Vol 49(1).

Warlters, M., 2004, "Infrastructure privatization and the marginal cost of public funds," PhD Dissertation Université de Toulouse I Sciences Sociales, Midi-Pyrénnées School of Economics.

Windmeijer, F., 2000, "Efficiency comparisons for a system-GMM estimator in dynamic panel data models," in Heijmans, R.D.H., D.S.G. Pollock and A. Satorra (eds), *Innovations in Multivariate Statistical Analysis*.