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VOLUME AND QUALITY OF INFRASTRUCTURE AND THE DISTRIBUTION OF INCOME: AN EMPIRICAL INVESTIGATION

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We provide evidence on the link between infrastructure development and the distribution of income for the period 1960–97. We use roads, railways, telecommunications, and energy measures. The approach is comprehensive as individual measures and composite indices are used. Cross-country and panel regressions are applied. In the latter, we apply GMM dynamic methods to minimize for endogeneity problems. We find that both quantity 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.

1. INTRODUCTION

Is there any link between physical infrastructure and income inequality? As relevant as this question is, to our knowledge, it has not been studied adequately in the empirical literature. In a context where 25 percent of the poor have no access to electricity, 52 percent have no canalized water, 86 percent have no access to paved roads, and 90 percent have no telephone access (World Bank, 2000), the relevance of this question is clear. In fact, it is believed that since there is much less initial infrastructure in poor areas, the marginal product of additional infrastructure may be larger in such areas than in richer ones. Infrastructure may be important in linking poor and underdeveloped areas with those of core economic activity as it may allow access to additional productive opportunities to which the destitute have little reach. Investment in infrastructure in poorer regions may allow the reduction in production costs and transaction costs, fostering trade and making possible division of labor and specialization, regarded as crucial elements for sustainable economic growth (Gannon and Liu, 1997). Higher infrastructure density may promote specialization, thus enabling poor laborers to develop a more intensive agriculture based on modern inputs (Blocka and Webb, 2001). Infrastructure may help expand poor rural markets as it may foster the expansion of

Note: The views and interpretations of this paper are those of the authors and should not be attributed to the Central Bank of Chile or the Inter-American Development Bank or their corresponding directors.

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job opportunities to the less advantage in terms of reduction in time and cost involved in accessing product and factor markets and accessing basic services such as health and education (Smith *et al.*, 2001).[1] Finally, recent research shows that if poor farm areas behave like any asset, its price would equal the net present value of the benefits its cultivation generates. Thus, the relation between farmland value and distance to agricultural markets may be an indicator of the capital gains generated by the improvement of infrastructure that closes up areas, such as road and communication services (Jacoby, 2000).

While, as shown above, the available theory and evidence points towards a link between accessibility of infrastructure facilities and an improvement on the conditions in which the disadvantaged live, it is not clear that an improvement in the distribution of income will follow. For instance, it may be claimed that infrastructure may be complementary to private physical and human capital so that it may yield a higher return in richer areas, which are relatively abundant in private capital, which thus may result in an increase in income inequality instead. However, policymakers appear to have taken for granted the existence of a positive link between infrastructure development and the distribution of income, despite the fact that, to our knowledge, the empirical validity of such an association has not been examined closely, yet. This appears to be particularly true in developing countries.

Furthermore, according to the theory of political business cycles (Nordhaus, 1975; Rogoff, 1990; Dixit and Londregan, 1996) politicians try to manipulate the timing, composition, and geographic distribution of expenditures in infrastructure in order to maximize the likelihood of remaining in office. Increases in public expenditures on infrastructure are timed to coincide with elections to satisfy constituencies and are directed towards areas of the country that are considered critical for an incumbent's re-election bid.[2] Under the standard assumption that rulers are benevolent, the implications of infrastructure spending on the poor and disadvantaged are not only linked with short run "pork barrel" characteristics, but also with long run beneficial effects. Benevolent policymakers expect that the infrastructure built for electoral purposes this year will also have a positive impact on the poor in the long run, thus, improving the welfare of the poor and also reducing income inequality. This long run effect, however, needs to be empirically tested.[3]

We provide evidence on the link between infrastructure development and the distribution of income for the period 1960–97. To do this, we use recent data on

[1]Similarly, Lucas *et al.* (1996) show that roads are linked with freight cost reductions and time savings in Tanzania; Guimaraes and Uhl (1997) show that road quality and distance to markets affect agricultural production costs in Brazil; and Liu (2002) shows that permanent access to roads increases production in India.

[2]A recent classic example is the case of how the Peruvian Social Fund was used during the 1990s. Schady (2000) shows that the fund's expenditures increased significantly prior to national elections and that such projects were directed to provinces in which the marginal political impact of expenditures was likely to be the largest.

[3]It may be claimed that the causality may go from inequality to infrastructure. A wealthy elite may not feel a strong incentive to tax itself to invest in universal infrastructure that would benefit the poor majority. This, however, does not seem to be the case, as recent research has shown that historically the wealthy elite had an incentive to provide to the poor in order to avoid revolutions (Acemoglu and Robinson, 2001; Chong, 2004).

quantity and quality of infrastructure (Canning, 1998; World Bank, 1998) as well as relatively widely used data on income inequality (Deininger and Squire, 1997). In particular, we consider several broad categories in our research, such as roads, railways, telecommunications and energy measures. The approach is comprehensive as individual measures and three different aggregation methods are employed. Furthermore, both cross-country and panel regressions are applied. While in the cross-country case we use initial values for each period, in the latter we use a GMM dynamic panel data approach both with the aim of minimizing for endogeneity problems (Arellano and Bover, 1995; Blundell and Bond, 1998). Though this last is a relatively new method and not widely accepted yet, we believe that the application of such dynamic panel technique is a valuable contribution to a thorough understanding of our link of interest.[4] In general, our findings show that infrastructure development is negatively linked with income inequality. In particular, our panel results suggest that such a link goes from the former to the latter. Overall, such association 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. In fact, these findings are robust to a range of infrastructure broad categories, inequality measures, and econometric specifications.

Section 2 describes the data and methodologies used. Since our infrastructure categories tend to be highly correlated we use three different aggregation methods, principal components (Alesina and Perotti, 1996), unobserved components (Kaufmann, Kraay, and Zodio-Lobaton, 2002), and quartile index method (Hulten, 1996). Section 3 describes simple basic stylized facts among key variables. Section 4 presents cross-country regressions. 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 approach does not help disentangle whether infrastructure is the variable that drives changes in income inequality, or vice-versa. Thus in Section 5 we use panel data grouped in five-year periods and apply an autoregressive approach in order to tackle with serial correlation problems, which appear when running simple, least squares with dummies (LSDV) regressions. However, since this method does not deal with reverse causality and endogeneity problems, 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 (1998). Section 7 concludes.

2. Data and Methodology

We use two types of infrastructure categories. In particular, we employ both quantity-related measures, namely stock of physical infrastructure, as well as quality-related measures, typically related with efficiency. This quantity-quality

[4]In particular, the Arellano-Bover (1995) approach assumes "weak" exogeneity instead of "strong" exogeneity in the link between variables, which for practical purposes remain somewhat unclear. Additionally, some critics see this method as a black box that yields dubious small sample properties in Monte Carlo experiments. In particular, coefficient bias of 15 percent or more, over-rejection of the true null hypothesis, and others (Hsiao *et al.*, 2001).

TABLE 1

VARIABLES OF INTEREST AND DATA SOURCES

Infrastructure System	Variable of Interest	Data Source
Telecommunications	Volume: Telephone main lines connected to local exchanges per thousand inhabitants. Quality: Cross-country sample: unsuccessful local calls (% of total); Panel sample: waiting time, in years, for installation of main lines.	International Telecommunications Union (1994). World Telecommunications Development Report. Canning (1998)
Energy	Volume: Electricity generating capacity in kilowatts per thousand inhabitants. Quality: Electric power transmission and distribution losses as percentage of total output.	United Nations Energy Statistics Yearbook (1991). World Development Indicators, World Bank (1997). Canning (1998)
Roads	Volume: Paved road length in kilometers as a ratio of the country's area in squared kilometers. Quality: Percentage of non-paved road network in kilometers in relation to paved roads.	International Road Transport Union. World Transport Data. International Roads Federation (IRF). World Road Statistics. Canning (1998)
Railways	Volume: Railroad length in kilometers as a ratio of the country's area in squared kilometers Quality: Percentage of non-diesel locomotives.	World Bank Railways Database (World Bank, 1997). World Development Indicators, World Bank (1997).

approach is explicitly assumed throughout this research and loosely follows the work by Canning (1998).[5] Exact definitions and data sources are shown in Table 1.[6] The following broad categories are used: (i) telecommunications; (ii) energy; (iii) roads; and (iv) railways. The volume broad category in telecommunications is the number of telephone main lines connected to local exchanges. The quality broad category is the percentage of unsuccessful local calls in the case of our cross-section sample, and the waiting time for telephones in the panel case. The volume indicator in the energy category is the electricity generating capacity while the quality indicator is the transmission and distribution losses of electric-

[5]We use normalized physical units for equivalent monetary measures are difficult to obtain (Canning, 1998).

[6]The countries included are (i) Industrial: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States; (ii) East Asia and the Pacific: China, Fiji, Hong Kong, Indonesia, Malaysia, Philippines, Singapore, Taiwan, Thailand; (iii) Eastern Europe and Central Asia: Bulgaria, Czech Republic, Hungary, Poland, Russian Federation; (iv) Latin America: Argentina, Barbados, Bahamas, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela; (v) Middle East and North Africa: Algeria, Egypt, Iran, Iraq, Israel, Jordan, Tunisia, Turkey; (vi) South Asia: Botswana, India, Nepal, Pakistan, Sri Lanka; (vii) Sub-Saharan Africa: Bangladesh, Central African Republic, Cameroon, Chad, Congo, Cote d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mauritania, Mauritius, Morocco, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe.

ity. With respect to roads, the quantity category is the total road network, while the quality indicator is the percentage of non-paved road network.[7] Likewise, the quantity broad category in railways is length of railroad lines open to the public while the quality broad category is percentage of non-diesel locomotives.[8]

Notice that the higher the measure of any broad category of infrastructure volume, the higher the quantity of the corresponding stock. However, the higher the measure of any broad category of infrastructure quality, the lower the quality of the corresponding stock. Also, given the high co-linearity between the individual measures of infrastructure stocks and infrastructure quality, we are unable to distinguish the individual effects of each measure when some or all of them are included jointly in regression analysis (Hulten, 1996; Canning, 1998). Hence, we construct composite indices of both quantity and quality of infrastructure in order to capture the corresponding aggregate impact of infrastructure volume and infrastructure quality on income distribution. In order to calculate these composite measures of infrastructure, we use three different methods of aggregation: principal components (Alesina and Perotti, 1996), unobserved components or KKZ henceforth (Kaufmann, Kraay, and Zoido-Lobatón, 2002), and a quartile index aggregation method (Hulten, 1996). In each quantity and quality case, we construct corresponding three-variable indices using the broad categories on telecommunications, energy, and roads mentioned above.[9] An explanation of the three aggregation methods employed follows.

(1) *Principal Components Method*. The method of principal components aims at describing a variable or category with a set of variables of lower dimensionality. Specifically, we create n linear combinations (*principal components*) of the n columns of $X'X$ matrix. All principal components are orthogonal to each other. Note that the first principal component p_1 minimizes the trace of $(X - p_1a_1')'(X - p_1a_1')$, where a_1 is the eigenvector of the $X'X$ matrix associated with the largest eigenvalue. Intuitively, p_1 provides the best linear combination of the columns of X in a least squares sense. On the other hand, the i-th principal component (p_i, with $i > 1$) tries to describe the features of X not captured by p_1 by minimizing: $trace\left[\left(X - \sum_{j=1}^{i} p_j a_j'\right)'\left(X - \sum_{j=1}^{i} p_j a_j'\right)\right]$, with $i = 2, \ldots, n$; where a_j is the eigenvector associated with the j-th largest eigenvalue (Theil, 1973; Alesina and Perotti, 1996). When applying this method we obtain that in the aggregate index of infrastructure the first principal component explains 70 percent of the variance for infrastructure stocks (IK_3) and 60 percent for the quality of infrastructure (IQ_3). In particular, $IK_3 = 0.652*$

[7]These indicators do not reflect width, age, and maintenance of roads (Canning, 1998).

[8]While we also included irrigation measures we decided not to keep it since it is a worrisome indicator for it is only important in a small subset of countries that do not have enough rainfall but do have enough surface water to make irrigation necessary and feasible.

[9]We also construct a four-measure index for each method and case but, although, our results are very similar, our preferred method is the three-measure index as data on non-diesel locomotives, the quality indicator for railways, is very scarce. We would be happy to provide four-measure index results upon request.

(Main Lines) + 0.607*(Power) + 0.454*Roads and IQ_3 = 0.607*(Waiting Years) + 0.596*(Power Losses) + 0.526*(Non-paved Roads).[10]

(2) *Unobserved Components Method*. Following Kaufmann, Kraay, and Zoido-Lobaton (1999, 2001) we use a method which expresses the observed data in each cluster (each group of infrastructure) as a linear function of the unobserved common component of infrastructure, plus a disturbance term capturing perception errors and/or sampling variation in each indicator, as in the previous case, the data is first standardized.

(3) *Quartile Aggregation Index*. According to this method by Hulten (1996) we first sort the normalized individual measures into quartiles. Then, we assign a value for each of the ordered quartiles. A value of 1 is inputted 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. We only take into account averages where information on the four quartiles is present. In general, the correlation between each individual measure of infrastructure stock and infrastructure quality with its corresponding aggregate index is relatively high, typically greater than 0.5.[11] The correlation between the three aggregate indices is very high, too. In fact, the pair-wise correlation among the three aggregate indices of infrastructure stock fluctuates between 0.74 and 0.84, whereas such indices fluctuate between 0.68 and 0.77 in the case of infrastructure quality.

Based on previous empirical research by Li *et al*. (1998), Chong (2004), and several others, the basic controls that are included in our regression analysis are: (i) the log of the GDP per capita; (ii) the growth in GDP per capita; and (iii) the secondary education enrollment rate.[12] Whereas the first two measures are from Summers and Heston (1991) and the World Bank (1998), the latter is from Barro and Lee (1993). 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. Three layers of empirical evidence are introduced. First, we present 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.[13] Third,

[10]For the *four-variable index* we have that the first principal component explains 62 percent of the variance for infrastructure stocks (IK_4) and 56 percent for the quality of infrastructure (IQ_4): IK_4 = 0.562*(Main Lines) + 0.502*(Power) + 0.469*Roads + 0.461*Rails IQ_4 = 0.514* (Waiting Years) + 0.513*(Power Losses) + 0.487*(Non-paved Roads) + 0.486*(Non-diesel Locomotives).

[11]The exception is the correlation between power generating capacity and the KKZ index, which is lower than 0.50.

[12]Reduced forms that explain income distribution typically include GDP in order to capture level of development of the country.

[13]The panel consists of non-overlapping five-year periods spanning the 1960–97 period. Other frequencies were also tested (three-year and four-year). Results are similar and may be provided upon request.

we perform regression analysis for the full sample as well as for the sample of developing countries.

3. Basic Stylized Facts

Table 2 shows basic summary statistics on infrastructure stock and quality based on annual information for the period 1960–97 between the full and the developing countries sample. In fact, it is obvious that there is a considerable gap in infrastructure stock development between developing countries and the world as a whole. Such gap is even more considerable when comparing industrial and developing countries. On average, industrial countries not only have more telephone main lines than developing countries (302 vs. 45 lines per 1000 persons) but also produce more energy per people (1.5 vs. 0.3 GW per 1000 people) and have a longer road network (1.1 vs. 0.3 km per km^2). Also, industrial countries have a higher stock of infrastructure than developing countries regardless of the aggregation method used (e.g. 2.02 vs. –0.54 using principal components, and –0.84 vs. –1.99 using the KKZ method). While the mean of the aggregate index for industrial countries reaches the top of the second quartile (0.47), it reaches the bottom of the second quartile for developing countries (0.27) on average throughout the period. Similarly, there is a longer waiting period for main lines (0.38 vs. 0.03 years), more power losses (12.4 vs. 8.1 percent of power output), more roads in bad condition (70 vs. 27 percent of total roads), and lower quality of locomotives (31 vs. 16 percent of total locomotives).

In Table 3 we present sample correlations between income inequality with both measures of infrastructure stock and infrastructure quality. In general, we find that both types of measures are significantly associated with a more equal distribution of income. On the one hand, all individual and aggregate measures of infrastructure stocks are negatively correlated with the Gini coefficient. Corresponding correlation coefficients fluctuate from –0.35 (roads) to –0.53 (railroads) among individual measures, and from –0.38 (KKZ measure) to –0.55 (principal components) among aggregate measures. As expected, such correlation is negative with respect to the top quintile and positive with respect to the bottom quintile.[14] On the other hand, we find a strong positive correlation between aggregate quality measures and the Gini coefficient. Correlation coefficients range from 0.48 (principal components) to 0.58 (KKZ measure). These findings are consistent with the way our quality measure was defined, that is, the higher the measure yielded by the quality index, the lower the infrastructure quality. Also, improvements in both stock and quality of infrastructure are significantly associated with lower income inequality in developing countries.[15]

[14]Using the four-variable principal components index, the correlation between the Gini coefficient and the overall infrastructure stock is –0.55. On the other hand, the correlation with the top quintile is –0.51 and the correlation with the bottom 20 quintile is 0.33.

[15]The correlation between infrastructure stocks and income inequality tends to be statistically nonsignificant for industrial countries whereas the correlation with infrastructure quality is positive and significant. In fact, the correlation between the composite measure of infrastructure quality and the Gini coefficient is –0.24 and is significant at the 10 percent level, only. It appears that quality improvements in infrastructure are more important in reductions in inequality than stocks in this group.

TABLE 2

DESCRIPTIVE STATISTICS: QUANTITY AND QUALITY OF INFRASTRUCTURE

Series	Obs.	Average	Std. Error	Minimum	Maximum
Quantity of infrastructure					
I. Full sample of countries					
Individual measures					
Main lines (per 1000 people)	3811	96.0861	147.6860	0.1116	691.3079
Energy generating capacity (per 1000 people)	3838	0.5024	0.8058	0.0006	6.3973
Total roads (in km. per sq. km. area)	3698	0.4398	0.7069	0.0022	5.0129
Railroads (in km. per sq. km. area)	3831	0.0205	0.0307	0.0000	0.1789
Aggregate quantity index of infrastructure					
Principal components	3581	0.0000	1.4554	−1.0773	6.4113
KKZ measure	3581	−1.7445	0.7373	−2.5000	2.5000
Quartile index	3581	0.3095	0.1145	0.1667	0.7500
II. Sample of developing countries					
Individual measures					
Main lines (per 1000 people)	3051	44.8500	84.8372	0.1116	621.1455
Energy generating capacity (per 1000 people)	3078	0.2643	0.4759	0.0006	3.9386
Total roads (in km. per sq. km. area)	2938	0.2622	0.5025	0.0022	5.0129
Railroads (in km. per sq. km. area)	3071	0.0127	0.0239	0.0000	0.1789
Aggregate quantity index of infrastructure					
Principal components	2821	−0.5439	0.8527	−1.0773	5.7761
KKZ measure	2821	−1.9890	0.4718	−2.5000	2.5000
Quartile index	2821	0.2669	0.0587	0.1667	0.6667
Quality of infrastructure					
I. Full sample of countries					
Individual measures					
Waiting years for main lines	1860	0.2851	0.3682	0.0000	3.9641
Power losses (as a ratio to output)	2442	0.1104	0.0614	0.0020	0.3934
Non-paved roads (as ratio to total)	3618	0.6099	0.3235	−0.1407	1.0000
Non-diesel locomotives (as a ratio to total)	703	0.2624	0.1600	0.0100	0.8200
Aggregate quantity index of infrastructure					
Principal component	1481	0.0000	1.3384	−2.1064	7.7073
KKZ measure	1481	−1.2496	0.7037	−2.5000	2.5000
Quartile index	1481	0.4120	0.1479	0.1667	0.9167
II. Sample of developing countries					
Individual measures					
Waiting years for main lines	1367	0.3764	0.3890	0.0000	3.9641
Power losses (as a ratio to output)	1682	0.1235	0.0677	0.0020	0.3934
Non-paved roads (as ratio to total)	2858	0.7012	0.2694	−0.1273	1.0000
Non-diesel locomotives (as a ratio to total)	494	0.3053	0.1601	0.0100	0.8200
Aggregate quantity index of infrastructure					
Principal component	988	0.5718	1.2430	−1.9422	7.7073
KKZ measure	988	−0.9601	0.6452	−2.5000	2.5000
Quartile index	988	0.4646	0.1271	0.1667	0.9167

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 1960–97 for each variable and run cross-

TABLE 3

CORRELATION BETWEEN INEQUALITY AND INFRASTRUCTURE MEASURES

	All Countries			Developing Countries		
	Gini	Bottom 20	Top 20	Gini	Bottom 20	Top 20
I. Infrastructure stocks						
1.1. Individual measures						
Main telephone lines	−0.45878	0.2025	−0.4396	−0.2829	0.13604	−0.26812
(per 1000 people)	(0.000)	(0.010)	(0.001)	(0.004)	(0.054)	(0.006)
Energy generating capacity	−0.41819	0.18315	−0.39352	−0.34079	0.23676	−0.30017
(in GW per 100 people)	(0.001)	(0.014)	(0.001)	(0.002)	(0.009)	(0.004)
Total roads	−0.3516	0.2409	−0.36046	−0.22095	0.19578	−0.23953
(in km. per sq. km. area)	(0.001)	(0.005)	(0.001)	(0.010)	(0.019)	(0.010)
Railroads	−0.52529	0.47415	−0.4342	−0.4688	0.49479	−0.33005
(in km. per sq. km. area)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.003)
1.2. Aggregate stock measures						
Principal component	−0.49702	0.24522	−0.47798	−0.3613	0.2677	−0.33235
	(0.000)	(0.005)	(0.000)	(0.002)	(0.007)	(0.003)
KKZ measure	−0.4222	0.23472	−0.4216	−0.23837	0.16495	−0.25351
	(0.001)	(0.006)	(0.001)	(0.008)	(0.034)	(0.008)
Quartile index	−0.45611	0.21463	−0.43036	−0.3114	0.20208	−0.28869
	(0.000)	(0.009)	(0.001)	(0.003)	(0.018)	(0.005)
II. Infrastructure quality						
2.1. Individual measures						
Waiting years for main telephone lines	0.21883	−0.10379	0.26958	−0.01775	0.02205	0.02535
	(0.010)	(0.106)	(0.006)	(0.768)	(0.735)	(0.697)
Power losses	0.22144	−0.14891	0.24582	0.06167	−0.07195	0.06194
(as a ratio to output)	(0.011)	(0.043)	(0.008)	(0.360)	(0.335)	(0.397)
Non-paved roads	0.56232	−0.44648	0.52968	0.48992	−0.4492	0.41941
(as a ratio to total roads)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Non-diesel locomotives	0.41232	−0.3447	0.45105	0.27556	−0.32327	0.30387
(as a ratio to total locomotives)	(0.011)	(0.020)	(0.009)	(0.048)	(0.039)	(0.045)
2.2. Aggregate measures of quality						
Principal component	0.46938	−0.32927	0.51759	0.23571	−0.23203	0.28006
	(0.001)	(0.004)	(0.001)	(0.039)	(0.047)	(0.029)
KKZ measure	0.49987	−0.37532	0.54068	0.33389	−0.31927	0.37414
	(0.001)	(0.002)	(0.001)	(0.016)	(0.021)	(0.013)
Quartile index	0.43184	−0.30283	0.44434	0.264	−0.26605	0.34744
	(0.001)	(0.005)	(0.001)	(0.029)	(0.033)	(0.016)

country regressions in the spirit of Barro (1991). We postulate the following regression equation:

$$y_i = \beta_0 + X_i\beta_1 + S_i\beta_2 + \varepsilon_i \quad (1)$$

where y_i represents the income inequality indicator, as measured by the Gini coefficient, the income share of the top 20 percent of the population, or the bottom 20 percent of the population.[16] Similarly, X_i represents the matrix of basic controls based on previous work by Li *et al.* (1998), Chong (2004) and others. It

[16]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.

TABLE 4

INFRASTRUCTURE AND INCOME INEQUALITY CROSS-COUNTRY OLS REGRESSIONS, 1960–97; AGGREGATE MEASURES OF INFRASTRUCTURE QUALITY AND QUANTITY DEPENDENT VARIABLE: GINI COEFFICIENT

	All Countries			Developing Countries		
	Principal Component	KKZ Index	Quartile Index	Principal Component	KKZ Index	Quartile Index
Constant	37.4628**	58.7002**	44.6824**	28.1546**	46.3498**	40.8482**
	(18.150)	(13.986)	(13.456)	(20.874)	(18.425)	(17.116)
GDP per capita	0.3952	–1.7755	–0.9560	1.4590	–0.0317	0.5467
	(2.303)	(1.714)	(1.794)	(2.653)	(2.274)	(2.364)
Growth	–33.0222**	–24.9750**	–47.8764**	–19.6864**	–14.3676**	–33.1670**
	(6.791)	(6.223)	(6.223)	(7.576)	(6.924)	(7.039)
Schooling	–0.0941*	–0.0251	–0.1202**	–0.2010**	–0.0177*	–0.1860*
	(0.062)	(0.062)	(0.057)	(0.103)	(0.011)	(0.120)
Aggregate index of infrastructure						
Stock	–3.2065**	–1.8835	–30.6819**	–4.9052**	–1.9953**	–57.5036**
	(1.222)	(1.553)	(9.547)	(2.465)	(0.851)	(20.068)
Quality	2.0584*	6.1912**	29.1970**	1.6990**	6.8400**	27.9748**
	(1.118)	(1.651)	(9.366)	(0.306)	(1.927)	(13.298)
Observations	72	72	72	52	52	52
R**2	0.4097	0.4102	0.4215	0.2309	0.2296	0.2496
Adjusted R**2	0.3650	0.3655	0.3777	0.1473	0.1458	0.1661

Notes: *10 percent; **5 percent or higher. Standard errors in parenthesis. Robust coefficients (White, 1980).

includes the level of initial GDP per capita in 1960 in logs, the average annual growth rate of GDP per capita for the period 1960–97 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 three different specifications for equation (1), with changes only in the set of indicators used in the matrix S_i. In Table 4 we present robust OLS cross-country regression analysis for all countries and for developing countries using our different aggregate measures of infrastructure stock and infrastructure quality.[17] We report our regression equations using the Gini coefficient as the dependent variable, and controlling for a group of basic variables (GDP per capita, growth, and schooling), as well as our variables of interest, infrastructure stock and infrastructure quality, as represented by equation (1). The only difference between the regressions within a sample of countries is the method used to aggregate the different individual infrastructure measures, that is, principal components, KKZ method, and quartile index.

Our key findings are as follows. First, there is a negative and significant relationship between infrastructure stock and income inequality, regardless of the

[17]In addition, we also use initial measures of infrastructure stocks and quality in our regression analysis. The use of initial values helps 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 on this approach (Levine, 1999). However, for the sake of completeness, we did produce a set of IV results, which we would be happy to provide upon request. Results are very similar.

aggregation method used and whether the sample includes all the countries or developing countries, only. That is, the larger the stocks of infrastructure, the more equal the distribution of income. Second, there is a positive and significant relationship between infrastructure quality and income inequality regardless of the aggregation method used and sample of countries. In short, the higher the quality of the infrastructure, the more equal the distribution of income. Third, when compared to the full sample, in the case of developing countries the association between income inequality and infrastructure stocks increases, whereas in the case of infrastructure quality such correlation falls slightly. In fact, a one standard deviation increase in the infrastructure stocks is linked with a decrease that fluctuates between −2.7 points (KKZ method) and −6.1 points (principal components). When controlling for quality, such reduction only fluctuates between 1.4 and 4.7 points. Similarly, if the quality of the infrastructure stocks decreases by one standard deviation in any of our aggregate indices, we observe an increase in the Gini coefficient that fluctuates between 3.9 (principal components) and 4.8 points (quartile index). When controlling for stocks, this increase fluctuates between 2.8 and 4.4 points. Likewise, the long-run link between infrastructure stocks on income inequality is larger for developing countries than for the full sample. However, the association of infrastructure quality and inequality yields a smaller coefficient. If infrastructure stocks increase at a similar proportion in developing countries as in the world economy (one standard deviation for the full sample), the Gini coefficient would decrease by 8.7 points (principal components). Similarly, if infrastructure quality decreases by the same proportion as experienced by the world economy, the Gini coefficient would increase by 2.3 points (principal components).[18]

In Table 5 we replicate the same specification as in Table 4 but use individual measures instead of aggregate measures.[19] Notice that while this latter table shows that all infrastructure stocks aggregate indices and infrastructure quality aggregate measures have the expected signs and are, by the most part, statistically significant, the former table shows that the link between income inequality and some individual indicators is not as robust. In fact, although the signs come out as expected some individual broad categories are not statistically significant. In the infrastructure stock individual categories this is true in the case of roads. However, this is not the case of energy generating capacity, railroads, and telephone main lines which, for the most part, do yield a statistically significant relationship with both the Gini coefficient and with the corresponding top and bottom income shares, always with the expected signs. On the other hand, in the case of individual quality measures, waiting period for main lines, power losses, and to some extent, the railways measure, tend to be statistically insignificant. Still, the roads quality measure yields the expected signs and statistically significant relationships with both the Gini coefficient and income shares.

[18]Although not reported, when including infrastructure stock or infrastructure quality measures alone, we obtain similar qualitative results: a negative coefficient for the former and a positive coefficient for the latter, thus, further validating the conjecture that higher infrastructure stocks and quality help reduce income inequality.

[19]We only report the coefficients of our variables of interest. The other controls of equation (1) are omitted. Signs and statistical significance are similar to the previous table.

TABLE 5

INFRASTRUCTURE AND INCOME INEQUALITY CROSS-COUNTRY OLS REGRESSIONS, 1960–97; INDIVIDUAL INFRASTRUCTURE MEASURES DEPENDENT VARIABLE: GINI COEFFICIENT AND INCOME SHARES

	All Countries			Developing Countries		
	Gini	Bottom 20	Top 20	Gini	Bottom 20	Top 20
I. Infrastructure stocks						
1.1. Individual measures						
Telecommunications	–0.03921**	7.224E-0.5**	–0.000392**	–0.0454**	8.382E-05*	0.000477**
	(0.012)	(0.000)	(0.000)	(0.020)	(0.000)	(0.000)
Energy	–3.7646*	0.00652	–0.02627*	–11.04018**	0.02843**	–0.08174**
	(2.251)	(0.006)	(0.017)	(2.945)	(0.010)	(0.023)
Roads	–0.62389	0.00205	–0.01177	–1.09357	0.00435	–0.02286
	(1.142)	(0.002)	(0.009)	(2.258)	(0.005)	(0.019)
Railways	–154.4501**	0.42995**	–1.00097**	–228.5037**	0.61137**	–1.37713**
	(32.651)	(0.094)	(0.382)	(37.022)	(0.071)	(0.680)
1.2. Aggregate stock measures						
Principal component	–3.20653**	0.00541*	–0.02861**	–4.9052**	0.0123**	–0.04684**
	(1.222)	(0.003)	(0.011)	(2.465)	(0.006)	(0.018)
KKZ measure	–1.88354	0.00446	–0.01997*	–1.99532**	0.00558	–0.03248
	(1.553)	(0.003)	(0.012)	(0.851)	(0.007)	(0.027)
Quartile index	–30.68189**	0.05747**	–0.22755**	–57.50359**	0.11109*	–0.47538**
	(9.547)	(0.025)	(0.093)	(20.068)	(0.059)	(0.143)
II. Infrastructure quality						
2.1. Individual measures of quality						
Telecommunications	–1.86548	0.00194	–0.00566	–3.38824	0.00523	–0.0237
	(3.577)	(0.009)	(0.034)	(3.744)	(0.009)	(0.035)
Energy	–0.23497	0.0027	–0.19874	–9.55595	0.03357	–0.2845
	(20.296)	(0.047)	(0.207)	(19.646)	(0.040)	(0.198)
Roads	17.35173**	–0.04194**	0.14158**	20.77771**	–0.04955**	0.15957**
	(3.306)	(0.009)	(0.030)	(3.949)	(0.012)	(0.034)
Railways	7.86081	–0.0233	0.1484**	5.26949	–0.02798	0.12197
	(7.915)	(0.017)	(0.076)	(10.013)	(0.021)	(0.089)
2.2. Aggregate measures of quality						
Principal component	2.05844*	–0.00596*	0.01255	1.698976**	–0.00373	0.00496
	(1.118)	(0.003)	(0.010)	(0.306)	(0.003)	(0.011)
KKZ measure	6.19125**	–0.01553**	0.05693**	6.83999**	–0.01699**	0.0604**
	(1.651)	(0.005)	(0.013)	(1.927)	(0.005)	(0.014)
Quartile index	29.19701**	–0.05691**	0.25845**	27.97479**	–0.05237*	0.2575**
	(9.366)	(0.022)	(0.087)	(13.298)	(0.031)	(0.119)

Notes: *10 percent; **5 percent or higher. Standard errors in parenthesis. Robust coefficients (White, 1980).

For the sake of comparison, Table 5 also includes the findings using the three aggregate measures employed in this paper along with both the Gini coefficient, and income shares as dependent variables. Notice that in most cases, and more so in the case of the full sample rather than in the developing sample case the resulting signs are as expected. In the case of the Gini coefficient this means negative with respect to infrastructure quantity but positive with respect to infrastructure quality. In the case of income shares this means a negative sign with respect to the bottom 20 percent of income shares, and a positive sign with respect to the top 20 percent of income shares. Practically, all the resulting coefficients are statistically significant, with one exception, the quantity approach using the KKZ measure, which is, however, almost weakly statistically significant in the case of the Gini coefficient. The fact that aggregate infrastructure measures tend to be more strongly linked with income inequality is consistent with recent research that shows that bundling in the provision of services is superior than non-bundling provision (Chong, Hentschel, and Saavedra, 2003).[20]

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:[21]

$$y_{i,\tau} = \gamma_0 + y_{i,\tau-1}\phi + X_{i,\tau}\gamma_1 + S_{i,\tau}\gamma_2 + \eta_i + \varepsilon_{i,\tau} \quad (2)$$

where $y_{i,\tau}$ is the income inequality indicator (Gini coefficient, income shares) for country i over the five-year period τ; $y_{i,\tau-1}$ is the lagged income inequality indicator; and $X_{i,\tau}$ and $S_{i,\tau}$ are defined as in the cross-section. In fact, previous panel data research shows that inequality has been highly stable on 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 to the idea that past inequality may be an important predictor of current inequality (Chong, 2004). Using this *AR(1)* approach with fixed effects, the serial correlation problem is corrected. Results are shown in Table 8. We find that the results from the cross-section hold. That is, infrastructure stocks indices have a negative and significant relationship with the Gini coefficient, whereas the infrastructure quality indices have a positive and significant relationship with income inequality, regardless of the aggregation method used and the sample of countries (see Table 6).

If the overall infrastructure stock index for the full sample of countries were to increase by one standard deviation, the Gini coefficient would decrease by 1.7 points over the subsequent 5 years, and by 12.1 points over the next 35 years (using principal components). The result is quantitatively similar if we use the quartile aggregation method, and the increase is smaller if we use the KKZ method (0.7 points over the subsequent 5 years and 4.5 points over the next 35 years). Similarly, an improvement in infrastructure quality by one standard deviation (i.e. a decrease in our composite index by one standard deviation) decreases the Gini by 2.9 point over the next 5 years and 20 points over the subsequent 35 years (using the principal components).

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. A one standard deviation increase in infrastructure stocks would be associated with a drop in the Gini coefficient of 2.4

[20]Lack of data may also be a problem.

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

TABLE 6

INFRASTRUCTURE AND INCOME INEQUALITY, 1960–97; DEPENDENT VARIABLE: GINI COEFFICIENT FIXED EFFECTS *AR(1)* PANEL REGRESSIONS

	All Countries			Developing Countries		
	Principal Component	KKZ Index	Quartile Index	Principal Component	KKZ Index	Quartile Index
Constant	39.1487**	51.0227**	43.3573**	22.9721**	29.2181**	23.8671**
	(7.905)	(6.465)	(6.928)	(9.054)	(8.411)	(8.344)
GDP per capita	0.3776	–0.5461	–0.6049	2.9833	2.5512	2.4362
	(0.985)	(0.807)	(0.848)	(1.990)	(2.061)	(2.068)
Growth	–18.3461**	–11.3418**	–21.7602**	–10.5159**	–9.4829**	–4.4231**
	(3.488)	(3.446)	(4.502)	(4.304)	(4.401)	(2.099)
Schooling	–0.1075**	–0.1350**	–0.0950**	–0.2905**	–0.3098**	–0.2965**
	(0.033)	(0.033)	(0.036)	(0.059)	(0.052)	(0.062)
Aggregate index of infrastructures						
Stock	–1.1669**	–0.9058*	–13.9243**	–1.6635**	–1.1195	–14.4203
	(0.474)	(0.585)	(4.099)	(0.774)	(0.911)	(9.080)
Quality	2.1642**	4.5748**	18.5954**	0.8987	3.8726**	17.8422**
	(0.605)	(0.765)	(3.426)	(0.735)	(1.007)	(5.696)
Gini lagged	0.8592**	0.8524**	0.8419**	0.8493**	0.8455**	0.8347**
	(0.028)	(0.029)	(0.030)	(0.032)	(0.034)	(0.035)
No. countries	72	72	72	52	52	52
Observations	334	334	334	203	203	203
Serial correlation tests (p-value)						
1st order	(0.201)	(0.215)	(0.248)	(0.297)	(0.315)	(0.371)
2nd order	(0.689)	(0.342)	(0.485)	(0.396)	(0.646)	(0.588)
3rd order	(0.763)	(0.672)	(0.896)	(0.490)	(0.899)	(0.765)

Notes: *10 percent; **5 percent or higher. Standard errors in parenthesis.

points over the subsequent five-year period, and by 16.1 over the next 35 years. Also, higher quality in the stocks of infrastructure in this group reduces income inequality by 1.2 points over the following five-year period and by 8 points over the subsequent 35 years (using principal components).

With respect to individual measures, we find that all the stock indicators yield a negative and statistically significant relationship with the Gini coefficient. Furthermore, such individual quantity indicators yield a positive and, almost always, a statistically significant association with respect to the bottom 20 percent income share, and a negative and, always, statistically significant link with respect to the top 20 percent share of income. All this is consistent with the previous results and thus, with the fact that increases in quantity of infrastructure are associated with decreases in income inequality. This is shown in Table 7. Similarly, we find that most individual indicators of infrastructure quality yield, as expected, a positive link with the Gini coefficient. This link is, however, not very robust, as it is statistically not significant in the case of the energy and telecommunications measures. Worse, in some cases, signs become inverted, as is the case of energy and telecommunications in the developing country sample. Still, all the quality aggregate measures yield the expected sign, that is, positive for the Gini coefficient, negative for the bottom 20 percent of income shares, and positive for the top twenty percent of income shares, as well as statistically significance at typically 5 percent or higher.

TABLE 7

INFRASTRUCTURE AND INCOME INEQUALITY, 1960–97; DEPENDENT VARIABLE: GINI COEFFICIENT AND INCOME SHARES FIXED EFFECTS *AR(1)* PANEL REGRESSIONS

	All countries			Developing Countries		
	Gini	Bottom 20	Top 20	Gini	Bottom 20	Top 20
I. Infrastructure stocks						
1.1. Individual measures						
Telecommunications	–0.016649**	3.176E-05**	–0.000122**	–0.020716**	5.214E-05**	–0.000203**
	(0.004)	(0.000)	(0.000)	(0.008)	(0.000)	(0.000)
Energy	–1.402939**	0.0012212	–0.009253**	–3.625526**	0.0094455**	–0.025959**
	(0.435)	(0.001)	(0.004)	(1.227)	(0.004)	(0.011)
Roads	–0.269585	0.0013634*	–0.008702*	–0.445379	0.0024921*	–0.016862**
	(0.452)	(0.001)	(0.005)	(0.674)	(0.001)	(0.007)
Railways	–124.2151**	0.3511967**	–1.066192**	–162.0843**	0.4520345**	–1.312047**
	(20.528)	(0.052)	(0.196)	(43.099)	(0.096)	(0.445)
1.2. Aggregate stock measures						
Principal component	–1.166879**	0.0013392	–0.005868	–1.663536**	0.0041317**	–0.01492**
	(0.474)	(0.001)	(0.005)	(0.774)	(0.002)	(0.008)
KKZ measure	–0.905811*	0.0033132**	–0.002911	–1.119496	0.0039054**	–0.011703
	(0.585)	(0.001)	(0.006)	(0.911)	(0.002)	(0.009)
Quartile index	–13.92431**	0.0194484*	–0.081077**	–14.42027*	0.0073827	–0.116712
	(4.099)	(0.011)	(0.041)	(9.080)	(0.022)	(0.084)
II. Infrastructure quality						
2.1. Individual measures						
Telecommunications	–0.989919	0.000568	0.0063736	–3.289196*	0.0054744	–0.022502
	(1.773)	(0.005)	(0.015)	(1.800)	(0.005)	(0.015)
Energy	5.7302592	–0.032477	0.0167269	–8.42553	0.0085974	–0.107121
	(9.723)	(0.023)	(0.102)	(9.529)	(0.023)	(0.097)
Roads	14.635007**	–0.036217**	0.1146096**	16.439059**	–0.038299**	0.1108451**
	(1.311)	(0.003)	(0.013)	(1.688)	(0.004)	(0.017)
Railways	17.517115**	–0.045225**	0.2428089**	18.253503**	–0.054439**	0.2516075**
	(4.636)	(0.009)	(0.048)	(5.338)	(0.010)	(0.053)
2.2. Aggregate measures of quality						
Principal component	2.1642201**	–0.006651**	0.0244198**	0.8986901	–0.002843*	0.0092028
	(0.605)	(0.002)	(0.006)	(0.735)	(0.002)	(0.007)
KKZ measure	4.574779**	–0.01193**	0.0454283**	3.8726265**	–0.009896**	0.0319519**
	(0.765)	(0.002)	(0.008)	(1.007)	(0.002)	(0.010)
Quartile index	18.595354**	–0.045173**	0.1479574**	17.842224**	–0.052351**	0.2060476**
	(3.426)	(0.009)	(0.039)	(5.696)	(0.013)	(0.052)

Notes: *10 percent; **5 percent or higher. Standard errors in parenthesis.

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. Clearly, this is an important issue as described above (see footnote 3). To minimize this potential problem in this section we apply dynamic panel data GMM-IV techniques (Arellano and Bover, 1995; Blundell and Bond, 1998). 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. 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

TABLE 8

INFRASTRUCTURE AND INCOME INEQUALITY, 1960–97; DEPENDENT VARIABLE: GINI COEFFICIENT FIXED EFFECTS GMM-IV PANEL REGRESSIONS

	All Countries			Developing Countries		
	Principal Component	KKZ Index	Quartile Index	Principal Component	KKZ Index	Quartile Index
Constant	37.0787**	51.3893**	43.1974**	17.5698**	25.4341**	20.5154**
	(7.895)	(6.625)	(6.926)	(8.717)	(8.182)	(7.893)
GDP per capita	0.6727	–0.5153	–0.3340	3.7679	3.2813	3.3109
	(0.984)	(0.833)	(0.847)	(2.744)	(2.533)	(2.428)
Growth	–24.1172**	–15.8393**	–29.8036**	–16.8943**	–4.9477*	–13.7641**
	(8.609)	(7.675)	(12.599)	(7.802)	(2.397)	(6.218)
Schooling	–0.0875**	–0.1227**	–0.0511**	–0.2703**	–0.2918**	–0.2483**
	(0.034)	(0.035)	(0.026)	(0.058)	(0.057)	(0.064)
Aggregate index of infrastructure						
Stack	–1.3830**	–0.9317*	–20.2223**	–1.5085**	–0.6197**	–21.2867**
	(0.473)	(0.579)	(3.843)	(0.677)	(0.269)	(8.026)
Quality	2.2868**	4.8060**	18.3428**	0.9860**	4.1050**	15.1177**
	(0.613)	(0.756)	(3.376)	(0.492)	(0.985)	(5.578)
Gini lagged	0.8531**	0.8451**	0.8309**	0.8303**	0.8228**	0.8142**
	(0.033)	(0.034)	(0.036)	(0.041)	(0.044)	(0.045)
No. countries	72	72	72	52	52	52
Observations	292	292	292	181	181	181
Sargan test of overidentifying restrictions						
(p-value)	(0.317)	(0.465)	(0.538)	(0.465)	(0.392)	(5.024)
Serial correlation tests (p-value)						
1st order	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
2nd order	(0.523)	(0.504)	(0.498)	(0.497)	(0.425)	(0.419)
3rd order	(0.799)	(0.777)	(0.784)	(0.657)	(0.694)	(0.702)

Notes: *10 percent; **5 percent or higher. Standard errors in parenthesis.

process. Failure to reject the null hypothesis gives support to the model. The second test examines the hypothesis that the error term $\varepsilon_{i,t}$ 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.

In Table 8 we present GMM-IV dynamic panel results using the methodology of Arellano and Bover (1995) and Blundell and Bond (1998). 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 a positive and significant relationship 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. For instance, in the case of principal components, an increase in infrastructure stocks helps reduce income inequality and, specifically, the Gini coefficient by 2 points in the short-run (i.e. over the next five-year period) and by 11 points in the long-run (i.e. over the subsequent 35 years). Similarly, using the KKZ measure the decrease in the Gini coefficient is 0.7 over the next five years, and 4.4 points in the long-run. On the other hand, quality improvements in the infrastructure stocks generate a reduction in the Gini coefficient of 2.7 point in the next five-year period and of 12.5 points on the subsequent 35 years using the principal components estimation. The other two methods yield similar results.

The impact of infrastructure development on income inequality is only slightly greater in the case of developing countries. For example, using the Hulten quartile method, a one-quartile increase in infrastructure stocks is linked with a reduction in the Gini coefficient of 2.2 points in the short run and of 12 points in the long run. The qualitative results of principal components and the KKZ index are identical. Also, 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. Again, using the quartile method, an improvement in infrastructure quality reduces the Gini coefficient by 1.3 points and 7.8 points in the short run and the long run, respectively. In short, 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 physical infrastructure measures for stocks and quality. 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.

The results are similar when focusing on individual measures. This is shown in Table 9. In fact, as in previous cases, the link between the stock individual measures and the Gini coefficient is, as expected, negative and, for the most part, statistically significant. Similarly, the link using the bottom 20 percent of income shares is positive and the one using the top 20 percent of income shares is negative. Furthermore, the link between individual quality measures and the Gini coefficient is, as expected, positive and statistically significant in all cases. It is negative and statistically significant for all cases using the bottom 20 percent of income shares as the dependent variable, and it is positive and statistically significant in almost all the cases when using the top 20 percent of income shares as the dependent variable.

7. Conclusions

In this paper we showed 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,

TABLE 9

INFRASTRUCTURE AND INCOME INEQUALITY, 1960–97; DEPENDENT VARIABLE: GINI COEFFICIENT AND INCOME SHARES FIXED EFFECTS GMM-IV PANEL REGRESSIONS

	All Countries			Developing Countries		
	Gini	Bottom 20	Top 20	Gini	Bottom 20	Top 20
I. Infrastructure stocks						
1.1. Individual measures						
Telecommunications	−0.022405**	5.041E-05**	−0.000175**	−0.027191**	7.467E-05**	−0.000278**
	(0.004)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Energy	−1.3308**	0.0004	−0.0112**	−3.0671**	0.0056**	−0.0349**
	(0.400)	(0.001)	(0.004)	(1.028)	(0.002)	(0.012)
Roads	−0.1868	0.0016**	−0.0057	0.1579	0.0016*	−0.0106*
	(0.432)	(0.001)	(0.005)	(0.452)	(0.001)	(0.006)
Railways	−104.6905**	0.2929**	−1.0466**	−140.0932**	0.4655*	−1.9126*
	(22.433)	(0.058)	(0.201)	(68.958)	(0.254)	(1.084)
1.2. Aggregate stock measures						
Principal component	−1.3830**	0.0021*	−0.0080*	−1.5085**	0.0039**	−0.0151**
	(0.473)	(0.001)	(0.005)	(0.677)	(0.001)	(0.007)
KKZ measure	−0.9317*	0.0038**	−0.0028*	−0.6197**	0.0033**	−0.0077**
	(0.579)	(0.001)	(0.002)	(0.269)	(0.001)	(0.003)
Quartile index	−20.2223**	0.0388**	−0.1363**	−21.2867**	0.0279*	−0.1928**
	(3.843)	(0.010)	(0.040)	(8.026)	(0.018)	(0.082)
II. Infrastructure quality						
2.1. Individual measures						
Telecommunications	0.345932*	−0.003263*	0.0172528*	−2.274597**	0.0029116	−0.014804
	(0.205)	(0.002)	(0.010)	(0.910)	(0.004)	(0.014)
Energy	2.7913*	−0.0168**	0.0224	−10.8823**	0.0215	−0.1054
	(1.656)	(0.006)	(0.103)	(5.374)	(0.022)	(0.094)
Roads	13.6658**	−0.0306**	0.1241**	14.8598**	−0.0305**	0.1190**
	(1.317)	(0.003)	(0.013)	(1.656)	(0.004)	(0.017)
Railways	18.3078**	−0.0470**	0.2475**	17.4212**	−0.0510**	0.2425**
	(4.825)	(0.010)	(0.050)	(5.436)	(0.010)	(0.056)
2.2. Aggregate measures of quality						
Principal component	2.2868**	−0.0068**	0.0255**	0.9860**	−0.0028*	0.0099**
	(0.613)	(0.002)	(0.006)	(0.492)	(0.002)	(0.005)
KKZ measure	4.8060**	−0.0121**	0.0484**	4.1050**	−0.0100**	0.0357**
	(0.756)	(0.002)	(0.008)	(0.985)	(0.002)	(0.011)
Quartile index	18.3428**	−0.0448**	0.1472**	15.1177**	−0.0454**	0.1838**
	(3.376)	(0.008)	(0.039)	(5.578)	(0.013)	(0.053)

Notes: *10 percent; **5 percent or higher. Standard errors in parenthesis.

country specific effects, and potential reverse causality problems. Additionally, we showed that the result is very robust to the infrastructure aggregation method employed, be it the principal components measure, the KKZ index, or the Hulten quartile index. Given the fact that most individual measures are highly correlated the use of an aggregation method is a sensible approach. Still, we also tested individual measures and, while not as robust, the overall findings of using these measures are consistent with the aggregate results. Finally, the quantitative link appears to be stronger than the qualitative link, particularly in the case of developing countries.

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