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Mexico's economic infrastructure: international benchmark and its impact on growth

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Abstract

After much debate, many academic circles have concluded that under the right circumstances, infrastructure stocks may be a promoter for growth. This paper benchmarks Mexico's infrastructure quantity stocks and identifies Mexico's infrastructure bottlenecks in regard to 94 countries. With a sample of annual data from 1960 to 2014, the analysis focuses on three economic sectors—telecommunications, energy and transport—by three exercises: (1) reviewing trends (simple and conditional) from an international perspective, (2) estimating infrastructure's effect on growth with the *generalized method of moments* methodology, and finally, (3) calculating Mexico's infrastructure gap compared to region leaders. The main findings indicate that Mexico's infrastructure stocks were the lowest compared to similar countries in 1990. In 2010, Mexico improved its infrastructure stock provision, but still lags from the world mean. With 6-year average periods, there is statistically significant evidence of a positive effect of infrastructure on growth. Overall, Mexican infrastructure quantity is behind most regional leader's, barely surpassing that of India's.

Keywords: Economic infrastructure, Mexico, Development, Economic growth

JEL Classification: H54, O40, O54

1 Background

The World Economic Forum (WEF), Global Competitiveness Report for 2016–2017 positioned Mexico in the 57th place for the infrastructure category out of 140 countries. In regard to the region, it overperforms Brazil and Argentina (72nd and 85ft place, respectively), but lags from others like Chile (44th place). Its position suggests that the country's development falls within the better half of infrastructure-quality-providing countries, like other BRIC countries—namely China, India and Russia—and Turkey, which has a similar GDP to Mexico. However, it does not necessarily mean that Mexican infrastructure quantity stocks are delivered accordingly. Every year, Mexico spends large amounts of capital on economic infrastructure. Currently, the National Infrastructure Plan is an important driver for the energy, communication and transport sectors as a strategy to enhance the Mexican economy. President Enrique Peña Nieto has promised to spend 7.7 trillion pesos from 2014 to 2018, which would account for an annual

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average of 5.4% of GDP per year in that period, making it one of the largest investments in the Latin American region (Fay et al. 2017).

Since Aschauer's (1989) seminal work, and after many academic debates, it has been stated that under the right conditions, infrastructure may help reduce inequality (Calderón and Servén 2004; Fourie 2006; Leipziger et al. 2003), which in turn could lead to growth promotion (Aschauer 1988; Munnell 1990; Loayza and Oadawara 2010; Calderón and Servén 2008). As a critical component at the core of most public policies, infrastructure is used as a stimulus to activate economies by twofold. On one side, the demand agent conduces to a fiscal multiplier from the government's investment, as an indirect effect. The supply agent, on the other side, originates from the assets' building-capacity for economic growth, which is a direct effect and takes longer than the indirect effect to develop.

Infrastructure is structured by types, sectors, levels and dimensions. There are two types of infrastructure: economic and social infrastructure. The former is segregated into five sectors (telecommunications, energy, transport, water and sanitation, and waste). The latter does not have clear-cut segregation. However, these are driven by social, political and cultural institutions, specifically in sectors like health, education, commercial, housing, and security or defense. Levels refer to the projects' size development—namely municipal, state, national, among others, and dimensions are three: quantity, quality, and access.[1]

This assessment's objective is to verify Mexico's economic infrastructure quantity condition and its effect on growth by following three exercises: (1) address Mexico's provision and trends of stocks by benchmarking with similar regions and industrialized countries in simple and conditional comparisons, (2) empirically estimate infrastructure's effect on growth, and (3) with the infrastructure coefficient estimated in the regression, calculate Mexico's infrastructure gap compared to regional leaders. I consider some of the limitations of previous infrastructure studies: these are (1) a lack or shortage of information, (2) failing to consider an integral variable for infrastructure, (3) failing to address adequate causal relationships, and (4) trend removal in the time series of the individual infrastructure stocks.

Even though there have been massive efforts worldwide to gather data, the first main problem has been data availability.[2] In addition, it is not always consistent. In some cases, it cannot be summed or compared. For example, considering the transport sector, Australia and Spain's National Government Statistics have changed the way they report their roads over time, making the information inconsistent and poor (Estache and Fay 2009; Gramlich 1994). Information gathered at state level and federal level can have different definitions, e.g., rural roads, where regional incumbents are the only ones to recognize them as roads and other government levels do not.

However, even when the definition of infrastructure and measures are standardized, some issues exist—like causality between output and infrastructure stocks. It may be possible for infrastructure to improve real output while simultaneously economic

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[1] For a full definition of infrastructure, and to read more about levels and dimensions, see Cantú (2017).

[2] Some like Canning (1998), Estache and Goicoechea (2005), Perkins (2003), World Bank Development Indicators or national governments have attempted to build databases. However, they become obsolete fast or miss information for other sectors and are very expensive to update.

growth shapes the demand for infrastructure services. Although mentioned by some authors, there is still no clear answer on how to proceed about it (Calderón et al. 2015; Estache and Fay 2009; Gramlich 1994). Endogeneity will cause a bias in the estimation for the infrastructure sectors if not treated for adequately (Aschauer 1989; Munnell 1990).

Another econometric consideration is that the nature of the series for infrastructure stocks presents non-stationarity and tends to drift over time. Some have suggested that to remove the trend, the terms may be specified in first differences, which often yields results showing that the effect of public capital is small, sometimes negative, and generally not statistically significant (Munnell 1992; Gramlich 1994). Besides, first differencing destroys long-term relationship in the data, which is what is trying to be estimated most of the time in the first place. The variables should also be tested for co-integration, and adjusted and estimated accordingly (Munnell 1992). It is important to observe whether they grow together over time and converge their long-run relationship, or in other words, to what extent are they co-integrated (Calderón et al. 2015).

Furthermore, results vary if either investment stocks or physical stocks are considered as proxies for infrastructure variables. Both measures have caveats. Starting with the monetary term, the cost of public investment does not account for the value of public capital (Aschauer 1989), meaning what you buy is not always what you get, or as Pritchett (2000) concludes "… the cost of public infrastructure is not the same increment to public capital…". One reason is that spending does not measure efficiency (Hulten 1996). This issue is presented in Winston (1991) where he reviews the USA' spending on roads with inefficient prices and concludes that investment should be reduced. Some of these inefficiency issues or distinct pricing may be related to possible acts of corruption surrounding the project (Pritchett 1996).

On another note, the spatial characteristic of infrastructure levels may generate a bias on the infrastructure effect due to crowding-out effects from investments (Fedderke and Bogetic 2009). The spatial effect would require other kinds of methodologies like those provided by Anselin (1988) or Elhorst (2010) to estimate. Besides lacking spatial consideration, infrastructure investments also lack a time specification. They take time to show return rates (Calderón et al. 2015) and given the nature and magnitude of many infrastructure projects, which tend to be incubating projects, the investment's impact on growth varies (Pritchett 2000).

Not only that, but capital investment definitions are diverse. They may include different infrastructure sectors and types while also including non-infrastructure industrial, labor, and commercial activities. In the sense that it may consider overall public capital and not just infrastructure capital. Aggregate measures may hide the impact of infrastructure at a disaggregated level (Sánchez-Robles 1998; Fedderke and Bogetic 2009). Finally, since capital stock is not directly observable in a country, infrastructure investments must undergo a perpetual inventory method, which regards issues with the "beginning" and the "end" of the information. To calculate it you need (1) consistent time series data, (2) information on the initial stock and (3) information on the depreciation rate. Estimating the "beginning" or the initial stock of capital makes the methodology change among authors, which makes it inconsistent (Berlemann and Wesselhöft 2014) and, at the "end," it assumes that while capital depreciates, its value never falls to zero.

Physical measures are not perfect either. When Canning built his infrastructure stock dataset, he pointed out that the variables had high correlations among them as a weakness (1998). Moreover, a major concern for both kinds of measures, monetary and physical stocks, is the availability of data, but it is more problematic on the physical stock side, in the sense of variety of stocks. This may result in the use of physical infrastructure variables as flows (like energy consumption, instead of electricity generation at the state level), which build up on the demand side from society instead of the supply side, and will result in erroneous outcomes.

Regardless of the measure used, infrastructure is subject to congestion (Sánchez-Robles 1998) and makes it more complicated to measure any kind of infrastructure outcome. Canning and Pedroni (1999) identify a growth maximizing level of infrastructure, where having resources allocated to another productive sector may outweigh the gain from having more infrastructure. If infrastructure stays below this level, it will generate growth (Calderón and Chong 2004). However, in some developing countries where the infrastructure gap is wide (assuming that the estimation is calculated by a consistent defnition for infrastructure), financing infrastructure is not feasible due to costs or other policy priorities (Straub 2008).

In the end, if available, infrastructure physical stocks are less problematic. The issue with high correlations may be treated with principal component analysis (explained later). The second issue, congestion, may help observe the maximizing level for infrastructure.[3] Finally, the third issue, even though the desirable level of infrastructure may not be feasible to obtain, this assessment compliments knowledge on infrastructure optimal levels, and its impact on economic growth. For these reasons, infrastructure physical stocks are used for the estimation.

2 Infrastructure trends

The sample covers a worldwide unbalanced panel of three infrastructure *quantity* stocks in a yearly basis from 1960 to 2014, which were consistent and had availability for most countries and years: telecommunications, energy and transport.[4] By definition of stocks, the proxy must be able to be measured at a certain time and accumulate from the past. The common and available proxy for infrastructure stocks in telecommunications is fixed and mobile phone lines, electricity generating capacity for energy and number of roads for transport. To assess Mexico's current infrastructure trends, economic quantity stocks are reviewed from two distinct viewpoints. First, a simple cross-country comparison in three periods (1970, 1990 and 2010) is undertaken to evidence Mexico's infrastructure vis-á-vis to a selection of countries and regions.[5] The second, with the infrastructure proxies adjusted by geographic and demographic characteristics, analyzes worldwide infrastructure sector's relation to GDP.[6]

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[3] Not reviewed in this investigation but encouraged to do so.

[4] See Appendix 1 for pooled descriptive statistics.

[5] See Appendix 2 for complete list of regions.

[6] Assessment provides information for 1970 and 2010 due to length purposes.

2.1 Cross-country

The following paragraphs describe three of Mexico's economic infrastructure trends, in three periods—namely 1970, 1990 and 2010, by countries (Brazil, Chile, Argentina, Turkey and South Africa[7]) and regions (Latin America or *LAC*, and a selection of industrialized countries—interchangeably used with "IND"[8]). The telecommunications sector variable is the sum of fixed telephone and mobile lines for every 1000 workers.[9] The source is the World Development Indicators (WDI) from the World Bank. Latest years were manually updated for representative countries by reaching out to governments. Figure 1 presents an overview for telecommunications, with a 20-year gap in between each set. Technology has aided accessibility and affordability, which in turn have contributed to an extraordinary growth in stocks. Mexico depicts only 56 lines for every thousand workers in 1970, and then the sector expands in 2010 to an average of 2.1 lines per person.

In spite of the stock's improvement over time, in 2010 Mexico lags from all comparing countries and regions by presenting the lowest penetration of telecommunication services. LAC presents a median of 2.5 line mixture per worker, which is still 0.4 more than Mexico's figure. On the high end of the spectrum are Argentina, Chile, Turkey, and South Africa who average around the industrialized counties' mean with figures above 3.0 lines per worker. On the other hand, Brazil keeps a lower bound of stocks with 2.3 lines per worker.

For the energy sector, the most accessible way of calculating infrastructure stocks is by the nation's electricity generating capacity, measured by thousand KW per thousand workers.[10] The pooled data present an average of 1.36 and a lower standard deviation than the telecom sector's average of 1.91. Obtained from the U.S. Energy Information Administration (EIA), the data indicate that most countries have shown a gradual increase in the stock over time, except for South Africa, whose electric generating capacity increased in 1990, but then decreased by 0.48. Nonetheless, it still performed an overall-period increase of 0.81 KW by 2010 (see Fig. 2). Chile makes an astounding effort in the last period by increasing its stock from 0.71 to 1.14 thousand KW per worker. That is almost as much as Mexico or Brazil generated in total for 2010, and 0.43 more than the LAC median.

Notwithstanding the gradual increase in electric generating capacity stock in Mexico, it lags from most comparator countries, except Brazil. Still, it displays a performance than LAC, but lacks a substantial amount of stock to resemble the industrialized countries' level. Chile and Turkey increased their figures from 1970 to 2010 to over 1 KW per worker (in thousands). Mexico was unable to increase that amount.

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[7] The former three as Latin American peers, and the latter report current similar gross domestic product per capita in recent years.

[8] Both regions' figure is a median. The region includes the countries in each respective group as listed in Appendix 2, but Latin America and the Caribbean—LAC excludes Argentina, Brazil, Chile and Mexico.

[9] The correlation with population is very high (0.98). This measure is also used by Calderón and Servén (2004) and Sánchez-Robles (1998).

[10] Normalizing energy by workers—which in this case is defined by the total number of people engaged in employment—does not create conflict with informality because Loayza and Rigollini (2006) discuss that informality is countercyclical for most countries in the short run.

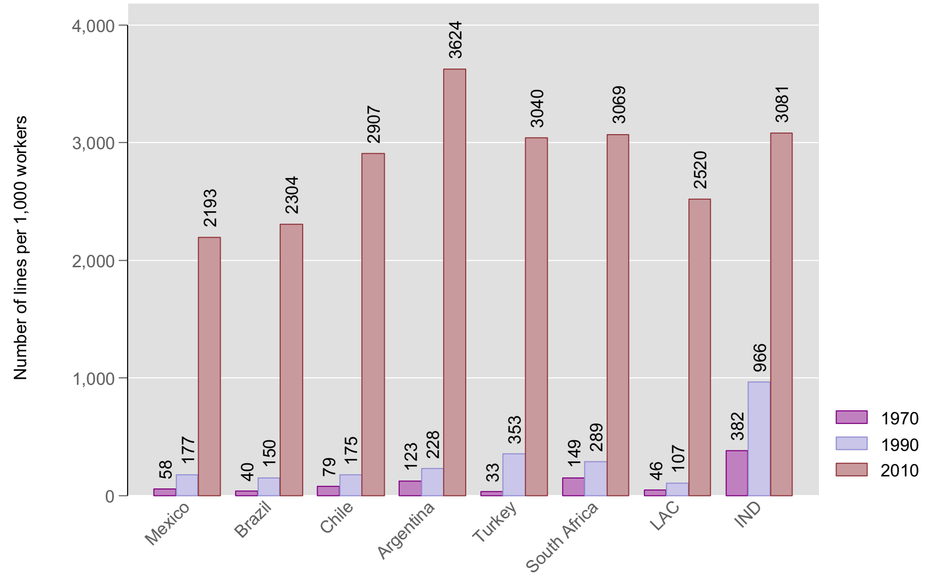

Fig. 1 Overview of telecommunications infrastructure. *Note* LAC region (excludes Mexico, Brazil, Argentina and Chile) and IND report medians *Source:* WDI and author's updates

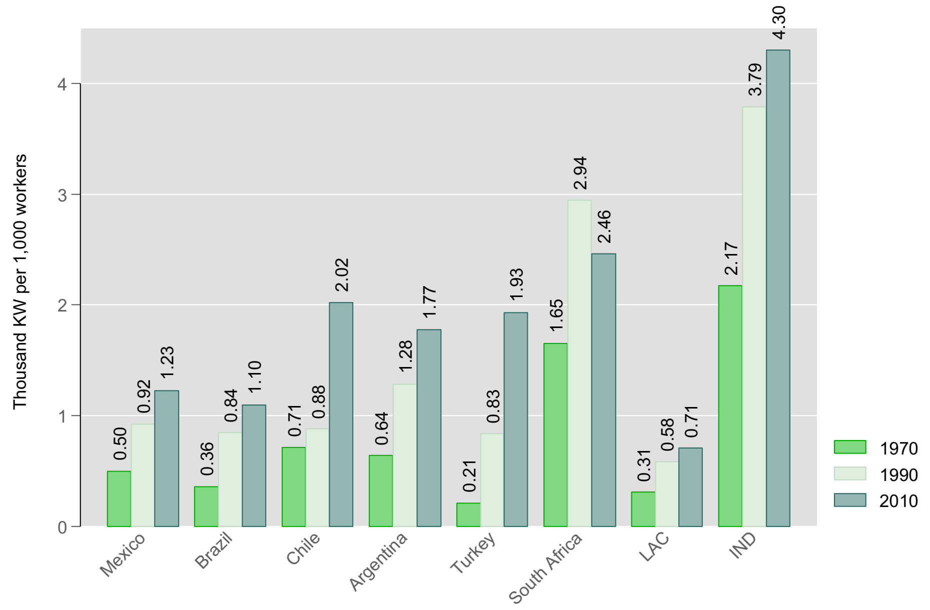

Fig. 2 Overview of energy infrastructure. *Note* LAC region (excludes Mexico, Brazil, Argentina and Chile) and IND report medians *Source:* EIA

From this perspective, Mexico's stock behavior compares to the LAC region: both have an increase in the last period of less than half a point. Mexico presents a 0.31 increase, while LAC lags with a median growth of 0.13. On the contrary, for 2010, the industrialized countries' median is 4.3 KW per worker with a growth of 0.51 in the last period. At that high rate, Mexico's "*catching up*" is not occurring soon. However, it would be more realistic to reach any other of the benchmark country levels. Compared to Mexico's stock of 1.2 KW per worker, South Africa, Turkey, Argentina and Chile present figures of 2.4, 1.9, 1.7 and 2.0 KW per worker, respectively.

Transport infrastructure stocks are measured by total road length in kilometers divided by the country's area. The source is the International Road Federation (IRF) and includes "all roads in a given area," like motorways, highways, main or national roads, secondary or regional roads, and other roads such as rural. Like the telecom sector, some information was missing and it was necessary to reach out to each country's government. In 2010, Mexico surpassed peer comparator countries' road network per area from the LAC region—Brazil, Chile and Argentina,—as the region itself. There was a constant increase for every following period in Mexico (see Fig. 3). However, compared to South Africa,[11] Turkey and IND, Mexico has a considerable gap to close, particularly, with the industrialized countries. Turkey has around 3 times more than Mexico's stock in 2010, and South Africa displays more than double the quantity offered by Mexico in 1990. Moreover, Mexico lags a whopping 1.139 from the median of IND in the last observation. Even though Mexico surpasses the comparator countries in the LAC region, these do not lag much behind. It is a tight situation where some of them, Brazil for example, may level the Mexican 2010 figure quickly.

2.2 Geographic and demographic adjustments

This section adjusts the variables by eliminating the geographic and demographic variances that affect each of the sectors and their correlation to GDP, as done by Canning (1998). Adjusting the variables makes it possible to observe the residual, which remains as simply the variance from the other elements that conform the variable. The partial regressions for each infrastructure stock variable are given by:

$$\ln(z_{1,2,3}) = f(\ln\ (\text{area})),\ \ln\ (\text{population}) \tag{1}$$

where $z_{1,2,3}$ = Each of the infrastructure sectors variables

In this way, they are conditioned to area and population. The component *area* corresponds to each country's land in square kilometers, and *population* corresponds to the number of people living in every country for every year. GDP per capita is adjusted by following the same procedure. It corresponds to Penn World Tables version 8.2, expenditure side of gross domestic product at current PPP per capita. Both residuals are graphed in a scatter plot for 1970 and 2010 to observe the behavior over time.

The signs from the OLS estimation concur with what is expected from the infrastructure sectors (see Table 1). For area, the larger the country's land is, the harder it will be to have higher infrastructure stocks. Hence, all the infrastructure stocks present negative coefficients for area (land), where only telecom and transport are significant. On the contrary, with population, the higher the numbers, the higher the infrastructure stock will be. For all the infrastructure sectors, this coefficient is positive and highly significant.[12] The residuals emit high correlations among themselves in a similar manner to the unadjusted variables (see Appendix 3).

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[11] Latest information available is from 1990.

[12] The signs match Canning's (1998) study for the *population* variable. The signs for *area* only match for the telecom sector.

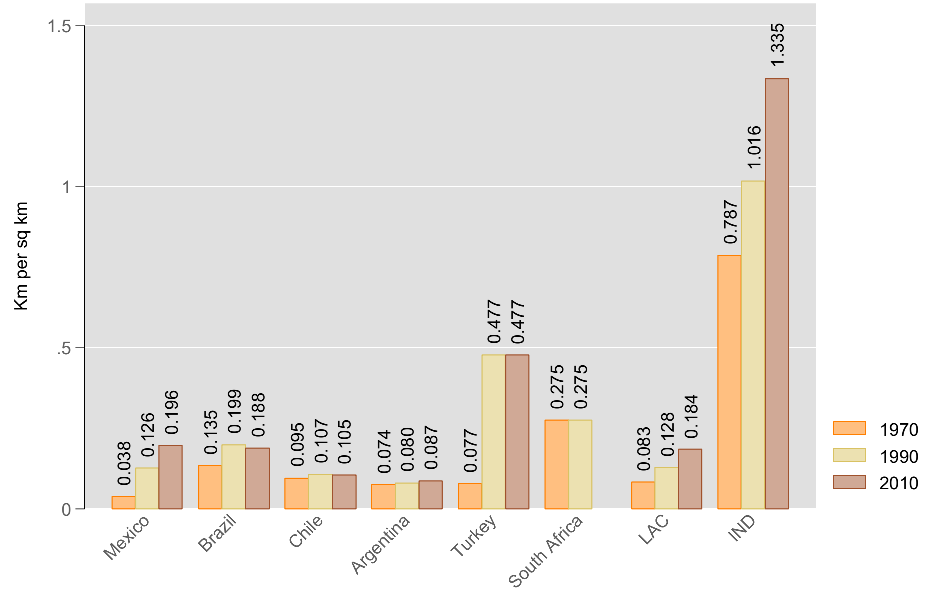


Fig. 3 Overview of transport infrastructure. *Note* LAC region (excludes Mexico, Brazil, Argentina and Chile) and IND report medians *Source:* IRF and author's updates

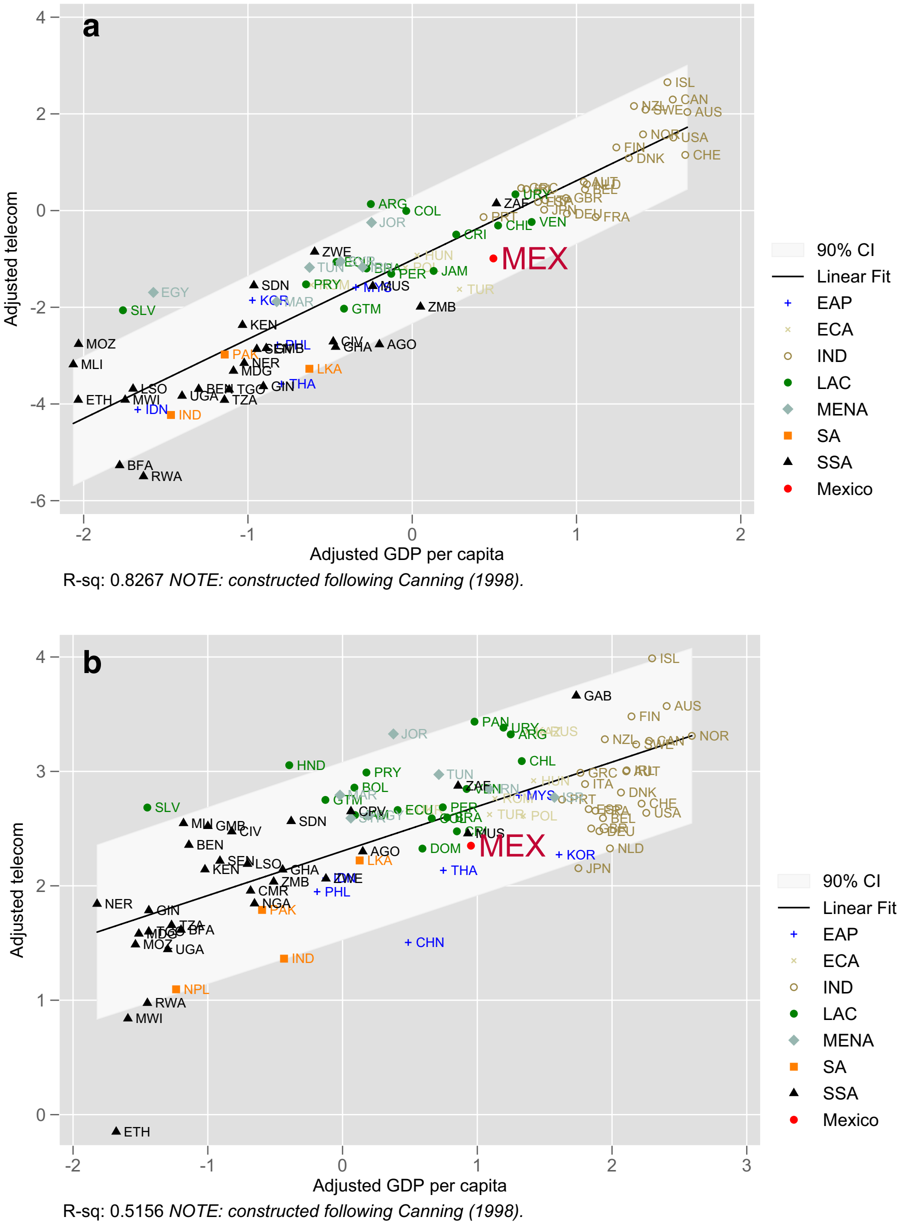
Table 1 Results from regression before acquiring residuals

Dependent variables	Telecommunications (fixed and mobile lines per 1000 workers)	Energy (electricity generating capacity per 1000 workers)	Transport (total kilometers of road network by area)
Log of area	− 0.257*** (0.02)	− 0.034 (0.02)	− 0.800*** (0.01)
Log of population	0.360*** (0.03)	0.141*** (0.02)	0.711*** (0.01)
Constant	4.856*** (0.24)	− 1.699*** (0.19)	1.628*** (0.10)
Observations	4877	4959	4903
R^2	0.0312	0.0097	0.5155

Standard errors in parenthesis

*** Significant at 99%

For telecommunications, the conditional comparison maintains a positive relationship with GDP. However, this correlation has weakened over time, from 0.8 in 1970 to 0.5 in 2010 (see Fig. 4). Telephone and mobiles lines' comparative advantage of accessibility has been declining. Connectivity, such as internet, has substituted the service. Different regions converge in similar areas. Mexico, clustered around the LAC countries, stays below the regression lines for both periods observed and inside the 90% confidence intervals. In 1970, even though Mexico was below the mean, it stood ahead other LAC countries. However, it has drifted slightly from the regression line and other LAC countries—namely Chile, Argentina Panama and Uruguay—have gained advantage. Compared to the industrial countries in the sample, Mexico has been underperforming in the telecom sector. On the other hand, compared to most Sub-Saharan Africa and South Asia, Mexico is better off.



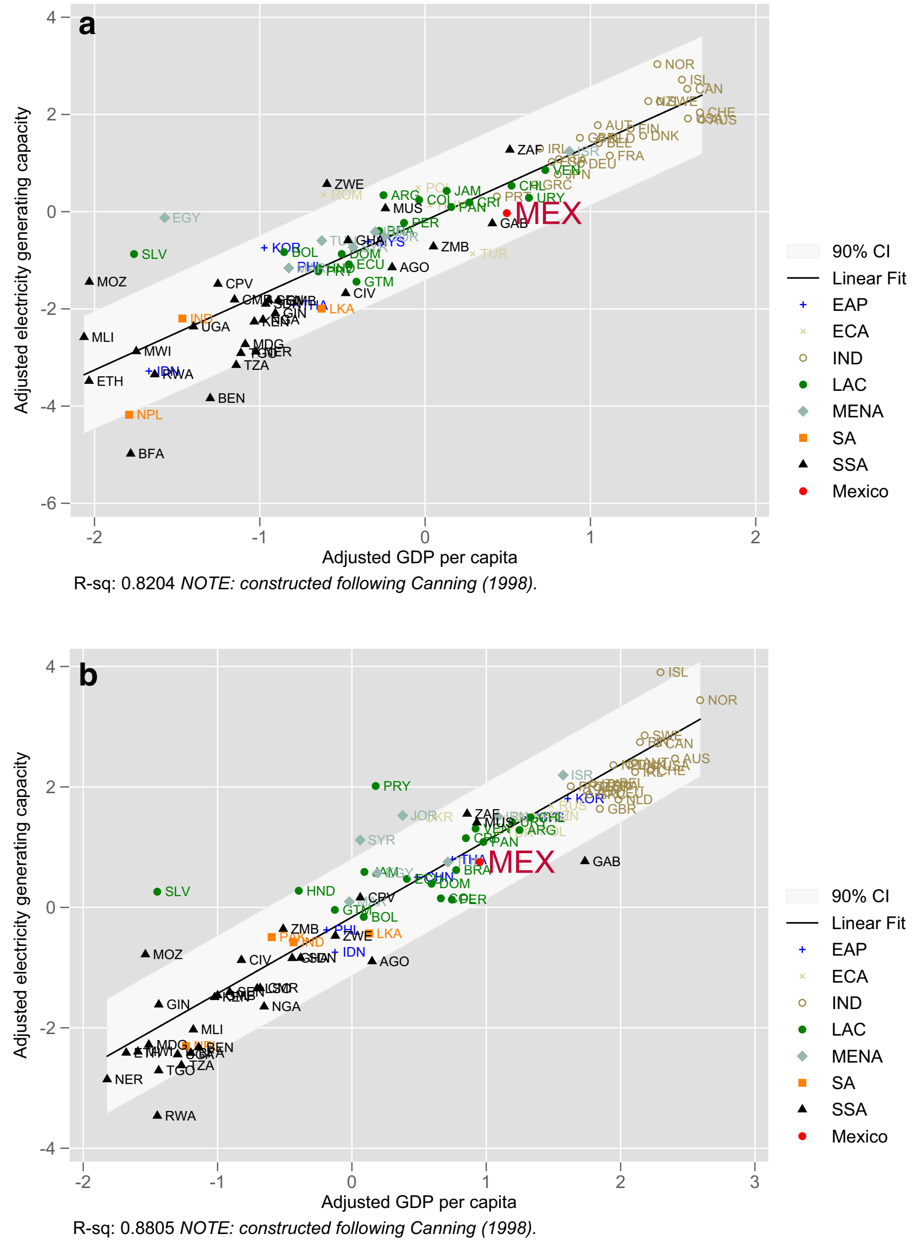
R-sq: 0.8267 *NOTE: constructed following Canning (1998).*

R-sq: 0.5156 *NOTE: constructed following Canning (1998).*

Fig. 4 Adjustments for Telecommunications Infrastructure

The energy infrastructure stocks' behavior is different from telecom's when eliminating the effects caused by population and area of each country (see Fig. 5). The sector exposes a general positive relation and, in contrast, shows a gain in correlation with GDP over time, from 0.82 in 1970 to 0.88 in 2010. Time has exposed the countries to different sources of energy as well as different technologies, keeping electricity as a main source of energy worldwide. Countries' energy stocks are scattered in 1970. In 2010, the countries that lag mostly belong to Sub-Saharan Africa.

Compared to LAC countries, Mexico has a below average electricity stock. A better performing country is Panama, despite having similar adjusted GDP per capita. On the contrary, a LAC country with a lower adjusted GDP per capita is Paraguay, but it has



R-sq: 0.8204 *NOTE: constructed following Canning (1998).*

R-sq: 0.8805 *NOTE: constructed following Canning (1998).*

Fig. 5 Adjustments for Energy Infrastructure

increased the most its electricity generating capacity during the period.[13] Still, Mexico has gotten closer to the world mean over time. On another front, in 1970, Mexico seemed to be following behind the industrialized countries, but in 2010, that gap has widened and now it is nowhere near any of them.

The transport sector displays a different behavior from both the previous sectors. This variable is more heterogeneous among countries. First, considering the adjustments, it is

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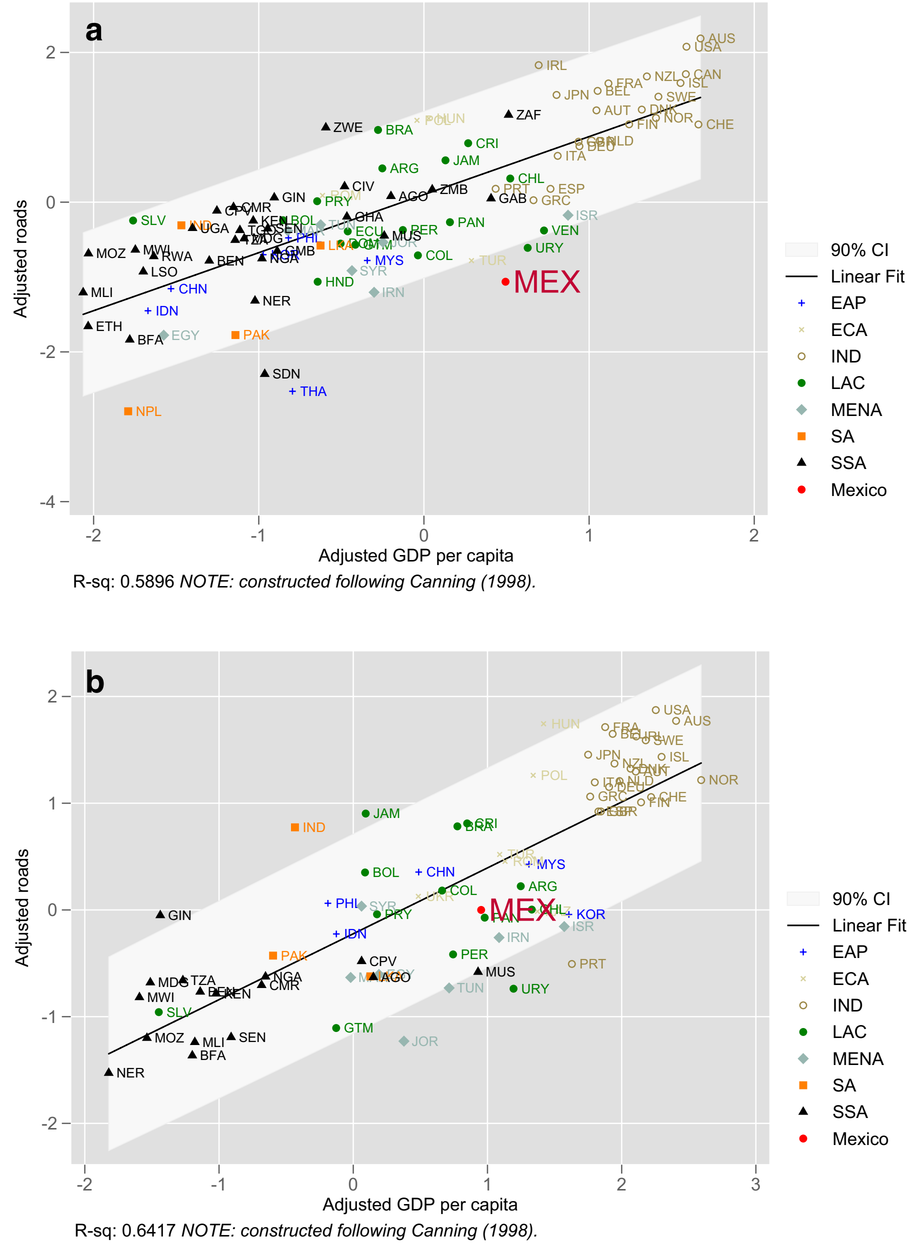
[13] This effort is mainly due to Itaipu, the dam.

Mexico's most underachieved infrastructure sector (see Fig. 6). For 1970, Mexico positions itself outside the confidence intervals of the regression, but later, in 2010, it manages to reach within. The country developed and improved over time, but still lags from the world mean. Surprisingly, Mexico's underperformance in 1970 is so low, that it lies outside the confidence lines like Sudan and Thailand. In 2010, better transport infrastructure-providing LAC countries include Colombia, Bolivia, Argentina, Costa Rica and Brazil, all of them with lower adjusted GDP per capita than Mexico.

The regions in 1970 do not display a clear pattern of behavior in the transport sector like the others. In 2010, the behavior is more segregated by type of region: The industrialized



R-sq: 0.5896 *NOTE: constructed following Canning (1998).*

R-sq: 0.6417 *NOTE: constructed following Canning (1998).*

Fig. 6 Adjustments for Transport Infrastructure countries have higher adjusted infrastructure stocks and adjusted GDP, while the African countries[14] have from a medium-to-low transport stock and adjusted GDP. The transport sector is the clearest example of how adjustments affect the behavior of the variables, which may be overseen in simple comparisons. When looking at the stock level, it seems that Mexico has been improving, compared to others in the region. However, at the conditioned variables, there are others which excel its development, and besides, Mexico does not even reach the world mean in any of the sectors or terms observed.

3 Infrastructure and long-term growth

Parting from the fact that Mexico has low infrastructure stocks, this section covers the reason why they should be improved. From a theoretical standpoint, the role of infrastructure on growth has evolved from the standard Solow-style model where infrastructure is an additional factor of production to models of endogenous growth in which it helps boost total factor productivity. This approach enables the decomposition of output growth into the contributions of capital (e.g., non-infrastructure and infrastructure), labor and productivity growth. In the spirit of Mankiw et al. (1992) and Barro and Sala-i-Martin (1992), the neoclassical production includes infrastructure as part of physical capital (K):

$$Y = K^{\alpha} A L^{1-\alpha} \tag{2}$$

where output (Y) depends on physical capital (K) including infrastructure, labor (L), the level of total factor productivity (A) and $0 < \alpha < 1$, or decreasing returns to every effective unit. This way, conditioned to the steady state level, between two countries that have the same preference and technology, the initially lower country (in terms of GDP) will grow faster in per capita terms.

If $\alpha = 1$ in Eq. (4), this model evolves to an endogenous growth model, in which contrary to the exogenous models, the factors contribute to growth indefinitely. Endogenous growth model results do not depend on an exogenous component, but on the choices of the public sector, the private sector, and the whole economy. They are a compliment to the research of productivity by projecting countries growth change rates. The neoclassical approach uses the following endogenous equation:

$$y_{i,t} - y_{i,t-1} = \alpha y_{i,t-1} + \beta' X_{i,t} + \varepsilon_{i,t} \tag{3}$$

where y is the log of output per capita, 'X is a set of growth determinants, and ε is the regression residual, for each i-country, in each t-period. Based on this, Sect. 3.1 details the model setup and growth determinant variables used, including the aggregate infrastructure index. Section 3.2 employs such methodology to estimate infrastructure's returns on growth. Section 3.3 is self-explanatory.

3.1 Setup and growth determinants

The econometric growth model to assess the impact of infrastructure on growth has a neoclassical approach, similar to Calderón and Servén (2004) and Loayza and Odawara (2010):

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[14] Figure 6, Panel B only displays 16 out of 29 sub-Saharan countries for 2010.

$$\Delta y_{it} = \beta_0 y_{i,t-1} + \beta_1{\prime} X_{i,t} + \beta_2 I_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \tag{4}$$

$$\Delta y_{it} = y_{i,t} - y_{i,t-1} \tag{5}$$

where y is the log of output per capita, subscript i stands for country, t for period, the dependent variable Δy_{it} stands for the growth rate (Eq. 5), μ_t and η_i are the unobserved time-specific and country-specific effects, respectively, and ε is the error term. The control variables are the infrastructure synthetic index ($I_{i,t}$), specified later, and ('X) are a standard set of growth control variables suggested by Barro (1991) and Loayza et al. (2005). They are divided into four main groups: (1) capital, (2) structural policies and institutions, (3) stabilization policies and (4) external conditions.

Before further detailing the variables, it is important to mention that they are constructed under several-year averages for the empirical estimation. The first reason is that the variable of interest—infrastructure stocks—does not change much on a yearly basis. By averaging the stocks, the variance is observed better. The second is due to business cycles, because they directly affect infrastructure. When business cycles contract, the first thing to experience building constraints is infrastructure (Grebler and Burns 1982; Wheaton 2015). To eliminate the undesirable effects, 5-year averages are used observe the short-run relationship and 10-year averages for the long run (Calderón and Servén 2008; Loayza and Soto 2002). However, Male (2011) calculates that the business cycle for Mexico is 5.37 years. Since the business cycle falls short from being in the 5-year average, the regression is estimated with 6-year averages.[15]

Besides infrastructure, or physical capital, the estimation includes seven growth determinants from the standard set of variables widely used in growth literature: human capital, financial debt, trade openness, government burden, governance, inflation and terms of trade shocks.[16] The focus of this investigation is on *physical infrastructure,* or as specified in the regression: $I_{i,t}$. Infrastructure is a multi-dimensional concept that should be treated as an integral variable. With three economic infrastructure sectors included (telecommunications, energy and transport), principal component analysis (PCA) helps construct a synthetic index that considers the minimum dimensionality of the variables and, in some cases, the error variance as well. It keeps as much variance possible and transforms the information into new variables, called principal components, which are no longer correlated between them (Pradhan et al. 2014; Torres et al. 2015). The new components are ranked in such a way that the first few retain most of the variation present in the original values and the differences in measures from the infrastructure stocks are eliminated,[17] e.g., kilometers and kilowatts (Alesina and Perotti 1996; Sánchez-Robles 1998; Jolliffe 2002; Calderón and Servén 2008). It estimates the aggregate effect to give a better approach, instead of modeling each of the sectors separately. The form used to calculate the index is:

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[15] In addition, Mexican presidential administrations run every 6 years: Adolfo Lopez Mateos: 1958–1964; Gustavo Diaz Ordaz, 1965–1970; Luis Echeverría, 1971–1976; Jose Lopez Portillo, 1977–1982; Miguel de la Madrid, 1983–1988; Carlos Salinas de Gortari, 1989–1994; Ernesto Zedillo, 1995–2000; Vicente Fox, 2001–2006; Felipe Calderón, 2007–2012; Enrique Peña Nieto, 2008–2014.

[16] See Appendix 4 for descriptive statistics.

[17] A limitation is that the results become ambiguous and relies on linear assumptions and orthogonal transformations.

$$\text{Synthetic infrastructure index } = \sum_{i=1}^{3} a_{ij} \frac{X_{ij}}{\mathrm{Sd}(X_i)} \tag{6}$$

In this equation, Sd is the standard deviation, X_{ij} is the ith sector variable in the jth year and a_{ij} is a component load or weight derived by PCA. The synthetic infrastructure index used in this investigation corresponds to the first principal component constructed by the eigenvectors of the infrastructure sectors in logs.[18] It captures 75% of the total variation and has a strong correlation with the original variables. The energy sector holds the highest correlation of 0.92, followed closely by the telecom sector with 0.91, and last is the transport sector with a correlation of 0.76. Based on the high correlations, it is safe to say the first principal component is a strong measure for infrastructure. The calculated weights are 0.60 for telecom, 0.61 for energy and 0.50 for transport.[19] These were normalized to equal 1. The corresponding weights are expressed by:

$$\mathrm{SII} = 0.3229\left(\mathrm{LOG}\frac{\mathrm{Telecom}}{L}\right) + 0.3542\left(\mathrm{LOG}\frac{\mathrm{Energy}}{L}\right) + 0.2927\left(\mathrm{LOG}\frac{\mathrm{Transport}}{L}\right) \tag{7}$$

Figure 7 displays how the index has evolved in all regions on 1970, 1990 and 2010.[20] Due to standardization, means will be 0. All the regions have improved their index score over time. As expected, the industrialized countries maintain the highest score in every period. Sub-Saharan Africa, on the other hand, lags from the rest of regions in all periods.

Human capital also has a direct role as a factor of production, and jointly with physical capital, serves as a complement to other factors by contributing to technology and efficiency, thus to growth. It is measured as the ratio of population attending secondary school, regardless of their age (Mankiw et al. 1992; Barro and Lee 2001; Loayza and Soto 2002; Lee and Lee 2016).

As part of the endogenous growth, or the decisions taken by the public sector, private sector and the whole economy, the second category—*structural policies and institutions*—includes four variables: financial depth, trade openness, government burden and governance. *Financial depth* consists of the financial resources provided to the private sector by domestic money banks as a share of GDP. Domestic money banks comprise commercial banks and other financial institutions that accept transferrable deposits, such as demand deposits. *Trade openness* results from the regression of the log of the ratio of exports and imports (2005 US$) on the log of area, population and dummies created for oil-exporting and landlocked countries. All variables were gathered from the WDI. *Government burden* describes the ratio of government consumption to GDP in 2005 US$ in logs. Finally, for this category, after the work by Mauro (1995), government behavior and society's reaction to it has received much attention. By these means,

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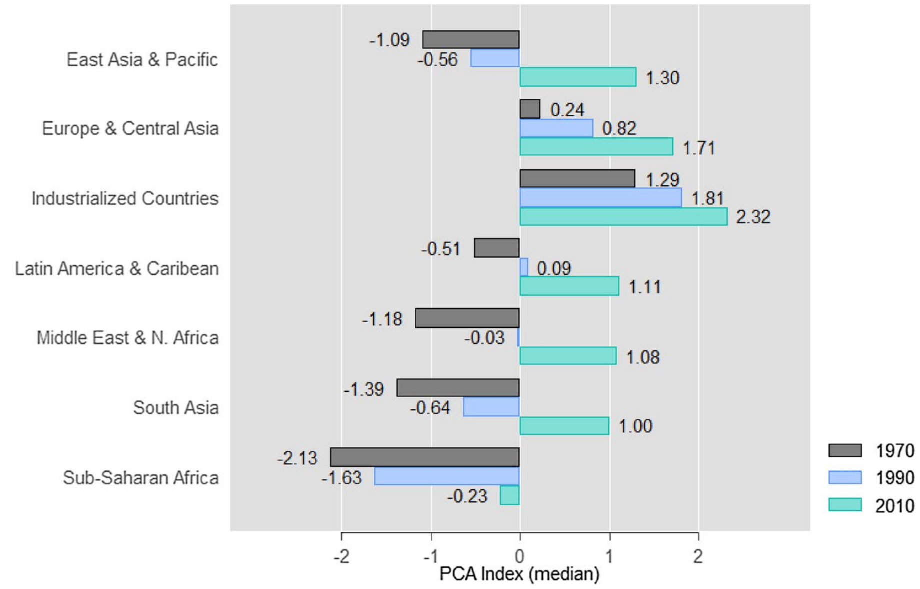
[18] The variables used are: for telecommunication is the number of fixed and mobile lines divided by 1,000 workers, the energy sector is electricity generating capacity divided by 1,000 workers, and transport is total road network divided by the area (in square kilometers) of each country.

[19] The results are similar to Calderón and Servén (2004, 2008), Calderón et al. (2014).

[20] These dates were selected to be consistent with previous exercises.



Source: Author's calculations.

Fig. 7 Principal component analysis snapshots

a *governance index* is added. It is built in a similar manner to the synthetic infrastructure index, by using principal components, and introducing four variables—namely prevalence of law and order, quality of bureaucracy, absence of corruption and accountability of public officials. The information for governance variables is reported by the risk governance framework.

For the *stabilization policies'* variables, the *lack of price stability* is represented by inflation, or the average annual percent changes in consumer prices. Finally, *external conditions* accounts for *terms of trade shocks* measured as the national account export price index divided by the imports price index, with 2005 equaling 100 (Easterly et al. 1993; Fischer 1993; Easterly et al. 1997).[21]

The absence of high correlations discards multicollinearity (see Appendix 5). The highest is held by the infrastructure index with GDP (0.78) and human capital (0.79). The infrastructure index maintains a positive correlation with almost all the variables except inflation and terms of trade; however, these are relatively small. In fact, these variables have negative correlations with almost all the variables. Inflation has a positive relationship with trade openness, government burden and inflation, but very close to zero. Terms of trade is correlated positively, but also very close to zero with government burden.

3.2 Estimation by generalized method of moments

The empirical strategy is based on panel data relating economic growth to the reviewed set of controls, including the infrastructure index. The methodology assumes the process is dynamic and includes level of output per capita at the start of the corresponding

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[21] Descriptive statistics on Appendix 4.

period in the set of independent variables. Arellano and Bond (1991) evolved the first dynamic model developed by Holtz-Eakin et al. (1988) and named it generalized method of moments (GMM) difference. Later, Arellano and Bover (1995) and Blundel and Bond (1998) developed GMM system. The method is consistent and asymptotically efficient in the presence of heteroscedasticity.

The first estimator developed by Arellano–Bond allows the researcher to use lags of the dependent or independent variables as needed, if both (the lag and un-lagged observation) are available in the data. By using lagged observations, (1) endogeneity (or causality) is eliminated, and (2) the country time-invariant characteristics are removed from the explanatory variables that may be correlated. By using GMM you also (3) eliminate autocorrelation that arises because of the independent term: $y_{i,t-1}$ (from Eq. 4). Finally, (4) it also solves the problem of data scarcity, and the equations need models that allow a short time dimension and a larger country dimension to produce robust results.

The way the GMM methodology and its lags solve these problems is by (1) including endogenous regressors as instrumental variables eliminate endogeneity. It uses (2) first differences to transform the regressors and remove the fixed country effects. In this analysis, common factors are dealt with the inclusion of period-specific dummies and unobserved country effects are handled by differencing. To deal with (3) autocorrelation, the first differenced dependent variable is also instrumented by past observations. Finally, the (4) short panel data problem is corrected because this method can only use around $t = 10$. Larger T panels diminish the error term that includes the shocks of fixed effects with time; in the same manner, this effect occurs to the lagged variables in a model estimated with GMM.

Arellano and Bover (1995) suggested an extra set of moment conditions. So, Blundell and Bond (1998) evolved the first estimator by Arellano–Bond where, instead of just taking the lagged variable as an instrument, it subtracts the average of all future observations, allowing a minimal loss of data. This evolved model by Blundell and Bond (1998) is called system GMM. It is computable for all the observations, except for the last one. When the conditions are satisfied, the resulting estimator has better finite sample properties. The expanded estimator has a cost of involving a set of additional restrictions on the initial conditions of the process in generating the dependent variable, which in turn leads to system GMM creating a higher number of instruments, which are internal to the regression. These are based on lagged versions of the level variable (Arellano and Bond 1991; Roodman 2006), which may be endogenous or not strictly exogenous. The procedure uses a moment condition that is based on the level equations, together with the usual Arellano and Bond estimator-type orthogonality conditions (Table 2).

In GMM system, the main conditions favor a panel analysis due to the consideration that fixed effects might be distributed arbitrarily and the time variation can be used to calculate the parameters. The estimators handle the invariance of fixed effects and endogeneity of regressors, while avoiding panel dynamic bias. Besides the idiosyncratic disturbances found in the fixed effects, heteroscedasticity and serial correlation may be present in patterns, which would remain uncorrelated across individuals.

Table 2 Standard set of growth determinant variables *Source*: Adapted from Loayza et al. (2005)

	Determinants of growth	Variable	Source(s)
1. Physical and human capital	Infrastructure	Synthetic infrastructure index—first principal component for telecommunications, energy and transport	Constructed from telecommunications (WDI), energy (EIA) and transport (IRF) sector
	Human capital	Ratio of total secondary school enrollment, regardless of age, to the population that respond to that level of education	Barro and Lee, Educational attainment dataset
2. Structural policies and institutions	Financial depth	Ratio to GDP of the stock of claims on the private sector by deposit money banks	Global financial development database (GFDD)
	Trade openness	Residual of a regression of the log of the ratio of export and imports (2005 US$) on the logs of area, population and dummies for oil-exporting and landlocked countries	Self-constructed with information from world development indicators by World Bank 2016
	Government burden	Government Consumption in 2005 US$, in logs	World development indicators by World Bank 2016
	Governance	Index from four series: prevalence of law and order, quality of bureaucracy, absence of corruption and accountability of public officials	IRGC risk governance framework, database
3. Stabilization policies	Lack of price stability	Inflation, annual percent change of consumer prices, in logs	World Development Indicators by World Bank 2016
4. External conditions	Terms of trade	Shows the national accounts export price index divided by the imports price index, with 2005 equaling 100	World Development Indicators by World Bank 2016

3.3 Results from GMM

Table 3 reports the results from the growth regression for 6-year averages, or $t = 9$ from the complete sample of 96 countries from 1960 to 2014, by using different two-step system GMM[22] estimations. The difference from each estimation lays on the instruments, which were carefully selected to identify the best model. When using GMM, the ideal is to have a small t, or less than 10–12 periods per individual. The 6-year periods fit this description accordingly. Column 1 uses endogenous instruments, which means that since it is a two-step estimation, it uses its own differenced and lagged variables. These

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[22] GMM system conditions are the following: $E\left[\left(y_{i,t-p}\right)\left(\eta_i\right)\right] = E\left[\left(y_{i,t-q}\right)\left(\eta_i\right)\right], E\left[\left(X_{i,t-p}\right)\left(\eta_i\right)\right] = E\left[\left(X_{i,t-q}\right)\left(\eta_i\right)\right]$ for all p and q, $E\left[\left(y_{i,t-1} - y_{i,t-2}\right)\left(\eta_i + \varepsilon_{i,t}\right)\right] = 0$, and $E\left[\left(X_{i,t-1} - X_{i,t-2}\right)\left(\eta_i + \varepsilon_{i,t}\right)\right] = 0$.

Table 3 Infrastructure stocks and economic growth: panel regression analysis

	(1) GMM system—only endogenous instruments	(2) GMM system exogenous: population	(3) GMM system exogenous: labor	(4) GMM system exogenous: urban pop
Lag output per capita (logs)	− 0.188***	− 0.181***	− 0.180***	− 0.178***
	(0.000)	(0.000)	(0.000)	(0.000)
Infrastructure index	0.102***	0.110***	0.108***	0.117***
	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	0.0221	0.0150	0.0181	0.0188*
	(0.135)	(0.299)	(0.164)	(0.046)
Financial depth	0.0909***	0.0923***	0.0908***	0.0911***
	(0.000)	(0.000)	(0.000)	(0.000)
Trade openness	− 0.107***	− 0.0984***	− 0.0746**	− 0.0640*
	(0.000)	(0.000)	(0.001)	(0.015)
Government burden	− 0.0726**	− 0.0395**	− 0.0450**	− 0.0621***
	(0.002)	(0.007)	(0.002)	(0.000)
Inflation	0.000284***	0.0002***	0.0002***	0.0003***
	(0.000)	(0.001)	(0.000)	(0.000)
Terms of trade shocks	0.142***	0.171***	0.153***	0.161***
	(0.000)	(0.000)	(0.000)	(0.000)
Governance	0.0222***	0.0139**	0.0117*	0.00927*
	(0.000)	(0.002)	(0.020)	(0.026)
Observations	402	402	402	402
Groups	70	70	70	70
No. instruments	68	80	80	80
Specification tests				
Hansen test	0.298	0.497	0.557	0.624
First-order correlation	0.030	0.035	0.045	0.035
Second-order correlation	0.127	0.119	0.121	0.147

Using *system GMM* estimations

Dependent variable: growth of GDP per capita

Sample of 96 countries, 1960–2014, 6-year averages, $t = 9$

p values in parentheses

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

instruments include GDP per capita, infrastructure, financial depth, government burden, governance and human capital, and the respective periods. Column 2 follows the same procedure, but uses population as an exogenous instrument for infrastructure, Column 3 uses labor as an exogenous instrument for infrastructure, and Column 4 uses urban population for the same purpose as Columns 2 and 3.

The three exogenous variables—population, labor and urban population—all have in common that they are demographic variables. The main reason to use these as exogenous instruments for infrastructure is twofold: (1) Infrastructure may not be completely exogenous—future projects may be affected by stocks today and (2) there may be a measurement error in the data, as explained as one of the caveats for physical infrastructure in *Introduction*. In addition, because it is people who place demand for infrastructure, there is no reason to believe that these demographic variables have a systematic relation with the measurement error in infrastructure, including the rest of the standard set of growth variables.[23]

The validity of the instruments may be checked through two channels: First, the number of instruments is validated[24] through the Hansen test.[25] Specifically, it addresses the instruments' validity by analyzing the sample analog of the moments conditions used in the estimation process. The second validation is aqcuired by the *first-order* and *second-order correlation.* It verifies the correlation of the errors. The first-order serial correlation of the differenced error term is expected even if the original error term is uncorrelated, unless the latter follows a random walk. Second-order serial correlation of the differenced residual indicates that the original error term is serial correlated and follows a moving average process of at least order one. Failure to reject the null hypothesis gives support to the model. In the estimated models from Table 3, the Hansen test and second-order correlation confirm little evidence against the validity of the moment conditions chosen for all the model specifications, but the results from *Column 4* are the preferred estimators due to the extra confidence that the external instrument delivers and the validity of the test results.

In all the models, regardless of the technique used, the variable of interest, infrastructure, is statistically significant and positive, ranging from 0.10 to 0.12. Also, initial GDP has a significant negative coefficient as evidence of "conditional convergence" (Barro and Sala-i-Martin 1992). As the tests conclude that *Column 4* gives the best fit, infrastructure stocks and economic growth are positively associated with a coefficient of 0.117. Human capital (0.018), financial depth (0.091), inflation (0.0003), terms of trade shocks (0.161) and the governance index (0.009) foster growth, while government burden (− 0.062) and trade openness (− 0.064) affect it adversely. When using GMM, it is expected that trade openness displays a negative coefficient due to short-term adjustments and a probable nonlinear relationship (Gries and Redlin 2012; Huchet-Bourdon et al. 2011).

As a robustness check, by following previous literature estimations (Calderón and Servén 2008; Loayza and Odawara 2010), Table 4 reports different year averages (5, 6 and 10 years for each method, respectively) for *system* GMM with endogenous instruments (Columns 1–3) and urban population as an exogenous instrument (Columns 4–6). It is interesting to observe the evolution of the coefficients for different year averages, but for both methodologies, the specification tests select the 6-year average, specifically Column 5 (the same as Colum 4 in Table 3), as the preferred estimator.[26] The infrastructure index coefficient approximately doubles for the 10-year average, compared to the 6-year average and slightly improves from the 5-year average coefficients. Even though these are positive and highly significant in all models, the specification does

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[23] As expected, the exogenous variables have high correlation among themselves: population and labor have a correlation of 0.98; population and urban population 0.9173, and urban population and labor 0.915. The models return the constant as zero because all the dummies were included.

[24] This is of concern because the instruments should not be correlated with the variables.

[25] Sargan's test of overidentifying restrictions was omitted because Soderbom et al (2015) state that this test serves the same purpose as the Hansen J test. The Saragn is used more in the UK, while the Hansen test is used more in the USA. In addition, the Sagran test may sometimes reject while the Hansen fails to reject because Hansen test is more robust than Sargan. Sargan's statistic is a special case of Hansen's J under the assumption of homoscedasticity. Therefore, for robust GMM the Sargan test statistic is inconsistent.

[26] The coefficient for infrastructure index from this estimation (*Column 5* from Table 4 or *Column 4* from Table 3) will be used in the next section to undermine the gap for Mexico.

Table 4 Infrastructure stocks and economic growth: panel regression analysis

	Endogenous instruments			**Exogenous instrument: urban population**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	GMM system 5 years, $t = 11$	**GMM system 6 years, $t = 9$**	**GMM system 10 years, $t = 5$**	**GMM system 5 years, $t = 11$**	**GMM system 6 years, $t = 9$**	**GMM system 10 years, $t = 5$**
Lag output per capita (logs)	− 0.116***	− 0.188***	− 0.394***	− 0.0821***	− 0.178***	− 0.381***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Infrastructure index	0.0862***	0.102***	0.250***	0.0804***	0.117***	0.246***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	− 0.0204	0.0221	0.0773	− 0.0255	0.0188*	0.0817
	(0.114)	(0.135)	(0.519)	(0.051)	(0.046)	(0.483)
Financial depth	0.0621***	0.0909***	0.238***	0.0627***	0.0911***	0.230***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Trade openness	− 0.165***	− 0.107***	− 0.410*	− 0.242***	− 0.0640*	− 0.381*
	(0.000)	(0.000)	(0.031)	(0.000)	(0.015)	(0.032)
Government burden	− 0.0701*	− 0.0726**	− 0.0761	− 0.105**	− 0.0621***	− 0.102
	(0.017)	(0.002)	(0.585)	(0.001)	(0.000)	(0.432)
Inflation	0.0000133	0.000284***	0.0000181	− 0.0000143	0.000304***	0.000104
	(0.448)	(0.000)	(0.974)	(0.511)	(0.000)	(0.833)
Terms of trade shocks	0.0859***	0.142***	0.278	0.0721*	0.161***	0.330
	(0.000)	(0.000)	(0.293)	(0.023)	(0.000)	(0.101)
Governance	0.0191***	0.0222***	-0.0180	0.0105*	0.00927*	-0.0192
	(0.000)	(0.000)	(0.461)	(0.029)	(0.026)	(0.426)
Observations	500	402	247	500	402	247
Groups	70	70	70	70	70	70
No. instruments	90	68	31	110	80	32
Specification tests						
Hansen test	0.888	0.298	0.425	0.997	0.624	0.507
First-order correlation	0.180	0.030	0.211	0.146	0.035	0.207
Second-order correlation	0.022	0.127	0.065	0.022	0.147	0.060

Using different estimation techniques and sample periods

Dependent variable: growth of GDP per capita

Sample of 96 countries, 1960–2014, different year averages

P values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

not confirm, in either of them, any evidence in favor of the validity of the moment conditions chosen.

4 Counterfactual exercise: Mexico's infrastructure gap

Assuming the effect is equal across countries, this section estimates the economic infrastructure gap for Mexico compared to other countries as a counterfactual exercise. Following convergence and growth theory (Mankiw et al. 1992), by using the last observation for the infrastructure stocks of the data for 6-year averages (2008–2014), Mexico's infrastructure gap is calculated compared to the other region's leaders—namely EAP: South Korea, ECA: Hungary, IND: Belgium, LAC: Costa Rica, MENA: Israel, SA: India and for SAA: South Africa. I take the coefficient resulting from the growth regression from the Sect. 3: $\hat{\beta}_2$ or 0.117 to estimate the infrastructure gap and following the simple arithmetic of:

$$g_{\mathrm{it}} = -\hat{\beta}_2 (I_{\mathrm{mex}} - I_{\mathrm{bench}}) \tag{8}$$

where g_{it} is the expected growth, $\hat{\beta}_2$ is the estimated coefficient for infrastructure,[27] I_{mex} is the infrastructure index score for the last period of observation in the 6-year average dataset, and I_{bench} is the region leader's index score for the last period of observation. Equation 8 suggests that if Mexico lags from the selected leader, the figure will be negative. Positive signs indicate that Mexico is ahead of that region leader.

Table 5 presents the information for Mexico's infrastructure lags on each region leader by using Eq. 8 with the coefficient and the last infrastructure index figure available. These figures were taken from the last observation available (6-year average, specifically for 2008–2014). The results indicate that Mexico lags from all the region's leaders, except South Asia. The greatest gap, as expected, is behind the industrialized countries. This suggests that if Mexico were to have Belgium's infrastructure, it would grow 0.20 percentage points in a 6-year average period. Mexico only exceeds India, the South Asian leader. This counterfactual exercise is meant to be illustrative more than conclusive due to the heterogenous effect of infrastructure on growth (Sachs et al. 2004; Collier 2006). However, it gives an idea of the economic significance of the effects of infrastructure on economic growth.

5 Conclusions

This study was motivated by the fact that Mexico was positioned in position 59 out of 140 countries for its infrastructure quality, according to the World Economic Forum—Global Competitiveness Report. This suggests that Mexico delivers infrastructure quality in accordance with the better half of performing countries worldwide. However, the trends and empiric results demonstrate that Mexico infrastructure quantity provision does not seem to be holding up with the upper half of better performing countries. It lags on the economic infrastructure dimension of quantity from every region leader, except South Asia's: India.

The results may be summarized in three points. First, regarding the individual sector trends in the simple and conditional comparisons, Mexico delivers on or below the world mean. In telecommunications, Mexico underperforms in delivering phone lines related to all peer countries and its own region. This can also be seen when controlling for area and population in the country. In addition, there has not been substantial improvement in the last 40 years. In the energy sector, Mexico has a lot of room for improvement. It is a low performing country in electricity generating capacity in relation to LAC and similar GDP countries. When adjusting for geography and demography, Mexico displays a slight increase in electricity delivery, but still underperforms worldwide. Lastly, for

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[27] This is the preferred estimator from the growth regression with urban population as an exogenous instrument for infrastructure lags in system GMM. The estimations are displayed in *Column 4* in Table 3 and *Column 5* in Table 4.

Table 5 Mexico's infrastructure stocks compared to region leaders

	EAP South Korea	ECA Hungary	IND Belgium	LAC Costa Rica	MENA Israel	SA India	SSA[a] South Africa
Region leaders							
Mexico	− 0.1231	− 0.1430	− 0.2010	− 0.0417	− 0.1372	0.0069	− 0.0910

Using information for the last period of observation (averages from 2008 to 2014)

[a] The latest 6-year average available was 2001–2007

transport infrastructure, Mexico performs well related to the peer countries. However, when adjusting the variable, Mexico underperforms greatly, in spite of the huge increase in road network stock.

Second, the results from the econometric estimation prove that infrastructure is a promoter of growth on the medium to long term when using the neoclassical approach. These results control for reverse causation and survive a couple of tests used for misspecification. There are no coincidental effects of infrastructure stocks on growth.

Finally, the illustrative experiment on the counterfactual exercise shows that the empirical findings from the estimation also have an economic purpose besides having a significant statistic. If Mexico were to improve its stocks, like other overperforming region leaders, its medium-term per capita growth gains would increase from 0.04 to 0.20. To improve the economy, Mexico's policies should aim at improving infrastructure stocks. Perhaps not to the point of Belgium's amount of infrastructure (which was determined as the regional leader for the industrialized countries), but possibly like a country similar to the ECA or MENA regions' leaders (Korea and Israel, respectively) or other similar GDP countries. With a medium- to long-term policy, Mexico could reach these higher infrastructure provision standards and improve its economy.

Authors' contributions

The author was the main contributor to the whole analysis.

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Competing interests

The author declared that she has no competing interests.

Availability of data and materials

See Table 4 of the manuscript for all data sources.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

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Appendices

Appendix 1: Infrastructure sector descriptive statistics

	Telecommunications[a]	**Energy**[b]	**Transport**[c]
Pool data for 96 countries, (1960–2014)			
Number of observations	4877	4959	4911
Mean	736.9262	1.36414	0.4608006
SD	1044.549	1.91449	0.7368662
Minimum	0.4453508	0.0009754	0.0018115
Maximum	6472.938	14.32213	5.125825

[a] Telecommunications variable: number of fixed and mobile lines per 1000 workers

[b] Energy variable: electricity generating capacity in KW per 1000 workers

[c] Transport variable: total road network divided by square km of land in each country

Appendix 2: List of countries in the dataset

1. *Latin America and the Caribbean—LAC* Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad & Tobago, Uruguay, Venezuela.
2. *East Asia & the Pacific—EAP* China, Indonesia, South Korea, Malaysia, Philippines, Thailand.
3. *Europe & Central Asia—ECA* Hungary, Kazakhstan, Poland, Romania, Russia, Turkey, Ukraine.
4. *Industrialized Countries—IND* Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, USA.
5. *Middle East & North Africa—MENA* Algeria, Egypt, Iran, Israel, Jordan, Morocco, Syria & Tunisia.
6. *Sub-Saharan Africa—SSA* Angola, Benin, Burkina Faso, Cabo Verde, Cameroon, Cote d' Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia & Zimbabwe
7. *South Asia—SA* India, Nepal, Pakistan & Sri Lanka.

Appendix 3: Adjusted variable correlations

	GDP	**Telecom**	**Energy**	**Transport**
High triangle: 2010, low triangle: 1970				
GDP	1	0.7181	0.9384	0.8011
Telecom	0.9092	1	0.7648	0.3953
Energy	0.9058	0.9499	1	0.7347
Transport	0.7678	0.7372	0.7791	1

Lower information is for 1970. Upper information describes correlations for 2010

Appendix 4: Descriptive statistics

Variables	(1) Obs.	(2) Mean	(3) SD	(4) Min	(5) Max
Panel A: Complete dataset					
GDP per capita	4758	8.117	9.217	0.226	53.16
Infrastructure index	4421	− 1.38e − 10	1.505	− 4.274	2.871
Human capital	814	31.07	19.94	0.233	84.09
Financial depth	4200	36.66	35.35	0.730	272.9
Trade openness	4694	2.53e − 11	0.4696136	− 2.131255	1.421597
Government burden	4609	14.89222	5.551352	0	54.51542
Inflation	4666	37.65354	483.0418	− 11.68611	24411.03
Terms of trade	4077	105.8914	34.34547	18.53863	490.9047
Governance	4647	0.1213757	1.762805	− 3.285828	3.440391
Panel B: Latin America region					
GDP per capita	988	5.416374	3.355031	0.6022928	21.2904
Infrastructure index	923	0.0658746	0.8092293	− 2.313954	2.341152
Human capital	220	27.5079	14.80122	3.176233	70.17853
Financial depth	1021	24.55996	14.3169	1.86	97.32
Trade openness	1037	− .1506695	0.433003	− 1.354602	1.037975
Government burden	1033	11.97429	4.03801	2.975538	43.47921
Inflation	1083	83.53347	631.4006	− 3.9	11749.64
Terms of trade	961	105.7847	32.60215	18.53863	256.1968
Governance	1080	− .5413714	1.393137	− 3.167193	3.122853
Panel C: Mexico					
GDP per capita	52	8.890151	2.022574	5.047661	12.40321
Infrastructure index	53	0.0212597	0.7509076	− 1.393679	1.122937
Human capital	11	28.50249	16.84309	6.609861	50.62455
Financial depth	53	20.1817	6.814827	8.69	33.31
Trade openness	55	− .19139	0.5254232	− .9091222	0.607848
Government burden	55	9.752379	2.097284	5.61412	13.17055
Inflation	56	20.40931	28.93231	0.564055	131.8267
Terms of trade	55	129.854	42.99768	75.87042	209.9908
Governance	54	0.2137503	0.382475	− .7846359	0.9410892

Latin American Region includes: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad & Tobago, Uruguay, Venezuela

Appendix 5: Correlation of standard set of growth determinants

***Source*: see Table 4**

	GDP per capita	Infrastructure index	HUMAN CAPITAL	Financial depth	Trade openness	Government Burden	Inflation	Terms of Trade	Governance
GDP per capita	1.0000								
Infrastructure	0.7811	1.0000							
Human capital	0.6980	0.7947	1.0000						
Financial depth	0.7329	0.6180	0.5069	1.0000					
Trade openness	0.4050	0.2839	0.3634	0.2729	1.0000				
Gov. burden	0.4050	0.3659	0.3985	0.2871	0.3178	1.0000			
Inflation	− 0.0330	− 0.0408	− 0.0153	− 0.0580	0.0042	0.0055	1.0000		
Terms of trade	− 0.1565	− 0.1860	− 0.1757	− 0.0652	− 0.1421	0.0049	0.0044	1.0000	
Governance	0.6531	0.6333	0.5011	0.5043	0.0666	0.3245	− 0.0426	− 0.0466	1.0000

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