The Effects of Infrastructure Development on Growth and Income Distribution

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Abstract

This paper provides an empirical evaluation of the impact of infrastructure development on economic growth and income distribution using a large panel data set encompassing over 100 countries and spanning the years 1960-2000. The empirical strategy involves the estimation of simple equations for GDP growth and conventional inequality measures, augmented to include among the regressors infrastructure quantity and quality indicators in addition to standard controls. To account for the potential endogeneity of infrastructure (as well as that of other regressors), we use a variety of GMM estimators based on both internal and external instruments, and report results using both disaggregated and synthetic measures of infrastructure quantity and quality. The two robust results are: (i) growth is positively affected by the stock of infrastructure assets, and (ii) income inequality declines with higher infrastructure quantity and quality. A variety of specification tests suggest that these results do capture the causal impact of the exogenous component of infrastructure quantity and quality on growth and inequality. These two results combined suggest that infrastructure development can be highly effective to combat poverty. Furthermore, illustrative simulations for Latin American countries suggest that these impacts are economically quite significant, and highlight the growth acceleration and inequality reduction that would result from increased availability and quality of infrastructure.

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1. Introduction

It has long been recognized that an adequate supply of infrastructure services is an essential ingredient for productivity and growth.[1] In recent years, however, the role of infrastructure has received increased attention. From the academic perspective, a rapidly growing literature – starting with the seminal work of Aschauer (1989) – has sought to quantify the contribution of infrastructure to income and growth.[2] From the policy perspective, the renewed concern with infrastructure can be traced to two worldwide developments that took place over the last two decades. The first one was the retrenchment of the public sector since the mid 1980s, in most industrial and developing countries, from its dominant position in the provision of infrastructure, under the increasing pressures of fiscal adjustment and consolidation. The second was the opening up of infrastructure industries to private participation, part of a worldwide drive toward increasing reliance on markets and private sector activity, which has been reflected in widespread privatization of public utilities and multiplication of concessions and other forms of public-private partnership. While this process first gained momentum in industrial countries (notably the U.K.), over the last decade it has extended to a growing number of developing economies, particularly in Latin America.

Infrastructure has become an ubiquitous theme in a variety of areas of the policy debate. For example, there is persuasive evidence that adequate infrastructure provision is a key element in the "behind the border" agenda required for trade liberalization to achieve its intended objective of efficient resource reallocation and export growth. Also, a number of studies have argued that generalized access to infrastructure services plays a key role in helping reduce income inequality.[3] Against this background, there is a growing perception that in many countries the pressures of fiscal consolidation have led to a compression of public infrastructure spending, which has not been offset by the increase in private sector participation, thus resulting in an insufficient provision of infrastructure services with potentially major adverse effects on growth and inequality.[4]

The goal of this paper is to provide a comprehensive empirical evaluation of the impact of infrastructure development on growth and income inequality. To do this, we build a large data set of infrastructure quantity and quality indicators covering over 100 countries

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[1] For an encompassing assessment of the role of infrastructure in economic development, see World Bank (1994).
[2] Early contributions to this literature are surveyed by Gramlich (1994).
[3] On trade, see for example Lederman, Maloney and Servén (2004). The links between infrastructure services and inequality are discussed by Estache, Foster and Wodon (2002), Estache (2003) and World Bank (2003).

and spanning the years 1960-2000.[5] Using this data set, we estimate empirical growth and inequality equations including a standard set of control variables augmented by the infrastructure quantity and quality measures, and controlling for the potential endogeneity of infrastructure indicators.[6]

The paper relates to several strands of the literature focused on different macroeconomic dimensions of infrastructure. It is closely related to recent empirical studies assessing the contribution of infrastructure to the level and growth of aggregate output (Sánchez-Robles 1998, Canning 1999, Demetriades and Mamuneas 2000, Röller and Waverman 2001, Esfahani and Ramirez 2002, Calderón and Servén 2003a). It also follows a rapidly expanding literature on the distributive impact of infrastructure provision and reform, which arose largely as a result of the worldwide trend toward increased private sector participation in infrastructure (Estache, Foster and Wodon 2002; Calderón and Chong 2004).

We extend these previous studies along various dimensions. First, unlike most of the previous literature, which focuses on one specific infrastructure sector, we consider simultaneously transport, power and telecommunications, and present also some experiments involving the water sector. Second, we take into account both quantity and quality of infrastructure, in contrast with earlier studies, which typically consider only quantity. Third, we explore the effects of infrastructure on both growth and distribution, and in the latter case employ a variety of inequality measures. Finally, our study is conducted using an updated cross-country time-series data set of infrastructure indicators.

The rest of the paper is organized as follows. In Section 2 we offer a brief review of recent literature concerned with the effects of infrastructure development on growth and distribution. Section 3 lays out the empirical strategy, describes the data set and the measures of infrastructure quantity and quality used in the analysis, and discusses the econometric issues that arise when attempting to measure the impact of infrastructure. Section 4 presents the empirical results. Finally, section 5 concludes.

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[4] On these concerns, see Blanchard and Giavazzi (2003) for the case of the European Union, and Easterly and Servén (2003) for that of Latin America.
[5] These data are documented in Calderón and Servén (2004).
[6] On these issues, the paper updates and complements the research presented in Easterly and Servén (2003) and Calderón and Servén (2003b).

2. Infrastructure, growth and distribution: a brief overview

In this section we provide a quick overview of recent literature on the effects of infrastructure on the growth of income and its distribution. For the sake of brevity, the discussion is selective rather than exhaustive.

2.1 Infrastructure and growth

That infrastructure accumulation may promote growth is hardly news for developing-country policy makers. In the macroeconomic literature, a number of studies have found empirical support for a positive impact of infrastructure on aggregate output. In a seminal paper, Aschauer (1989) finds that the stock of public infrastructure capital is a significant determinant of aggregate TFP. However, the economic significance of his results was deemed implausibly large, and found not to be robust to the use of more sophisticated econometric techniques (Holtz-Eakin, 1994; Cashin, 1995; Baltagi and Pinnoi, 1995). Gramlich (1994) provides an overview of this literature.

A more recent empirical literature, mostly in a cross-country panel data context, has confirmed the significant output contribution of infrastructure. Such result is reported, for example, by Canning (1999) using panel data for a large number of countries and by Demetriades and Mamuneas (2000) using OECD data. Roller and Waverman (2001) also find large output effects of telecommunications infrastructure in industrial countries, in a framework that controls for the possible endogeneity of infrastructure accumulation.[7] Similar results for roads are reported by Fernald (1999) using industry data for the U.S.

In Calderón and Servén (2003a), we present a similar empirical analysis with a focus on Latin America. Using GMM estimates of a Cobb-Douglas production technology obtained from a large cross-country panel data set, we find positive and significant output contributions of three types of infrastructure assets – telecommunications, transport and power. The estimated marginal productivity of these assets significantly exceeds that of non-infrastructure capital. On the basis of those estimates, we conjecture that a major portion of the per-capita output gap that opened between Latin America and East Asia over the 1980s and 1990s can be traced to the slowdown in Latin America's infrastructure accumulation in those years.[8]

In contrast with the relatively large literature on the output contribution of infrastructure, studies of the impact of infrastructure on long-term growth are much less

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[7] A related result is that of Cronin et al. (1991), who find that telecommunications investment Granger-causes aggregate U.S. output.

abundant. In a study of the growth impact of government spending, Easterly and Rebelo (1993) find that public expenditure on transport and communications significantly raises growth.[9] Also, Sanchez-Robles (1998) finds that summary measures of physical infrastructure are positively and significantly related to growth in GDP per capita. Easterly (2001) reports that a measure of telephone density contributes significantly to explain the growth performance of developing countries over the last two decades. Loayza, Fajnzylber and Calderón (2003) find that the same telecommunications indicator is robustly related to growth in a large panel data set including both industrial and developing countries.

To our knowledge, López (2003) is the only paper assessing the contribution of infrastructure to both growth and income distribution, again using telephone density as the infrastructure indicator. In a panel framework and controlling for possible reverse causation, he finds that infrastructure both raises growth and reduces income inequality.

A few papers go beyond measures of infrastructure spending and infrastructure stocks and consider the issue of infrastructure efficiency. Hulten (1996) finds that differences in the effective use of infrastructure resources explain one-quarter of the growth differential between Africa and East Asia, and more than 40 percent of the growth differential between low- and high-growth countries. Esfahani and Ramirez (2002) report significant growth effects of infrastructure in a large panel data set in which the contribution of infrastructure is affected by institutional factors.

2.2 Infrastructure and Inequality

Aside from the effects of infrastructure development on aggregate income growth, another strand of recent literature has examined its effects on income inequality. The underlying idea is that, under appropriate conditions, infrastructure development can have a positive impact on the income and welfare of the poor over and above its impact on average income.[10] This hypothesis is confirmed empirically in the study by López (2003) cited earlier.

There are good reasons why infrastructure development may have a disproportionate positive impact on the income and welfare of the poor. From an aggregate

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[8] This infrastructure-induced output deceleration has potentially important consequences for the long-term effect of public infrastructure compression on the government's solvency; see Calderón, Easterly and Servén (2003).

[9] In contrast, Devarajan et al. (1996) find a negative relationship between the share of infrastructure expenditure in total expenditure and economic growth for a sample of developing countries. They argue that this result may be due to the fact that excessive amounts of transportation and communication expenditures in those countries make such expenditures unproductive.

[10] For overviews of the infrastructure-distribution link, see Estache, Foster and Wodon, (2002), Estache (2003) and World Bank (2003).

perspective, Ferreira (1995) presents a model of public-private capital complementarity in which expanding public investment reduces inequality. Conceptually, infrastructure helps poorer individuals and underdeveloped areas to get connected to core economic activities, thus allowing them to access additional productive opportunities (Estache, 2003). Likewise, infrastructure development in poorer regions reduces production and transaction costs (Gannon and Liu, 1997). [11] In this vein, Estache and Fay (1995) find that enhanced access to roads and sanitation has been a key determinant of income convergence for the poorest regions in Argentina and Brazil. Along the same lines, infrastructure access can raise the value of the assets of the poor. For example, recent research links the asset value of poor farm areas -- as proxied by the net present value of the profits generated by their crops —to the distance to agricultural markets. Improvements in communication and road services imply capital gains for these poor farmers (Jacoby, 2000).

Infrastructure development can also have a disproportionate impact on the human capital of the poor, and hence on their job opportunities and income prospects. This refers not only to education, but most importantly to health. A number of recent papers has focused specifically on the impact of expanding infrastructure services on child (and maternal) mortality, and educational attainment.[12] This literature shows that policy changes that enhance the availability and quality of infrastructure services for the poor in developing countries have a significant positive impact on their health and/or education and, hence, on their income and welfare as well.

Brenneman and Kerf (2002) summarize some recent evidence on these impacts. Regarding education, a better transportation system and a safer road network help raise school attendance. Electricity also allows more time for study and the use of computers (Leipziger et al. 2003). Regarding health, access to water and sanitation plays a key role. Several studies have identified instances in which access to clean water has helped significantly to reduce child mortality (Behrman and Wolfe, 1987; Lavy et al. 1996; Lee et al. 1997; Jalan and Ravallion, 2002). [13] In Argentina, for example, a recent study by Galiani et al. (2002) concludes that expanded access to water and sanitation has reduced child mortality by 8 percent, with most of the reduction taking place in low-income areas where the expansion in the water network was the largest. More generally, Leipziger et al. (2002)

[11] For example, in poor rural areas infrastructure expands job opportunities for the less advantaged by reducing the costs to access product and factor markets (Smith et al. 2001).

[12] In a recent cross-country study, Leipziger, Fay and Yepes (2003) find that a 10 percent increase in an index of water and sanitation leads to a reduction of child and infant mortality by 4-5 percent, and maternal mortality by 8 percent. Thus, such infrastructure improvement may save 9 children under 5 years old (for each 1000 live births) and nearly 100 mothers (for each 100000 live births) for a poor country like Central African Republic.

[13] Water-related diseases related to drinking contaminated water and to the lack of safe water and sanitation for the household hygiene are among the main causes of child mortality (World Health Organization, 2002).

find that a quarter of the difference in infant mortality and 37% of the difference in child mortality between the rich and the poor is explained by their respective access to water services. Allowing the poor to access safe water at the same rate as the rich would reduce the difference in child mortality between the two groups by over 25 percent.

Of course, for infrastructure expansion to reduce income inequality, it must result in improved access and/or enhanced quality particularly for low-income households. Hence the key issue is how the development of infrastructure impacts access by the poor (Estache et al. 2000).[14]

One question that has attracted considerable attention is the distributive impact of private participation in infrastructure. This involves both macro and microeconomic linkages.[15] Among the former, employment effects have been particularly controversial, as private providers taking over public firms often make them more profitable by downsizing (Estache et al. 2002). The distributive impact of downsizing depends on the access of lower income segments of the population to public sector employment in infrastructure, and on the monetary compensation to workers laid-off for efficiency reasons. If the investment by the newly reformed providers of infrastructure promotes growth and new jobs, the process of job destruction in the public sector may be offset by the creation of employment in other sectors (Benitez, Chisari and Estache, 2000).

Aside from employment effects, another macro channel concerns the composition of public expenditure, which may be affected by private sector participation in infrastructure. This may lead to elimination of subsidies in the provision of infrastructure services, and may also generate privatization revenues.[16] If these resources are used to implement a pro-poor expansion of infrastructure services, then the result can be a more egalitarian income distribution (Estache, Gomez-Lobo and Leipziger, 2000).

From the micro perspective, infrastructure reform – whether through private participation or without it —may involve price or supply strategies that hamper the access and affordability of infrastructure services for the poor. For example, withdrawal of subsidies may lead to higher prices post-reform; new private providers of infrastructure may

[14] We should also note that there may be two-way causality in this relationship, that is, income inequality may prevent the access of poorer people to the infrastructure services. For example, Estache, Manacorda and Valletti (2002) show that income inequality adversely affect the access to internet, while Alesina, Baqir and Easterly (1999) argue that more unequal societies devote less effort to the provision of public goods, including infrastructure.

[15] See Estache et. al. (2000).

[16] In the case of Argentina, Chisari et al. (1999) and Navajas (2000) showed that the privatization of infrastructure service hurt the middle class relatively more than the rest through the elimination of existing subsidies, and may have benefited the poor by granting them increased access to services. Estache, Gomez-Lobo and Leipziger (2000) argue that the poorest groups of the population did not have access to many utility services and did not benefit from their expansion prior to the privatization.

charge higher connection fees than under public provision, or may be reluctant to serve poorer areas (Estache, Foster and Wodon, 2002).[17] As a result, infrastructure services may become unaffordable to lower-income groups. Whether this happens in practice, however, depends on the overall design of the reforms, and there are numerous episodes in which the poor have benefited from reforms involving private participation.[18]

3. Empirical Strategy[19]

To assess the impact of infrastructure on growth and income distribution, we use a large macroeconomic panel data set comprising 121 countries and spanning the years 1960-2000. Not all countries possess complete information over the period under analysis; hence the panel is unbalanced. Since our focus is on long-run trends in growth and inequality rather than their behavior over the business cycle, we work with data averaged over five-year periods to smooth out short-term fluctuations.

3.1 Measuring the quantity and quality of infrastructure

Most of the previous literature, particularly that concerned with the growth effects of infrastructure, focuses on one single infrastructure sector. Some papers do this by design, e.g., Röller and Waverman (2001) evaluate the impact of telecommunications infrastructure on economic development, and Fernald (1999) analyzes the productivity effects of changes in road infrastructure. Other papers take a broad view of infrastructure but employ a single indicator for their empirical analysis of growth or inequality determinants.[20] The reason for this simplification is the high correlation among measures of various kinds of infrastructure -- telecommunications, power capacity, road and railway networks, water and sanitation, etc. For example, in a large panel data set similar to the one used in this paper, Calderón and Servén (2003b) find that the correlation between measures of telephone density and power generating capacity is 0.94, while the correlation between main lines and roads or roads and power generating capacity is close to 0.6.

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[17] Rapid expansion of the mobile phone service has increased significantly access to a wide array of suppliers in this sector. However, this has not been the case in the power sector, where reforms have often failed to provide low-cost solutions to remote households in rural areas (Foster, Tre and Wodon, 2001).

[18] A recent review of Latin America's experience (World Bank, 2003) offers several examples. In Guatemala improved access to electricity, water and telephones for poorer groups lead to more equal incomes. Expansion of infrastructure services to rural areas in El Salvador reduced the time required to reach markets and generated huge gains for poorer groups. Improving road quality had a significant impact on income and, especially, on wage employment in Peru.

[19] This section draws from Calderón and Servén (2003b).

[20] In the case of growth, the number of telephone lines per capita is usually taken as the preferred indicator of overall infrastructure availability; see for example Easterly (2001) and Loayza, Fajnzylber and Calderón (2003). For inequality, a recent example of the same approach is López (2003).

In a linear regression framework, this close association among different infrastructure categories makes it difficult to obtain reliable estimates of the individual coefficients of variables representing different kinds of infrastructure assets, as we shall see below.[21] For this reason, below we follow a different strategy: we build synthetic indices that summarize various dimensions of infrastructure and its quality. To build these indices, we follow Alesina and Perotti (1996) and Sánchez-Robles (1998) and apply principal component analysis to disaggregate infrastructure indicators; our synthetic indices are given by the first principal component of the underlying variables.

The Aggregate Index of Infrastructure Stocks

We build the aggregate index using data from the telecommunication sector (number of main telephone lines per 1,000 workers), the power sector (the electricity generating capacity of the economy —in MW per 1,000 workers), and the transportation sector (the length of the road network —in km. per sq. km. of land area). All three variables are expressed in logs. The underlying data are described in Calderón and Servén (2004).

To assess the robustness of the results obtained with this formulation, we also compute aggregate indices using other measures of infrastructure stocks in telecommunications —main lines augmented by mobile phones— and transportation —length of the paved road network, as well as total road length augmented by the railroad length. The correlation between these alternative global indices is very high and the growth and inequality estimation results obtained with each of them are qualitatively similar.[22]

The first principal component of the three stock variables accounts for 81% of their overall variance and, as expected, it is highly correlated with each individual measure included.[23] Specifically, the correlation between the first principal component and main telephone lines is 0.96, its correlation with power generating capacity is 0.95, and its correlation with the length of the road network is 0.78. In addition, all three infrastructure stocks enter the first principal component with approximately similar weights:

$$PI(z)_{it} = 0.6159 \cdot \ln\left(\frac{Z_1}{L}\right)_{it} + 0.6075 \cdot \ln\left(\frac{Z_2}{L}\right)_{it} + 0.5015 \cdot \ln\left(\frac{Z_3}{A}\right)_{it}$$

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[21] For example, Calderón and Servén (2003b) found that when infrastructure indicators of telecommunications, power and roads were included together in a growth regression equation, the estimated coefficient of power was negative and not statistically significant, whereas either main lines or road network were statistically insignificant in some regressions.

[22] These alternative measures are not reported but are available upon request. The estimation results obtained using them are presented in Tables A.1 and A.2.

where *P1(z)* is the synthetic index of infrastructure stocks, *(Z_1/L)* is the number of main telephone lines (per 1,000 workers), *(Z_2/L)* is the electricity generating capacity (in GW per 1,000 workers), and *(Z_3/A)* represents the total road length normalized by the surface area of the country (in km. per sq.km.).

Finally, we should note that the choice of infrastructure indicators underlying the synthetic index is consistent with the literature on the output contribution of infrastructure, which has focused on power, transport and (especially) telecommunications. However, as we discussed earlier, the literature on inequality gives special importance to a different infrastructure indicator, namely access to safe water. For this reason, rather than building a different synthetic index for the empirical analysis of inequality, we shall present some estimation results below assessing the impact of this variable on income distribution.[24]

The Aggregate Index of Infrastructure Quality

We proceed in a similar fashion to build an aggregate index of the quality of infrastructure services.[25] In this case, we apply principal component analysis to three indicators of quality in the services of telecommunications (waiting time for telephone main lines —in years), power (the percentage of transmission and distribution losses in the production of electricity), and transport (the share of paved roads in total roads).[26] The first of these three variables is admittedly not a direct indicator of the quality of telecommunications networks, but is significantly positively correlated with the conceptually-preferable measure (the number of telephone faults per 100 main lines) whose availability is severely limited in our sample.[27] In any case, we also performed some empirical experiments employing an alternative synthetic index, derived as the first principal component of the first two of these three quality measures.

The first principal component of these indicators of infrastructure quality captures approximately 73 percent of their total variation, and it shows a high correlation with each

[23] Before applying principal component analysis, the underlying variables are standardized in order to abstract from units of measurement.
[24] Construction of an alternative synthetic index including water access is also problematic because the availability of information on this variable is much more limited than for the other infrastructure variables.
[25] An alternative approach to measuring the effectiveness of infrastructure capital is that of Hulten (1996). He sorts information on infrastructure effectiveness across the world by quartiles, inputting the highest values of 1 to the top quartile and 0.25 to the bottom quartile. He then averages the values assigned for each infrastructure sector. This procedure, however, entails loss of information, as these indicators could show a wide degree of variation within the quartiles.
[26] We rescale all three quality measures so that higher values indicate higher quality of infrastructure.
[27] Over the available sample, the correlation coefficient is 0.3. Unfortunately, the coverage of unsuccessful local calls is extremely limited, with information only for 2 to 3 selected years in the 1990s and a maximum cross-section coverage of 68 countries.

of the three individual quality indicators (0.74 for telecommunications, 0.73 for power, and 0.70 for transport). The synthetic index can be expressed as:

$$Pl(qz)_{it} = 0.5923\,(Q_1)_{it} + 0.5814\,(Q_2)_{it} + 0.5578\,(Q_3)_{it}$$

where *P1(qz)* represents the first principal component of our measures of infrastructure quality, Q_1 represents the measure of waiting time for installation of main lines, Q_2 is the share of power output net of transmission and distribution losses in total output, and Q_3 is the share of paved roads in total roads.

It is worth noting that quantity and quality indicators share a good deal of common information. The correlation between the two synthetic indices is a whooping 0.74. Across infrastructure sectors, the respective stocks and their quality are also positively correlated, particularly so in the case of roads (0.51) and power (0.45).

3.2 Econometric Methodology[28]

Assessing empirically the impact of infrastructure on growth and income distribution in our panel data set poses some econometric issues that can be illustrated in the context of a simple dynamic equation:

$$\begin{aligned} y_{it} - y_{it-1} &= \alpha y_{it-1} + \phi' K_{it} + \gamma' Z_{it} + \mu_t + \eta_i + \varepsilon_{it} \\ &= \alpha y_{it-1} + \beta' X_{it} + \mu_t + \eta_i + \varepsilon_{it} \end{aligned} \tag{1}$$

Here K is a set of standard growth or inequality determinants, and Z is a vector of infrastructure-related measures. The terms μ_t and η_i respectively denote an unobserved common factor affecting all countries, and a country effect capturing unobserved country characteristics. The second equality follows from defining $X_{it} = (K'_{it}, Z'_{it})'$ and $\beta = (\phi', \gamma')'$.

For the growth equation, y denotes (log) per capita GDP. For the inequality equation, y denotes a suitable (in)equality indicator, and the equation omits any dynamics – i.e., it is a simplified version of the above expression with α = -1, so that the lagged dependent variable drops out from both sides.

Estimation of (1) faces the potential problem of endogeneity of the regressors. In principle, this affects both the standard determinants of growth in K (e.g., variables such as inflation, financial depth and so on, commonly included in growth and/or inequality regressions) as well as the infrastructure measures in Z, since it can be argued that these are jointly determined with the rest of the economy's endogenous variables – indeed, they may by subject to reverse causation from income and/or inequality.[29] Furthermore, in the growth equation the lagged dependent variable y_{it} is also endogenous due to the presence of the country-specific effect.

To deal with endogeneity, we need suitable instruments. However, apart from the terms of trade, which we shall assume strictly exogenous, there are no obviously exogenous variables at hand to construct them, and therefore we shall rely primarily on *internal* instruments, along the lines described by Arellano and Bond (1991). These are provided by suitable lags of the variables. In principle, however, note that the presence of unobserved country characteristics likely means that $E[X_{is}\eta_i] \neq 0$, and hence lagged levels of the regressors are not valid instruments for (1). Therefore, we first eliminate the country-specific effect by taking first-differences of equation (1):

$$y_{it} - y_{it-1} = (1+\alpha)\left(y_{it-1} - y_{it-2}\right) + \beta'\left(X_{it} - X_{it-1}\right) + \left(\varepsilon_{it} - \varepsilon_{it-1}\right) \quad (2)$$

Assuming that (i) the time-varying disturbance ε is not serially correlated, and (ii) the explanatory variables X are weakly exogenous (*i.e.* they are uncorrelated with future realizations of the time-varying error term), lagged values of the endogenous and exogenous variables provide valid instruments.[30] In other words, we assume that:

$$E\left[y_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3, \ldots, T \quad (3)$$

$$E\left[X_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3, \ldots, T \quad (4)$$

These conditions define the *GMM-difference* estimator. In spite of its simplicity, it has some potential shortcomings. When explanatory variables are persistent over time, their lagged levels are weak instruments for the regression equation in differences (Alonso-Borrego and Arellano, 1996; Blundell and Bond, 1998). This raises the asymptotic variance of the estimator and creates a small-sample bias.[31]

To avoid these problems, below we use a *system* estimator that combines the regression in differences and in levels (Arellano and Bover 1995, Blundell and Bond 1998).

[28] This section draws from Appendix II of Calderón and Servén (2003b).
[29] For example, infrastructure accumulation could be driven by output growth and/or inequality. The latter possibility has been explored by Alesina, Baqir and Easterly (1999).
[30] Note that this still allows current and future values of the explanatory variables to be affected by the error term.
[31] An additional problem with the simple *difference* estimator relates to measurement error: differencing may exacerbate the bias due to errors in variables by decreasing the signal-to-noise ratio (see Griliches and Hausman, 1986).

The instruments for the regression in differences are the same as above. The instruments for the regression in levels are the lagged *differences* of the corresponding variables. These are appropriate instruments under the additional assumption of no correlation between the *differences* of these variables and the country-specific effect. Formally, we assume

$$E[y_{i,t+p} \cdot \eta_i] = E[y_{i,t+q} \cdot \eta_i] \quad and$$
$$E[X_{i,t+p} \cdot \eta_i] = E[X_{i,t+q} \cdot \eta_i] \quad for\ all\ p\ and\ q \tag{5}$$

This leads to additional moment conditions for the regression in levels:[32]

$$E[(y_{i,t-1} - y_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \tag{6}$$

$$E[(X_{i,t-1} - X_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \tag{7}$$

Using the moment conditions in equations (3), (4), (6), and (7), we employ a Generalized Method of Moments (GMM) procedure to generate consistent estimates of the parameters of interest and their asymptotic variance-covariance (Arellano and Bond, 1991; Arellano and Bover, 1995). These are given by the following formulas:

$$\hat{\theta} = (\overline{X}' W \hat{\Omega}^{-1} W' \overline{X})^{-1} \overline{X}' W \hat{\Omega}^{-1} W' \overline{y} \tag{8}$$

$$AVAR(\hat{\theta}) = (\overline{X}' W \hat{\Omega}^{-1} W' \overline{X})^{-1} \tag{9}$$

where θ is the vector of parameters of interest (α, β), $\overline{y}$ is the dependent variable stacked first in differences and then in levels, $\overline{X}$ is the explanatory-variable matrix including the lagged dependent variable (y_{t-1}, X) stacked first in differences and then in levels, W is the matrix of instruments derived from the moment conditions, and $\hat{\Omega}$ is a consistent estimate of the variance-covariance matrix of the moment conditions.[33]

Consistency of the GMM estimators depends on the validity of the above moment conditions. This can be checked through two specification tests suggested by Arellano and Bond (1991) and Arellano and Bover (1995). The first is a Sargan test of over-identifying restrictions, which tests the overall validity of the instruments by analyzing the sample

[32] Given that lagged levels are used as instruments in the differences specification, only the most recent difference is used as instrument in the levels specification. Using other lagged differences would result in redundant moment conditions (see Arellano and Bover, 1995).

[33] In practice, Arellano and Bond (1991) suggest the following two-step procedure to obtain consistent and efficient GMM estimates. First, assume that the residuals, $\varepsilon_{i,t}$, are independent and homoskedastic both across countries and over time. This assumption corresponds to a specific weighting matrix that is used to produce first-step coefficient estimates. Then, construct a consistent estimate of the variance-covariance matrix of the moment conditions with the residuals obtained in the first step, and use this matrix to re-estimate the parameters of interest (i.e. second-step estimates). Asymptotically, the second-step estimates are superior to the first-step ones in so far as efficiency is concerned.

analog of the moment conditions used in the estimation process. Failure to reject the null hypothesis that the conditions hold gives support to the model. Furthermore, validity of the *additional* moment conditions required by the system estimator relative to the difference estimator can likewise be verified through difference Sargan tests.

The second test examines the null hypothesis that the error term $\varepsilon_{i,t}$ is serially uncorrelated. As with the Sargan test, failure to reject the null lends support to the model. In the *system* specification we test whether the differenced error term (that is, the residual of the regression in differences) shows second-order serial correlatation. First-order serial correlation of the differenced error term is expected even if the original error term (in levels) is uncorrelated, unless the latter follows a random walk. Second-order serial correlation of the differenced residual indicates that the original error term is serially correlated and follows a moving average process at least of order one. This would render the proposed instruments invalid (and would call for higher-order lags to be used as instruments).

So far we have limited our discussion to internal instruments. But as a double check that our results concerning infrastructure are not driven by invalid instruments, we also experiment below with a set of external instruments provided by demographic variables. This is motivated by the results of Canning (1998) and Roller and Waverman (2001), who show that much of the observed variation in infrastructure stocks is explained by demographic variables such as population density and urbanization. Thus, in some regressions below, we drop all lags of the infrastructure indicators —both quality and quantity— from the set of instruments and replace them with current and lagged values of these demographic variables.

4. Empirical results

We turn to the evaluation of the impact of infrastructure stocks and the quality of infrastructure services on growth and inequality. We first examine the effects on growth, and then those on income distribution.

4.1 Infrastructure and Long-Term Growth

As noted, our strategy involves estimation of an infrastructure-augmented growth regression. Following Loayza *et al.* (2003) we include the following standard (i.e., non-infrastructure) growth determinants: indicators of human capital, financial depth, trade openness, government burden, governance, inflation and real exchange rate overvaluation, and terms of trade shocks.[34] In addition, the set of explanatory variables includes the indices of infrastructure quality and quantity described earlier. For our empirical experiments, we use an unbalanced panel data set of 5-year averages over the 1960-2000 period, with a total number of observations exceeding 400.

Before discussing the regression results, it is worth noting that the correlation between growth and the principal component of infrastructure stocks equals 0.18 (figure 1). The correlation of growth with the individual stocks is also positive (0.15 for main lines, 0.13 for power generating capacity, and 0.21 for road length). On the other hand, growth is also positively correlated with the global index of infrastructure quality (the correlation coefficient equals 0.21, see figure 2) and its individual components (0.12 for quality in telecommunications and power, and 0.17 for quality of roads).

4.1.1 Growth and Infrastructure Stocks

Table 1 reports the regression results obtained with the basic growth equation augmented by the synthetic index of infrastructure stocks, using different estimation techniques. In column [1] we present pooled OLS estimates. These ignore both unobserved country-specific and common factors as well as the possible endogeneity of the regressors. The signs of the standard growth determinants are as expected, except for the trade openness indicator, which carries a negative but insignificant coefficient. As for infrastructure, we find that infrastructure stocks and economic growth are positively associated. An increase of one standard deviation in the aggregate index of infrastructure is associated with a 0.9 percent increase in the growth rate. However, the equation's diagnostic statistics show considerable evidence of serial correlation of the residuals.

In columns [2] and [3] of Table 1, we control for unobserved country- and common time-effects, respectively. The within-group estimator (country effects) again finds a positive and significant coefficient for the stock of infrastructure, and its size more than doubles the OLS estimate. In contrast, the time-effects estimate is more in line with the OLS coefficient (positive, significant and closer in magnitude).

As already noted, these estimators do not correct for the likely endogeneity of variables such as human capital, financial depth, trade openness, governance, inflation, or infrastructure itself. In column [4] we address this issue by employing the GMM-IV difference estimator, which uses lagged levels of the explanatory variables as internal

[34] For a detailed exposition on the inclusion of these variables and their theoretical effects on growth, see Loayza et al. (2003).

instruments.[35] We find that the coefficient estimate of the infrastructure stock is still positive and significant, and its order of magnitude is similar to that in the preceding column. Neither the Sargan test of overidentifying restrictions nor the test of second order serial correlation reveals symptoms of misspecification.

The estimates in column [4] may suffer from the problem of weak instruments, given that we have some persistent regressors (say, output per capita, human capital, governance, among others). In such conditions, the GMM-IV System estimator, which combines the first-difference model (instrumented with lagged levels of the regressors) with its original version in levels (instrumented with lagged differences of the regressors) may be preferable. Columns [5] and [6] of Table 1 report two alternative implementations. In column [5] we present the GMM-IV estimator using only internal instruments (that is, lagged levels and lagged differences of the explanatory variables). In column [6] we drop the lagged values of the infrastructure variables from the instrument set and replace them with external instruments provided by the lagged levels of urban population, the labor force, and population density. The latter specification should help allay any concerns with potential endogeneity of the infrastructure variables, and for this reason it represents our preferred estimator. In both cases, the specification tests shown in the table appear to validate the system estimates for statistical inference.

The system estimates in both columns suggest that (a) there is evidence of conditional convergence. (b) Growth is enhanced by deeper financial systems, more human capital, more open economies, better governance, and positive terms of trade shocks. (c) Growth is adversely affected by higher inflation, a larger government burden and a higher degree of RER overvaluation.

According to our preferred estimate —column [6] of Table 1—the coefficient on the infrastructure stock is positive and significant, pointing to a positive contribution of infrastructure to growth. How important is this effect ? Let us consider a one-standard deviation increase in the aggregate index of infrastructure; this amounts to an increase of 1.3 in the global index, which represents an improvement of the aggregate infrastructure stock from 0.4 (the level exhibited by Ecuador and Colombia in the 1996-2000 period) to 1.7 (the level displayed by Korea and New Zealand in the same period).[36] The coefficient estimate in column [6] implies that, other things equal, such increase in the index of

[35] To compute the GMM-IV estimators we need at least 3 consecutive observations. Hence, we restrict the sample to countries that satisfy that criterion.

[36] Such increase in infrastructure stocks has in fact been achieved between 1976-80 and 1996-2000 by countries such as China, Indonesia, Turkey, Korea, and Malaysia.

infrastructure stocks would raise the growth rate of the economy by 3 percentage points – a fairly substantial effect.

Among Latin American countries, we find that if the infrastructure levels in Peru (located in the 25th percentile of the region) were to rise to the levels of Chile (75th percentile of the region) or Costa Rica (leader in the region) during the 1996-2000 period, Peru's growth rate would rise by 1.7 or 3.1 percentage points, respectively. Note these growth benefits imply a very significant expansion of the infrastructure network. According to the figures for the 1996-2000 period, an improvement in the infrastructure of Peru to the levels exhibited by Costa Rica implies an increase in: (a) main lines (per 1000 workers) from 164 to 457, (b) electricity generating capacity (per 1000 workers) from 0.5 to 0.9, and (c) roads (in km. per sq.km.) from 0.06 to 0.70

The Impact of Different Categories of Infrastructure. In Table 2 we present the estimates of our growth regression using the different categories of infrastructure — telecommunications, power, and transportation— individually or jointly. In this analysis, we use only the GMM-system estimator with internal instruments for the non-infrastructure growth determinants, that is lagged levels and differences of the explanatory variables, and instrument the infrastructure stocks with actual and lagged levels as well as lagged differences of the demographic variables (as in column [6] of Table 1).

In columns [1]-[5] of Table 2, we use one infrastructure indicator at a time. We evaluate the impact on growth of main telephone lines, main lines and cellular phones, power generating capacity, length of the road network, and length of the road and railways network. We find that the two indicators of telecommunications —that is, main telephone lines and total lines per 1000 workers— have a positive and significant coefficient, and the latter measure has a larger effect on growth than the former. Power generating capacity also has a positive and significant coefficient, but smaller than the growth effects of an expansion in telecommunications. Finally, an expansion in the transportation network — measured by either the length of the road network or the length of the road and railways system— has a positive and statistically significant effect. We should note that the impact of roads and rails is slightly larger than the impact of roads alone.

From these point estimates, we can infer the following:

- A one standard deviation increase in either main telephone lines (1.65) or total lines (1.69), raises the growth rate of the economy between 2.6 and 3.1 percentage points. Such increase implies a surge in the number of lines from the levels of Indonesia (located in the bottom quintile of the distribution with 51 main lines per 1,000 workers) to the levels Japan (in the top quintile of the distribution with 977 main lines per workers) in the 1996-2000 period.

- An increase of one standard deviation in power generating capacity (1.43) —that is, from the levels exhibited in India (with 0.7 GW per 1,000 workers at the bottom quintile of the distribution) to the levels in Israel and Hong Kong (with 2.8-2.9 GW per 1000 workers at the top quintile of the distribution) during the 1996-2000 period— will enhance the growth rate of income per capita by 1.7 percentage points.
- Finally, if the road and railways system expands by one standard deviation (1.88) — which implies an increase from the levels displayed in Argentina (with 0.6 km. per sq.km. of area at the bottom quintile of the distribution) to levels in Korea and Taiwan (with 3 km per sq.km. of surface area at the top quintile of the distribution)— growth will be higher by 1.4 percentage points.

In the final four columns of Table 2 we report the growth regression analysis including the three categories of infrastructure as explanatory variables. In almost all these regressions, the indicators of telecommunications and transport are positive and significant (at the 5 percent level). On the other hand, the indicator of power (*i.e.* electricity generating capacity) is positive although statistically insignificant in all cases except for the regression in column [7]. In this regression, the growth benefits of telecommunications are higher than those of power and transport. For example, consider a one standard deviation increase in all sectors (that is, 1.7 in telecommunications, 1.44 in power, and 1.33 in roads). This raises growth by: (a) 2.6 percentage points due to the telecommunications improvement, (b) 1.9 percentage points would be attributed to the power sector, and (c) 1.2 percentage point is due to transportation. In other words, a simultaneous one standard deviation increase in all sectors would raise the growth rate by 5.7 percentage points.

4.1.2 Growth, Infrastructure Stocks and the Quality of Infrastructure Services

In Table 3 we add the aggregate index of infrastructure quality to the regressors, using the same array of econometric techniques as in Table 1. The coefficient of the synthetic infrastructure stock index is positive and significant regardless of estimation technique. It ranges from 0.0047 (GMM-difference estimator) to 0.0219 (GMM-system estimators). In contrast, the coefficient of infrastructure quality is not statistically significant, except for our preferred GMM-IV estimate in column [6] of Table 2. One possible reason for this is the strong correlation between infrastructure quantity and quality noted earlier. It is possible that the growth effects of infrastructure quality may be largely captured by the quantity index.

In any case, we focus on the estimates in column [6]. According to them, a one standard deviation increase in the index of infrastructure stocks (1.3) would raise the growth rate by 2.9 percentage points, whereas an analogous increase in the infrastructure quality index (1.15) would raise the growth rate by 0.68 percentage points. The growth impact of a faster accumulation of infrastructure combined with better quality thus amounts to 3.6 percentage points.

From these estimates, we can also assess the contribution of infrastructure development to growth across the regions in the world. For example, the average growth rate in Latin American countries increased by 2.8% per year in the period 1996-00 relative to the period 1981-85. Our empirical growth model predicts an increase of 2.5% in the growth rate – slightly short of the observed increase.

During this period, the average increase in the synthetic index of infrastructure across Latin American countries exceeded 40% (with Chile's increasing almost 60% during this period). On the other hand, the synthetic index of quality in 1996-00 was 30% lower than in 1981-85 period (with Brazil exhibiting the largest decrease). Using the estimated regression coefficients, we find that the faster accumulation in infrastructure stocks accounts for an increase in the growth rate of 0.9% per year. However, declining quality in the provision of infrastructure services explains a decrease in the growth rate of 0.2% per year. In sum, infrastructure development accounts for 0.7% of the acceleration of growth in Latin America in the period mentioned – about one-fourth of the actual increase.

Further Explorations. In Table 4, we explore other specifications using the GMM-system estimates with internal and external instruments (i.e. demographic variables) as in column [6] of Table 3.[37] In column [1] we repeat the results of the last column of Table 3 for ease of comparison. In columns [2]-[4], we include in the regression the quantity and quality of individual infrastructure sectors. In column [2] we find that the indicators of quantity and quality of telecommunications —main lines and waiting years for main lines— carry positive and significant coefficients. The same happens with roads (column [4]).

[37] We also conducted some additional experiments using the first principal component of alternative sets of indicators of infrastructure. For example, we used total lines (main lines and cellular phones) and the length of the road and railways system as proxies for the telecommunication and transportation infrastructure. We find that regardless of the set of variables used to compute the first principal component of infrastructure stocks, its coefficient is positive and significant. To save space, we do not report these results, but they are available upon request.

However, in column [3] we observe that this result does not hold for power: the quantity indicator carries a significant coefficient but the quality indicator does not.

Finally, in column [5] of Table 4 we include simultaneously indicators of quantity and quality in all three infrastructure sectors considered in our analysis — telecommunications, power and transportation. Collinearity problems are severe, and we find that main lines, total road network, and the indicator of telecom quality are the only variables that have a significant impact on growth.

The Growth Payoff from Infrastructure Development. We can use our econometric estimates to get an idea of the growth payoff from infrastructure development. For the purpose of illustration, take the case of Latin America and consider the growth consequences of raising the level of infrastructure development of Peru (at the lowest quartile of the distribution in the region) to those of Chile (at the highest quartile in the region) and Costa Rica (the leader in the region). For the calculation, we use the GMM-IV system estimates in column [6] of Table 3. Based on the 1996-2000 figures, if the level of infrastructure development in Peru reached that observed in Chile, Peru's growth rate would increase by 2.2 percentage points per year (1.7 percentage points due to larger stocks and 0.5 percentage points due to better quality of infrastructure services). If Peru were to catch up with Costa Rica the growth effects would be even larger: Peru's growth rate would rise by 3.5 percentage points (3 percentage points due to larger stocks and 0.5 percentage points due to higher quality of infrastructure).

More generally, in Table 5 we compute the growth increase that each LAC country would experience if it were to reach the levels of infrastructure development of the regional leader (Costa Rica) or the median country in East Asia (Korea), both in terms of larger stocks of infrastructure assets and higher quality of infrastructure services, again using the GMM-IV system estimates in column [6] of Table 3.

Consider first the scenario of catch up with the regional leader (Costa Rica). Countries at already relatively high levels of infrastructure development, such as Chile and Uruguay, would get relatively modest growth increases -- 1.1 and 1.3 percentage points per annum, respectively. But countries where infrastructure is lagging behind, such as Honduras, Bolivia, and Nicaragua, would experience grow accelerations of over 4 percent per annum.

Next, consider infrastructure catch up with Korea (the median of East Asia and the Pacific). Even the Latin America leader (Costa Rica) would see its growth rate rise by 1.5 percentage points (1 percent due to larger infrastructure stocks and 0.5 percent to better quality of infrastructure services) if its level of infrastructure development rose to match Korea's. In Bolivia, Guatemala, Honduras, Nicaragua, and Peru the impact would be huge -- growth would speed up by at least 5 percentage points per year.

While the magnitude of these growth effects is quite substantial, we should keep in mind that they refer to the long run, and that transition toward the increased level of infrastructure stocks assumed in these calculations would demand large sustained increases in infrastructure investment – particularly in the scenario of catch-up with the East Asia median country. This would likely pose tough policy choices to the authorities, as they would have to reconcile these large investment increases with the maintenance of adequate spending on other growth-enhancing items (such as education) while at the same time preserving macroeconomic stability and keeping in check the overall burden of government, which in light of our regression results are also significant drivers of long-run growth.

4.2 Infrastructure and Income Distribution

We turn to the empirical relationship between aggregate infrastructure development and income inequality. We use as main dependent variable the Gini coefficient. The main data source is Deininger and Squire (1996). However, we only have information from this source until 1995. For the final 5 years we extrapolated data for income shares and the Gini coefficient for the countries present in the analysis of Milanovic (2002a, 2002b).[38] In some experiments below we also use as dependent variables the income shares of top, bottom and middle quintiles of the population. This allows us to analyze the robustness of our results to the choice of dependent variable.

On the other hand, the choice of explanatory variables follows the existing empirical literature on the determinants of income inequality (Milanovic, 2000; Chong, 2002). Among the regressors we include the (log) level of GDP per capita (from the Penn World Tables 6.1 as gathered by Heston, Summers and Aten 2002) and its square, to test for nonlinear effects in the spirit of the conventional Kuznets curve effect.[39] In addition, we include two indicators of human capital: the average years of secondary schooling attained by population 25+ years from Barro and Lee (2001) —as a proxy of education— and the number of physicians per 1,000 people from the World Bank World Development Indicators —as a proxy of health development. The other regressors are financial depth (the ratio of credit to the private sector to GDP from Beck, Demirguc-Kunt and Levine 2000),

[38] For the countries absent from Milanovic's papers, we generated information on the Gini coefficient based on the coefficient of variation of income and the linear correlation of income with ranks of all income groups (e.g. ranging from values of 1 for the poorest percentile to 100 for the richest one) as in Milanovic (1997).
[39] The same specification is used by Milanovic (2000) and Gradstein, Milanovic and Ying (2001).

macroeconomic instability (proxied by the CPI inflation rate), and the size of the modern sector, which following Milanovic (2000) is calculated as the share of industry and services in the economy's total value added. Again, infrastructure stocks and quality are measured by the summary indices derived from principal components analysis described in section 3.

Prior to the discussion of estimation results we comment on the correlation between income inequality and infrastructure development for the full sample of countries. The Gini coefficient is negatively correlated with the indices of infrastructure stock and quality (the correlations equal –0.49 and –0.54, respectively; see figures 3 and 4). Among the infrastructure sectors, the Gini coefficient is also negatively correlated with infrastructure stocks in telecommunications (-0.39), power (-0.44), and transport (-0.48 for roads, and –0.57 for roads and rails). Regarding the quality of infrastructure services, the Gini coefficient is also negatively related to quality in telecommunications (-0.34), power (-0.26) and transportation (-0.55).

The empirical results are presented in Tables 6 through 10. Table 6 reports estimation results using different techniques -- pooled OLS and time-effects estimators as well as GMM-IV difference and system estimators. Our discussion will focus on the results from the GMM-IV system estimators. The diagnostic tests in Table 6 lend support to the specification of the model and the choice of instruments. Importantly, the sign and statistical significance of our variables of interest —infrastructure stock and quality— are quite consistent across estimates, that is, negative and significant.

Among the other explanatory variables, we find a non-linear relationship between income per capita and income inequality, consistent with the Kuznets curve hypothesis — that is, inequality rises in the early stages of development and it decreases afterwards. Also, human capital —as captured by education and health indicators— contributes significantly towards the reduction of income inequality. Finally, the larger the size of the modern (i.e. non-agricultural) sector, the more unequal the distribution of income.

As already noted, we find that both infrastructure stocks and the quality of their services have a negative and significant impact on the Gini coefficient. This is consistent with the view that infrastructure development enhances the ability of poor individuals and residents of backward areas to access additional productive opportunities.

Columns [4] and [5] of Table 6 report the GMM-IV system estimators using different sets of instruments. In column [4] we use internal instruments (i.e. lagged values and lagged differences of the explanatory variables including the infrastructure indicators), while in column [5] we use internal instruments for all explanatory variables except for the infrastructure indicators. The latter are instrumented with lagged values and lagged differences of demographic variables -- urban population, labor force, and population density.

According to our preferred GMM-IV system estimator (column [5] of Table 6), a one standard deviation increase in the index of infrastructure stocks (1.2) reduces the Gini coefficient by 0.06. An analogous increase in the index of infrastructure quality (1.13) reduces the Gini coefficient by 0.01. Hence, a one standard deviation increase in both quantity and quality of infrastructure services would reduce the Gini coefficient by 0.07.

In Table 7 we report additional system-GMM estimates of the income inequality regression using as dependent variable the income shares of selected quintiles of the population. In general, the results confirm the significant negative effect of infrastructure quantity and quality on income inequality. In the first column, we repeat the results of column [5] of Table 6 for ease of comparison. In the second column, we use as dependent variable the ratio of income shares of the top and bottom quintiles of the population. While the magnitude of the coefficient estimates changes, the patterns of sign and significance do not – with the exception of inflation, which now has a significant impact on inequality. According to these estimates, a one standard deviation increase in both infrastructure quantity and quality would reduce this income share ratio by 3.9 and 0.3, respectively.

These results are corroborated in column [3], which uses as dependent variable the income share ratio of the top to bottom 40% of the population. The parameters are still negative and significant although smaller in magnitude. If the quantity and quality of infrastructure were to increase by one standard deviation, this income ratio would decrease by 0.9 and 0.1, respectively.

Finally, in column [4] of Table 7 we report regression results using the income share of the middle quintile. This new dependent variable is often interpreted as a measure of equality and, therefore, we should expect the coefficients to reverse sign. We indeed find that the coefficient estimates for infrastructure quantity and quality are now both positive and statistically significant – i.e., infrastructure development has a positive impact on the income share of the middle class. A one standard deviation increase in the aggregate indices of quantity and quality would increase the income share of the middle quintile by 2.2 and 0.3 percentage points.

Redistributive Benefits of Higher Infrastructure Development. How significant economically are these results? Consider the experiment of raising Peru's level of infrastructure development to match that of Chile. According to the estimates in column [5] of Table 6, Peru's Gini coefficient would decline by 0.044 (where 0.036 would be due to the increased stocks of infrastructure and 0.008 to their quality enhancement). Alternatively, if Peru were to reach the infrastructure levels and quality of Costa Rica, its Gini coefficient would decline by 0.071 (of which 0.063 due to the effect of larger stocks and 0.008 to better quality of infrastructure services). The same experiment can be cast in terms of the regression equation whose dependent variable is the income share ratio of the top quintile to the bottom quintile of the population —column [2] of Table 7. If Peru were to reach the levels of infrastructure development of Chile, its income share ratio would decrease from an average of 16.9 during the 1996-2000 period to 14.3 (that is, a reduction of 2.6). If Peru reached the levels of infrastructure development of Costa Rica, the income share ratio would decline by 4.5.

In Table 8, we perform similar calculations to compute the redistributive effects that each LAC country would experience if they were able to close the infrastructure gap (in terms of both quantity and quality) with respect to the leaders in LAC and East Asia — Costa Rica and Korea, respectively. The calculations use the GMM-IV system estimates in column [5] of Table 6.

Consider first a very strong effort that brings infrastructure in countries like Bolivia, Guatemala, Honduras and Nicaragua to the levels of the regional leader (Costa Rica). This would reduce their Gini coefficients by an amount ranging between 0.08 and 0.10. Next, consider an even larger effort that brings these countries from the bottom quartile of the distribution of infrastructure development to the infrastructure levels of the representative country in East Asia (that is, South Korea). Their Gini coefficients would decline between 0.11 and 0.13. Like in the case of growth, however, we must caution that the increases in infrastructure development assumed in these calculations would likely entail large investment needs over a sustained period, whose feasibility and desirability would have to be assessed vis-à-vis other growth and welfare-enhancing policies.

The Impact of Water on Income Distribution. As we stated in subsection 2.2, the empirical literature has underscored the role of access to safe water and sanitation in reducing income inequality, through its impact on the human capital of the less favored sectors of the population (see Brenneman and Kerf, 2002; Galiani, Gertler and Schargrodsky, 2002). To assess this claim, we perform some additional experiments including the percentage of the population with access to safe water as an additional regressor in the inequality equation. In Table 9 we report GMM-IV estimates using internal and external instruments in the same fashion as in column [5] of Table 6.

Column [1] repeats the earlier estimates (from the last column in Table 6) for ease of comparison. In column [2] of Table 9 we include the percentage of population with access to clean water as the only infrastructure indicator. We find that the development of the water network has a negative and significant impact on income inequality. Specifically, we find that a one standard deviation increase in access to safe water (0.24) reduces the Gini coefficient of income inequality by 0.025. When we condition on the global index of infrastructure —which involves the stocks in telecommunications, power, and transportation— we still find a negative and significant impact on income inequality of both water access and the other infrastructure stocks (column [3] of Table 9).

In column [4] of Table 9, we add also the synthetic index of infrastructure quality. It also carries a negative and significant sign, and the same applies to the index of stocks and the water access variable. Once we control for all these infrastructure variables, we can recalculate the impact on the Gini coefficient of a one standard deviation increase in the access to safe water (0.24). Based on figures for the 1996-00 period, this is the difference in access between Chile (91 percent) and Guatemala (67 percent). According to this regression, this one standard deviation increase in the access to safe water reduces the Gini coefficient by 0.017. An analogous increase in the infrastructure quantity and quality indices would decrease the Gini coefficient by 0.023 and 0.015, respectively. In sum, the Gini coefficient falls by 0.055 in response to a one standard deviation increase in all indicators of infrastructure, including water access.

We can now reconsider the contribution of infrastructure —augmented by water access — to reducing income inequality. Take again the cases of Peru and Chile (25^{th} and 75^{th} percentile in the distribution of infrastructure). According to the regression in column [4] of Table 9, we find that if the levels and quality of infrastructure as well as the access to safe water in Peru reached the levels displayed in Chile, Peru's Gini coefficient would decline by 0.037. Of this total reduction, 0.013 would be due to expansion of water access, 0.013 is to the rise in other infrastructure stocks, and 0.011 to the higher quality of infrastructure services.

Finally, we can replicate the simulation reported in Table 8 of the changes in inequality due to higher infrastructure development, including this time the effects of water access (see Table 10), and stressing again the potentially large investment costs involved. Consider again the inequality consequences of catching up with the LAC leader in terms of infrastructure (which continues to be Costa Rica) and the median East Asian country (still Korea). Countries such as Chile and Uruguay would reap only modest reductions in income inequality (0.02), because they already are in the top quintile of the infrastructure distribution. On the other hand, countries like Nicaragua, Honduras and Bolivia would reap much larger Gini declines, on the order of 0.08. About one-fourth of that total would be due to their enhanced access to safe water.

5. Conclusions

In this paper we have provided an empirical evaluation of the impact of infrastructure development —as measured by larger stocks of infrastructure assets and improved quality of their services— on economic growth and the distribution of income. Our assessment is based on the estimation of infrastructure-augmented growth and income inequality regressions using data for a sample of 121 countries over the 1960-2000 period, and employing a variety of instrumental variable techniques to control for the potential endogeneity of infrastructure and non-infrastructure growth and inequality determinants.

Our main results can be summarized in five points. First, the volume of infrastructure stocks has a significant positive effect on long-run economic growth. This conclusion is robust to changes in the infrastructure measure used as well as the estimation technique applied. In contrast, the link between infrastructure quality and growth appears empirically less robust, although this might reflect limitations of our quality measures or also the fact that quantity and quality are strongly correlated, so that quality effects on growth are already captured by the quantity measures.

Second, infrastructure quantity and quality have a robust negative impact on income inequality. Regardless of the econometric technique and the inequality measure employed (Gini coefficients or income shares), we find that inequality declines not only with larger infrastructure stocks but also with an improved quality of infrastructure services. Moreover, separate experiments (using a reduced sample) show that improved access to safe water has an additional positive impact on income equality.

Third, these results are obtained in a framework that controls for reverse causation, and survive a variety of statistical tests that fail to show any evidence of misspecification. From this we conclude that the above results reflect causal, and not merely coincidental, effects of infrastructure on growth and inequality.

Fourth, a variety of illustrative experiments show that our empirical findings are significant not only statistically but also economically. For example, were all Latin American countries to catch up with the region's leader in terms of infrastructure quantity and quality, their long-term per capita growth gains would range between 1.1 and 4.8

percent per annum, and their Gini coefficients would decline between 0.02 and 0.10. Catch up with the East Asian median country would involve even larger gains – ranging from 3.2. to 6.3 percent extra growth and 0.05 to 0.13 lower Ginis. Furthermore, when we bring water access into the picture, we find that if countries in Latin America and the Caribbean were to catch-up to the leader along this dimension as well, their Gini coefficients should decline between 0.02 and 0.09. Access to safe water makes a median contribution of almost 35% to this reduction in the Gini coefficient in Latin America and the Caribbean. It is important to note, however, that these catch-up scenarios implicitly assume potentially very large investment efforts in the transition toward the increased levels of infrastructure development.

Finally, and perhaps most importantly, the conclusion that infrastructure both raises growth and lowers income inequality implies that infrastructure development may be a key win-win ingredient for poverty reduction. In addition to raising society's overall level of income, it would help raise the income of the poor more than proportionately.[40] This suggests that infrastructure development should rank at the top of the poverty reduction agenda.

[40] The same conclusion is reached independently by López (2004).

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Table 1
Infrastructure Stocks and Economic Growth: Panel Regression Analysis
Using Different Estimation Techniques
Dependent Variable: Growth in GDP per capita
Sample of 121 countries, 1960-2000 (5-year averaged data)

	Pooled OLS	Country-Effects	Time-Effects	GMM-IV (D)	GMM-IV System Estimator 1/	
Variable	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**
Constant	0.1527 **	-.-	0.1712 **	0.2214 **	0.2956 **	0.3064 **
	(0.03)		(0.03)	(0.02)	(0.04)	(0.06)
Output per capita	-0.0147 **	-0.0663 **	-0.0145 **	-0.0143 **	-0.0325 **	-0.0381 **
(in logs)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Human Capital	0.0020	-0.0045	0.0059 **	0.0079 **	0.0081 *	0.0059
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Financial Depth	0.0024 *	0.0057 **	0.0030 **	0.0036 **	0.0026 **	0.0020 *
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Government Burden	-0.0102 **	-0.0190 **	-0.0091 **	0.0016	-0.0128 **	-0.0172 **
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)
Trade Openness	-0.0051	0.0276 **	0.0007	-0.0046 *	0.0267 **	0.0215 **
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Governance	0.0038 **	0.0011	0.0030 **	0.0005	0.0027 **	0.0039 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Inflation	-0.0190 **	-0.0177 **	-0.0166 **	-0.0204 **	-0.0236 **	-0.0214 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
RER Overvaluation	-0.0053 *	0.0035	-0.0064 **	-0.0131 **	-0.0046 **	0.0017
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Terms of Trade Shocks	0.0251	0.0221	0.0140	0.0733 **	0.0391 **	0.0464 **
	(0.03)	(0.02)	(0.03)	(0.01)	(0.02)	(0.02)
Infrastructure Stock 2/	0.0072 **	0.0195 **	0.0059 **	0.0043 **	0.0207 **	0.0226 **
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Observation	399	331	399	331	331	331
R**2	0.199	0.346	0.274	0.219	0.409	0.407
Specification Tests (p-value)						
- Sargan Test	-.-	-.-	-.-	(0.52)	(0.71)	(0.81)
- 2nd Order Correlation	(0.01)	(0.84)	(0.11)	(0.90)	(0.78)	(0.81)

*Numbers in parenthesis below the coefficient estimates are standard errors. * (**) implies that the variable is significant at the 10 (5) percent level.*
1/ The GMM-IV System estimations presented in columns [5] and [6] differ in the set of instruments used. In [5] we used only internal instruments (lagged levels and lagged differences of all the explanatory variables in the regression. In [6] we use internal instruments for the growth determinants except for the infrastructure variable. For our variable of interest (infrastructure), we use actual and lagged levels as well as lagged differences of demographic variables such as the urban population, the size of the labor force and population density. 2/ The aggregate infrastructure stock is the first principal component of the following normalized variables: main telephone lines per 1000 workers, energy generating capacity (in GW per 1000 workers), and total roads (in km. per sq. km.)

Table 2
Infrastructure Stocks and Economic Growth: Panel Regression Analysis
Using Different Categories of Infrastructure
Dependent Variable: Growth in GDP per capita
Estimation Technique: GMM-IV System Estimator (Arellano and Bover, 1995)
Sample of 121 countries, 1960-2000 (5-year averaged data)

Variable	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Constant	0.2000 **	0.2291 **	0.1844 **	0.1430 **	0.1854 **	0.2905 **	0.2767 **	0.3278 **	0.3328 **
	(0.06)	(0.07)	(0.05)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)
Output per capita	-0.0300 **	-0.0355 **	-0.0232 **	-0.0194 **	-0.0203 **	-0.0412 **	-0.0405 **	-0.0441 **	-0.0460 **
(in logs)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Human Capital	0.0111 *	0.0093 *	0.0098 *	0.0124 **	0.0118 **	0.0083	0.0062	0.0050	0.0019
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Financial Depth	0.0040 *	0.0046 *	0.0032 *	0.0004	0.0001	0.0028 *	0.0029 *	0.0023	0.0020
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Government Burden	-0.0221 **	-0.0208 **	-0.0282 **	-0.0205 **	-0.0218 **	-0.0231 **	-0.0257 **	-0.0199 **	-0.0219 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trade Openness	0.0170 *	0.0134	0.0137	0.0240 **	0.0269 **	0.0187 *	0.0192	0.0279 **	0.0262 *
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Governance	0.0035 **	0.0041 **	0.0040 **	0.0041 **	0.0028 **	0.0044 **	0.0041 **	0.0023 **	0.0028 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Inflation	-0.0232 **	-0.0240 **	-0.0250 **	-0.0229 **	-0.0192 **	-0.0242 **	-0.0271 **	-0.0207 **	-0.0234 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
RER Overvaluation	-0.0013	0.0008	-0.0010	0.0031	-0.0030	0.0033	0.0033	-0.0014	-0.0019
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Terms of Trade Shocks	0.0219	0.0229	0.0428 **	0.0353 **	0.0424 **	0.0457 **	0.0429 **	0.0497 **	0.0412 **
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Main Lines	0.0157 **	…	…	…	…	0.0130 **	…	0.0145 **	…
	(0.01)					(0.00)		(0.01)	
Main Lines + Cell	…	0.0187 **	…	…	…	…	0.0153 **	…	0.0184 **
		(0.01)					(0.01)		(0.01)
Power	…	…	0.0120 *	…	…	0.0102	0.0129 *	0.0095	0.0082
			(0.01)			(0.01)	(0.01)	(0.01)	(0.01)
Roads	…	…	…	0.0070 **	…	0.0084 **	0.0093 **	…	…
				(0.00)		(0.00)	(0.00)		
Roads + Rails	…	…	…	…	0.0077 **	…	…	0.0072 **	0.0077 **
					(0.00)			(0.00)	(0.00)
Observation	338	332	334	335	326	331	325	322	316
R**2	0.417	0.411	0.415	0.393	0.398	0.387	0.390	0.413	0.411
Specification Tests (p-value)									
- Sargan Test	(0.45)	(0.33)	(0.49)	(0.72)	(0.73)	(0.63)	(0.44)	(0.62)	(0.62)
- 2nd Order Correlation	(0.50)	(0.38)	(0.54)	(0.78)	(0.83)	(0.79)	(0.63)	(0.86)	(0.72)

*Numbers in parenthesis below the coefficient estimates are standard errors. * (**) implies that the variable is significant at the 10 (5) percent level.*

Table 3
Economic Growth and Infrastructure Stocks and Quality: Panel Regression Analysis Using Different Estimation Techniques
Dependent Variable: Growth in GDP per capita
Sample of 121 countries, 1960-2000 (5-year averaged data)

Variable	Pooled OLS [1]	Country-Effects [2]	Time-Effects [3]	GMM-IV (D) [4]	GMM-IV System Estimator 1/ [5]	GMM-IV System Estimator 1/ [6]
Constant	0.1676 **	-.-	0.1849 **	0.1983 **	0.2833 **	0.2990 **
	(0.04)		(0.04)	(0.05)	(0.05)	(0.07)
Output per capita	-0.0180 **	-0.0677 **	-0.0171 **	-0.0122 **	-0.0337 **	-0.0348 **
(in logs)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Human Capital	0.0012	-0.0046	0.0051 *	0.0095 **	0.0064	0.0038
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Financial Depth	0.0025 **	0.0053 **	0.0033 **	0.0045 **	0.0020 *	0.0026
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Government Burden	-0.0156 **	-0.0190 **	-0.0133 **	0.0046	-0.0206 **	-0.0158 **
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trade Openness	-0.0083	0.0283 **	-0.0018	-0.0004	0.0276 **	0.0225 *
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Governance	0.0036 **	0.0010	0.0028 *	0.0005	0.0033 **	0.0031 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Inflation	-0.0173 **	-0.0178 **	-0.0157 **	-0.0212 **	-0.0246 **	-0.0225 **
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)
RER Overvaluation	-0.0045	0.0022	-0.0060 *	-0.0108 *	-0.0036	-0.0026
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Terms of Trade Shocks	0.0195	0.0133	0.0001	0.0697 **	0.0386 **	0.0451 **
	(0.04)	(0.03)	(0.04)	(0.02)	(0.02)	(0.02)
Infrastructure Stock 2/	0.0095 **	0.0191 **	0.0083 **	0.0047 **	0.0219 **	0.0219 **
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Infrastructure Quality 3/	0.0023	0.0031	0.0012	-0.0029	-0.0022	0.0059 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observation	384	308	384	306	306	306
R**2	0.227	0.356	0.301	0.237	0.313	0.349
Specification Tests (p-value)						
- Sargan Test	-.-	-.-	-.-	(0.63)	(0.61)	(0.59)
- 2nd Order Correlation	(0.02)	(0.69)	(0.06)	(0.79)	(0.59)	(0.66)

*Numbers in parenthesis below the coefficient estimates are standard errors. * (**) implies that the variable is significant at the 10 (5) percent level.*
1/ 2/ See footnote in Table 1. 3/ The aggregate index of infrastructure quality is the first principal component of the following normalized variables: waiting years for main lines, electricity transmission and distribution losses (as percentage of output), and the share of paved roads in total roads. All these variables have been rescaled so that higher values denote higher quality of infrastructure stocks.

Table 4
Economic Growth and Infrastructure Stocks and Quality: Panel Regression Analysis Using Different Proxies of Infrastructure Quality
Dependent Variable: Growth in GDP per capita
Estimation Technique: GMM-IV System Estimator
Sample of 121 countries, 1960-2000 (5-year averaged data)

Variable	[1]	[2]	[3]	[4]	[5]
Constant	0.2990 **	0.2467 **	0.2507 **	0.1691 **	0.4279 **
	(0.07)	(0.05)	(0.05)	(0.06)	(0.08)
Output per capita	-0.0348 **	-0.0342 **	-0.0314 **	-0.0217 **	-0.0482 **
(in logs)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Human Capital	0.0038	0.0103 *	0.0062	0.0142 **	0.0021
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Financial Depth	0.0026	0.0037 **	0.0044 *	0.0004	0.0031
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Government Burden	-0.0158 **	-0.0188 **	-0.0301 **	-0.0216 **	-0.0211 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trade Openness	0.0225 *	0.0164	0.0289 **	0.0247 **	0.0173
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Governance	0.0031 **	0.0048 **	0.0040 **	0.0039 **	0.0032 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Inflation	-0.0225 **	-0.0213 **	-0.0251 **	-0.0202 **	-0.0216 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
RER Overvaluation	-0.0026	-0.0031	-0.0014	0.0011	-0.0046
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Terms of Trade Shocks	0.0451 **	0.0451 **	0.0634 **	0.0385 **	0.0554 **
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Infrastructure Stock	0.0219 **	…	…	…	…
	(0.01)				
Infrastructure Quality	0.0059 **	…	…	…	…
	(0.00)				
Telecom Stocks	…	0.0119 **	…	…	0.0261 *
		(0.00)			(0.01)
Power Stocks	…	…	0.0170 **	…	0.0049
			(0.01)		(0.01)
Road Stocks	…	…	…	0.0072 **	0.0053 *
				(0.00)	(0.00)
Telecom Quality	…	0.0048 **	…	…	0.0086 **
		(0.00)			(0.00)
Power Quality	…	…	0.0015	…	-0.0050
			(0.00)		(0.00)
Road Quality	…	…	…	0.0075 *	0.0068
				(0.00)	(0.00)
Observation	306	306	306	306	306
R**2	0.349	0.282	0.263	0.281	0.315
Specification Tests (p-value)					
- Sargan Test	(0.59)	(0.42)	(0.48)	(0.69)	(0.54)
- 2nd Order Correlation	(0.66)	(0.49)	(0.52)	(0.76)	(0.59)

Numbers in parenthesis below the coefficient estimates are standard errors.
** (**) implies statistical significance at the 10 (5) percent level.*

Table 5
Growth Improvement in LAC Countries due to Higher Infrastructure Development
(in percentages)

Country	Improvement to levels of LAC Leader			Improvement to levels of EAP Median		
	Stocks	Quality	Total	Stocks	Quality	Total
Argentina	1.3%	0.4%	1.7%	2.2%	0.9%	3.2%
Bolivia	3.8%	0.5%	4.3%	4.8%	1.0%	5.8%
Brazil	1.5%	1.4%	2.9%	2.4%	1.9%	4.4%
Chile	1.3%	0.0%	1.3%	2.3%	0.6%	2.8%
Colombia	1.9%	1.2%	3.1%	2.9%	1.7%	4.6%
Costa Rica	...	...	...	1.0%	0.5%	1.5%
Dominican Rep.	1.3%	0.1%	1.4%	2.3%	0.7%	2.9%
Ecuador	2.0%	1.0%	3.0%	3.0%	1.5%	4.5%
Guatemala	3.3%	0.4%	3.7%	4.2%	0.9%	5.2%
Honduras	3.1%	1.1%	4.2%	4.1%	1.6%	5.7%
Mexico	1.4%	0.2%	1.7%	2.4%	0.8%	3.2%
Nicaragua	3.4%	1.4%	4.8%	4.4%	1.9%	6.3%
Panama	1.4%	0.2%	1.5%	2.4%	0.7%	3.1%
Peru	3.0%	0.6%	3.5%	4.0%	1.1%	5.0%
El Salvador	1.6%	0.4%	2.1%	2.6%	1.0%	3.6%
Uruguay	0.7%	0.4%	1.1%	1.7%	0.9%	2.6%
Venezuela	1.1%	0.4%	1.4%	2.0%	0.9%	2.9%

Observations: The calculations of the potential growth effects are based on the coefficient estimates of column [6] of Table 3. Also, the median country of East Asia and the Pacific (EAP) in our analysis is the Republic of Korea.

Table 6
Income Inequality and Infrastructure Stocks and Quality
Sample of All Countries, 1960-2000, Panel data of 5-year non-overlapping observations
Dependent Variable: Gini Coefficient (0-1)

	Pooled OLS	Time-Effects	GMM-IV (D)	GMM-IV System Estimator 1/	
Variable	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
Constant	-1.3226 **	-1.3622 **	-0.0035	-1.0508 **	-2.9737 **
	(0.37)	(0.37)	(0.00)	(0.30)	(0.37)
Income per capita	0.3702 **	0.3850 **	0.4603 **	0.3203 **	0.7754 **
	(0.09)	(0.09)	(0.05)	(0.08)	(0.09)
Income per capita squared	-0.0207 **	-0.0213 **	-0.0286 **	-0.0186 **	-0.0442 **
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
Human Capital	-0.0289 **	-0.0311 **	-0.0086 **	-0.0104 *	-0.0273 **
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Financial Depth	0.0020	0.0030	0.0217 **	0.0092 **	0.0104 **
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Health	-0.0250 **	-0.0297 **	-0.0088 **	-0.0068 *	-0.0120 **
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
CPI Inflation	0.0199	0.0505	-0.0457 **	-0.0098	-0.0205
	(0.04)	(0.04)	(0.01)	(0.03)	(0.02)
Size of the Modern Sector	0.2592 **	0.2331 **	-0.1777 **	0.1919 **	0.1523 **
	(0.07)	(0.07)	(0.04)	(0.09)	(0.06)
Infrastructure Stock 2/	-0.0327 **	-0.0314 **	-0.0518 **	-0.0462 **	-0.0464 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Infrastructure Quality 3/	-0.0146 **	-0.0126 **	-0.0117 **	-0.0101 **	-0.0102 *
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
Observations	279	279	247	247	247
R Squared	0.504	0.519	0.420	0.499	0.521
Turning Point	8.92	9.04	8.04	8.61	8.77
Specification Tests (p-value)					
- Sargan Test	-.-	-.-	(0.31)	(0.35)	(0.45)
- 2nd. Order Correlation	(0.65)	(0.56)	(0.53)	(0.66)	(0.55)

*Numbers in parenthesis below the coefficient estimates are standard errors. *(**) implies statistical significance at the 10(5) percent level.*
For 1/ and 2/ see footnotes in Table 1, and for 3/ see footnote in Table 3.

Table 7
Income Inequality and Infrastructure Stocks and Quality
Using different measures of income inequality

Sample of All Countries, 1960-2000, Panel data of 5-year non-overlapping observations
Dependent Variable: Gini Coefficient (0-1)
Estimation Technique: GMM-IV System Estimator (Arellano and Bover, 1995)

	Gini	Income Shares		
	Coefficient	Top / Bottom 20	Top / Bottom 40	Middle 20
Variables	**[1]**	**[2]**	**[3]**	**[4]**
Constant	-2.9737 **	-40.0290 **	-11.5700 **	0.7424 **
	(0.37)	(10.15)	(2.35)	(0.14)
Income per capita	0.7754 **	17.7804 **	3.0302 **	-0.1267 **
	(0.09)	(2.77)	(0.44)	(0.03)
Income per capita squared	-0.0442 **	-0.9587 **	-0.1774 **	0.0072 **
	(0.01)	(0.21)	(0.02)	(0.00)
Human Capital	-0.0273 **	-0.5153 **	-0.5461 **	0.0071 *
	(0.01)	(0.10)	(0.03)	(0.00)
Financial Depth	0.0104 **	0.2609 **	0.0648 **	-0.0018 **
	(0.00)	(0.06)	(0.01)	(0.00)
Health	-0.0120 **	-0.9821 **	-0.3186 *	0.0068 **
	(0.01)	(0.48)	(0.17)	(0.00)
CPI Inflation	-0.0205	3.0815 *	1.3123 **	0.0081
	(0.02)	(1.88)	(0.14)	(0.01)
Size of the Modern Sector	0.1523 **	13.8984 **	6.7559 **	-0.0874 **
	(0.06)	(3.21)	(0.51)	(0.04)
Infrastructure Stock	-0.0464 **	-3.1462 **	-0.7374 **	0.0175 **
	(0.01)	(0.54)	(0.10)	(0.00)
Infrastructure Quality	-0.0102 *	-0.2545 **	-0.0439 **	0.0025 **
	(0.01)	(0.08)	(0.02)	(0.00)
Observations	247	226	226	226
R Squared	0.521	0.316	0.382	0.472
Turning Point	8.77	9.27	8.54	8.75
Specification Tests (p-value)				
- Sargan Test	(0.45)	(0.49)	(0.34)	(0.41)
- 2nd. Order Correlation	(0.55)	(0.77)	(0.38)	(0.52)

See footnote in Table 6.

Table 8
Changes of Inequality in LAC Countries due to Higher Infrastructure Development
(Changes in the Gini coefficient)

	Improvement to levels of LAC Leader			Improvement to levels of EAP Median		
Country	**Stocks**	**Quality**	**Total**	**Stocks**	**Quality**	**Total**
Argentina	-0.03	-0.01	-0.03	-0.05	-0.02	-0.06
Bolivia	-0.08	-0.01	-0.09	-0.10	-0.02	-0.12
Brazil	-0.03	-0.02	-0.06	-0.05	-0.03	-0.09
Chile	-0.03	0.00	-0.03	-0.05	-0.01	-0.06
Colombia	-0.04	-0.02	-0.06	-0.06	-0.03	-0.09
Costa Rica	...	...	...	-0.02	-0.01	-0.03
Dominican Rep.	-0.03	0.00	-0.03	-0.05	-0.01	-0.06
Ecuador	-0.04	-0.02	-0.06	-0.06	-0.03	-0.09
Guatemala	-0.07	-0.01	-0.08	-0.09	-0.02	-0.11
Honduras	-0.07	-0.02	-0.09	-0.09	-0.03	-0.12
Mexico	-0.03	0.00	-0.03	-0.05	-0.01	-0.06
Nicaragua	-0.07	-0.02	-0.10	-0.09	-0.03	-0.13
Panama	-0.03	0.00	-0.03	-0.05	-0.01	-0.06
Peru	-0.06	-0.01	-0.07	-0.08	-0.02	-0.10
El Salvador	-0.03	-0.01	-0.04	-0.06	-0.02	-0.07
Uruguay	-0.02	-0.01	-0.02	-0.04	-0.02	-0.05
Venezuela	-0.02	-0.01	-0.03	-0.04	-0.02	-0.06

Observations: The calculations of the potential growth effects are based on the coefficient estimates of column [5] of Table 6.

Table 9
Income Inequality and Infrastructure: The Role of Water
Sample of All Countries, 1960-2000, Panel data of 5-year non-overlapping observations
Dependent Variable: Gini Coefficient (0-1)

Variable	**[1]**	**[2]**	**[3]**	**[4]**
Constant	-2.9737 **	-0.7860 **	-1.2592 **	-0.8732 **
	(0.37)	(0.26)	(0.28)	(0.29)
Income per capita	0.7754 **	0.3187 **	0.3957 **	0.3194 **
	(0.09)	(0.07)	(0.07)	(0.08)
Income per capita squared	-0.0442 **	-0.0185 **	-0.0218 **	-0.0171 **
	(0.01)	(0.00)	(0.00)	(0.00)
Human Capital	-0.0273 **	-0.0348 **	-0.0290 **	-0.0270 **
	(0.01)	(0.01)	(0.01)	(0.01)
Financial Depth	0.0104 **	0.0115 **	0.0116 **	0.0116 **
	(0.00)	(0.00)	(0.00)	(0.00)
Health	-0.0120 **	-0.0279 **	-0.0254 **	-0.0276 **
	(0.01)	(0.01)	(0.00)	(0.01)
CPI Inflation	-0.0205	0.0962 **	0.0905 **	0.0991 **
	(0.02)	(0.03)	(0.03)	(0.03)
Size of the Modern Sector	0.1523 **	0.2503 **	0.2115 **	0.2105 **
	(0.06)	(0.06)	(0.06)	(0.06)
Infrastructure Stock 2/	-0.0464 **	…	-0.0226 **	-0.0170 **
	(0.01)		(0.01)	(0.01)
Infrastructure Quality 3/	-0.0102 *	…	…	-0.0135 **
	(0.01)			(0.01)
Access to Safe Water	…	-0.1023 **	-0.0734 **	-0.0725 **
		(0.03)	(0.03)	(0.03)
Observations	247	211	211	211
R Squared	0.521	0.522	0.526	0.529
Turning Point	8.77	8.63	9.08	9.31
Specification Tests (p-value)				
- Sargan Test	(0.45)	(0.63)	(0.56)	(0.65)
- 2nd. Order Correlation	(0.55)	(0.73)	(0.79)	(0.74)

*Numbers in parenthesis below the coefficient estimates are standard errors. *(**) implies statistical significance at the 10(5) percent level. For 1/ and 2/ see footnotes in Table 1, and for 3/ see footnote in Table 3.*

Table 10
Changes of Inequality in LAC Countries due to Higher Infrastructure Development and Access to Safe Water
(in percentages)

	(A) Improvement to levels of LAC Leader				(B) Improvement to levels of EAP Median			
Country	**Stocks**	**Quality**	**Water**	**Total**	**Stocks**	**Quality**	**Water**	**Total**
Argentina	-0.01	-0.01	-0.02	-0.04	-0.02	-0.02	-0.02	-0.06
Bolivia	-0.03	-0.01	-0.02	-0.06	-0.04	-0.02	-0.02	-0.08
Brazil	-0.01	-0.03	-0.02	-0.06	-0.02	-0.04	-0.01	-0.07
Chile	-0.01	0.00	-0.01	-0.02	-0.02	-0.01	0.00	-0.03
Colombia	-0.01	-0.03	-0.02	-0.06	-0.02	-0.04	-0.01	-0.07
Costa Rica	...	...	...	...	-0.01	-0.01	0.01	-0.01
Dominican Rep.	-0.01	0.00	-0.02	-0.03	-0.02	-0.01	-0.01	-0.05
Ecuador	-0.02	-0.02	-0.02	-0.06	-0.02	-0.03	-0.02	-0.07
Guatemala	-0.03	-0.01	-0.02	-0.06	-0.03	-0.02	-0.02	-0.07
Honduras	-0.02	-0.02	-0.02	-0.07	-0.03	-0.04	-0.01	-0.08
Mexico	-0.01	-0.01	0.00	-0.02	-0.02	-0.02	0.00	-0.03
Nicaragua	-0.03	-0.03	-0.03	-0.09	-0.03	-0.04	-0.02	-0.10
Panama	-0.01	0.00	-0.01	-0.02	-0.02	-0.02	0.00	-0.04
Peru	-0.02	-0.01	-0.02	-0.06	-0.03	-0.02	-0.01	-0.07
El Salvador	-0.01	-0.01	-0.02	-0.05	-0.02	-0.02	-0.02	-0.06
Uruguay	-0.01	-0.01	0.00	-0.02	-0.01	-0.02	0.00	-0.03
Venezuela	-0.01	-0.01	-0.01	-0.03	-0.02	-0.02	-0.01	-0.04

Observations: The calculations of the potential growth effects are based on the coefficient estimates of column [4] of Table 9.

Figure 1. Infrastructure Stocks vs. Economic Growth

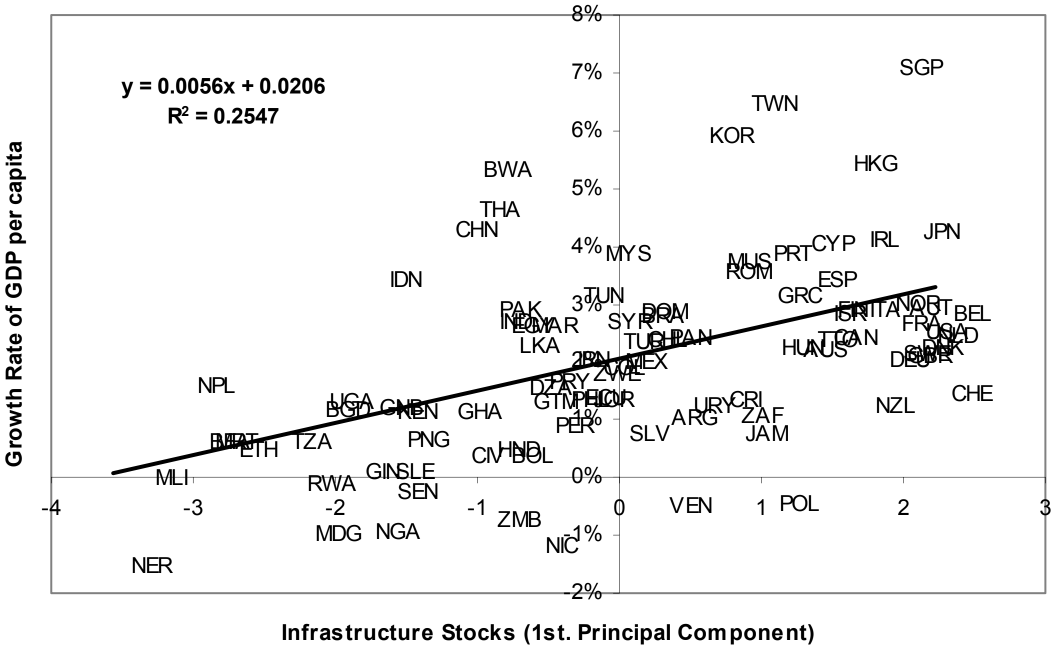

Figure 2. Infrastructure Quality vs. Economic Growth

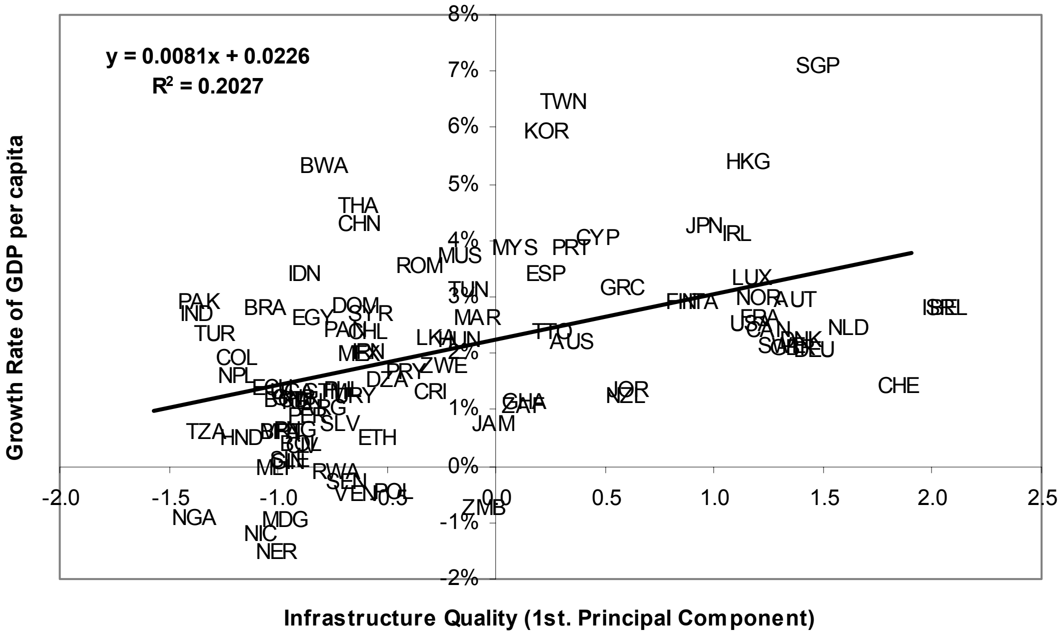

Figure 3. Infrastructure Stocks vs. Income Inequality

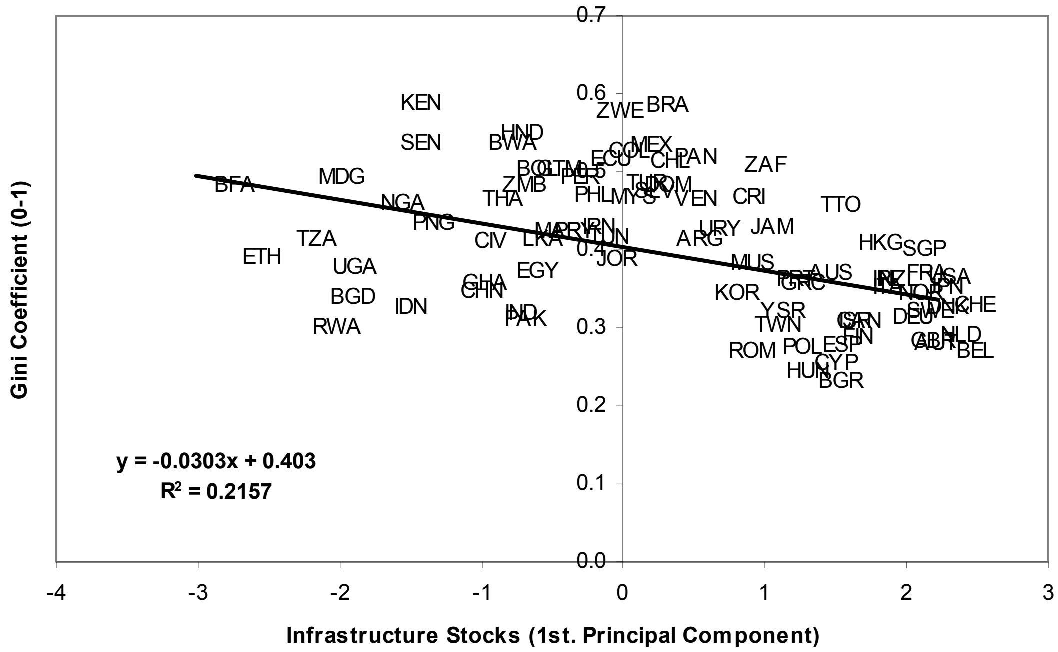

Figure 4. Infrastructure Quality vs. Income Inequality