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Benchmarking economic infrastructure efficiency: How does the Latin America and Caribbean region compare?

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ABSTRACT

The Latin America and Caribbean (LAC) region has a sizable infrastructure gap. Physical assets, maintenance, and service provision are inadequate and below average for a region at its level of development. The most promising way to close the service gap is to increase efficiency. Relying on data on more than 80 countries for 2000 and 2016, this paper innovates by 1) developing a single economic infrastructure index to compare countries; 2) presenting an efficiency analysis that assesses whether LAC countries have room for improvement in the provision of the quantity and quality of economic infrastructure; 3) proposing a novel peer-identification conceptual framework to identify which countries are the relevant benchmarks for the region; and 4) providing evidence on how sound governance, regulation, rule of law, and the lack of corruption are related to infrastructure efficiency at the country level.

1. Introduction

The Latin America and Caribbean (LAC) region has a sizable infrastructure gap.[1] Multiple studies conclude that the region needs to invest at least 5 percent of GDP in infrastructure over a prolonged period to close this gap (Bhattacharya et al., 2012; Calderón and Servén, 2003; Perrotti and Sánchez, 2011). LAC countries have invested an average of 3.5 percent of their annual GDP in infrastructure since 2008 (see Fig. 1). If the estimates are correct, LAC requires additional infrastructure investment of 2.0–2.5 percent of GDP or $120 to $150 billion a year (based on 2013 GDP figures).

According to the World Economic Forum's survey (WEF, 2018) of perceptions of infrastructure quality, the quality of infrastructure in LAC lags that of advanced economies and fast-growing Asian economies. Even worse, the quality gap with Sub-Saharan Africa is shrinking: Africa's quality indicators may soon match or even surpass those of LAC (Serebrisky et al., 2015). Lack of physical assets, inadequate maintenance, and poor provision of infrastructure services explain the perception that infrastructure services in the region are of low quality (Serebrisky et al., 2017).

Infrastructure in the region is less developed than it should be given the region's income level, adversely affecting the quality of life and competitiveness. Investment is insufficient, and the quality of services is low (Cerra et al., 2016). Most countries in the region score lower on infrastructure quality than expected given their level of per capita income.[2] The International Monetary Fund (IMF) developed country-specific benchmarks for the region's six largest economies (Argentina, Brazil, Chile, Colombia, Mexico, and Peru) by identifying the top five competitors for each of the top five export products in each country. The results show that Chile is the only country in LAC-6 with infrastructure that can compete with that of its trading rivals. And even in Chile, the competitiveness of its exports declined between 2008 and 2015 (IMF, 2016).

A simple way forward for the LAC region to close its infrastructure gap would be to invest more. However, in the last several decades, infrastructure investment has not increased to the level compatible with closing the gap. LAC has tried to overcome low levels of public investment in infrastructure fostering private investment. Ongoing policy reforms since the mid-1990s increased private sector investment from a negligible amount to one percent of GDP by 2015. Despite the increase, private investment has not constituted the “game changer” and the public sector still accounts for more than two-thirds of total investment

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[1] The most common approach to measuring the infrastructure gap is in terms of needs with respect to meeting a target economic growth rate, achieving a specific objective such as a coverage rate, or achieving an infrastructure stock similar to that of another country or group of countries (Serebrisky et al., 2015).

[2] The quality of infrastructure in Argentina, Bolivia, Brazil, Paraguay, and Venezuela is considerably lower than expected given their income levels. Guatemala, Panama, and El Salvador have better-than-expected infrastructure quality, according to the World Economic Forum (2016).

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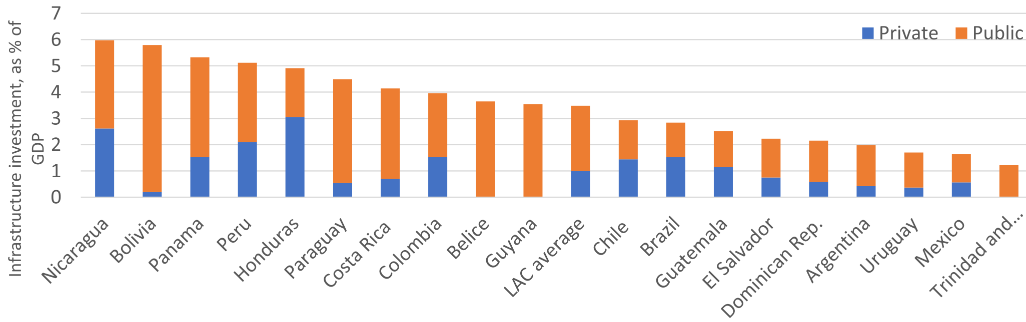

Fig. 1. Average investment in infrastructure as a percentage of GDP in LAC, by country, 2008–15.
Source: www.infralatam.info.
Note: The correlation for the period of analysis between total investment and infrastructure investment is quite low (0.35). While some countries, such as Panama or Nicaragua, show high levels of total and infrastructure investment, others–such as Paraguay (low level of total investment, with a high share spent on infrastructure) or Dominican Republic (high level of total investment, low level of infrastructure investment) are examples that explain the low correlation. As a region, total investment in Latin American was, on average, 22 percent of GDP in the period of analysis, while infrastructure investment reached 3.5 percent of GDP.

in the region (Serebrisky et al., 2017).

The evolution of public investment in LAC indicates that relying on public funding for infrastructure investment can be risky in times of fiscal imbalance. Within LAC, allocations to public infrastructure investment have been cut in times of deteriorating fiscal balances.[3] Moreover, the LAC region is characterized by a bias against capital expenditures in favor of current expenditures. A clear indication of this bias is provided by what happened during the commodities boom in LAC, a period where one would expect to see a strong increase in capital expenditures. In fact, from 2007 to 2014, public expenditure in LAC increased 3.8 percent of GDP but capital expenditure only explained 8 percent of that increase (Cavallo and Serebrisky, 2016).

For every country, the efficiency of infrastructure investment should be a policy priority, yet this is even more important for LAC. Given the low level of fiscal space traditionally allocated to infrastructure, the fact that public investments in infrastructure are highly dependent on the economic cycle, as well as the insufficient level of private investment, the most promising way to close the quantitative and qualitative infrastructure gap in LAC is to increase efficiency.

What do we know about the efficiency of infrastructure provision in LAC? An emergent strand of empirical studies attempts to measure the efficiency of infrastructure in LAC, producing sector-specific analyses, and mainly focused on ports, airports, electricity distribution, water, and sanitation. In the Appendix, Table A1. comprises a sample of recent studies on sector-based efficiency analysis. The evidence shows that the efficiency of service provision in LAC has ample room for improvement.

No study has heretofore addressed the efficiency of infrastructure as a whole in the region. The present paper fills that gap. The ultimate objective is to measure the efficiency by which a country translates its capital stock (the accumulated history of investment) into an indicator that reflects the endowment and quality of its infrastructure. The paper first describes the infrastructure endowment, quality, and capital stock in the region and compares it with other countries to understand where the region stands today and historically. This paper then investigates whether there is room for efficiency improvements and whether such improvements could help close the infrastructure gap in LAC. Frontier analysis is used to measure how efficiently resources are employed to develop infrastructure services. Resources are represented by countries' efforts in the development of infrastructure (proxied by the capital stock to GDP ratio), and infrastructure services are measured by a set of indicators, mainly access to services, weighted by quality.

2. How does Latin America and the Caribbean compare with other regions? developing a single indicator for benchmarking economic infrastructure

The analysis of infrastructure quality and endowment is usually carried out at the sector level. This is explained by sector specificities. The World Economic Forum's survey on perceptions of infrastructure reveals that the quality of infrastructure in LAC is lagging, particularly compared with the developed world (Serebrisky et al., 2017).[4] When it comes to infrastructure endowment, despite low levels of investment, access to infrastructure services improved greatly in LAC between 2000 and 2015. The region still lags the developed world, however, although access levels are higher than in South Asia and Africa. LAC faces the "last-mile connection" problem: universal access to electricity, water, and sanitation has still not been achieved. Access has been a policy priority in the electricity and water sectors although rural areas lag behind. On a country-by-country analysis, we find these access problems are concentrated in a few countries. Moreover, access to the Internet remains a challenge and requires targeted and continuous policy action to make discrete progress towards universal coverage. Regarding transport, the share of the paved road network in LAC experienced almost no change over the last two decades.[5]

[3] Carranza et al. (2014) argue that between 1987 and 1992, a period of financial and fiscal crisis in LAC, " one-third of the improvement in fiscal accounts can be effectively attributed to lower infrastructure investment." Public deficits were reduced to 6 percent of GDP, and public investments in infrastructure diminished to 2 percent of GDP on average, the equivalent of a reduction of more than 60 percent of public infrastructure investment (Serebrisky et al., 2015). Total expenditures in LAC increased by 3.7 percent of GDP between 2007 and 2014, but more than 90 percent of the increase went to current expenditures; only 8 percent was devoted to longer-term investments (Cavallo and Serebrisky, 2016).

[4] While WEF's quality of infrastructure indicator has been criticized–as their results may not be perfectly comparable among economies and the concept of overall infrastructure may be hard to conceptualize by respondents–it constitutes the only source of information for quality assessment in the infrastructure sector worldwide. Future research should explore tailor-made indicators for every sector and subsector.

[5] The transport sector reveals the complexity involved in selecting representative indicators. In the case of roads, this problem is acute. The share of paved roads is weakly correlated with other transport indicators, including the number of containers moved (r = 0.32), kilometers of rail lines (r = 0.37), and the number of air transport passengers (r = 0.40). Other subsectors may be more affected by third-party or indirect users, such as transshipment traffic when it comes to maritime transport, or international passengers in an international hub when it comes to air transport. Following this reasoning, the state

Developing a single indicator that captures the state of infrastructure is difficult because it has to consider not only the access dimension of infrastructure (after all, access is the necessary condition to satisfy the demand for a given service) but also its quality (how users value the services provided). The motivation to have a single indicator that aggregates all economic infrastructure sectors is the possibility of producing cross-country and time-series comparisons that cater to audiences outside the infrastructure sector, such as ministries of finance, who tend to be responsible for allocating public resources to fund infrastructure.

The present paper develops a single indicator for infrastructure services that captures both access (or it can even be interpreted as capturing availability) and quality of services. It is possible to reduce the number of variables while retaining much of the information in the original data, using principal component analysis (PCA) (Jolliffe and Cadima, 2016). PCA is a *multivariate technique that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components* (Abdi and Williams, 2010). This approach allows researchers to identify patterns in data: once these patterns are found, the data can be compressed by reducing the number dimensions without significant loss of information (Andres, 2007).

Through PCA, the information contained in the variables on access to economic infrastructure (electricity, water and sanitation, and the Internet) together with two other supply-oriented variables (electricity generation and the paved road network) are summarized in a single indicator.[6] All of these variables are weighted by the users' perception of infrastructure quality from the WEF data. This infrastructure index accounts for almost 90 percent of the information (see Appendix Table A.3 for estimation results and scores by country).[7] Fig. 2 displays the results of the PCA calculations for 2000 and 2016.

A glance at the infrastructure indicator provides a clear conclusion: LAC is far from the developed world; only South Asia and Sub-Saharan African countries perform worse. Performance improved slightly between 2000 and 2016, but LAC countries remain far from the top and lost some of their advantage relative to South Asian and Sub-Saharan African countries.

It is reasonable to expect that increasing investment in infrastructure should have a positive impact on the indicator as it is likely that both access and quality increase. However, the correlation is far from one. Data on the total capital stock (the sum of historical investment), which is a proxy for infrastructure stock,[8] reveal huge differences across regions (Fig. 3, Panel a) when measured on a per capita basis. These differences narrow once the size of regional economies is accounted for (Fig. 3, Panel b). This finding is consistent with growth accounting exercises that show that the amount of physical capital accumulation (as a share of GDP) in LAC was similar to other regions in GDP relative terms (Cavallo and Powell, 2018).

Countries in different regions allocate similar shares of their resources to their capital stocks, but the assets developed and the quality of services produced by these assets are much lower in LAC than in other regions. Cavallo and Powell (2018) show that overall investment efficiency, defined as the ratio of GDP growth (net of the contribution of raw labor and skills) to the net investment rate, is lower in LAC than in the rest of the world.[9]

The working hypothesis of this paper (confirmed by the data) is that LAC underperforms when it comes to infrastructure efficiency: The region is not making the most of the resources allocated to produce infrastructure services. To test this hypothesis, the next section develops an efficiency frontier using DEA methodology on a sample of 81 countries.

3. Frontier analysis of economic infrastructure efficiency

3.1. Data Envelopment Analysis (DEA)

DEA is a nonparametric, deterministic method that uses mathematical programming techniques to envelop the data as compactly as possible with the aim of building a piece-wise linear frontier. DEA *differs from a simple efficiency ratio in that it accommodates multiple inputs and outputs and provides significant additional information about where efficiency improvements can be achieved and the magnitude of these potential improvements* (Sherman and Zhu, 2006). It does so without the need to know the relative values (prices) of the outputs and inputs, which are needed for the computation of productivity indexes.

This methodology may cover a range of singularities regarding the final model setting, mainly the model orientation and returns to scale. When it comes to model orientation, an input-oriented model implies that efficiency analysis is concerned with minimizing inputs to produce a specific level of output; in an output-oriented model, the objective is to maximize the proportional increase in output while remaining within the production possibility set. Regarding returns to scale, the constant returns to scale model (DEA-CCR, CRS) allows for comparison among units of different size, such that all observed production combinations can be scaled up or down proportionally. The variable returns to scale model (DEA-BCC, VRS) allows for the determination of scale efficiency as the distance between both variable and constant returns to scale frontiers.[10] Fig. 4 shows how DEA works in a one-input, one-output scenario. Two frontiers can be estimated, one assuming constant returns to scale and another assuming variable returns to scale.

(*footnote continued*)
of roads in a country such as Sri Lanka or Panama would be more representative of transport infrastructure services in the country than the number of cargo containers or air transport passengers moved. The share of paved roads is highly correlated with other infrastructure indicators (energy, water, sanitation, and telecommunications), possibly implying that it represents a more appropriate proxy for the overall state of infrastructure services in a country.

[6] Data on electricity generation are from the OECD Dataset on World Energy Balances.

[7] The first PCA component, which explains 90 percent of total variance, is highly correlated with quantity-quality variables, e.g., in 2000: sanitation (0.98), electricity (0.96), water (0.96), telecommunications (0.96), transport (0.86), and electricity generation (0.52).

[8] The total capital stock variable was developed by the IMF (2015). The authors constructed the capital stock indicator from data on general investment (gross fixed capital formation). According to the World Bank, *Gross fixed capital formation (formerly gross domestic fixed investment) includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and roads, railways, schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. According to the 1993 SNA, net acquisitions of valuables are also considered capital formation.* Using a stock dimension avoids the usual huge variations observed in investment. The IMF inventory-based methodology makes it possible to calculate a capital stock variable by considering historical investment and accounting for depreciation. This variable comprises much more than economic infrastructure (investments in energy, telecommunications, transport, water, and sanitation). However, there is no historical and comparable information on investment in infrastructure for a large sample of countries worldwide. There is a strong need to develop stock accounting exercises for infrastructure. However, Appendix Table A.2 shows that the average investment in infrastructure represents about 15 percent of total gross fixed capital formation. Appendix Fig. A1 shows how stable this share has been over time. Therefore, for estimation/calculation purposes, the capital stock may constitute a suitable proxy for the infrastructure stock.

[9] Cavallo and Powell find that a one percentage point increase in investment as a share of GDP increases GDP by about 0.28 percentage points in emerging Asia and by only about 0.20 percentage points in LAC.

[10] In their seminal work, Charnes et al. (1978) assumed constant return to scale, that is, all observed combinations can be scaled up or down proportionally (the DEA-CCR model). Later work (Banker et al., 1984) allowed for variable returns to scale (the DEA-BCC model).

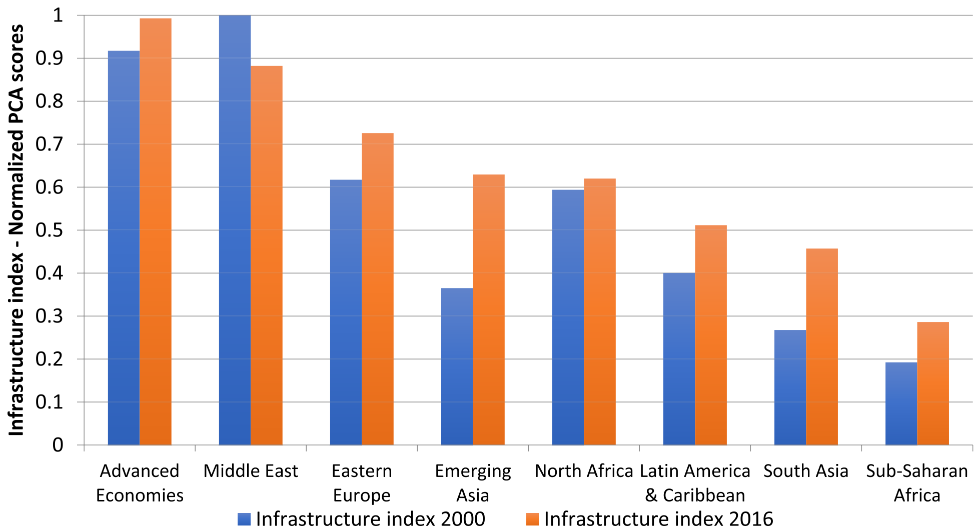

Fig. 2. Infrastructure index by region, 2000 and 2016.
Source: Data from World Bank (2018) and CIA World Factbook.
Note: Infrastructure index shows normalized scores based on PCA results.

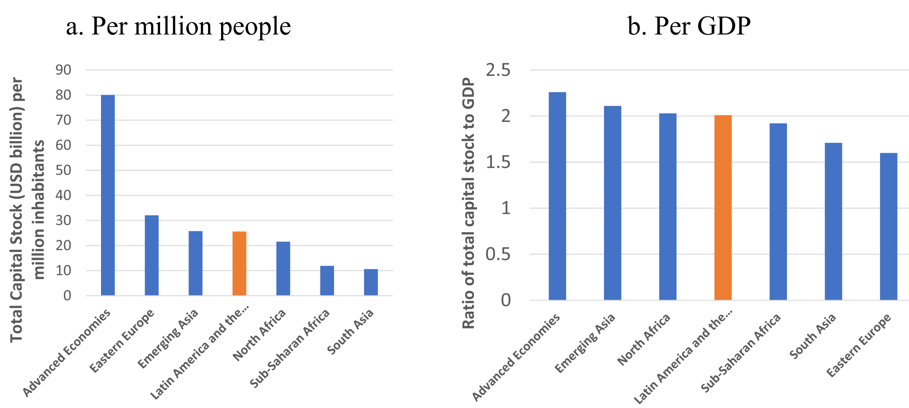

Fig. 3. Total capital stock by region, 2016.
Source: Data from the IMF.

The points A, B, C, D, and E in Fig. X illustrate the observed quantities of input used and output produced by different countries. A is the only point at which a country is efficient under both constant and variable returns to scale. B and C are efficient under variable returns to scale, with B in the region of increasing returns to scale and C in the region of decreasing returns to scale. D and E are inefficient. They could produce more output with the same input quantity. Country E uses quantity R of input x to produce quantity RE of output y (Herrera-Dappe and Suárez-Alemán, 2016).

The vector EE_C measures the distance to the best practice frontier. It can be decomposed into two parts. EE_V corresponds to pure inefficiency; E_VE_C denotes inefficiency caused by the scale of operation (scale inefficiency). Countries A and C form the piecewise linear combination benchmark with which port E is compared. The peers for countries D are B and A. Under constant returns to scale, country A is the benchmark for all the other countries (Herrera-Dappe and Suárez-Alemán, 2016). For a detailed explanation of the DEA mathematical specification see Coelli et al. (2005).

3.2. The efficiency frontier

We develop a production function in which total capital stock (relative to GDP) is used to produce infrastructure services. We use the variable capital stock/GDP to account for varying availability of resources to produce given outputs. By relativizing to GDP, we account for the relative effort of each country and the higher/lower relative costs of developing infrastructure in richer/poorer countries. We rely on Herrera and Pang (2005), who proceed in this way in a study on efficiency in public spending in education across the world (140 countries). In their study, public spending in education is deflated by GDP considering that relative prices and wages are driven by the marginal productivity of labor at the country level. Also, they argue that the elasticity of demand for publicly provided services increases with economic development, as postulated by Wagner's Law on Increasing State Spending. The exercise was also implemented with an alternative measure of capital stock that corresponding to public sector investments exclusively, computed by the IMF (2015) as well. Efficiency frontier results from total capital stock (reported in this paper) and just the public capital stock are highly correlated (0.96).[11]

Infrastructure endowment variables include access to the Internet; access to improved water, electricity, and sanitation; electricity

[11] If the assumption that the total share is stable over time is accepted as valid (see footnote 8 for justification), the different endowment of infrastructure stock among countries is picked up by the DEA (there is a difference in magnitude, but the relative comparison across economies is similar when we account for total stock or infrastructure stock).

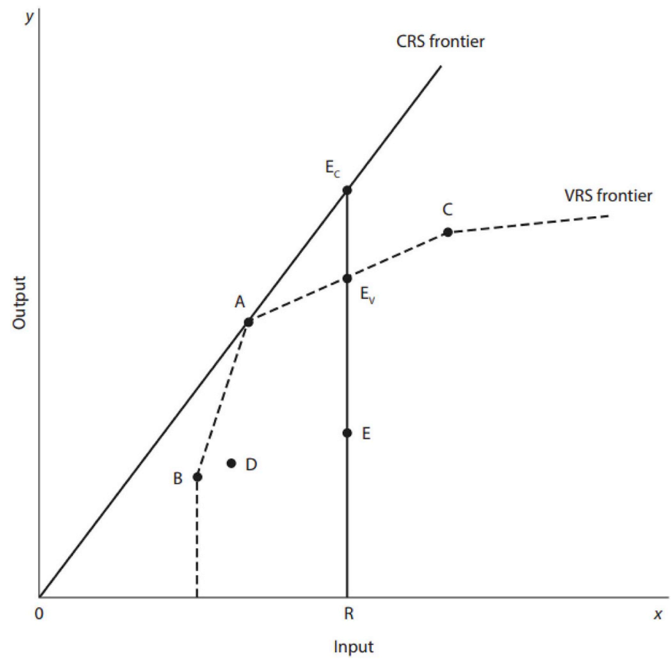

Fig. 4. Data Envelopment Analysis representation – One input, one output. Source: Herrera-Dappe and Suárez-Alemán (2016).

generation per GDP; and the share of paved roads relative to total roads. Since DEA methodology allows for multiple outputs and inputs, this exercise employs as outputs the original variables (that is, the variables that reflect access and endowment of infrastructure from the previous section). It weights all infrastructure outputs by the service quality provided (based on users' quality perceptions).[12] Fig. 5 presents the conceptual framework and input and output variables included in the analysis.

Fig. 6 presents the results of an output-oriented DEA efficiency analysis assuming variable returns to scale.[13] A single infrastructure production frontier for 2016 is computed to benchmark 81 countries against one another. The inclusion of 81 countries is explained by the lack of available and reliable data for other countries. Ideally, this exercise should include as many countries as possible.

As indicated before, the DEA model allows the decision-making units to reach their maximum efficiency using their most favorable weights (Wu et al., 2016). As the selection of weights is free, in many cases it implies output shares equal to 0 or 100 percent. To avoid these extreme cases, in our computations we restrict output shares to a minimum of 10 percent for each of the six economic infrastructure sectors. Therefore, in fact, the model allows the remaining shares (40 percent). This exercise is replicated for a minimum share of 15 percent for each infrastructure output and for non-constrained DEA (free weights). The results are highly correlated (0.91 with the free weights case and 0.99 with the constrained shares at 15 percent), indicating that the restrictions on output shares do not highly affect efficiency scores.

France, Germany, Japan, Moldova,[14] New Zealand, Norway, Switzerland, and the United States are the top performers among the 81 countries included in the sample; Benin, Haiti, and Tanzania are the least efficient. Although there is a positive relationship between income and efficiency, being efficient is not a question of size or scale, as countries such as Moldova are as efficient as countries 90 times larger (United States), 42 times richer (Switzerland), and 3 times denser (Japan).[15] Efficiency frontier analysis using variable returns to scale allows for accounting for the size effect.[16] Going beyond the technicalities of the exercise, in simple terms, being more efficient means making better use of resources to produce good-quality economic infrastructure or in other words, countries that are top performers are those that have more efficient investment in infrastructure. Within LAC, Chile is the best performer but most countries in the region are concentrated in the bottom of the distribution.

Indeed, LAC performs poorly (Fig. 7). The region is on par with South Asian countries. Only Sub-Saharan African countries make worse use of existing resources.

3.3. *Is efficiency improving? Changes between 2000 and 2016*

We were able to collect input and output data back to 2000; to measure progress in efficiency we develop a single intertemporal infrastructure efficiency frontier with input and output data for 2000 and 2016.[17] Fig. 8 presents the results.

Every region experienced an improvement in infrastructure efficiency between 2000 and 2016. LAC improved its average efficiency score by about 25 percent, but it lost competitiveness relative to Asia, and by 2016, South Asia had surpassed LAC.[18]

[12] The WEF data only includes "overall infrastructure," disaggregated data for the transport sectors (roads, railroad, port, and air transport), and electricity supply. Since there is no disaggregated data for every single sector considered, we opted to use the overall value–which refers to every infrastructure sector–and the respondent is supposed to consider all of them when answering. This data limitation should be considered by future research – when available sector-specific quality indicators at the worldwide level.

[13] The choice of specification depends on the conceptual framework and analytical purpose. Results from the DEA-BCC and DEA-CRS models are highly correlated in this exercise (above 0.8).

[14] The case of Moldova is particularly relevant and perfectly exemplifies the relative concept of efficiency. This is a lower middle-income economy, with a scarce population and medium density. When it comes to its capital stock, the country is below the fifth percentile of the sample (only exceeding Azerbaijan, Guinea, and Burundi). Yet electricity access is 100 percent, water access reaches 88.4 percent, sanitation 76.4 percent, Internet 71 percent, and 94 percent of the total road network is paved. On a scale from 1 to 7, quality of infrastructure reaches 3.5. As efficiency is a relative concept–how much you get from what you spend–this country is well placed as it gets considerably good results with very low resources.

[15] Average efficiency was 83 for high-income, 57 for upper-middle-income, 45 for lower-middle-income, and 20 for low-income countries.

[16] Given that all variables are in ratios or percentages, potential scale effects on efficiency are with respect to values these variables take. In the case analyzed here, it is the input value (infrastructure capital stock/GDP) that varies from 1.22 to 3.3 among the LAC countries considered that determines the (increasing, constant, or decreasing) scale of infrastructure production.

[17] Data on the quality of infrastructure have been collected since 2005. *The Global Competitiveness Report* of the World Economic Forum included the following question: *How would you assess general infrastructure (e.g., transport, telephony, and energy) in your country? [1 = extremely underdeveloped/among the worst in the world; 7 = extensive and efficient/among the best in the world]*. The infrastructure endowment for 2000 was then weighted by the reported perceived quality in 2005 (we may assume a lag between when the investment is done and the effect on the provision of good quality infrastructure services).

[18] We implemented a Malmquist decomposition to understand the role of technical progress in the productivity evolution over time. On average, Malmquist decomposition results show that technical progress over the period of analysis has been positive but low (1.6 percent for the 2000–2016 period). Several reasons may explain why this figure is quite low. First, the output in the model specification is defined as the interaction between access and quality of the main infrastructure subsectors. One should expect that the impact of technological changes is much higher on the cost of the provision of infrastructure services rather than in the development of assets – and the construction sector is a low productivity industry as reported in Barbosa et al. (2017). Secondly, with the notable exception of the telecommunications sector, and partly the energy sector, the provision of most infrastructure services in the region has not experienced notable changes over the last two decades. The technical design of road infrastructure in the region remained the same over the

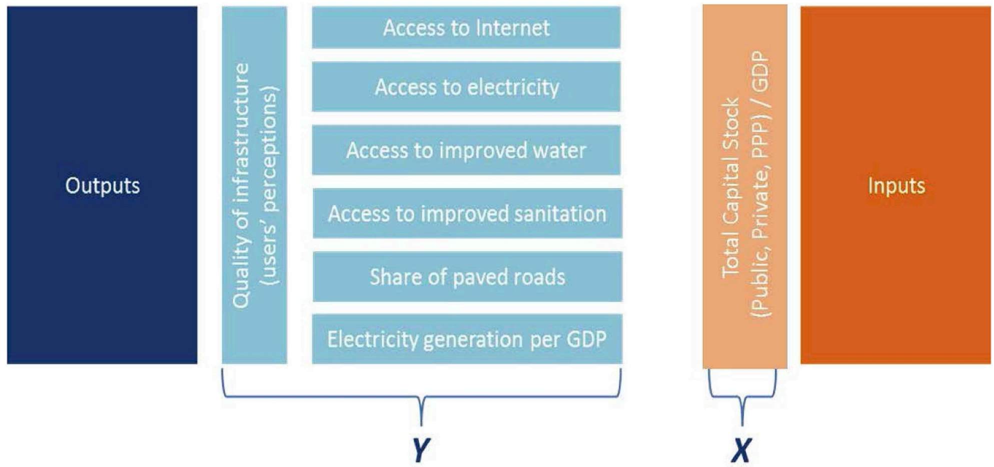

Fig. 5. Conceptual framework of infrastructure efficiency frontier.

The change in the efficiency frontier shows that most countries in LAC improved economic infrastructure efficiency over time (Fig. 9). The exception is Chile, yet it was the most efficient country in the region in 2000.[19] Chile still was so in 2016, but several countries are catching up (most notably Panama). The good news in the region is that countries that were the worst performers in 2000 (Bolivia, Nicaragua, Honduras) made impressive improvements.

The relationship between efficient provision of infrastructure services and total investment is not automatic, although we should expect both variables to move close together. However, how investment and access to infrastructure translate into access and quality of services is a key driver for progress in the efficiency indicator. Bolivia and Ecuador made large investments in infrastructure over the last decade and improved their services.[20] But other countries that experienced large efficiency improvements, such as Guatemala, Honduras, and Nicaragua, did not increase their investment or did it in smaller amounts. Investment in Argentina, Brazil, and Panama decreased from 2008 to 2015, but they became more efficient in the way they produce infrastructure services with their assets (Fig. 10).

4. Learning from best practices

Countries can increase infrastructure efficiency by learning best practices from others and by understanding and enhancing the drivers of performance. They can use efficiency frontier analysis to set targets by benchmarking their performance against the performance of comparable countries that represent best practices.

But which is the relevant country to set benchmarks? The identification of peer groups is crucial for benchmarking. Unfortunately, the literature that has studied the efficiency of investment in infrastructure in LAC has not provided a well-justified answer. It is common to set as aspirational targets Spain and Korea. The former probably due to its historical influence in the region and its remarkable progress in developing infrastructure while the latter is due to its ability to close infrastructure gaps in a very short period. But setting countries to benchmark performance without underlying economic justification can lead to unrealistic expectations. To that end, the identification of homogenous peer groups (*whom to compare with*) is crucial. However, the DEA model does not account for the existing economic constraints for each country to reach a certain level of inputs (amount of total capital stock) or outputs production (high levels of quality and access provision of all infrastructure services). Well aware of this limitation, we combine the traditional DEA peer efficiency analysis with some economic rationality behind the chances of a country to reach a specific peer (a better/top performer).

There are a wide set of country characteristics that influence the ability of a country to provide high-quality infrastructure services. Certainly, many of them are institutional and summarized by lack of planning, insufficient capacity, and skills, weak transparency, or high incidence of corruption. But beyond institutional variables, there are factors that can be objectively measured and in many cases out of the immediate control of a country that allow to divide countries in groups: its economic power (income level), the size of the population it needs to serve (demand), and the economics of scale in providing infrastructure

(*footnote continued*)
last twenty years, and quality improvements have been small and slow (Fay and Morrison, 2006). Studies for the port sector, such as Suárez-Alemán et al. (2016) shows how port productivity growth rates in LAC are explained by pure efficiency changes rather technological changes over the last two decades. When it comes to water provision, there has been almost no significant change over the last decades in the way the region produces (treatment plants) and distributes (traditional pipes) water. Third, when it comes to infrastructure, the literature shows the existence of a lag between technological changes and productivity improvements. As an example, Murray (2015) shows how when electricity became available in the late 1890s factory owners initially replaced their steam engines with large electric motors. Not until 20 years later they develop new factories laid out to take full advantage of the ease with which electrical power can be distributed; doubling productivity. While some sectors have experienced the recent arrival of disruptive technologies (for instance water smart metering, energy efficiency programs, transportation network companies), the full impact on productivity may take some time. Further research should explore the relationship between technology and productivity changes in the region.

[19] The case of Chile is explained by a decline in the perception of infrastructure quality. As the country is the top performer in the Latin America region, with high levels of access since 2000, the fall in the quality perception from 2000 to 2016 strongly affects its relative results. In a way, we could say that this is the "curse" of top performers in efficiency analysis–once you get to the top, a little fall may affect your relative position drastically.

[20] As an example, the progress of Bolivia is well documented. According to Infralatam (2018), a database on investments in economic infrastructure in LAC, Bolivia is the LAC country with the highest investment in infrastructure as a percentage of GDP–close to 9 percent in 2015, far from the regional average (3.5 percent between 2008 and 2015). Also, according to the IMF's Public Investment Management Efficiency Index, Bolivia is placed in the first quartile of most efficient countries, outperforming the world and regional average in each sub-index (appraisal, selection, management, and evaluation) (Dabla-Norris et al., 2012). On a meta-analysis of different indicators regarding planning and project selection, Serebrisky et al. (2018) find that Bolivia is among the strongest countries in the region.

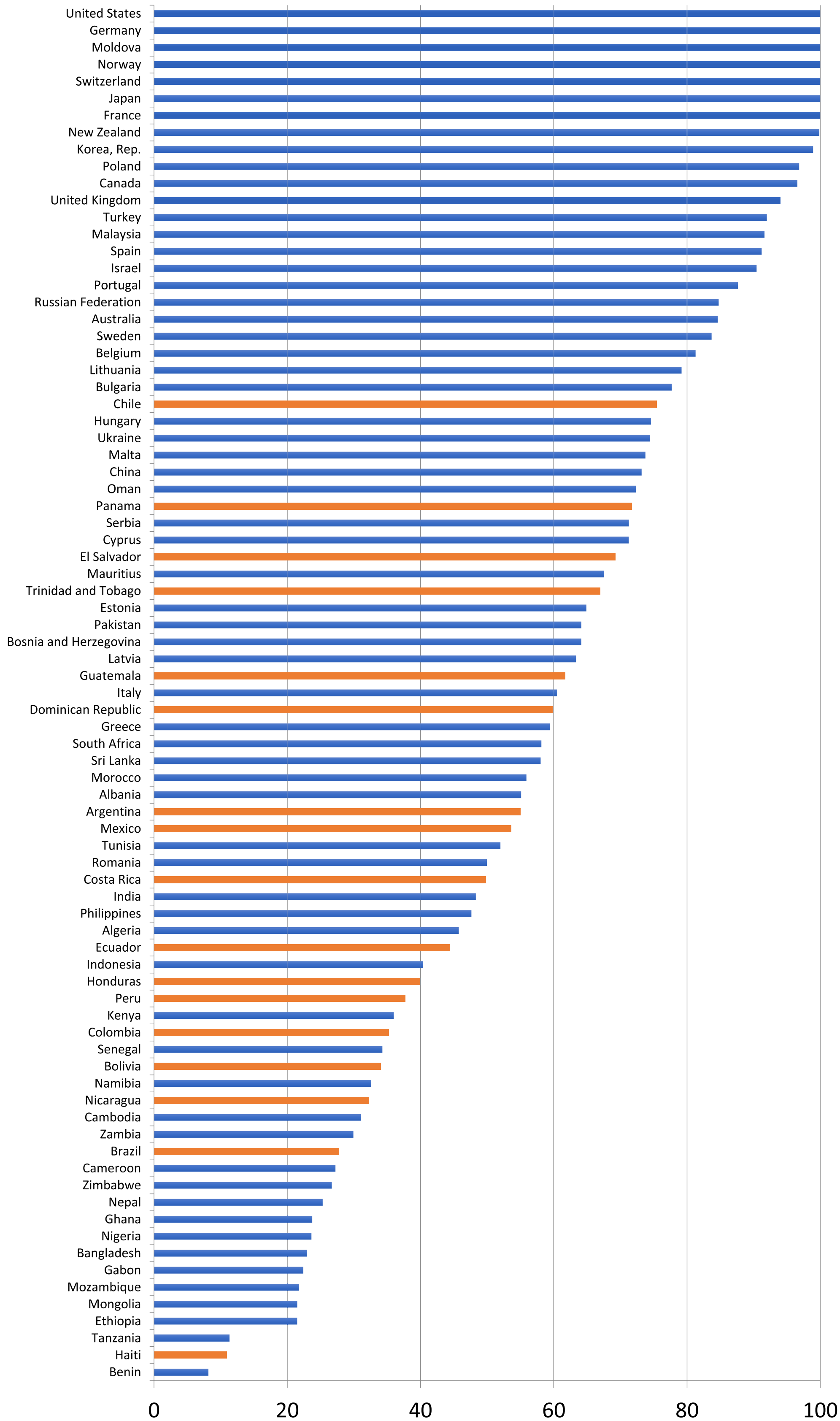

Fig. 6. Estimated infrastructure efficiency of selected countries, 2016.
Source: Data from World Bank, IMF, and CIA World Factbook.
Note: Countries in orange are in LAC.

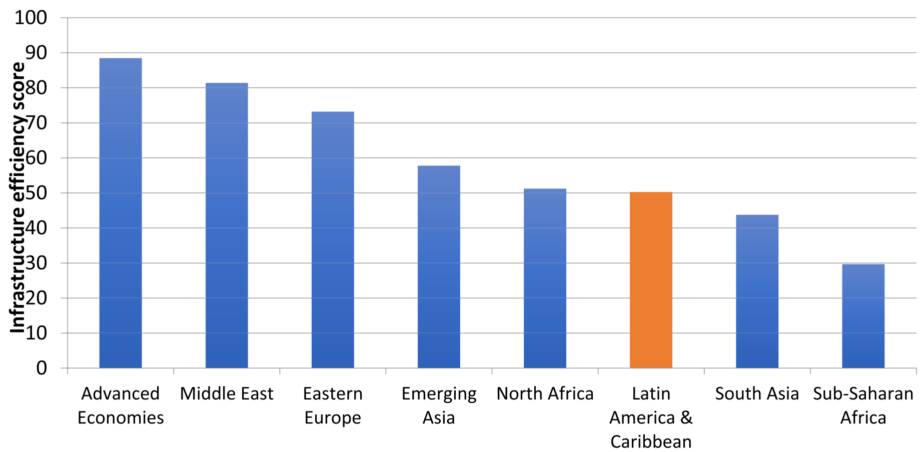

Fig. 7. Estimated infrastructure efficiency by region, 2016.
Source: Data from World Bank, IMF, and CIA World Factbook.

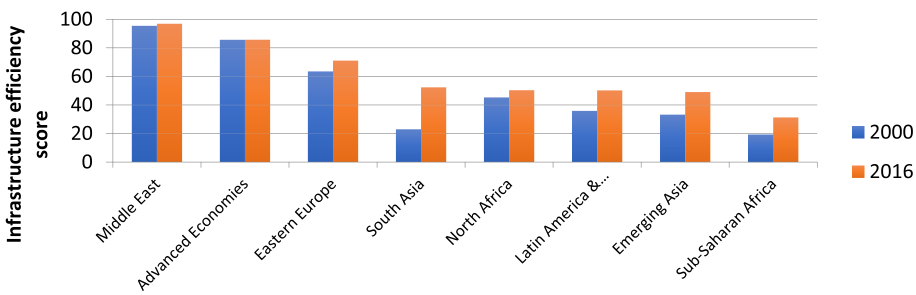

Fig. 8. Estimated infrastructure efficiency by region, 2000 and 2016.
Source: Data from World Bank, IMF, and CIA World Factbook.
Note: Efficiency scores are based on the reduced sample of 52 countries (the balanced panel). The Middle East is the top-performing region because Israel is the only country in the region included in this sample.

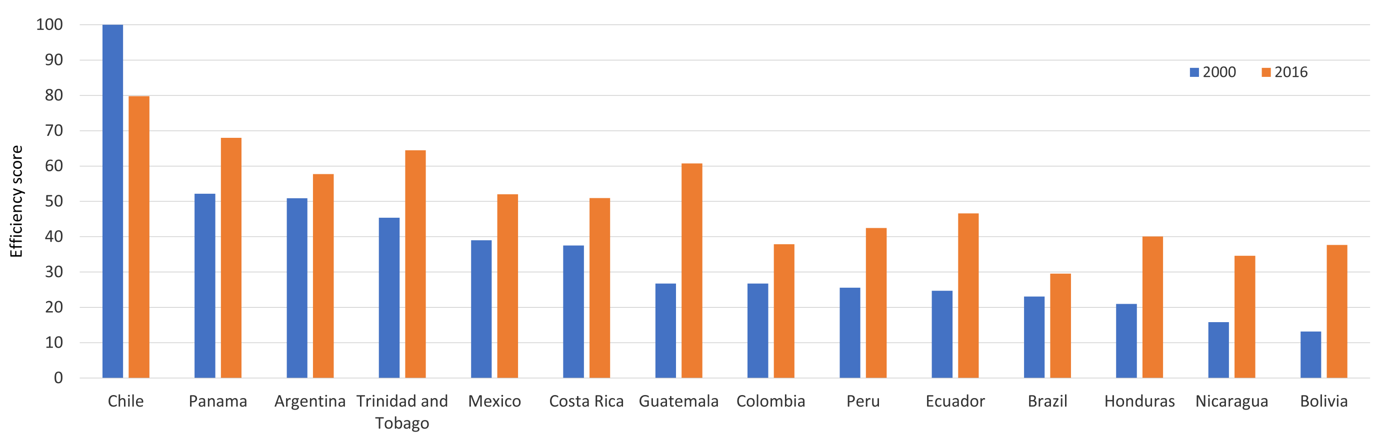

Fig. 9. Estimated infrastructure efficiency by LAC country, 2000 and 2016.
Source: Data from World Bank, IMF, and CIA World Factbook.
Note: Efficiency scores for 2016 are not the same as in the previous section because the frontier here is calculated over the reduced sample of 52 countries.

services, proxied by the density of the population (people per square kilometer). Fig. 11 summarizes the proposed conceptual framework for peer identification. The objective is to group countries as similar as possible in their income level, population, and density, and then place LAC countries within groups and identify countries within or outside the region that can serve as economically reasonable benchmarks/peers.[21]

Following the peer-identification conceptual framework and relying on the 2016 DEA analysis results, Table 1 classifies LAC and most comparable peer countries by income, population, and density.

The results of the benchmarking exercise presented in Table 1 are a first step toward understanding the relative position of each country. Those results need to be complemented with in-depth country analysis. Just to provide an example, let us take the case of Colombia. In terms of

[21] Efficiency frontier analysis may already compare peers. And some techniques such as SFA (not suitable here due to the low number of observations) or even some DEA specifications allow for including our elements (income, population, or density) into the analysis. However, this paper attempts to respond to the need to calculate easy-to-understand and easy-to-replicate efficiency scores not affected by any other variable out of the quantity-quality-stock framework we develop in this exercise. Thus, the efficiency scores keep the essence

(*footnote continued*)
of contrasting inputs and outputs. This ex-post peer framework allows for intuitive country comparisons, but it represents an initial exercise that requires further work. Some potential avenues of research for better comparisons are the development of panel data to develop SFA or the inclusion of the proportion of urban areas by country as an alternative dimension.

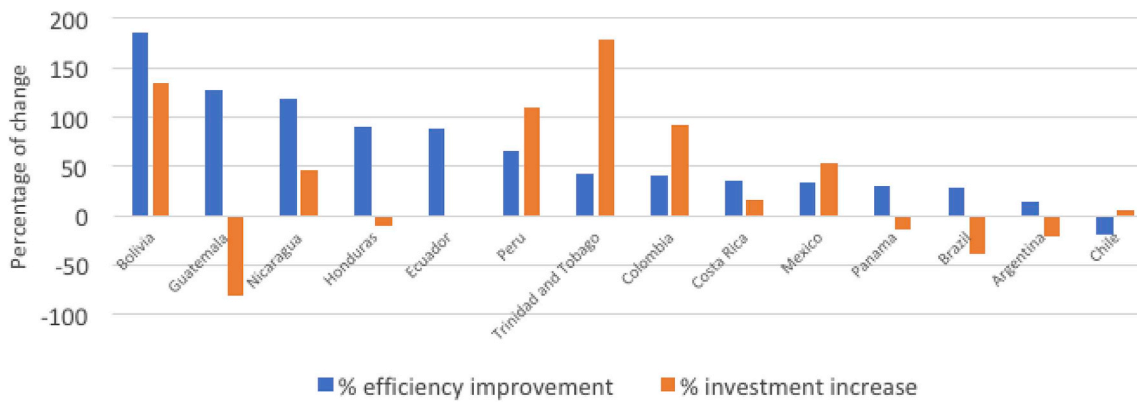

Fig. 10. Changes in infrastructure efficiency and infrastructure investment in Latin America and the Caribbean between 2000 and 2016, by country.
Source: Data from World Bank, IMF, Infralatam, and CIA World Factbook.

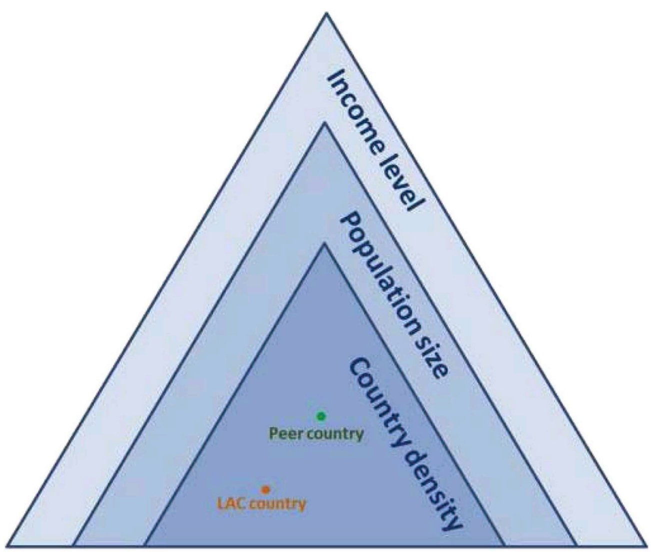

Fig. 11. Peer-identification conceptual framework.
Source: Authors.

making the most of its existing assets, Colombia is lagging behind its regional benchmark, Argentina (35 percent vs. 55 percent). Access levels to infrastructure services, such as electricity, water, sanitation, and the Internet, are considerably lower in Colombia than in the southern cone country – although the quality reported is quite similar in both (about 3 on a 1 to 7 scale). But comparing with the best-performing country in Colombia's peer group (Turkey), we observe how Colombia is lagging not only in terms of access provision–particularly when it comes to paved roads–but also in terms of quality provided (Turkey scored 5 on a 1 to 7 scale), despite allocating a very similar share of its resources to the provision of infrastructure services.

The frontier and peer identification exercise opens up the possibility for policy-based questions to understand what drives the changes in the efficiency of infrastructure investment. We explore some of them. The analysis is preliminary and hopefully motivates additional research.

5. Does better governance and regulation increase infrastructure efficiency?

Are high levels of economic efficiency in the provision of infrastructure services related to high-quality regulation and higher government effectiveness?[22] The Worldwide Governance Indicators project reports governance indicators for more 200 countries over the period 1996–2016. This section uses its data on regulatory quality (based on perceptions of the ability of the government to formulate and implement sound policies and regulations) and government effectiveness (based on *perceptions of the quality of public services, the quality of the civil service/degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies*, Kaufmann et al., 2010).[23] Fig. 12 shows the correlations between these indexes and economic infrastructure efficiency.

Both regulatory quality and government effectiveness are highly correlated with infrastructure efficiency (Fig. 12). The correlations with regulatory quality were 0.78 in 2016 and 0.84 in 2000; the correlations with government effectiveness were 0.79 in 2016 and 0.88 in 2000.[24]

In recent years, the infrastructure sector has been hard hit by corruption, particularly in LAC.[25] Without action, almost $6 trillion a year could be lost to corruption, mismanagement, and inefficiency (World Economic Forum, 2016).

To test the relationship between the rule of law and the control of corruption on infrastructure efficiency, we use data from the Worldwide Governance Indicators project. Rule of law reflects *perceptions of the extent to which agents have confidence in and abide by the rules of society; the quality of contract enforcement, property rights, the police, and the courts; and the likelihood of crime and violence* (Kaufmann et al., 2010). The control of corruption indicator reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, and the "capture" of the state by elites and private interests. Both variables are positively correlated with the infrastructure efficiency indicator (the correlation for the first measures is 0.67 for 2016 and 0.84 for 2000; the correlation for the second measure is 0.71 for 2016 and 0.83 for 2000). These results

[22] For an analysis of the effects of regulation and governance on performance,

(footnote continued)
see Estache and Rossi (2002) and Estache et al. (2004) for electricity; Estache et al. (2002) for transport; Estache and Rossi (2002) for water; and Da Motta and Moreira (2006) for sanitation.

[23] These indicators are based on more than *30 underlying data sources reporting the perceptions of governance of a large number of survey respondents and expert assessments worldwide* (World Economic Forum, 2016). For details on the underlying data sources, the aggregation method, and the interpretation of the indicators, see Kaufmann et al. (2010). Data for 2016 can be found at http://info.worldbank.org/governance/wgi/index.aspx#home.

[24] An important matter for future research is the development of the right policies and instruments to improve infrastructure governance. Some key recent references in this area for the LAC region are Andrés et al. (2013), Fay et al. (2017), and Jaimurzina and Sánchez (2017).

[25] Kenny (2009) reviews the evidence on corruption in infrastructure in transition economies and developing countries.

Table 1
Suggested peers for countries in Latin America and the Caribbean, 2016.[a]
Source: Data from World Bank, IMF, and CIA World Factbook.

Country	Income level[b]	Population size[c]	Density[d]	Efficiency score
Norway	High	Small	Low	100
Australia	High	Small	Very low	85
Sweden	High	Small	Low	84
Chile	High	Small	Low	75
Sweden	High	Small	Low	84
Malta	High	Very small	Very high	74
Cyprus	High	Very small	Medium	71
Trinidad and Tobago	High	Very small	High	67
Russian Federation	Upper middle	Big	Very low	85
China	Upper middle	Huge	Medium	73
Mexico	Upper middle	Big	Low	54
Brazil	Upper middle	Big	Low	28
Turkey	Upper middle	Medium	Medium	92
Malaysia	Upper middle	Medium	Medium	92
South Africa	Upper middle	Medium	Low	58
Argentina	Upper middle	Medium	Low	55
Algeria	Upper middle	Medium	Low	46
Peru	Upper middle	Medium	Low	38
Colombia	Upper middle	Medium	Low	35
Bulgaria	Upper middle	Small	Low	78
Serbia	Upper middle	Small	Medium	71
Dominican Republic	Upper middle	Small	High	60
Romania	Upper middle	Small	Medium	50
Ecuador	Upper middle	Small	Low	44
Mauritius	Upper middle	Very small	High	68
Albania	Upper middle	Very small	Medium	55
Costa Rica	Upper middle	Very small	Medium	50
Panama	Upper middle	Very small	Low	72
Bosnia and Herzegovina	Upper middle	Very small	Low	64
El Salvador	Lower middle	Small	High	69
Guatemala	Lower middle	Small	Medium	62
Sri Lanka	Lower middle	Small	High	58
Honduras	Lower middle	Small	Medium	40
Cambodia	Lower middle	Small	Medium	31
Ghana	Lower middle	Small	Medium	24
Tunisia	Lower middle	Small	Low	52
Bolivia	Lower middle	Small	Very low	34
Senegal	Low	Small	Medium	34
Nepal	Low	Small	High	25
Haiti	Low	Small	High	11

Note: Table shows only categories that include a LAC country. See Appendix Table A.3 for the full list.

[a] Suggested cut-offs for groups of countries included in each box (colors) are defined by considering those countries with the same income and population levels and with identical or very similar (those having the next greater or lesser degree) density level.

[b] Income levels are defined by the World Bank, based on per capita Gross National Income (GNI) in 2015. The cut-offs are as follows: low: $1025 or less; lower-middle: $1026–$4035; upper-middle: $4036–$12,475; high: $12,476 or more.

[c] Population groups are defined as follows: very small: fewer than 5 million people; small: 5–30 million; medium: 30–100 million; big: 100–400 million; huge: more than 1 billion.

[d] Density groups are defined as follows: very low: fewer than 10 people per square kilometer; low: 10–80; medium: 80–200; big: 200–1000; huge: more than 1000 people.

signal potential infrastructure efficiency gains by strengthening the fight against corruption (Fig. 13).

6. Policy implications

Latin American and Caribbean countries are not sufficiently efficient when it comes to the provision of infrastructure services. This constitutes the main conclusion derived from the present study. LAC countries currently present efficiency levels below 50 percent. This means that the region could, in theory, double output (that is, the provision of different economic infrastructure services) with the same resources used today. Our findings also confirm that, faced with the persistently unfulfilled promise of much more investment, the most fruitful way to close the infrastructure services gap in the region today may be to focus on improving the efficiency in the sector.

LAC has worked hard to improve the quality and access to infrastructure services over the past few decades. Differences across subregions and countries are narrowing, as all countries have closed some of the most urgent access gaps, especially in electricity, water, and sanitation. Service provision is still far lower than in other regions, however. LAC performs much worse than advanced economies, and the gap between LAC and emerging economies and South Asian countries is wider than it was two decades ago. The quality of infrastructure services in most LAC countries has declined since 2010 (the Dominican

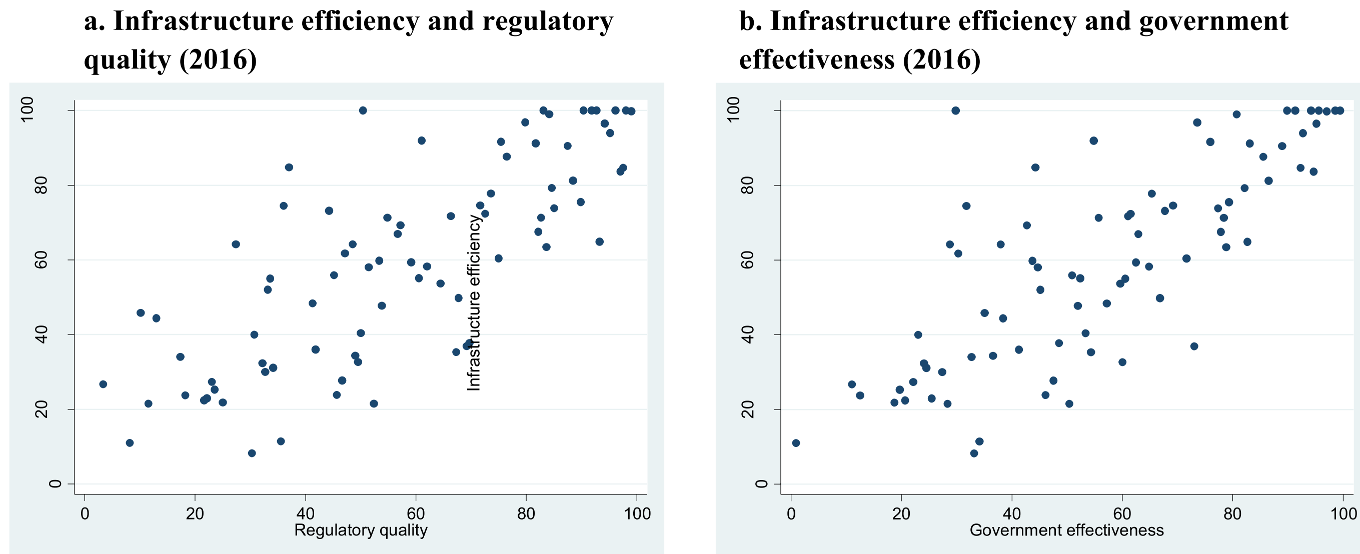

Fig. 12. Correlation between infrastructure efficiency, regulation, and governance indicators.
Source: Data from World Bank, IMF, Kaufmann et al. (2010), and CIA Factbook.

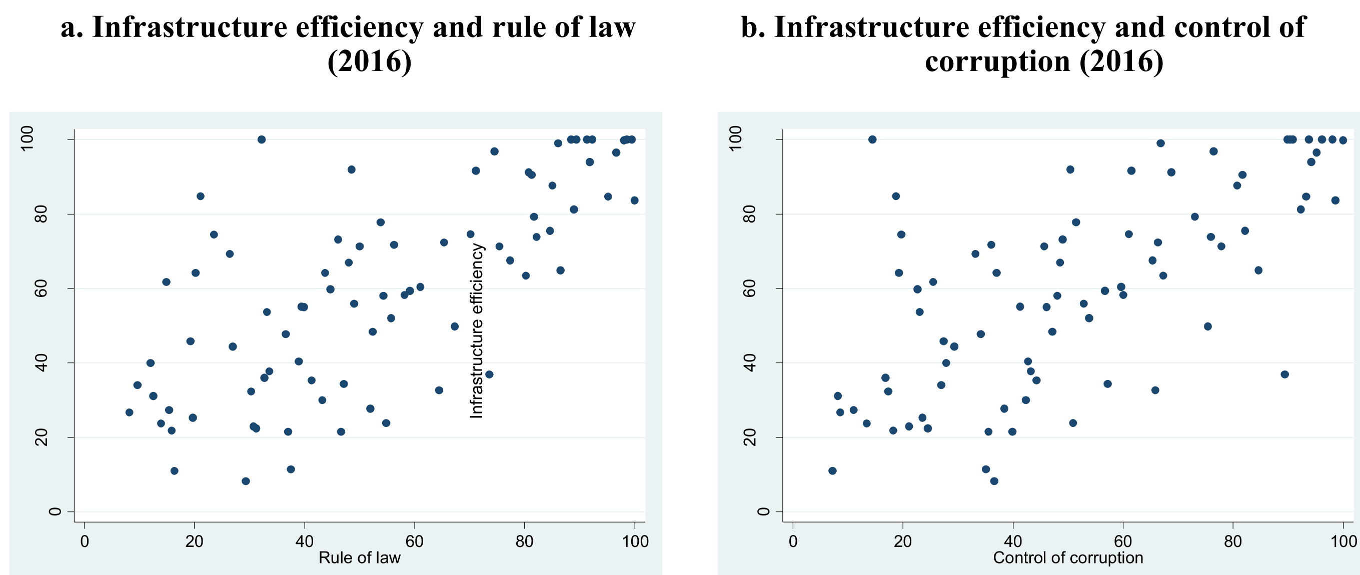

Fig. 13. Correlation between infrastructure efficiency and the rule of law and corruption.
Source: Data from World Bank, IMF, and CIA Factbook.

Republic, Panama, and Mexico are notable exceptions). There are some success stories in the region. Bolivia, Ecuador, and Nicaragua improved efficiency, mainly through massive and effective investment over the last decade. Guatemala and Honduras improved efficiency despite cuts in investment, proving that efficiency is not only a matter of more resources.

How to improve and keep improving necessarily involves learning from others' successful practices. In turn, this requires being able to identify what and who to learn from. In the search of a methodology to identify comparable peers for LAC, we developed a peer identification framework based on income, population, density, and DEA results. This exercise allows us to match up *comparable countries* in a way that LAC countries are able to look at the experiences of other countries facing similar problems and demands for infrastructure services, even though the other countries might be outperforming them in terms of efficiency. In so doing, as an example, Chile may find how Norway or Australia constitute reasonable international peers, while Ecuador might learn from the Bulgarian experience, and Bolivia may gain from the case of Tunisia.

Last but not least, it is useful to recall the role of some "*usual suspects*" as drivers of infrastructure performance in a country, that is, regulatory quality and government effectiveness. Globally, infrastructure efficiency is highly correlated with the ability of governments to develop sound policies and regulations, the quality of policy formulation and implementation, and governments' credibility. Reducing corruption, which remains a formidable problem in the region, is critical to increasing the efficiency of infrastructure. On this matter, our research could constitute a starting point for modeling that quantifies the gains from reducing corruption and improving the regulatory and governance frameworks of the infrastructure sector.

Appendix A

Table A1
A sample of sector-based infrastructure efficiency analysis.

Sector	Paper	Main results
Electricity	Damonte et al. (2012)	Average efficiency scores of 74–93 percent (depending on the methodology used) for 61 electricity distributors in Brazil.
Electricity	Oliveira and Tostes (2017)	Best performance projects of the energy-efficiency program in Brazil's electricity distribution sector was achieved by projects representing five percent of total investments. Top performers were in the industrial and cogeneration categories.
Electricity	Pombo and Taborda (2006)	Efficiency levels of distribution companies in Colombia improved and the efficient distributors, which are the larger utilities, remain on the best practice frontier. Inefficient power distributors remain, however, and they became less efficient after 1995.
Telecom	Llungo-Ortiz (2014)	The author evaluates the efficiency of the telecommunications sector in Latin America at the regional, country, and firm levels. He finds that privatization and technological advances improved service quality, efficiency, and productivity.
Airports	Serebrisky (2012)	LAC airports are less efficient than airports in Asia and North America. The technical efficiency of LAC airports varies widely. Six of the 22 LAC airports in the sample are on the efficiency frontier. On average, LAC airports are 69 percent as efficient as the most efficient airport.
Ports	Suárez-Alemán et al. (2016)	Ports in LAC are far less efficient than the top-performing Chinese ports. They show that private sector participation, the reduction of corruption in the public sector, improvements in liner connectivity, and the existence of multimodal links increase the level of port efficiency in developing regions.
Ports	Serebrisky et al. (2016)	Average technical efficiency of ports in LAC rose from 52 percent in 1999 to 64 percent in 2009.
Airlines	Wanke et al. (2016)	Authors find high levels of efficiency in LAC airlines (75–82 percent). They also report that public ownership is related to higher levels of efficiency in the region, probably because of higher entrance barriers to launching an airline in those countries.
Roads	Braconier et al. (2013)	Authors assess the efficiency of road transport in 32 OECD countries, including Chile and Mexico. They show that efficiency could be improved by 5–25 percent.
Water	Ferro et al. (2011)	LAC average efficiency rates of 42–48 percent.
Water	Bonifaz and Barboza (2014)	Private companies outperform public companies. Inefficiency is positively correlated with firm size and the length of a network. On average, inefficiency adds 32 percent to the costs of Latin American water companies.
Water	Da Silva et al. (2007)	They find no evidence that private firms and public firms differ significantly in terms of efficiency in Brazil.
Water	Ferro et al. (2014)	Authors find that inefficiency in the water and sanitation sectors decreased by 4.9 percent a year in the period of analysis.

Source: authors.

Table A2
Investment in infrastructure as percent of gross fixed capital formation in selected countries in Latin America and the Caribbean

Country	1980–2012		2000–12	
	Average	Standard deviation	Average	Standard deviation
Argentina	20.4	10.3	15.6	5.1
Brazil	20.8	9.2	18.2	6.6
Chile	17.6	8.5	14.5	5.8
Colombia	17.2	5.3	13.5	3.8
Mexico	11.3	4.2	10.5	3.8
Peru	10.4	5.5	15.0	3.3

Source: Data from World Bank (2018) and Calderón and Servén (2003).

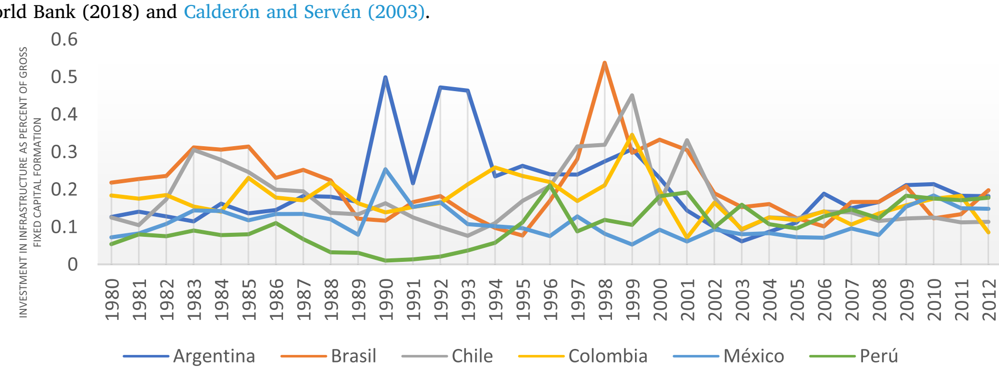

Fig. A.1. Investment in infrastructure as percent of gross fixed capital formation in selected countries in Latin America and the Caribbean.
Source: Data from World Bank (2018) and Calderón and Servén (2003).

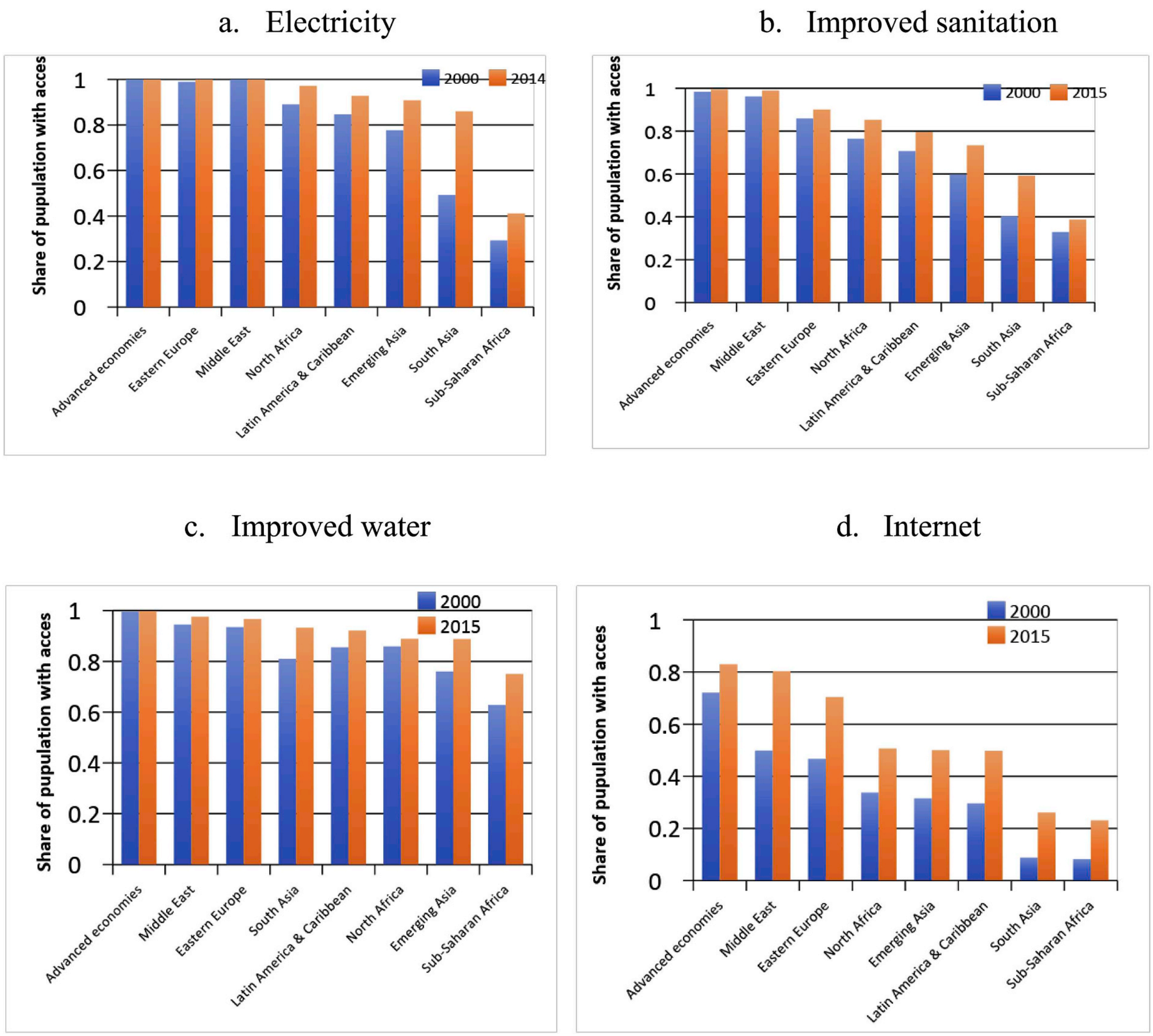

Fig. A2a. Access to infrastructure services by region, 2000 and 2015.
Source: World Bank database.
Note: In panel a, data shown by the orange bars are for the most recent available data (2014 for electricity).

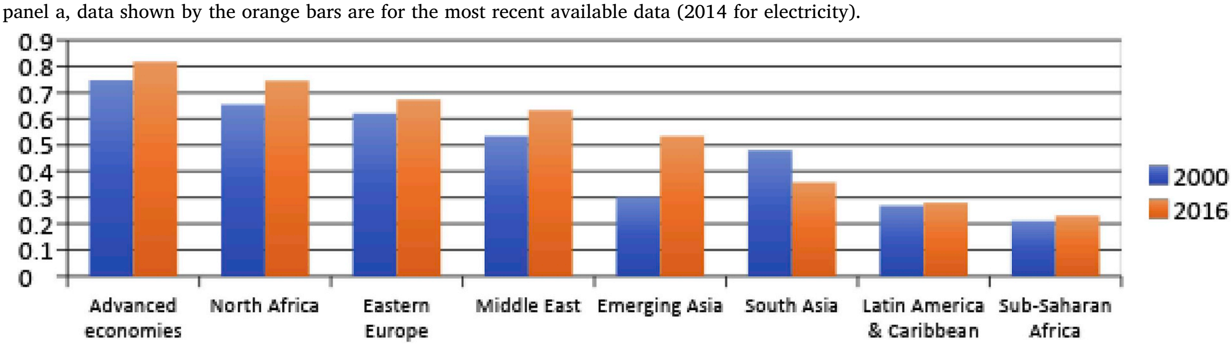

Fig. A2b. Share of paved roads in the road network, by region, 2000 and 2016.
Source: CIA World Factbook data.
Note: Algeria (77 percent) and Tunisia (76 percent) explain the high value of the North Africa region when it comes to paved roads as a share of total roads.

Table A.3
Infrastructure index (results of Principal Component Analysis).

2016 data

```
Principal components/covariance                Number of obs    =        103
                                               Number of comp.  =          1
                                               Trace            =   123229.7
    Rotation: (unrotated = principal)          Rho              =     0.8870
```

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	109308	100170	0.8870	0.8870
Comp2	9137.77	6765.56	0.0742	0.9612
Comp3	2372.22	1069.2	0.0193	0.9804
Comp4	1303.01	194.441	0.0106	0.9910
Comp5	1108.57	.	0.0090	1.0000

Note: Correlations between Comp1 and infrastructure quantity-quality variables are 0.96 (energy), 0.95 (telecom), 0.86 (transport), 0.97 (sanitation), and 0.96 (water).

2000 data

```
Principal components/covariance                Number of obs    =         66
                                               Number of comp.  =          1
                                               Trace            =     134053
    Rotation: (unrotated = principal)          Rho              =     0.9000
```

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	120649	114026	0.9000	0.9000
Comp2	6622.54	2977.19	0.0494	0.9494
Comp3	3645.35	1569.46	0.0272	0.9766
Comp4	2075.89	1015.56	0.0155	0.9921
Comp5	1060.33	.	0.0079	1.0000

PCA normalized results, by country

Country	Normalized PCA score	Country	Normalized PCA score
Switzerland	1.00	Bosnia and Herzegovina	0.43
Japan	0.92	Vietnam	0.43
France	0.91	Serbia	0.42
Germany	0.91	Algeria	0.42
Spain	0.87	Dominican Republic	0.42
Korea, Rep.	0.83	Costa Rica	0.41
United Kingdom	0.83	Guatemala	0.40
Portugal	0.82	Bhutan	0.40
Malaysia	0.81	Indonesia	0.39
Bahrain	0.80	Argentina	0.37
United States	0.80	Honduras	0.37
Belgium	0.79	Pakistan	0.37
Norway	0.76	India	0.36
Sweden	0.73	Philippines	0.35
Canada	0.73	Colombia	0.34
New Zealand	0.71	Brazil	0.32
Lithuania	0.70	Namibia	0.32
Turkey	0.69	Peru	0.31
Australia	0.66	Swaziland	0.31
Seychelles	0.66	Bolivia	0.29
Israel	0.65	Senegal	0.29
Malta	0.65	Paraguay	0.28
Cyprus	0.65	Gambia, The	0.28
Estonia	0.64	Nicaragua	0.28
Mauritius	0.64	Rwanda	0.28
Oman	0.64	Gabon	0.27
Hungary	0.62	Mongolia	0.25
Azerbaijan	0.62	Nepal	0.24
Saudi Arabia	0.62	Cambodia	0.22
Kazakhstan	0.61	Ghana	0.21
Italy	0.60	Bangladesh	0.21
Latvia	0.59	Kenya	0.21
China	0.58	Lesotho	0.21
Trinidad and Tobago	0.57	Zambia	0.20
Poland	0.57	Cameroon	0.20
Chile	0.56	Zimbabwe	0.17
Greece	0.55	Uganda	0.16
Russian Federation	0.55	Malawi	0.16
Panama	0.54	Mali	0.16
Ukraine	0.53	Nigeria	0.15
Sri Lanka	0.53	Mauritania	0.14
Morocco	0.53	Ethiopia	0.14
Bulgaria	0.52	Burundi	0.12
Ecuador	0.50	Benin	0.11
Albania	0.49	Mozambique	0.11
Mexico	0.49	Haiti	0.10
Tunisia	0.48	Liberia	0.10
Moldova	0.48	Tanzania	0.10
Romania	0.45	Guinea	0.09
El Salvador	0.45	Madagascar	0.08
Uruguay	0.44	Sierra Leone	0.07
South Africa	0.43		

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