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Volume and Quality of Infrastructure and the Distribution of Income: An Empirical Investigation

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Abstract[*]

We provide evidence on the link between infrastructure development and the distribution of income for the period 1960-1995. To do this, we use several proxies such as roads, railways, telecommunications and energy measures. The approach is comprehensive as cross-country and panel methods are applied. In the latter case, we apply GMM dynamic panel methods in order to minimize for endogeneity problems. Both quantity of infrastructure and quality of infrastructure are negatively linked with income inequality. The quantitative link tends to be stronger in developing countries than the qualitative link. These findings hold when using different econometric methods and most infrastructure measures.

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1. Introduction

The question that this paper addresses is straightforward. What is the link between physical infrastructure and income inequality? As direct and relevant as this question is, to our knowledge, it has not been studied adequately in the empirical literature. The conventional wisdom has it that physical infrastructure in the form of paved roads, railways, telephone lines, energy generating equipment and others, are important in linking poor, rural and other underdeveloped and peripheral regions with areas of core economic activity, as it is believed that infrastructure development allows access to additional productive opportunities. In this context, it is believed that physical infrastructure development can help improve the distribution of income as impact is expected to be larger in poorer areas than in richer ones (World Bank, 1994). This is said to be particularly true in developing countries. In fact, such a view is consistent with the belief of policymakers that in order to maximize political returns, large increases in infrastructure expenditures are a necessary condition, especially in the face of each new political cycle (Schady and Paxson, 1999). However, the expected link between infrastructure development and the distribution of income appears to have been taken for granted by policymakers since, to our knowledge, the empirical validity of such an association has not been examined closely. Part of this is clearly due to lack of suitable data. Another reason appears to be a lack of appropriate econometric methods to minimize for potential endogeneity.[1]

In this paper we provide empirical evidence on the link between infrastructure development and the distribution of income by using recent data on quantity and quality of infrastructure (Canning, 1998; World Bank, 1998; and others) as well as the relatively widely used income inequality data by Deininger and Squire (1996). To the extent possible, our empirical approach is systematic and comprehensive, as we use both cross-country and panel methods and deal with possible endogeneity problems explicitly. In fact, while in the cross-country case we use initial values for each period, in the panel case we use a GMM dynamic panel data approach (Arellano and Bover, 1995; Blundell and Bond, 1997). Though the latter is a relatively new method and not widely accepted yet, we believe that the application of such a dynamic panel technique is a valuable contribution to a thorough understanding of our link of

[1] The latter has been a recurrent problem when studying the links between infrastructure and economic performance and also has plagued several studies on distribution of income (Chong, 2001).

interest.[2] In general, our findings show that infrastructure development is negatively linked with income inequality. In particular, our panel results suggest that this link may go from infrastructure development to income inequality. Overall, such impact appears to be greater in poor countries rather than in rich ones. However, quality issues appear to be particularly important in industrial countries and relatively less important in poorer countries. Our results are robust to a wide range of infrastructure proxies, inequality measures, and econometric specifications.

The paper is structured as follows. Section 2 describes the data and variables used. Section 3 describes a simple correlation among key variables and cross-country regressions. In Section 4 we acknowledge the fact that pure cross-country regressions, though indicative of a long-run link between infrastructure and income inequality, suffer from potential endogeneity problems, as such an approach does not help disentangle whether infrastructure is the variable that drives changes in income inequality, or vice-versa. In Section 5 we use panel data grouped in five-year periods and apply an autoregressive approach in order to tackle the serial correlation problems that appear when running simple least squares with dummies (LSDV) regressions. However, this method does not deal with reverse causality and endogeneity problems. Consequently, in Section 6 we use a dynamic panel data approach that helps minimize such endogeneity problems by taking advantage of the methodology of Arellano and Bover (1995) and Blundell and Bond (1997). Section 7 presents GMM-IV results, and Section 8 concludes.

2. Data and Variables of Interest

Our approach is to use two types of infrastructure components. We employ both a quantity component in the form of stock of physical infrastructure, as well as an impact component, measured in terms of quality of the service provided by infrastructure. This quantity-quality approach is explicitly assumed throughout this research and loosely follows the work by Canning (1998).[3] Definition and data sources are shown in Table 1. The following broad categories are used: (i) telecommunications; (ii) energy; (iii) roads; (iv) railways; and (v) public works. The volume proxy in (i) is the number of telephone main lines connected to local exchanges while the

[2] In particular, the Arellano-Bover (1995) approach assumes "weak" exogeneity instead of "strong" exogeneity in the link between variables. This is sometimes criticized.
[3] We use normalized physical units for equivalent monetary measures are difficult to obtain (Canning and Fay, 1993; Canning, 1998).

quality proxies are the percentage of unsuccessful local calls (cross-section) and the waiting list for telephones (panel).[4] Similarly, the volume indicator in (ii) is the electricity generating capacity, while the quality indicator is the transmission and distribution losses of electricity as a percentage of total output. With respect to (iii) the quantity proxy is paved road and the quality indicator is the percentage of main paved network in good condition (World Bank, 1994).[5] Likewise, the quantity proxy in (iv) is length of railroad lines open to the public while the quality proxy is percentage of diesel locomotives (Canning, 1998). Finally, in (v) the quantity proxy is the ratio of irrigation land as percentage of crop land.[6]

We also construct composite indices of both quality and quantity of infrastructure in order to capture the corresponding aggregate impact of infrastructure volume and infrastructure quality on income distribution. To do this, we follow Hulten (1996).[7] The methodology is as follows. First, we sort the normalized individual measures (shown in Table 1) into quartiles. Second, we assign a value for each of the ordered quartiles. A value of 1 is imputed to observations belonging to the top quartile, a value of 0.75 is given to observations in the second quartile, a value of 0.50 to those in the third quartile, and finally, a value of 0.25 to observations in the bottom quartile. From this infrastructure ranking we construct an aggregate index by taking simple averages (Hulten, 1996). An advantage of this method is that it allows keeping as many countries as possible while using the data of the different infrastructure systems.[8]

Based on previous empirical research by Li *et al*. (1998), Chong (2001), and several others, the basic controls that are included in our regression analysis are: (i) the log of GDP per capita, (ii) the growth in GDP per capita, and (iii) the secondary education enrollment rate. Whereas the first two measures are from Summers and Heston (1991) and the World Bank (1997), the latter is from Barro and Lee (1996). The dependent variable comes from Deininger and Squire (1996). We use Gini coefficients and income shares for quintiles of the population. The Gini coefficient ranges from 0 to 100, while the income shares for the top and bottom quintiles of the population are ratios that fluctuate between zero and one.

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[4] The difference in proxies in cross-section and panel approaches is due to different availability of data.
[5] These indicators do not reflect width, age, and maintenance of roads (Canning, 1998).
[6] Because of data constraints we were not able to use a quality proxy in this category.
[7] Another method is to use principal components. The method by Hulten has the advantage of taking into account aggregation and non-linearity problems explicitly.
[8] Not all the quartile values are available for all countries. We calculate an overall index for countries with at least two indicators. In general, this method provides an infrastructure stock sample of 84 countries and an infrastructure quality sample of 63 countries.

Three layers of empirical evidence are introduced. First, we present a simple correlation that helps establish basic stylized facts between infrastructure and inequality. Second, we use several regression techniques at different data frequencies. As mentioned above, not only do we assess this relationship on a cross-section of countries, but also on a panel of countries.[9] Third, we perform regression analysis for the full sample as well as for the sample of developing countries.

3. Basic Stylized Facts

At a first layer of analysis, a simple correlation yields the following stylized facts: First, there is a considerable gap in infrastructure development between industrial and developing countries. While the mean of the aggregate index for industrial countries during the 1960-95 period reaches the middle of the top quartile (0.89 for stocks and 0.71 for quality), the average for developing reaches the second and third quartiles only (0.56 for stocks and 0.42 for quality). Second, increases in infrastructure stocks and quality are significantly associated with a more equal distribution of income. In fact, infrastructure stocks are negatively correlated with the Gini coefficient (-0.43). As expected, such a correlation is negative with respect to the top quintile and positive with the bottom quintile.[10] Furthermore, the composite quality index has a somewhat stronger negative correlation with the Gini coefficient (-0.46) than the index for infrastructure stocks. Third, the correlation between infrastructure stocks and income inequality tends to be not statistically significant for industrial countries, whereas the correlation with infrastructure quality is negative and significant.[11] For these countries, it appears that quality improvements in infrastructure are more important in reductions in inequality than stock. Fourth, improvements in both stock and quality of infrastructure system are significantly associated with lower income inequality in developing countries (–0.24 and –0.27, respectively).

[9] As explained above, the panel consists of non-overlapping 5-year periods spanning the 1960-95 period. Other frequencies were also tested (3-year and 4-year), and the results are similar.

[10] The correlation between the Gini coefficient and the overall infrastructure stock is -0.44. On the other hand, the correlation with the top 20 and 40 quintiles are -0.44 and -0.41, respectively; the correlation with the middle quintile is 0.32, and the correlation with the bottom 20 and 40 quintiles are 0.36 and 0.23, respectively.

[11] The correlation between the composite measure of infrastructure quality and the Gini coefficient is -0.24 and is significant at the 10 percent level.

4. Cross-Country Regressions

In order to test for the existence of a significant link between quantity and quality of infrastructure and income inequality a first econometric approach is to take simple averages for the period 1960-1995 for each variable and run cross-country regressions in the spirit of Barro (1991). We postulate the following regression equation:

$$y_i = b_0 + X_i b_1 + S_i b_2 + e_i \qquad (1)$$

where y_i represents the income inequality indicator, as proxied by the Gini coefficient (or the income share of the top 20 percent or bottom 20 percent of the population).[12] Similarly, X_i represents the matrix of basic controls based on previous work by Li *et al*. (1998), Chong (2001) and others. It includes the level of initial GDP per capita in 1960 in logs, the average annual growth rate of GDP per capita for the period 1960-1995 and the secondary enrollment rate. Finally, S_i represents the matrix of our variables of interest, that is, a broad array of infrastructure measures as shown in Table 1. We show five different specifications for equation (1), with changes only in the set of indicators used in the matrix S_i. Regression [1] and regression [2] in Table 5 use the initial and average value of the composite measure of infrastructure stocks, respectively.[13] Equation [3] includes the quality indicator only; regressions [4] and [5] use both the stock and quality indicators, with the former using the starting value and the latter the average value for the stock.[14] The key findings are: (i) there is a negative and significant relationship between infrastructure stock and income inequality [regressions 1 and 2 in Table 5]; (ii) there is a negative and significant relationship between infrastructure quality and income inequality [regression 3 of Table 5]; (iii) not surprisingly, when also controlling for infrastructure quality, the correlation between infrastructure stocks and income inequality drops [regressions 4 and 5 in Table 5]; (iv) compared to the full sample, in the case of developing countries the

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[12] The analysis was also done with top 40, middle 20, and bottom 40 percent of the population. Though not presented here, those results are consistent with the ones reported above. We would be happy to provide them upon request.

[13] Regressions using initial values help minimize reverse causality problems. Since panel data results are also presented, we decided against using an instrumental variables approach in the cross-section, as good instruments are hard to obtain and researchers have shown skepticism regarding this approach (Levine, 1999). However, for the sake of completeness, we did produce a set of IV results that we would be happy to provide upon request. The results are very similar.

[14] Because of data limitations it was not possible to use initial quality indicators, but only average quality indicators. Also, all regressions have heteroskedasticity consistent standard errors (White, 1980).

association between income inequality and infrastructure stocks increases, whereas in the case of infrastructure quality such correlation falls slightly. In fact, a one quartile improvement in the quartile ranking of infrastructure stocks in 1960 is linked with a decrease of 5.6 points in the Gini coefficient during the period of study (regression 1, Table 5). When controlling for quality, such a reduction is only 4.4 points (regression 4, Table 5). Similarly, a one quartile improvement in infrastructure quality is linked with a drop in the Gini index of 4.7 points (regression 3, Table 5). Furthermore, the long-run link between infrastructure stocks and income inequality is greater for developing countries than for the full sample, though the association of infrastructure quality is smaller. An increase in infrastructure stock is linked with a decrease in the Gini coefficient by 7.2 points. Quality improvements in infrastructure for developing countries are linked with a reduction in the Gini coefficient by 4.2 points (regression 8, Table 5). While the link of the composite infrastructure quantity and quality measures are negative and statistically significant with respect to the Gini coefficient, the link of the individual indicators is not as robust (Table 6). In fact, although the signs come out as expected, some individual proxies are not statistically significant. In the stock proxies this is true in the case of roads. However, energy, railways, telecommunications, and public works do have a robust relationship with inequality. In the case of quality measures, telecommunications and energy tend to be statistically insignificant, but the other quality measures yield robust relationships with income inequality. Finally, notice also that the results hold when quality and quantity indicators are included in the same regression equation (Table 6).

5. Panel Data: AR(1) Approach

From the pure Barro-type cross-country regressions above, there appears to be compelling evidence on the link between infrastructure and income inequality. However, in spite of this apparent implicit link the cross-country results do not take advantage of the time variation of the data and thus cannot be taken as “true” time series findings. In fact, a panel approach can help better exploit the data by explicitly taking into account the dynamics of the cross-sectional evidence presented. Since the errors are serially correlated, the literature suggests formulating a dynamic specification of the form:[15]

[15] A least squares with dummy variables (LSDV) fixed effect approach results in a specification with serial correlation in errors.

$$y_{i,t} = g + y_{i,t-1}\ f + X_{i,t}\ g + S_{i,t}\ g + h_i + e_{i,t} \qquad (2)$$

where $y_{i,t}$ is the income inequality indicator (Gini coefficient) for country i over the 5-year period t; $y_{i,t-1}$ is the lagged income inequality indicator, and $X_{i,t}$ and $S_{i,t}$ are defined as in the cross-section. In fact, previous panel data research shows that inequality has been highly stable in recent decades (Li *et al*., 1998). It has been estimated that the correlation of inequality between the 1960s and 1980s is around 0.85 (Bruno *et al*., 1998). These findings provide support for the idea that past inequality may be an important predictor of current inequality (Chong, 2001). Using this AR(1) approach with fixed effects the serial correlation problem is corrected, as shown in Table 7. We find that: (i) both infrastructure stocks and infrastructure quality have a negative and significant relationship with the Gini coefficient for the full sample (regressions 1-5, Table 7). For instance, an improvement in the quartile ordering of infrastructure stocks reduces the Gini coefficient by 0.62 point over the subsequent 5 years, and by 4.31 points over the next 35 years (regression 1, Table 7). Similarly, an improvement in the quartile order for infrastructure quality decreases the Gini by 0.5 point over the next 5 years and 3.49 points over the subsequent 35 years (regression 3, Table 7). Moreover, the impact of infrastructure stocks on income inequality is greater for developing countries, whereas the impact of infrastructure quality is somehow smaller in this group of countries (regressions 6-10, Table 7). Quartile improvements in infrastructure stocks are associated with a fall in the Gini coefficient of 0.76 point over the subsequent 5-year period, and by 5.32 over the next 35 years (regression 6, Table 7). Also, higher quality in the stocks of infrastructure reduces income inequality by 0.31 points over the following 5-year period, and by 2.14 over the subsequent 35 years (regression 8 in Table 7). With respect to individual measures, we find that all indicators but energy have a negative and significant relationship with the Gini coefficient (Table 8). In terms of stocks, we find that roads and railways have a negative and significant relationship with income inequality. With respect to infrastructure quality, we also find that improvements in telecommunications and transport help reduce income inequality. As before, the results above hold even when including both measures of stocks and quality in the same regression equation.[16]

[16] Due to space considerations these results have not been reported. We would be happy to provide them upon request to the corresponding author.

6. GMM-IV Dynamic Panel Data Approach

Although the AR(1) method above controls for serial correlation problems, potential problems of simultaneity and reverse causation remain. To minimize this problem in this section we apply dynamic panel data GMM-IV techniques (Arellano and Bover, 1995; Blundell and Bond, 1997). By using this method we estimate a regression equation in differences and a regression equation in levels simultaneously, with each equation using its own specific set of instrumental variables. A basic outline of the procedure is presented below. For ease of exposition, each section of the system is presented separately although, as mentioned above, the entire system is estimated jointly.

(i) System in First Differences. We eliminate the unobserved country-specific effects by specifying the regression equation (2a) in first differences:

$$y_{i,t} - y_{i,t-1} = (y_{i,t-1} - y_{i,t-2})\ f + (X_{i,t} - X_{i,t-1})\ g + (S_{i,t} - S_{i,t-1})\ g + (e_{i,t} - e_{i,t-1}) \qquad (3)$$

For this specification, the choice of instruments requires dealing with two problems. First, the possible endogeneity of the explanatory variables, Z = [X’ S’]’, which is reflected in the correlation between these variables and the error term. Second, the new error term, $(e_{i,t} - e_{i,t-1})$, is correlated by construction with the differenced lagged dependent variable, $(y_{i,t-1} - y_{i,t-2})$. According to this procedure, we allow for the possibility of simultaneity and reverse causation, instead of assuming *strict exogeneity* (i.e., no correlation between the explanatory variables and the error term at all leads and lags). We adopt the more flexible assumption of *weak exogeneity*, with the current explanatory variables being affected by past and current realizations of the dependent variable but not by its future innovations. Under the assumptions that (a) the error term, e, does not exhibit serial correlation, and (b) the explanatory variables are weakly exogenous, the following moment conditions apply:

$$E[y_{i,t-s} \times (e_{i,t} - e_{i,t-1})] = 0\ ;\ \ for\ s \geq 2,\ and\ t = 3,\ldots,T \qquad (4)$$

$$E[Z_{i,t-s} \times (e_{i,t} - e_{i,t-1})] = 0\ ;\ \ for\ s \geq 2,\ and\ t = 3,\ldots,T \qquad (5)$$

The GMM-IV estimator based on the moment conditions (4) and (5) is known as the *differences* estimator. Although asymptotically consistent, this estimator has low asymptotic precision and large biases in small samples, which leads to the need to complement it with the regression equation in levels.[17]

(ii) System in Levels. For this part of the system, the country-specific factor is not directly eliminated but must be controlled for by the use of instrumental variables. The appropriate instruments for the regression in levels are the lagged *differences* of the corresponding variables if the following assumption holds. Although there may be correlation between the levels of the right hand side variables and the country-specific effect, there is no correlation between the *differences* of these variables and the country-specific effect. This assumption results from the following stationarity property,

$$E[y_{i,t+p} \times h_i] = E[y_{i,t+q} \times h_i] \;\; and \; E[Z_{i,t+p} \times h_i] = E[Z_{i,t+q} \times h_i] \; ; \;\; " \; p,q \tag{6}$$

Therefore, the additional moment conditions for the second part of the system (the regression in levels) are given by the following equations:[18]

$$E[(y_{i,t-s} - y_{i,t-s-1}) \times (h_i + e_{i,t})] = 0 \; ; \;\; for \; s=1 \tag{7}$$

$$E[(Z_{i,t-s} - Z_{i,t-s-1}) \times (h_i + e_{i,t})] = 0 \; ; \;\; for \; s=1 \tag{8}$$

Using the moment conditions (4), (5), (7) and (8), and following Arellano and Bond (1991) and Arellano and Bover (1995), we employ a Generalized Method of Moments (GMM) procedure to generate consistent estimates of the parameters of interest. The weighting matrix for GMM estimation can be any symmetric, positive-definite matrix, and we obtain the most efficient GMM estimator if we use the weighting matrix corresponding to the variance-covariance of the moment conditions. Since this variance-covariance is unknown, Arellano and Bond (1991) and Arellano and Bover (1995) suggest the following two-step procedure. First, assume that the residuals, $e_{i,t}$, 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

17 Alonso-Borrego and Arellano (1996) and Blundell and Bond (1997) show that when the lagged dependent and the explanatory variables are persistent over time, lagged levels of these variables are weak instruments for the regression equation in differences. This weakness has repercussions on both the asymptotic and small-sample performance of the *differences* estimator. As persistence increases, the asymptotic variance of the coefficients obtained with the *differences* estimator rises. An additional problem with the simple *differences* estimator relates to measurement error: Differencing may exacerbate the bias due to errors in variables by decreasing the signal-to-noise ratio (Griliches and Hausman, 1986). Blundell and Bond (1997) suggest that the use of Arellano and Bover’s (1995) *system* estimator reduces the potential biases and imprecision associated with the usual *differences* estimator.

18 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. Other lagged differences would result in redundant moment conditions (Arellano and Bover 1995).

coefficient estimates. We construct a consistent estimate of the variance-covariance matrix of the moment conditions with the residuals obtained in the first step, and we use this matrix to re-estimate our parameters of interest (i.e., second-step estimates). Asymptotically, the second-step estimates are superior to the first-step ones insofar as efficiency is concerned. In this paper the moment conditions are applied such that each corresponds to all available periods, as opposed to each moment condition corresponding to a particular time period. In the former case the number of moment conditions is independent of the number of time periods, whereas in the latter case, it increases more than proportionally with the number of time periods. Most of the literature dealing with GMM estimators applied to dynamic models of panel data treats the moment conditions as applying to a particular time period. This approach is advocated on the grounds that it allows for a more flexible variance-covariance structure of the moment conditions (Ahn and Schmidt, 1995). Such flexibility is achieved without placing a serious limitation on the degrees of freedom required for estimation of the variance-covariance matrix because the panels commonly used in the literature have both a large number of cross-sectional units and a small number of time-series periods (typically not more than five). We have, however, chosen to work with the more restricted application of the moment conditions (each of them corresponding to all available time periods) that allows us to work with a manageable number of moment conditions, so that the second-step estimates, which rely on estimation of the variance-covariance matrix of the moment conditions, do not suffer from over-fitting biases (see Altonji and Segal, 1994, and Ziliak, 1997).

The consistency of the GMM estimator depends on whether lagged values of the explanatory variables are valid instruments in the regression. We address this issue by considering 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 analog of the moment conditions used in the estimation process. Failure to reject the null hypothesis gives support to the model. The second test examines the hypothesis that the error term $e_{i,t}$ is not serially correlated. We test whether the differenced error term (that is, the residual of the regression in differences) is first-, second-, and third-order serially correlated. 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. If the test fails to reject the null hypothesis of absence of second-order serial correlation, we conclude that the original error term is serially uncorrelated and use the corresponding moment conditions.

7. GMM-IV Dynamic Panel Results

In Table 9 we present GMM-IV dynamic panel results using the methodology of Arellano and Bover (1995) and Blundell and Bond (1997). Similar to the previous section we find a negative and significant relationship between corresponding measures of infrastructure stock and the Gini coefficient, as well as between measures of infrastructure quality and the Gini index. In addition, our findings are also similar to the previous section in that in most cases, the impact of infrastructure stocks on income inequality is larger for developing countries, while the impact of infrastructure quality is not as high. An increase in infrastructure stocks helps reduce income inequality and, specifically, the Gini coefficient by 0.49 in the short-run (i.e., over the next 5-year period) and by 3.48 points in the long run, (i.e., over the subsequent 35 years). This is shown in regression 2 in Table 9.[19] The impact of infrastructure stocks is significantly higher after controlling for quality in the same regression. In fact, the Gini coefficient decreases by 0.70 points in the short run, whereas it decreases by 4.90 points in the long run (regression 5, Table 9). On the other hand, quality improvements in the infrastructure stocks generate a reduction in the Gini coefficient of 0.92 point in the next 5-year period and of 6.46 points on the subsequent 35 years (regression 3, Table 9). Consistent with our previous results, the impact of an enhanced infrastructure quality tend to decrease when also controlling for infrastructure stocks. In this case, quality improvements reduce the Gini coefficient by 0.81 and 5.66 points in the short- and long-run, respectively.

Once again, the impact of infrastructure development on income inequality appears to be greater in the case of developing countries. A one-quartile increase in infrastructure stocks is linked with a reduction in the Gini coefficient of 0.87 point in the short-run and of 6.11 points in the long-run (regression 7, Table 9). The decrease in income inequality is somewhat larger when also controlling for quality. The Gini coefficient falls 0.90 point and 6.28 points in the short- and

[19] Because of space considerations we provide comments on regressions that use average values for infrastructure stocks, only. Simulations using initial values of infrastructure stocks yield very similar results.

long-run, respectively (regression 10, Table 9). Finally, the impact of quality improvements in infrastructure stocks is smaller in developing countries, compared to the results for the sample of all countries, which indicates that the relative impact in industrial countries is greater. An improvement in infrastructure quality reduces the Gini coefficient by 0.58 point and 4.08 points in the short and long run, respectively (regression 8, Table 9). As expected, the impact of quality improvements is smaller when we also control for stocks as the Gini coefficient decreases 0.56 points and 3.96 points in the short and long run, respectively (regression 10, Table 9). In summary, once we control for unobserved country-effects and minimize for joint endogeneity by using the Arellano and Bover method, we still find a negative and significant relationship between income inequality and all individual physical infrastructure measures for stocks and quality (Table 10). In addition, we find that, for the sample of developing countries, the impact of higher infrastructure stocks is larger and the impact of quality improvements is relatively smaller in relation to the full sample of countries.

8. Conclusions

In this paper we have shown that there is a negative and statistically significant link between quantity of infrastructure and income distribution and between quality of infrastructure and income distribution. That is, infrastructure development is associated with an improvement in the distribution of income. This basic result is maintained when using either a pure cross-country approach or a panel data approach. Moreover, in the latter case, this result is robust to the application of different econometric techniques that deal with serial correlation problems, country-specific effects, and potential reverse causality problems. Additionally, the quantitative link appears to be stronger than the qualitative link, particularly in the case of developing countries. In general, the results above are consistent with the conventional wisdom of politicians that increased expenditures in physical infrastructure may be a necessary condition to succeed in a new political cycle.

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Appendix 1. List of Countries

Industrial
01. Australia
02. Austria
03. Belgium
04. Canada
05. Denmark
06. Finland
07. France
08. Germany
09. Greece
10. Ireland
11. Italy
12. Japan
13. Netherlands
14. New Zealand
15. Norway
16. Portugal
17. Spain
18. Sweden
19. Switzerland
20. United Kingdom
21. United States

East Asia and the Pacific
22. China
23. Fiji
24. Hong Kong
25. Indonesia
26. Malaysia
27. Philippines
28. Singapore
29. Taiwan
30. Thailand

Eastern Europe & C. Asia
31. Bulgaria
32. Czech Republic
33. Hungary
34. Poland
35. Russian Federation

Latin America
36. Argentina
37. Barbados
38. Bahamas
39. Bolivia
40. Brazil
41. Chile
42. Colombia
43. Costa Rica
44. Dominican Republic
56. Ecuador
46. El Salvador
47. Philippines
48. Guyana
49. Honduras
50. Jamaica
51. Mexico
52. Nicaragua
53. Panama
54. Paraguay
55. Peru
56. Trinidad and Tobago
57. Uruguay
58. Venezuela

Middle East & North Africa
59. Algeria
60. Egypt
61. Iran
62. Iraq
63. Israel
64. Jordan
65. Tunisia
66. Turkey

South Asia
67. Botswana
68. India
69. Nepal
70. Pakistan
71. Sri Lanka

Sub-Saharan Africa
71. Bangladesh
72. Central African Rep.
73. Cameroon
74. Chad
75. Congo
76. Cote d'Ivoire
77. Ethiopia
78. Gabon
79. Gambia
80. Ghana
81. Guinea
82. Guinea-Bissau
83. Kenya
84. Lesotho
85. Madagascar
86. Malawi
87. Mauritania
88. Mauritius
89. Morocco
90. Niger
91. Nigeria
92. Rwanda
93. Senegal
94. Seychelles
95. Sierra Leone
96. South Africa
97. Sudan
98. Tanzania
99. Uganda
100. Zambia
101. Zimbabwe

Table 1. Variables of Interest and Data Sources

Infrastructure System	Variable of Interest	Data So
Telecommunications	Volume: Telephone main lines per thousand inhabitants. Quality: Cross-Country sample: unsuccessful local calls (% of total); Panel sample: waiting list for main lines.	International Telecon Union (ITU). World Telecommunications Report. Canning (199
Energy	Volume: Electricity generating capacity in kilowatts per thousand inhabitants. Quality: Electric power transmission and distribution losses as percentage of total output.	United Nations Energ Yearbook. World Development I Bank (1997). Canning
Roads	Volume: Paved road length in kilometers as a ratio of the country's area in squared kilometers. Quality: Percentage of main paved roads in good condition	International Road Tr World Transport Data Roads Federation (IR Statistics. Canning (1
Railways	Volume: Railroad length in kilometers as a ratio of the country's are in squared kilometers Quality: Percentage of diesel locomotives.	World Bank Railways World Development I Bank (1997).
Public Works	Volume: Irrigation land as percentage of crop land	World Development I Bank (1997).

Table 2. Stock of Infrastructure, 1960-1995
Summary Statistics

	Obs	*Mean*	*Std. Error*	*Minimum*	*Maximum*
Full Sample					
Telecommunications	103	83.24	114.10	0.33	500.75
Energy	102	0.44	0.68	0.00	4.25
Roads	94	0.32	0.70	0.00	3.81
Railways	102	0.02	0.03	0.00	0.17
Public Works	92	13.50	17.52	0.10	100.00
Quantity Index	103	0.63	0.22	0.25	1.00
Developing Countries					
Telecommunications	82	33.53	47.91	0.33	210.97
Energy	81	0.19	0.29	0.00	1.59
Roads	77	0.18	0.52	0.00	3.17
Railways	81	0.01	0.03	0.00	0.17
Public Works	75	13.43	17.65	0.10	100.00
Quantity Index	82	0.56	0.19	0.25	1.00

Calculation of quantity index and quality index follows Hulten (1996) as explained in text.

Table 3. Quality of Infrastructure, 1960-1995
Summary Statistics

	Obs	*Mean*	*Std. Error*	*Minimum*	*Maximum*
Full Sample					
Telecommunications	78	30.43	21.52	0.00	85.96
Energy	83	11.17	5.63	0.59	28.99
Roads	95	0.38	0.30	0.01	1.00
Railways	64	72.08	15.19	31.80	94.00
Quality Index	102	0.48	0.22	0.08	0.92
Developing Countries					
Telecommunications	63	35.52	19.54	0.79	85.96
Energy	62	12.19	6.06	0.59	28.99
Roads	78	0.31	0.26	0.01	1.00
Railways	46	67.12	14.17	31.80	89.31
Quality Index	81	0.42	0.19	0.08	0.88

Calculation of quantity index and quality index follows Hulten (1996) as explained in text.

Table 4. Simple Correlation

	Gini Index	Top 20 percent	Bottom 20 percent
Full Sample			
A. Quantity			
Composite Stocks Index	-0.44 *	-0.44 *	0.23 *
Telecommunications	-0.28 *	-0.31 *	0.05
Energy	-0.36 *	-0.39 *	0.16 **
Roads	-0.26 *	-0.31 *	0.11
Railways	-0.47 *	-0.45 *	0.38 *
Public Works	-0.19 *	-0.16 **	0.15 **
B. Quality			
Composite Quality Index	-0.46 *	-0.54 *	0.26 *
Telecommunications	0.15	0.23 *	0.04
Energy	0.17 **	0.17 **	-0.04
Roads	-0.54 *	-0.56 *	0.39 *
Railways	-0.40 *	-0.44 *	0.35 *
Developing Countries			
C. Quantity			
Composite Stocks Index	-0.24 *	-0.22 **	0.11 **
Telecommunications	-0.04	-0.03	-0.08
Energy	-0.16 **	-0.22 **	0.13
Roads	-0.05	-0.11	-0.09
Railways	-0.36 *	-0.36 *	0.33 *
Public Works	-0.27 *	-0.26 *	0.21 **
D. Quality			
Composite Quality Index	-0.27 *	-0.34 *	0.19 **
Telecommunications	-0.07	0.01	0.15
Energy	-0.01	-0.04	0.07
Roads	-0.43 *	-0.45 *	0.32 *
Railways	-0.20 **	-0.21 **	0.33 *

(*) Five percent statistical significance; (**) ten percent statistical significance. Calculation of quantity index and quality index follows Hulten (1996) as explained in text.

Table 5. Dependent Variable: Gini Coefficient
Ordinary Least Squares Cross-Country Regressions, 1960-1995

	Full Sample					Developing Cou		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Constant	55.92 *	48.44 *	65.43 *	52.90 *	45.25 *	28.98 *	23.07 **	49.85 *
	-(11.81)	-(11.99)	-(10.38)	-(11.73)	-(12.06)	-(14.75)	-(14.60)	-(15.14)
GDP per capita	-0.20	1.35	-2.33 **	0.59	2.21	4.10 **	5.40 *	-0.15
	-(2.03)	-(2.03)	-(1.50)	-(2.00)	-(2.03)	-(2.39)	-(2.32)	-(2.11)
Growth in GDP	-48.65	25.67	-18.12	26.27	92.89	-17.31	63.43	2.95
	-(60.30)	-(65.38)	-(53.51)	-(60.14)	-(66.59)	-(64.42)	-(71.13)	-(62.32)
Schooling	0.06	0.03	0.08	0.07	0.05	0.09	0.05	0.00
	-(0.07)	-(0.07)	-(0.06)	-(0.06)	-(0.07)	-(0.15)	-(0.14)	-(0.15)
Initial Stock Index	-22.38 *			-17.40 *		-28.96 *		
	-(8.20)			-(7.57)		-(10.00)		
Avg Stock Index		-30.65 *			-26.44 *		-36.94 *	
		-(7.52)			-(6.82)		-(8.40)	
Avg Quality Index			-18.65 *	-15.99 *	-15.29 *			-16.81 *
			-(4.83)	-(4.61)	-(4.59)			-(5.86)
Observations.	89	89	89	89	89	68	68	68
R-Squared	0.25	0.30	0.28	0.31	0.36	0.15	0.21	0.11

Standard errors in parenthesis; (*) Five percent statistical significance; (**) ten percent statistical significance. Calculation of qu follows Hulten (1996) as explained in text. “Initial” index refers to values at the beginning of five-year periods. “Average” inde period.

Table 6. Ordinary Least Squares Cross-Country Regressions, 1960-95
Individual Measures

	Full Sample			*Developing Countries*		
	Gini	*Top20*	*Bot 20*	*Gini*	*Top20*	*Bot 20*
Infrastructure Stocks						
Quantity Index	-30.653 *	-0.297 *	0.078 *	-36.93 *	-0.345 *	0.097 *
	(7.520)	(0.068)	(0.017)	(8.395)	(0.078)	(0.021)
Telecommunications	-0.040 *	-0.000 *	0.000 *	-0.056 **	-0.001 *	0.000 **
	(0.0142)	(0.000)	(0.000)	(0.037)	(0.000)	(0.000)
Energy	-4.081 **	-0.041 *	0.008	-10.621 *	-0.110 *	0.032 *
	(2.338)	(0.021)	(0.006)	(3.039)	(0.029)	(0.009)
Roads	-1.459	-0.022 **	0.003	-0.428	-0.018	0.006
	(1.487)	(0.013)	(0.004)	(2.017)	(0.018)	(0.006)
Railways	-100.64 *	-0.895 *	0.260 *	-112.07 *	-1.005 *	0.269 *
	(21.551)	(0.218)	(0.053)	(24.854)	(0.215)	(0.069)
Public Works	-0.108 *	-0.001 *	0.000 *	-0.156 *	-0.001 *	0.000 *
	(0.043)	(0.000)	(0.000)	(0.048)	(0.000)	(0.000)
Infrastructure Quality						
Quality Index	-18.647 *	-0.248 *	0.043 *	-16.806 *	-0.219 *	0.045 *
	(4.825)	(0.037)	(0.012)	(5.863)	(0.044)	(0.015)
Telecommunications	0.018	0.000	3.7E-05	-0.035	-0.000	0.00013
	(0.056)	(0.000)	(0.000)	(0.065)	(0.000)	(0.000)
Energy	-0.022	0.000	0.000	-0.083	-0.000	0.000
	(0.252)	(0.002)	(0.001)	(0.238)	(0.002)	(0.0006)
Roads	-18.308 *	-0.195 *	0.045 *	-21.042 *	-0.224 *	0.050 *
	(3.959)	(0.035)	(0.009)	(4.774)	(0.039)	(0.012)
Railways	-0.164 **	-0.002 *	0.001 *	-0.113	-0.001 *	0.000 **
	(0.088)	(0.001)	(0.000)	(0.118)	(0.001)	(0.000)

Standard errors in parenthesis; (*) five percent statistical significance; (**) ten percent statistical significance. Regressions with average measures yield very similar results. Calculation of quantity index and quality index follows Hulten (1996) as explained in text.

Table 7. Fixed Effects AR(1) Panel Regressions using Infrastructure Indices, 196(
Dependent Variable: Gini Coefficient

	Full Sample					*Developing Countr*			
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	
Constant	6.27 *	6.12 *	7.23 *	6.82 *	6.66 *	3.77 *	3.43 *	5.48 *	4
	-(1.98)	-(1.98)	-(1.96)	-(1.97)	-(1.97)	-(2.59)	-(2.61)	-(2.31)	-(
GDP per capita	0.24	0.39	0.07	0.35	0.49	0.58	0.79 **	0.13	0
	-(0.29)	-(0.30)	-(0.29)	-(0.35)	-(0.35)	-(0.48)	-(0.49)	-(0.41)	-(
Growth in GDP	-4.38	-2.88	-2.67	-0.95	0.40	-6.95	-5.48	-5.80	-4
	-(5.81)	-(5.83)	-(6.08)	-(6.16)	-(6.20)	-(6.16)	-(6.17)	-(6.62)	-(
Schooling	-0.04 *	-0.04 *	-0.06 *	-0.05 *	-0.05 *	-0.02 **	-0.02	-0.03 **	-(
	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.02)	-(
Initial Stock Index	-2.46 **			-2.32 **		-3.03 **			-
	-(1.50)			-(1.53)		-(1.88)			-(
Avg Stock Index		-3.76 *			-3.55 *		-4.48 *		
		-(1.61)			-(1.63)		-(2.05)		
Avg Quality Index			-1.99 *	-1.95 **	-1.96 **			-1.22 *	-
			-(1.21)	-(1.22)	-(1.21)			-(0.60)	-(
Gini Lagged	0.85 *	0.85 *	0.86 *	0.84 *	0.83 *	0.86 *	0.85 *	0.86 *	0
	-(0.02)	-(0.02)	-(0.02)	-(0.02)	-(0.02)	-(0.02)	-(0.02)	-(0.02)	-(
No. Countries	84	84	82	82	82	63	63	61	
No. Observations	426	426	418	418	418	307	307	299	2
Serial Correlation									
- 1st. Order	0.25	0.16	0.37	0.29	0.20	0.14	0.16	0.17	0
- 2nd. Order	0.83	0.88	0.88	0.92	0.96	0.78	0.85	0.79	0
- 3rd. Order	0.61	0.62	0.65	0.68	0.69	0.73	0.75	0.73	0

Panel of five-year periods. Standard errors in parenthesis; (*) five percent statistical significance; (**) ten percent statistical sig quantity index and quality index follows Hulten (1996) as explained in text. "Initial" index refers to values at the beginni "Average" index refers to the five-year averages.

Table 8.
Fixed Effects AR(1) Panel Regressions with Individual Measures, 1960-95
Dependent Variable: Gini Coefficient and Income Shares

	Full Sample						Developing Countries					
	Gini		Top20		Bot 20		Gini		Top20		Bot 20	
Infrastructure Stocks												
Avg. Stock Index	-2.461	**	-0.063	*	0.011	*	-3.037	**	-0.081	*	0.010	*
	-(1.507)		-(0.018)		-(0.004)		-(1.880)		-(0.021)		-(0.005)	
Telecommunications	-0.002	**	0.000	**	0.000	**	-0.000	*	0.000	*	0.000	*
	-(0.001)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Energy	-0.131		-0.003		0.000		0.929		-0.002		-0.002	
	-(0.229)		-(0.002)		-(0.000)		-(0.919)		-(0.013)		-(0.000)	
Roads	-0.246	**	-0.002		0.001	**	-0.097	**	-0.001	**	0.000	**
	-(0.149)		-(0.002)		-(0.001)		-(0.059)		-(0.001)		-(0.000)	
Railways	-14.283	*	-0.169	*	0.050	*	-11.469	*	-0.268	*	0.017	*
	-(5.623)		-(0.068)		-(0.020)		-(5.337)		-(0.109)		-(0.009)	
Public Works	-0.013	**	-0.000	**	0.000	**	-0.019	*	-0.000	**	0.000	**
	-(0.007)		-(0.000)		(0.000)		-(0.009)		-(0.000)		(0.000)	
Infrastructure Quality												
Avg. Quality Index	-1.993	*	-0.039	*	0.008	*	-1.223	*	-0.038	*	0.005	**
	-(1.219)		-(0.010)		-(0.003)		-(0.606)		-(0.013)		-(0.003)	
Telecommunications	0.000	**	0.000		0.000	**	0.000	*	0.000	*	0.000	*
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Energy	-0.034		0.000		0.000		-0.049	**	-0.000	*	0.000	**
	-(0.059)		-(0.000)		-(0.000)		-(0.027)		(0.000)		-(0.000)	
Roads	-2.748	*	-0.034	*	0.008	*	-2.754	*	-0.040	*	0.006	*
	-(0.893)		-(0.011)		-(0.002)		-(1.215)		-(0.014)		-(0.002)	
Railways	-0.020	*	-0.000	**	0.000	*	-0.018	*	-0.000	*	0.000	*
	-(0.010)		-(0.000)		-(0.000)		-(0.009)		-(0.000)		-(0.000)	

Panel of five-year periods. Regressions are based on analogous specifications to those in Table 7, but only the coefficients of the variables of interest are reported. Standard errors in parenthesis; (*) five percent statistical significance; (**) ten percent statistical significance. Calculation of quantity index and quality index follows Hulten (1996) as explained in text. We use average stock and average quality indexes. Using initial indices yields similar results.

Table 9. Fixed Effects GMM-IV Panel Data using Infrastructure Indices, 1960-9
Dependent Variable: Gini Coefficient

	All Countries					Developing Coun		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Constant	6.64 *	6.70 *	9.08 *	6.11 *	6.52 *	3.66 *	3.77 *	5.07 *
	-(0.71)	-(0.70)	-(0.64)	-(0.75)	-(0.77)	-(1.04)	-(1.35)	-(1.47)
GDP per capita	0.18 *	0.09	0.06	0.39 *	0.51 *	0.43 *	0.56 *	0.25
	-(0.09)	-(0.07)	-(0.08)	-(0.10)	-(0.12)	-(0.16)	-(0.22)	-(0.23)
Growth in GDP	-17.11 *	-7.06 *	-2.77	-2.18	1.02	-9.11 *	-3.27	-7.60 **
	-(3.82)	-(3.37)	-(2.51)	-(3.99)	-(4.07)	-(4.70)	-(5.35)	-(4.90)
Human Capital	-0.03 *	-0.03 *	-0.06 *	-0.04 *	-0.04 *	-0.01 *	-0.02 *	-0.03 *
	-(0.01)	-(0.00)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)
Initial Stock Index	-2.12 *			-1.62 *		-2.02 *		
	-(0.49)			-(0.52)		-(0.63)		
Avg Stock Index		-1.98 *			-2.80 *		-3.48 *	
		-(0.26)			-(0.63)		-(0.93)	
Avg Quality Index			-3.69 *	-2.95 *	-3.23 *			-2.32 *
			-(0.39)	-(0.39)	-(0.40)			-(0.80)
Gini Lagged	0.86 *	0.86 *	0.84 *	0.85 *	0.84 *	0.87 *	0.86 *	0.87 *
	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)	-(0.01)
Countries	84	84	82	82	82	63	63	61
Observations	426	426	418	418	418	307	307	299
- Sargan Test	0.37	0.67	0.57	0.68	0.59	0.47	0.39	0.40
Serial Correlation								
- 1st. Order	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- 2nd. Order	0.86	0.80	0.94	0.96	0.96	0.77	0.83	0.81
- 3rd. Order	0.65	0.63	0.60	0.65	0.64	0.71	0.72	0.72

Panel of five-year periods. Standard errors in parenthesis; (*) five percent statistical significance; (**) ten percent statistical s quantity index and quality index follows Hulten (1996) as explained in text. “Initial” index refers to values at the begin “Average” index refers to the five-year averages.

Table 10. Fixed Effects GMM-IV System with Individual Measures, 1960-95
Dependent Variable: Gini Coefficient and Income Shares

	Full Sample			Developing Countries		
	Gini	Top20	Bot 20	Gini	Top20	Bot 20
Infrastructure Stocks						
Avg. Stock Index	-1.988 *	-0.096 *	0.017 *	-3.489 *	-0.094 *	0.015 *
	-(0.265)	-(0.007)	-(0.002)	-(0.931)	-(0.005)	-(0.002)
Telecommunications	-0.003 *	0.000 *	0.000 *	-0.004 *	0.000 *	0.000 *
	(0.000)	(0.000)	(0.000)	-(0.002)	(0.000)	(0.000)
Energy	-0.207 *	-0.004 *	0.001 *	-0.279 *	-0.014 *	0.000 **
	-(0.046)	-(0.001)	(0.000)	-(0.141)	-(0.007)	(0.000)
Roads	0.000 *	0.000 *	0.000 *	-0.003 *	-0.001 *	0.000 *
	(0.000)	(0.000)	(0.000)	-(0.001)	(0.000)	(0.000)
Railways	-0.013 *	0.000 *	0.000 *	-0.015 *	0.000 *	0.000 *
	-(0.001)	(0.000)	(0.000)	-(0.006)	(0.000)	(0.000)
Public Works	-0.015 **	0.000 *	0.000 *	-0.026 *	0.000 *	0.000 **
	-(0.009)	(0.000)	(0.000)	-(0.012)	(0.000)	(0.000)
Infrastructure Quality						
Avg. Quality Index	-3.691 *	-0.046 *	0.007 *	-2.329 *	-0.042 *	0.004 *
	-(0.394)	-(0.001)	-(0.001)	-(0.800)	-(0.011)	-(0.001)
Telecommunications	0.000 *	0.000	0.000 *	0.000 **	0.000	0.000 *
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Energy	0.058 *	0.000 *	0.000 *	0.083 *	0.001 **	0.000 *
	-(0.002)	(0.000)	(0.000)	-(0.037)	(0.000)	(0.000)
Roads	-2.277 *	-0.030 *	0.008 *	-2.195 *	-0.027 *	0.003 *
	-(0.177)	-(0.003)	-(0.001)	-(0.973)	-(0.012)	-(0.001)
Railways	-0.067 *	-0.001 *	0.000 *	-0.048 **	-0.001 **	0.000 *
	-(0.007)	(0.000)	(0.000)	-(0.027)	(0.000)	(0.000)

Panel of five-year periods. Regressions are based on analogous specifications to those in Table 9, but only the coefficients of the variables of interest are reported. Standard errors in parenthesis; (*) five percent statistical significance; (**) ten percent statistical significance. Calculation of quantity index and quality index follows Hulten (1996) as explained in text. We use average stock and average quality indexes. Using initial indices yields similar results.