Economic Growth and Infrastructure Gap in Latin America

Federica Liberini*
Università degli Studi di Roma “Tor Vergata”

This paper analyses the recent trends in infrastructures of Latin America, with the aim of addressing the problem of measuring and evaluating the infrastructural gap. Departing from the recent literature on economic growth and public finance, we defined the infrastructure need of a country through a model of demand. The use of a large dataset (121 countries spanned over 1960-1999) made it possible to estimate the optimal level of infrastructure provision. To conclude, a comparative inter-regional analysis of the infrastructural gap between the Latin American, East Asian, OECD and middle income countries was conducted to check if the reduction in infrastructural investment was caused by the evolution of infrastructure needs, or if it was due to a widespread inefficiency caused by the underestimation of actual needs. [JEL Classification: H54, O54]

1. - Introduction

Latin America is a geographic area with undoubted economic capacity. Nonetheless, political events and economic policy choices in the past have prevented the region from creating conditions

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conducive to take full advantage of its economic potential. Today, the countries of Latin America are still classified as low and middle income countries, marked by deep-rooted income inequality and economic structures that are unable to generate any kind of decisive change.

The reforms undertaken by governments in the late 80s, in particular, seem to have had serious negative consequences: the liberalization and privatization processes launched at that time were not sufficient to compensate for the retrenchment of public expenditure on infrastructure. Hence, the sharp fall in investment has been and still is an additional threat to economic development in terms of both poverty reduction and re-launch of competitiveness.

This paper analyses the recent trends in infrastructure in the Latin American region, with the aim of addressing a problem that is still faced by many countries: the measure and the evaluation of what is generally referred to as the “infrastructural gap”.

The empirical work consists of two parts. The first focuses on a demand model necessary to define and estimate the infrastructure needs of a given economy (reference is made to recent publications on the economic growth of different groups of countries). The second uses the above estimations to calculate the width of the infrastructure gap, defined as “under-provision” of infrastructures.

Thanks to the large dataset used (121 countries over the forty years time-span 1960-1999), it was possible to obtain statistically significant results consistent with our expectations. This allowed us to define the “optimal level of infrastructure provision” for a given country (also called infrastructure need) exclusively on the basis of that said country’s economic and geo-demographic characteristics.

To conclude, a comparative inter-regional analysis of the infrastructural gap between the Latin American, East Asian, OECD and middle income countries was conducted to check if the reduction in infrastructural investment is caused by the evolution of infrastructure needs, or is due to the widespread inefficiency caused by the underestimation of actual needs.

The evidence suggests that in the 90s, after the weak recovery
at the end of 80s, Latin America experienced the adverse effects of disinvestment. In all sectors, the infrastructural gap reached its maximum peaks during the debt crisis and at the end of the 90s, thus proving the inefficiency of infrastructure privatization programmes and the inability of the private sector to make up for the lack of public investment.

2. - Infrastructure and Economic Growth

The benefits that the society can gain from its infrastructure and from an adequate allocation of public funds to infrastructural investments seem obvious even to those who have not studied in depth the economic literature existing on the subject.

Nevertheless, the topic related to infrastructure stock and investment was ignored by economists for a long time. During the two decades between 1970 and 1990, there was no mention in the economic literature of the consequences of the deterioration of the infrastructure stock resulting from a general reduction of public investment.

It was only at the end of the 80s, and with the seminal paper by David Aschauer\(^1\), that economists increasingly began to turn their attention to infrastructure policies and to the development economic literature focused on the consequences of the increase or reduction and the improvement or deterioration of the infrastructures available to a given country. Consistently with the neoclassical approach, according to which “expansions of public investment spending should have a larger stimulating impact on private output than equal-sized increases in public consumption expenditure”\(^2\), Aschauer based his work on the intuition that certain types of public investment could affect the total factor productivity more than others. He used a Hicks-technology neutral aggregate production function with constant returns for both private and public factors of the form

\[ y_t = a_t + e_N \cdot n_t + e_K \cdot k_t + e_G \cdot g_t \]

He distinguished different categories of public spending depending on the avenue of allocation (among others, infrastructure sectors), he estimated the elasticity of output to these factors and therefore related together econometrically the changes in infrastructure investment and those in aggregate productivity.

The results of his statistically significant analysis confirmed that a certain kind of infrastructure, later called “core infrastructure”, has a very high marginal productivity (0.24): this proved the pivotal role played by infrastructure in the economic growth of a country.

Barro\(^4\) had in the same period proposed a work in which the effect of different factors on growth were estimated by a series of cross-section regressions over 98 countries. The evidence suggested that public expenditure in consumption services had a negative effect on the economic growth rate, while the effect of public investment was econometrically insignificant. Moreover, the correlation between the gross public investment (as a share of total investment) and the output growth rate was high in all cases when the government did not follow an optimizing behaviour\(^5\).

In an earlier publication\(^6\), Barro had presented a model of endogeneous growth where the basic \( Ak \) production function\(^7\) had

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\(^3\) Eq. \((I)\) is the logarithmic version of \( Y_t = A_t \cdot f(N_t, K_t, G_t) \). \( N, K \) and \( G \) denote, respectively, the aggregate employment, the aggregate capital stock and the flow of public services, while \( A \) is technology and \( Y \) the aggregate output. \( e \) denotes the elasticity of output to the factor it is referred to. From this, given the constant returns assumption, we can derive the Total Factor Productivity and the output per unit of capital equations. These are, respectively:

\[
\begin{align*}
p_t = a_t + e_G (g_t - s_N n_t - s_K k_t) & \quad \text{with} \quad & s_i = \theta \cdot e_i, \; i = N, K \\
y_t - k = a_t + e_N (n_t - k_t) + e_G (g_t - k_t) & 
\end{align*}
\]


\(^5\) In choosing a level of public investment higher or lower than the one given by the solution to the optimization problem. The correlation between the growth rate and the public investment resulted to be negative in the first case and positive in the second.


\(^7\) I.e. a production function of the form \( y = f(k) \), where constant returns are assumed over capital and \( y = Ak \) denotes the constant marginal product of capital.
been modified to include the public sector. The Government production was divided between those services that constitute inputs for the private production (the same approach of Aschauer) and those which supply additional consumption to the households. Maintaining the assumption of overall constant returns\(^8\), the resulting model showed how private and public capital are complementary, and the decreasing returns of private capital are predominant whenever the public capital does not expand at the same rate of the former.

As we restrict the study solely to the region of South America, the focus goes on the growing optimism brought about by the large reforms for the privatization of infrastructures, after the crisis of the 80s. Both governments and investors, who had carefully planned the privatization programmes for those sectors that had always been government owned in the past, expected that their reforms would have allowed a consolidation of government finances and also a quantitative and qualitative improvement of the economic and social infrastructures. All together this would have resulted in a strong acceleration of the economic growth.

Conversely, the privatizations did not live up to expectations and total investment in infrastructure experienced a sharp decrease. As stated in the 1994 in the “World Development Report on Infrastructure and Development”\(^9\), even though there were grounds for high expectations, the South American public sectors should have continued to play their role and maintain responsibility for infrastructure investments during the period of reforms and the opening up of infrastructures to private capitals.

The works recently published by Easterly, Calderón e Servén\(^{10}\) used sophisticated econometric techniques to analyse the infrastructural deterioration in terms of the costs caused to economic growth.

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\(^8\) The returns of scale are constant in \(k\) and \(g\) (the flow of public sector services) considered together; but decreasing in \(k\) alone.

\(^9\) THE WORLD BANK (1994).

Calderón and Servén\textsuperscript{11} base their study on the assumption that the analysis of the fiscal policy choices regarding public investments (among which investment in infrastructure) should be conducted with respect to the intertemporal budget constraint\textsuperscript{12}, the dynamics of public debt being defined by

\begin{equation}
 b(t) = (r - g)b(t) - \sigma(t)
\end{equation}

If the total rate of return on public capital is positive and higher than the discount rate of future government revenues, a cutback in infrastructure investment (and thus a reduction in infrastructure stock), will, other things being equal, affect the GDP growth rate so negatively to induce a reduction in the volume of future revenues. Furthermore, the evidence revealed by Easterly\textsuperscript{13} shows that the worse the initial public debt position, the higher the cost in terms of GDP growth slow down due to the fall of infrastructure investment.

Calderón and Servén\textsuperscript{14} enhance their work with the presentation

\begin{equation}
 b(t + \tau) = e^{(r-g)\tau}b(t) - \int_{t}^{t+\tau} e^{(r-g)(s-t)} \sigma(s) ds
\end{equation}

which implies government solvency if the transversality condition

\[ \lim_{\tau \to \infty} [e^{(r-g)\tau}b(t + \tau)] \leq 0 \]

holds. Easterly and Servén proceed decomposing the augmented primary surplus in the three components of seigniorage, infrastructure expenditure and all other voices not entering in these first two, so that

\[ \sigma(t) = p(t) - i(t) + \mu(t) h(t) \]

with \( p \) as the initial primary surplus, \( i \) the infrastructure expenditure and \( \mu \cdot h \) the money stock times the money stock to GDP ratio.

\textsuperscript{11} EASTERLY W. - SERVÉN L. (2003), Chapter 4, *Infrastructure Compression and Public Sector Solvency in Latin America*.

\textsuperscript{12} In equation (2), \( b \) corresponds to the debt to GDP ratio, \( r \) to the real interest rate, \( g \) to the economic growth rate and \( \sigma \) to the augmented public primary surplus. Departing from equation (2), the authors define the intertemporal budget constraint in a form similar to that used by Buiter (BUITER W., 1990) for describing an economy approaching the equilibrium with constant output. They write:

\[ b(t + \tau) = e^{(r-g)\tau}b(t) - \int_{t}^{t+\tau} e^{(r-g)(s-t)} \sigma(s) ds \]

which implies government solvency if the transversality condition

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\textsuperscript{13} EASTERLY W. (2001).

\textsuperscript{14} EASTERLY W. - SERVÉN L. (2003), Chapter 3, *The Output cost of Latin America's Infrastructure Gap*.
of empirical tests designed to identify and measure the consequences that the 80s infrastructure devolution had on the decline of Latin America economies. The results of their study confirm the existence of a statistically relevant positive relation between the infrastructure capital (always disaggregated at the level of the sectors that constitute the so-called core infrastructure) and the human and physical capital. A permanent and continuous reduction in the quantity and quality of infrastructures reduces the total factor productivity, makes production- and transport-costs higher for producers, disincentives private investors and overall reduces the firm's profitability and the economy's output growth\textsuperscript{15}.

The methodology approach, again, uses a Cobb-Douglas production function. Here infrastructural capital ($z$) enters separately from human ($h$) and total capital stock ($k$)

\begin{equation}
(3) \quad y = \alpha k + \beta h + \gamma z + (1 - \alpha - \beta - \gamma)l^{16}
\end{equation}

Assuming that infrastructural capital is a constant portion of the total capital stock, estimations of the elasticity of output to infrastructural capital are computed, accounting for the fact that infrastructural capital actually enters the equation in both $k$ and $z^{17}$.

The authors perform a series of estimates considering a per-worker version of equation (3)\textsuperscript{18} and using panel-data techniques to correct the bias due to cross-country heterogeneity, common factors, measurement error, and endogeneity.

In a second publication dated 2004\textsuperscript{19}, Calderón and Servén continue the analysis in two different directions. On the one hand,

\begin{itemize}
  \item [\textsuperscript{15}] For similar results see Demetriades P. - Mamuneas T. (2000) and Esfahani H. - Ramirez M.T. (2002).
  \item [\textsuperscript{16}] Equation (3) assumes constant returns of scales. $l$ stands for labour. All variables are expressed in logarithmic form.
  \item [\textsuperscript{17}] Canning D. (1999) discusses how to derivate an exact measure of the elasticity of output to infrastructural investment in such an equation. Calderón and Servén point out that $\gamma$ actually measures the difference in terms of productivity between the infrastructural and the non-infrastructure capital.
  \item [\textsuperscript{18}] $(y_{it} - l_{it}) = a_i + b_i + \alpha (k_{it} - l_{it}) + \beta (h_{it} - l_{it}) + \gamma (z_{it} - l_{it}) + \varepsilon_{it}$.
  \item [\textsuperscript{19}] Calderón C. - Servén L. (2004a).
\end{itemize}
contributing to the branch of literature originated by Canning\textsuperscript{20}, they present empirical applications similar to those carried out in 2003 and more specifically focused on the linkage between infrastructure expenditure and the growth of \textit{per capita} GDP. On the other hand, they investigate the consequences of an improvement in the infrastructural stock (both quantitative and qualitative), to find evidence of a positive correlation between the provision of infrastructure available to a certain economy and the welfare of the poorest section of the population (through a negative correlation between the former and an income inequality indicator).

The choice of the second research theme is due mainly to the intuition (confirmed by the results of a study conducted by López\textsuperscript{21}) that the development of infrastructures has a real redistributive impact on average income and on the welfare of the poorest section of the population.

These works provide undeniable proof of how the role of infrastructure is fundamental in the economic development process of a country. However, to tackle the infrastructure issue by analysing the correlation between the infrastructure investment and the economic growth rate does not lead to objective or absolute evaluations of the policy conducted by a country’s government.

A different and potentially more difficult matter, which we try to look at in this work, is to determine whether a government provides its country of the quantity (and eventually the quality) of infrastructure that satisfies the economy’s actual needs.

To be able to judge the appropriateness of the infrastructural public policies of a country, a model for the infrastructure demand-supply equilibrium is required. In building it, problems such as the public nature of the goods and services related to infrastructures and the scarce availability of data on certain factors, such as prices, have to be faced.

Doing so, it is possible to investigate the possibility of an

\textsuperscript{20} CANNING D. (1998).

\textsuperscript{21} LOPEZ H. (2004).
inverse causal relationship between the infrastructure endowment of a country and this country’s potential rate of growth. If this relationship is proved to exist, then one could analyse the “infrastructure needs” (defined as the minimum physical stock of infrastructure needed by a country to launch its development process and to ensure its advancement) and check whether the policy makers take into account this infrastructure “target” while deciding about public investment. The more advanced the economy, the higher its growth rate and the larger the infrastructure stock required to make the economy improve at the reached speed.

Calderón, Easterly and Servén give a fundamental result related to this issue. They show how the retrenchment of public expenditure in infrastructure investment, made in order to enhance the public policy and improve the government’s solvency position, has negative effects on the growth rate of per capita GDP. More importantly, these negative effects become stronger when the country is highly indebted and, despite the liberalization reforms, the private capitals are not able to replace the reduced public infrastructure investments22.

In this contest, if the gap between the optimal and the actual infrastructure endowment is large, the policy decisions for the reduction of infrastructure expenditure are even more harmful to the economy. Instead of satisfying the infrastructure need and reducing the existing gap, such decisions will exacerbate and broaden the obstacles to the country’s economic development.

Calderón, Easterly and Servén define the infrastructural gap following the “stock-target approach”. They assume that the East Asian countries represent the economic potential of Latin

22 Easterly W. - Servén L. (2003) found that the correlation between private and public capital is statistically insignificant. Furthermore, they regress the volume of public infrastructure investment on private infrastructure investment with a dataset collected over the 80s reform period in LAC. The result shows that, despite a great heterogeneity between the different countries, the cutback of public infrastructure expenditure is not followed by any particular increase in private infrastructure investment. In particular, all the regressions reveal a positive coefficient of private on public infrastructure investment, suggesting that the two are complements rather than substitute.
American countries, and conditional on that they measure the gap through a direct comparison of the infrastructural conditions of the two regions. In other words, they measure the level of infrastructure stock that Latin America would have if its investments followed the same trend as those of the East Asian countries, with all the consequences on economic growth rates.

We conduct our infrastructural-gap analyses adopting an econometric approach. In the light of the recent economic literature, we found essential to seek for an analytical measure and the consequent econometric estimation of what is referred to as the “optimal infrastructure endowment”. It is only when the actual infrastructure gap of a country is established that it is possible to assess the fiscal policy measures related to public expenditure on infrastructure investment and their consequent impact on economic growth.

3. - A Model for the Demand of Infrastructures

Few works in the economic literature focused on the research of a consistent measure of the infrastructural gap. This paper aims to find an indicator capable of describing in detail the evolution and trend of the infrastructural gap of Latin American low and middle income countries over the last two decades.

A recent publication of the World Bank classifies the different approaches that can be followed to estimate the needs of infrastructure depending on the objective against which these needs have to be measured. In particular, a difference is made between the approach of stock or flow targets and that of econometric techniques. To adopt, as Calderon and Servén did, the first approach means to take the expenditure in infrastructure of a certain country (or region) as a target and then ask what level of infrastructure stock the country of interest would achieve if its expenditure were equivalent to that of the target country (or region).

Here we follow the econometric approach. We estimate the volume of infrastructures that responds to the needs of a country
and that should therefore be looked at as the policy target. To do so, conditional on the natural and technological capacity limits as well as on the institutional constraints of a country’s economy, we define the “optimal” demand of infrastructural services and goods as a function of the potential GDP\(^{23}\) on the basis of the existing relationship between income level and infrastructure service demand.

We depart from the model used by Fay and Yepes\(^{24}\) to predict future infrastructural demand. The two authors define a future demand that allows predictions over the evolution of the infrastructural stock. They treat infrastructures in their dual-role of additional input for the firms and additional consumption goods (or services) for the individuals. They sketch a basic model where the aggregate demand of infrastructure is dependent on real GDP; therefore, they proceed to their econometric application substituting the predicted GDP values to the actual ones in order to derive the projections of the infrastructural stock.

On the consumption side, we have \(j\) individuals that demand a quantity \(I_j^c\) of infrastructure depending on the level of their income (\(Y_j\)) and on the price of the services associated to the infrastructure (\(p_j\)):

\[
I_j^c = f(Y_j, p_I)\tag{4}
\]

Assuming that the function of equation (4) is linear in both income and prices, we aggregate over the entire population (\(N\) denotes the number of consumers) and get the aggregate demand of infrastructures (\(I^c\)), which, expressed in per capita terms, is equivalent to

\[
\frac{I^c}{N} = \frac{1}{N} \sum_{j=1}^{N} I_j^c = F\left(\frac{Y}{N}, p_I\right)\tag{5}\]

\(^{23}\) We refer here to potential GDP as to the aggregate output that would be produced if each firm had access to the total capital, labour and technology available in the economy. It is taken as a measure of the productive capacity of a country’s economy.


\(^{25}\) \(Y/N\) is per capita income.
On the production side, we have firms that use the infrastructure stock $I_i^p$ as an additional input factor. These firms maximize their profit function, so that the amount of infrastructures used depends on the ratio between the cost of the infrastructure services and the price of the final good. With a Cobb-Douglas production function augmented of infrastructural capital, the first order condition to the optimization problem is

$$\frac{\partial Y_i}{\partial I_i^p} = \frac{p_I}{w_i}$$

where $Y_i$ is the final output of the local firm in terms of goods $i$ and $w_i$ is the price of one unit of the same good. Therefore, we can re-express this FOC as,

$$K_i^\alpha I_i^\beta \phi I_i^{\phi-1} = \frac{p_I}{w_i}$$

where we explicitly have the capital input, divided in the two components of physical \(^26\) ($K_i$) and human ($L_i$) capital, and the flow of infrastructure services ($I_i^{\phi-1}$) used by the firm to produce good $i$.

Finally, we can solve for the demand of $I_i^p$ (equation (8)) and aggregate over all firms to estimate their overall demand of infrastructure services (equation (9)):

$$I_i^p = \left( \frac{w_i}{p_I} K_i^\alpha L_i^\beta \right)^{1/(1-\phi)}$$

$$I^p = \sum_i I_i^p = \sum_i \left( \frac{w_i}{p_I} K_i^\alpha L_i^\beta \right)^{1/(1-\phi)}$$

To estimate equation (8) econometrically some problems arise due to the intrinsic nature of infrastructures. No information is available at the individual firm level; considerations have to be done regarding technology and its effect on infrastructure.

\(^26\) Here ($K_i$) denotes the only non-infrastructural physical capital. This is a simplification, with respect to the analysis of Easterly W. - Serven L. (2003), who had to deal with a double inclusion of infrastructural capital in the production function, as mentioned above.
deterioration and on firms' productivity level; no data is available on the relative price of infrastructure goods and services.

Fay and Yepes solve these problems by taking total national output ($Y$) as a proxy of the aggregate demand of firms and accounting for the different demand elasticity across sectors (they introduce the portion of GDP derived by agriculture ($Y_{AG}$) and by industry ($Y_{IND}$)). They add technology ($A$)$^{27}$. They approximate the weighted average of relative price, ($w_i/p_i$), with the real price of infrastructure, ($p_i/w$) (where $w$ is the general price level).

As a result, equation (8) can be expressed as a function of the aggregate output, the real price of infrastructure, the two shares of GDP produced by agriculture and industry, and the level of technology.

$$I^p = F\left(Y, \frac{w}{p_I}, Y_{AG}, Y_{IND}, A\right)$$

Combining both sides of the economy (i.e. equations (4) and (10)), the infrastructure demand is derived. We express it in per capita terms as$^{28}$

$$\frac{I}{N} = F\left(\frac{Y}{N}, \frac{p_I}{w}, Y_{AG}, Y_{IND}, A\right)$$

In the empirical application, time and cross-section dummies are introduced in order to solve for the lack of data on price and technology and to capture the differences across time and among countries of all relevant but unobservable factors.

The function derived in equation (11) defines the actual total demand of infrastructure. We disaggregate and estimate this demand function at the level of the three core economic

\[27\] The idea is that the parameter $\phi$ changes depending on how fast the infrastructural capital deteriorates because of new technologies and on whether the firm belongs to the agricultural or the industrial sector; that have a different demand elasticity. Introducing both technology and the two sectors output shares, the changes of $\phi$ should be controlled for.

\[28\] Fay M. - Yepes T. (2003) note that the model finds its reasons in the assumptions that, on the one hand, the market for infrastructure is competitive (otherwise prices would not be constant among different firms) and, on the other hand, the infrastructure aggregate supply is perfectly elastic.
infrastructure sectors (telecommunications, power and transport sectors).

Also, we control for the quality of existing infrastructures and include the geo-demographic variables already considered by Canning in an earlier publication\textsuperscript{29}. These are the total population, the population density, the urbanization rate and the geographical size of the countries of interest. Accordingly to Canning's results, we believe that the infrastructure needs of a country are strictly correlated not only with the economic variables that define its development path, but also with a series of characteristics that influence the conditions and means of the distribution of goods and services.

The geographical dimensions of a country certainly amplify the demand for infrastructure, and at the same time causes distribution of goods and services related to the same infrastructure to be costly and potentially complicated. The size of population affects positively the total demand, but has to be weighted by the introduction of some measure of population density and urban concentration: a low urbanization rate may imply diseconomies in the phase of distribution\textsuperscript{30}, while an high urbanization rate could be the cause of large externalities.

The demand described by equation (11) and estimable by including also the variables discussed above is assumed to represent consistently the set of factors that determine the infrastructure need of a given country. If we replace the effective level of output with a measure of potential output, equation (11) can therefore predict the level of infrastructure that the country should demand in case all resources were used in production and the economy were at his maximum potential. This change lets the equation define the "optimal" demand of infrastructure, \textit{i.e.} the demand of the optimal level of infrastructure. Accordingly, the share of the optimal infrastructure stock that is not financed, produced or distributed is the consequence of a market inefficiency or, in other terms, the response to an unperceived or underestimated infrastructure need.

\textsuperscript{29}\textsc{Canning D. (1998).}

\textsuperscript{30}For the same reason that the size of the geographical area of the country may be correlated inversely to infrastructure endowment.
Formally, if $I^*_m$ is the optimal infrastructure endowment (or need) of country $m$ and $I_m$ is its actual (or observed) endowment, then

$$\frac{I^*_m}{N} = F\left(\frac{Y^*}{N}, \frac{p_t}{w}, Y_{AG}, Y_{IND}, A, Urb, Pop, Area\right)^{31}$$

and thus

$$\frac{I^*_m}{N} - \frac{I_m}{N} = \text{Infrastructural Gap}_m^{32}$$

The presence of a large gap between the observed infrastructure endowment and the endowment estimated by equation (12) could indicate that the economy is hampered by a sort of constraint on the deployment of its economic growth potentials. In this contest, if the government adopts a fiscal policy pushing on cutbacks of the expenditure in infrastructure investment, the overall situation will deteriorate. In the light of the empirical results that follow, it could be of interest to reconsider the analysis of the evolution of public investment trends that have been well defined in the works of Calderón, Easterly and Servén, and check whether the dimension of the infrastructural gap is in any way considered in the policy makers’ decision process.

4. - The Dataset

We built the dataset for the empirical application of the proposed model departing from two different sources.

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31 Where $Y^*$ refers to potential GDP.

32 An alternative method of estimation of the infrastructural gap would have been to look at (12) as at the equation defining the level of infrastructure demand at equilibrium (assuming that the economy reaches its potential GDP growth rate only then). Given that, one could adopt a partial adjustment approach, rather than a definitional one, and define the gap as

$$\ln I_{it} - \ln I_{it-1} = \alpha_i (\ln I^*_{it} - \ln I_{it-1})$$

where the parameter $\alpha$ represents the speed of adjustment of each of the $i$ countries toward their own equilibrium, and $I^*_{it}$ is defined by equation (12).
Data on physical infrastructure stocks are taken from the large dataset collected by Calderón and Servén for a 2004 World Bank publication\textsuperscript{33}. They are central to our research, since they provide more than 900 observations (121 countries spanned over the period 1960-1999) on infrastructure quantity and quality for the three main infrastructure sectors.

For the Telecommunications sector, the number of fixed and mobile telephone lines per 1000 workers gives a quantitative indicator, while the average waiting period for the connection of a main phone line is the qualitative indicator. For the Power sector, the number of gig-watts (GW) produced and distributed per 1,000 workers gives a proxy of the quantity of power needed (of the power generating capacity), while the ratio between the number of GW used and that actually produced and distributed is the qualitative indicator. For the Transport sector, the number of kilometres of roads and railways per km\textsuperscript{2} of the country surface gives the quantitative indicator, and the ratio of kilometres of paved roads to total road kilometres gives the qualitative indicator.\textsuperscript{34}

The data on the economic and geo-demographic characteristics of the 121 countries included in the analysis are taken from the 2005 World Development Indicators (WDI)\textsuperscript{35}.

The size of the industrial sector is proxied by the percentage of total value added produced in one year by the industrial sectors: namely mining, manufacturing, construction, electricity, water, and gas (calculated without making deductions for depreciation of manufactured assets or depletion and degradation of natural resources). The size of the agricultural sector, analogously, is proxied by the percentage of total value added produced in one year by agriculture sectors: namely forestry, hunting, and fishing, as well as cultivation of crops and livestock production (calculated

\textsuperscript{33} Calderón C. - Servén L. (2004c).

\textsuperscript{34} Worth a note is that a measure of infrastructure on annual, rather than quinquennial, frequency and normalized by 1,000 inhabitants, rather than workers, would have given a more consistent and less volatile series of indicators, given that most of the countries included in the panel are developing economies.

\textsuperscript{35} These series are published monthly on the \textit{IMF World Economic Outlook Database}, and \textit{OECD Economic Outlook}.
without making deductions for depreciation of manufactured assets or depletion and degradation of natural resources).

The Geographic area is simply given by the number of km² of national land. The Total Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The Urbanization Rate (in percentage terms) counts the midyear population of areas defined as urban in each country and reported to the United Nations. The Population Density is defined as the number of inhabitants per squared kilometre.

The main problem encountered in the creation of our dataset was to find an indicator for the potential level of output, given that our dataset had to be merged with the one built by Calderón and Servén.

The OECD and the IMF both estimate and publish cross-sectional time series of potential GDP in annual and monthly frequency data. They define the potential GDP as the maximum feasible non-inflationary output level, given the existing technology and production capacity. Therefore, the classic method adopted to estimate potential GDP is to compute the level of output given by a simple production function, where the two factors are the economy’s total stock of capital and the natural rate of unemployment (NAIRU36). Alternatively, the two international institutions employ for the estimation of potential output the Hodrick-Prescott filter37 for data smoothening. Our problem was that both IMF and OECD provide statistics of the potential output series only for the OECD countries. Whereas the dataset collected by Calderon and Servén, as mentioned above, contains observations over 121 countries from all the world’s regions, so

36 Non Accelerating Inflation Rate of Unemployment. It corresponds to the “natural rate of unemployment” since this is defined as the unemployment rate of an economy whose inflation rate is constant over time.

37 Hodrick and Prescott (HODRICK R.J. - PRESCOTT E.C., 1997) suggest a way to isolate the cyclical component of a series from its trend by operating a minimization problem that considers the cost of the variance of the cycle component together with the cost of the lack of smoothness in the trend component. A value for the parameter λ has to be chosen depending on the frequency of the data. It represents the weight of the component of the loss function accounting for the cost of lack of smoothness in the trend component of the series.
that we could not combine it with the potential output data extracted from any of the institutional resources.

Having to find our own measure of potential output, we decided to follow the approach of Calderon and Servén\(^{38}\), who synthesize their original data in a five-year average frequency to eliminate the cyclical fluctuation from the long term trend. We claim that a data smothering of this sort allows us to reduce the fluctuation of output, which in the case of developing countries are given by both economic and political reasons (the latter are those such as corruption, lack of democracy or simply political instability). Therefore, we conclude that the five year average of the actual level of output can proxy the potential level of output for any of the countries included in our dataset\(^{39}\). The variable used for \textit{per capita} output is the real GDP \textit{per capita} in constant 2000 US$ provided by the World Bank and published in the 2005 World Development Indicator.

This paper makes the same five years average synthesis on all the other 2005 WDI series in order to constitute a large panel dataset of more than 900 observations for any variable. The included countries have also been classified as in the World Bank Country Classification on the basis of three different elements: the geographic location\(^{40}\); the average income level\(^{41}\); the indebtedness level\(^{42}\).


\(^{39}\) We attempted to proxy the potential output by using the HP filter with a \(\lambda = 100\) on the series of real GDP on yearly-frequency data and then normalizing the resulting long term trend by the population and reducing the series to a 5-years frequency one. We therefore used this proxy in our regressions. The results obtained substituting this proxy to the simple five-years average of the real \textit{per capita} GDP series were not econometrically consistent, due to the presence of autocorrelation of second order in the residuals reported by the Arellano and Bond test for second order serial correlation. The problem persisted even after the introduction of a second lag of the dependent variable and after the restriction of the instrument matrix specified in the regression. For this reason we show only the regressions obtained using the simple five-years average.

\(^{40}\) In alphabetical order: EAP (East Asia and Pacific), LAC (Latin America and Caribbean), OECD (OECD members) and O (Others).

\(^{41}\) In decreasing order: HI (High Income), UMI (Upper Middle Income), LMI (Lower Middle Income) e LI (Low Income). In Appendix 2 Graphs, the «Middle Income Countries» group contains both LMI and LI which are not part of the regional groups of EAP, LAC e OECD.

\(^{42}\) Indebtedness levels are SI (Severely Indebted), MI (Moderately Indebted) and LI (Less Indebted).
5. - Estimation of the Optimal Infrastructure Endowment

The analytical model presented above provides the theoretical basis to define the demand for infrastructure stock. The equation says that per capita infrastructure stock \( I/N \) is a function of potential per capita GDP \( Y^*/N \), the real prices of infrastructure \( p/w \), the share of total output produced by the agricultural \( Y_{AG} \) and industrial \( Y_{IND} \) sectors as well as the technology endowment \( A \):

\[
I/N = F\left( Y^*/N, p/w, Y_{AG}, Y_{IND}, A \right)
\]

In order to make of equation \( 14 \) an expression of the optimal level of infrastructure (that is the infrastructural endowment a country needs when it reaches its economic potential), some changes have to be made.

Firstly, we control for the quality of infrastructure \( \text{qual} \). We add the geo-demographic indicators to the other independent variables: the urbanization rate \( \text{urb} \), total population \( \text{pop} \), population density \( \text{dens} \) and the geographic area of the surveyed countries \( \text{area} \). We omit the measure of the share of GDP produced by agriculture \( Y_{AG} \), assuming that this sector does not have a strong influence on infrastructure needs (the infrastructure considered in the dataset belong to the macro-dimension of a country's economy and, in this sense, have a direct influence on all industrial activities)\(^{43}\).

We re-write equation \( 14 \) as:

\[
I^*/N = F\left( Y^*/N, Y_{IND}, \text{Urb}, \text{Pop}, \text{Qual}, \text{Area}, p/w, A \right)
\]

\(^{43}\) The classification of activities is based on the technology used in the production process rather than on the sector the final products belong to. Which means that we relate a large scale technology intense agricultural activity to the industrial sector, despite the nature of its final product. An alternative to the exclusion from the equation of the agricultural sector could have been the attribution of weights to both regressors \( Y_{AG} \) and \( Y_{IND} \). Those weights could have taken into account the different role played by each sector in determining the optimal stock of infrastructure.
To solve the problems caused by the lack of data on the real price of infrastructure and on the technology endowment we included both time and country-specific effects: only these dummy variables can, in fact, allow for the unobserved factors that may change over time but remain constant within the countries or, vice-versa, for those that change within the countries but remain invariable in time. In the econometric application every single regression is repeated with and without these dummies in order to reveal their capacity to increase the overall statistical consistency.

The econometric model used to estimate the infrastructural need is the dynamic model for panel data advocated by Arellano and Bond in 1991\textsuperscript{44}. Given the economic nature of the subject under investigation, it was considered of great importance to estimate the dynamic, rather than static, causality effects. The macroeconomic variables treated evolve in the long term, and, accordingly, it is reasonable that the current dimension of a certain aspect depends not only on the dimensions observed in the present, but also on those observed in the past periods.

The Arellano-Bond GMM model has also been chosen, in preference to other panel dynamic models, for two specific econometric reasons. First, its conditions fit perfectly the dimensions of our dataset, which has many cross-sections ($N = 121$ countries) but very few time periods ($T = 8$ five-year periods), and does not require any assumption over the initial condition\textsuperscript{45}. Secondly, it permits the resolution of two econometric problems due to the structure of the equation: the endogeneity of the first lag of the dependent variable and the non-stationarity of some regressors.

Given these assumptions, the model equation estimated for the three sectors of telecommunication (indicated with $TEL_a$ or $TEL_b$ depending on, respectively, the exclusion or inclusion of mobile phones), power ($ENE$) and transport (indicated with $TRA$ or $TR_b$ depending, respectively, on the exclusion or inclusion of railways) is specified as:

\textsuperscript{44} Arellano M. - Bond S. (1991).
\textsuperscript{45} For a discussion of the advantages offered by the Arellano-Bond model, see the survey of Bond (Bond S., 2002).
where $\text{Infr} = \{\text{TELa}, \text{TELb, ENE, STRa, STRb, INFR}\}$, $d_t = \{d_{1965}, \ldots, d_{1999}\}$, are the time dummies, $X_{it}$ is the vector of explanatory variables (namely potential GDP per capita ($pcgdp_{it}^*$), infrastructural quality ($qual_{it}$), industrialization rate ($ind_{it}$), total population ($pop_{it}$), population density ($dens_{it}$), urbanization rate ($urb_{it}$) and geographic area ($area_{it}$) of country $i$ at time $t^{46}$); $\eta_i$ is the country specific effect and $\nu_{it} \sim \text{IID} (0, \sigma^2_{\nu})$ is the hydioscratic error term.

In addition to the single sector indicators, the infrastructure aggregate index ($\text{Infrit}_i$) is also computed according to the Calderón and Servén synthetic indicator:

\begin{equation}
\text{Infrit}_i = 0.6159 \cdot \text{TELa} + 0.6075 \cdot \text{ENE} + 0.5015 \cdot \text{STRa}
\end{equation}

where the coefficients are the weights assigned by the two authors to the different infrastructure stocks. A separate regression is run for this aggregate index.

Before proceeding with the estimation of the regressions, we check for the presence of non-stationarity in the dataset variables. We selected a proper stationary test, considering that the longitudinal dimension of the data did not allow the use of a common ADF-test, and in accordance with the most recent econometric literature, dedicated to the specification of different tests for the research of unit roots in panel data.

Mainly, we looked at the Levin and Lin test (1992)$^{47}$, the Im, Pesaran and Shin test (1997)$^{48}$ and the Maddala and Wu (1999)$^{49}$ test. In line with previous papers dealing with infrastructures and

\footnotesize{
46 Both dependent variables and regressors are expressed in logs (we conventionally indicate them in lower-case). The only exception is the urbanization rate, which is in percentage terms. Note that the variable related to the country's geographic extension, $area_{it}$, will not be estimated by the Arellano-Bond model: due to its time-invariability it will be dropped in the first difference transformation of the original equation, together with the fixed-effect $\alpha_i$.

49 MADDALA G.S. - WU S. (1999).}
with the results of the direct comparison of these tests conducted by Konya (2001)\textsuperscript{50}, we decided to apply the Im, Pesaran and Shin Test (IPS-test)\textsuperscript{51}.

The IPS unit root test for panel data was used on the dependent as well as on the independent variables of the model, with the only exception of the geographic area (which is assumed \textit{a priori} to be stationary). The results obtained, as shown in Table 3, suggest that there are at least two regressors (the natural log of GDP per capita and the urbanization rate) and two dependent variables related to the telecommunication sector, which have a unit root.

We repeated the test on the first difference of the function that represents the density distribution of those two non stationary variables, to determine their order of integration. As the table shows, the non stationary variables are all integrated of order one, $I(1)$. This result enhances the choice of the Arellano-Bond GMM estimator for the regressions over equation (16)\textsuperscript{52}.

Two more important questions arose for the estimation of the optimal infrastructure demand: the first concerns the choice of the number of lags to be included both for the dependent and the independent variables of the model\textsuperscript{53}. The second concerns the identification of a common regression specification for all investigated sectors, which made it possible to compare the results obtained across infrastructures and to draw our conclusions. A two step process was adopted to answer these two questions.

For each of the infrastructure sectors (as well as for the Calderón and Servén synthetic indicator) we regressed six different equations, each containing a different number of lags of both the dependent and the regressor variables, up to a maximum of three

\textsuperscript{50}KONYA L. (2001).
\textsuperscript{51}For all variables tested, we adopted the \textit{Akaike Information Criteria (AIC)} to define the number of lags to be considered in the autoregressive regression on which the null hypothesis $H_0$ of non-stationary is tested. We also assumed for all variables the presence of an individual trend: the macroeconomic nature of most of the series, together with their long-term dimension, justifies its inclusion.
\textsuperscript{52}The first-difference form in which the regressions are performed eliminates the problems due to the presence of unit root in the level of the two variables.
\textsuperscript{53}The Information Criterias, AIC or BIC, cannot be applied to the dynamic panel data model.
for both. This made it possible to control the explicative capacity of the different lags as well as the variations in the consistency of the estimated coefficients.

Hence, we picked a consistent regression specification common to all sectors. This was used to chart tables that draw a direct comparison of the way in which the different factors affect the optimal infrastructure endowment of each of the specific sectors analysed.

Tests have been performed on all regressions to ensure that the results were coherent with the assumptions of the model, other than just statistically consistent.

Firstly, we tested the null hypothesis \( (H_0) \) that there is no second order auto-correlation in the residuals of the first differenced equation, which is essential for the overall validity of Arellano-Bond estimations. The importance of this test stands in the fact that the null hypothesis corresponds to one of the conditions on which the GMM estimator is built\(^5\): if \( H_0 \) does not hold, the lags of the regressors used in the instrumental matrix are correlated with the hydiosinocratic errors and the estimates are inconsistent.

Secondly, we looked at the Sargan test of overidentifying restrictions, to check for the validity of the instruments used. The hypothesis tested is that the instrumental variables are correctly specified, and therefore are acceptable instruments. We report in our table the Sargan test results obtained using the GMM two-steps estimator, as suggested by Arellano and Bond in their 1991 paper\(^5\).

Finally, the Wald test checks the joint significance of the regressor coefficients. The results shown in the regression tables of Appendix 1 illustrate the result of the Wald test applied on the explicit coefficients.

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\(^5\) The condition being \( E [\Delta v_{it} \Delta v_{it-2}] = 0 \).

\(^5\) The two-step GMM relaxes the assumption of homoskedasticity of the error terms and uses the homoskedastic GMM one-step estimator for estimating the variance matrix of the error terms. The GMM two-steps is found to provide a relatively low gain in efficiency and therefore is not suggested for inference on the coefficients. Nevertheless, Arellano and Bond advice its use for the Sargan Test on the validity of instruments of a regression where heteroskedasticity of the error terms is allowed for.
Tables 1 and Table 2 show the final results of the econometric application. Reading by column we get a measure of the effect that every single factor has on the infrastructure need of one particular sector, whereas reading by row we get a comparison of the role played by the same factor across the various sectors. Equation (16) has been regressed with the Arellano-Bond one-step difference-GMM estimator. Given that all dependent variables and regressors are expressed in the log form, it follows that the obtained coefficients represent the elasticity of infrastructure stocks to the factor they are referred to.

Before proceeding to the analysis of the econometric results reported in Appendix 1, it should be noted that the regressions shown in the two tables have been chosen because of their comparability across sectors. This does not however exclude the fact that, for some infrastructural sectors, these regressions may not be the most statistically significant of all those performed.

According to the results of second-order autocorrelation tests, in Table 1 the GMM estimates are confirmed to be consistent, since for none of the regressions we reject the null hypothesis of no autocorrelation. The Sargan Test questions the validity of the over-identifying restrictions only in the case of the main and mobile phone lines (second column).

The Wald test gives a positive result for the joint significance of all regressors included in the equations estimated (note that the tests performed do not control for the time specific dummies). The estimates of the elasticity of the infrastructure stocks to all the economic and geo-demographic factors included as regressors confirm the results that we expected and that are supported by some of the abovementioned literature belonging to the background theory of this research.

For the two economic explicative variables (potential per capita GDP and industrialization rate) the results are very different. The elasticity of infrastructure to per capita GDP is obviously positive: with the only exception of the power sector and the transport in case both roads and railways are considered (where, in any case, the p-value proves the lack of statistical
significance), the coefficients are always positive and their values, where significant, are in the range of 0.5.

The industrialization rate is less easy to interpret: even if its signs are always reasonably positive, the coefficients are never statistically significant (except for the synthetic indicator). This result does not allow a final conclusion about this explicative factor, or, to be more exact, suggests that the effect of the industrialization rate on the infrastructure needs of a country is negligible in some measure.

As regards the geo-demographic factors, the regressions give different results depending on the infrastructure sector considered.

The elasticity of infrastructure need to the urbanization rate, whose estimated coefficients are insignificant in the power and transport sectors, turns out to be positive for both the telecommunication and the synthetic indicator. A plausible interpretation of this phenomenon could be the increase of telecommunication and power needs that is generally experienced during the transition process of concentration of the population in few urban areas (the assumption here is that urban areas are more technologically advanced than rural areas). In effect, this same process could involve a decrease in the demand for transport infrastructure in a given country: the higher the concentration of total population in urban areas, the lower the geographical dispersion rate, with the consequence of a reduction of the infrastructure need related to this sector and a sharp rise in the cost of meeting the need.

Finally, we found the infrastructure quality indexes to be always negative, when significant. This correspond to the intuitive consideration that an higher level of existing infrastructure reduces the need for new infrastructure, due to the lower or slower deterioration.

The regressions of Table 1 are repeated in Table 2 under a constraint imposed on the spatial dimension of the original dataset: all 121 countries (divided in low, lower middle, upper middle and high income countries) were considered in the first table, whereas all OECD and other high income countries are excluded in the second.
Two reasons motivated this second econometric application. On the one hand, it is interesting to check whether the role played by the different regressors that affect the infrastructure optimal demand may vary depending on the income level of the countries. On the other hand, this second set of regressions produces a result that eliminates, to some extent, the distortions that may occur in the estimates of infrastructure need, when countries with an income position (i.e. a development and technological situation) far higher than the world average (i.e. OECD countries) are included in the model. The reasoning was that it could be incautious to estimate the infrastructure need of low income countries, such as those of sub-Saharan Africa, with a panel dataset that included economies such as those of the United States of America or Europe.

The results shown in table 2 follow the same scheme as that of the whole panel of Table 1.

Worth noting is that the coefficients of the industrialization rate gain in terms of statistical significance and have a higher value than in Table 1: following an evolutionary approach, this could be due to the fact that a lower country-income level implies that a one percentage point positive variation of the industrialization rate causes a larger increase of the infrastructure need.

6. - Analysis of the Infrastructure Gap

With the estimates of the optimal infrastructure demand resulting from the econometric application explained in the previous pages, it was possible to measure the physical stock of infrastructure needed by a country to avoid a recession in economic growth and, through it, to measure the width of the gap that exists between the optimal and the actual infrastructure stocks.

Following the economic model, the infrastructure gap is measured by the difference between the optimal and the real observed endowment of a certain type of infrastructure; formally,
it is given by the analysis of the residuals of the regressions performed to estimate the optimal endowment\textsuperscript{56}:

\begin{equation}
\frac{I_{it}^*}{N} - \frac{I_{it}}{N} = \frac{\hat{I}_{GMM, it}}{N} - \frac{I_{bn}}{N} = \text{Infrastructure Gap}_{it}.
\end{equation}

The procedure used to measure the gap through equation (18) follows three steps. The parameters estimated by the Arellano-Bond regressions are used as estimated coefficients for the equation in level to extract the values of the error terms, $\varepsilon_{it}$. The value of the fixed-effects is computed through the mean of $\varepsilon_{it}$. The fixed-effects are subtracted from the total error terms, $\varepsilon_{it}$, in order to interpret the resulting $\nu_{it}$ as a measure of the infrastructural gap, defined as the difference between the optimal and the real infrastructure endowment of country $i$ at time $t$\textsuperscript{57}.

Appendix 2 graphically analyses the estimates obtained in the study of the gap. Graph 1 uses the synthetic index advocated by Calderon and Servén to describe the evolution of the overall

\textsuperscript{56} Note that the estimation of the gap involved two econometric problems. The first one concerns the inverse causality of the relation between the gap and its explicative variables. One could assume that the amount of infrastructures a country owns affects, among other things, the future development of the country's economy. This would imply that the gap estimated for the poorest economies is smaller than that estimated for the most advanced economies. It could, in other words, happen that a country is constrained by its low economic development level so that it becomes unable to perceive part of its real physical infrastructure need. The residuals of the regressions would, in this case, correspond to an estimation of the gap at the time it is measured, without considering the effects on the economic growth path that a wider infrastructure endowment could induce in that same country.

The second, relatively less important, problem concerns the group of countries belonging to the East Asian region. Calderon and Servén proposed a direct comparison between Latin American and East Asian countries, motivated by the vigorous economic growth experienced by the latter during the twenty-year period between 1980-1999. EAP countries were Hong Kong, China, Indonesia, Korea, Malaysia, Singapore, Taiwan and Thailand. The problem is given by the fact that the panel used in this work lacks information on some of the most advanced economies of that area. For this reason, the difference between the gap of East Asia and that of Latin America is not as evident here as it was in Calderon and Servén results.

\textsuperscript{57} We assume that the hydiosincratic component of the error term is $v_{it} \sim IID(0, \sigma_v^2)$. Therefore we compute $\bar{\varepsilon} = E(\varepsilon_{it})$ and then obtain our infrastructural gap from the residuals

$$
\varepsilon_{it} - \bar{\varepsilon} = (v_{it} + \bar{\varepsilon}) - \bar{\varepsilon} = v_{it} \sim IID(0, \sigma_v^2)
$$

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infrastructural condition of the four different groups of countries: Latin America, East Asia, OECD and those Middle Income Countries which do not belong to the first three geographical areas.

It is clearly evident that the OECD countries have been disposing of the way largest infrastructure stock since the early Sixties. Starting from the mid Seventies, there seems to have been a general continuous expansion of infrastructures, as much as in the other regions, also in those countries whose initial position was unquestionably backward the world average.

Regarding these other groups of countries, the positive effects of the outstanding economic performance of East Asia are not so evident in the first graphic of the Graph: it seems that, during the last fifteen years, the growth rate of infrastructures in this region has not been high enough to let EA countries gain a real advantage over LA. Despite this, in the upper diagram of Graph 1 we can observe that this GDP growth rate allowed EA countries to control and contain the widening of their infrastructural gap, which results even lower than that of the OECD countries (in this way placing itself at a far better position than that of LAC).

On their side, Latin American countries presented a quite high level of infrastructure gap for the whole forty-year long period (1960-1999). What is even worse, they showed an evident difficulty in containing the widening of this gap during the years following the debt crisis. This was probably a consequence of the adverse situation due to the inadequateness of the private sector in making up for the disinvestment policy promoted by the early Nineties government administrations.

Graph 2 refers to the Telecommunication sector, proxied by the indicator that measures the number of main phone lines available each 1,000 workers in the four geographic regions. The results pictured in the Graph give evidence of the same phenomena underlined by the graphics referred to the overall infrastructure condition. At the sector level too, the OECD countries had an undoubtedly advantageous position over the other countries both in the physical stock and in the estimated gap (which is anyway smaller than that of the synthetic index of Graph A2.1).
The relevant result of this second Graph regards the evolution of East Asian infrastructure stock: it appears here, more clearly than in other Graphs, that the steady economic growth rates allowed this area’s countries to have a large infrastructure stock. Once more, indeed, the infrastructure gap of Latin American countries, after a slight downward deflection, appears to have become larger and to follow the trend of the other Middle Income countries, which — as for them — did not increase the physical endowments enough to control their gap level.

Regarding the power sector, the indicator being the number of Giga Watts produced and distributed each 1,000 workers, the results for the physical stock (Graph 3) are biased by the lack of data on the East Asian strongest economies. East Asia lies disadvantageously behind the most developed countries, so that here the interregional infrastructure stock distance looks wide both in the “OECD vs Latin American” and in the “OECD vs East Asian” comparisons. Also, no help comes from the analysis of the rate at which the physical stock of power infrastructures has grown, since Latin America seems to have performed better than East Asia even under this dimension.

Looking at the Power gap (second diagram, Graph 3), however, the estimates depict a situation similar to those of both the synthetic indicator and the Telecommunication sectors. East Asian countries, while suffering from the same conditions of other regions in the beginning of the Sixties, had later been able to reduce their gap and reach the level of OECD countries. On the contrary, Middle Income and Latin American countries did not manage to increase their conditions and the latter also experienced a widening of the power gap during the last quinquennium.

Graph 4 shows the evolution of the transport sector with the indicator measuring the kilometres of road built for each km² of national area. For this last sector, the evidence given by the gap estimations is in contrast with the previous results. A lack of data did not allow the estimation of the gap for the OECD countries in the period 1970-1979, but in all other region we report a strong decreasing trend that puts all countries in an overall comparable situation.
A plausible hypothesis explaining these results could be that, especially in the most developed countries, the demand of the services linked to the transport sector is very high, due to the increasing mobility of latest years.

7. - Conclusions

The empirical results obtained become even more relevant if considered in conjunction with the findings of the World Bank report published in August 2005 entitled *Infrastructure in Latin America and the Caribbean: Recent Development and Key Challenges*.\(^{58}\)

This report shows that, today, the countries of Latin America spend less than 2% of GDP on infrastructure (1.7 percentage points less than the investment made over the five-years period from 1980-85). Compared to other medium-income countries, particularly those in East Asia, this proves that the never started recovery of the economy is partly due to the continued widening of the infrastructure gap as estimated in the empirical analysis of this research. In the light of this situation of continuous decline and the size of the estimated gap, the “key” actions suggested by the World Bank are, in effect, essential components of a strategy to attain an optimal infrastructure endowment. These actions should be aimed at the following three objectives: (I) increase the economic and social return of infrastructure investments, (II) improve the management of Private Participations in Infrastructure (PPI), by increasing their capacity to replace public participations, (III) to promote the raising of funds necessary for infrastructure investments so as maintain the commitment to reduce the gap, under all circumstances.

The strategies proposed to attain these three objectives are diverse, and all are effectively convincing in the light of the results of this research. The search for sustainability of programs for the distribution services linked to infrastructure, together with an

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improvement in the efficiency of managing the same, would certainly increase the possibility of access for the poorest section of the population. This is particularly true in the light of the insufficiency of the current levels of subsidy allocated to this group.

An increased emphasis on reform to open infrastructure services to PPI, a strengthening of the role of governments with an increased promotion of the more recent concession projects combined with more effective risk management are necessary to optimize the management of PPI. Such measures are essential, given the disadvantageous condition of Latin American countries at present.

Finally, some observations on the strategy to raise larger amounts of funds for infrastructure investments, which is probably the most important objective for these countries, although one that they have most difficulty in attaining. Without this, however, they will probably not manage to reduce the infrastructure gap. These countries therefore require strategies for better risk management in order to attract new private investments, fund raising by through tolls and an increase of public investment in infrastructure combined with a strong institutional, legal and regulatory framework, which will permit more reliable and innovative financial structures.
<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Main Phone Lines</th>
<th>Main and Mobile Phone Lines</th>
<th>Power</th>
<th>Roads</th>
<th>Roads and Railways</th>
<th>Infrastructure Aggregate Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Dep_{t-1} )</td>
<td>0.530***</td>
<td>0.437***</td>
<td>0.514***</td>
<td>0.571***</td>
<td>0.679***</td>
<td>0.778***</td>
</tr>
<tr>
<td>( [0.121] )</td>
<td>( [0.116] )</td>
<td>( [0.126] )</td>
<td>( [0.109] )</td>
<td>( [0.076] )</td>
<td>( [0.081] )</td>
<td></td>
</tr>
<tr>
<td>Urbanization rate</td>
<td>Urb ( _{t-1} )</td>
<td>0.025***</td>
<td>0.027***</td>
<td>0.009</td>
<td>0.007</td>
<td>0.003</td>
</tr>
<tr>
<td>( [0.009] )</td>
<td>( [0.010] )</td>
<td>( [0.009] )</td>
<td>( [0.006] )</td>
<td>( [0.006] )</td>
<td>( [0.011] )</td>
<td></td>
</tr>
<tr>
<td>( Urb_{t-2} )</td>
<td>-0.020*</td>
<td>-0.017</td>
<td>-0.009</td>
<td>-0.008</td>
<td>-0.001</td>
<td>-0.036***</td>
</tr>
<tr>
<td>( [0.011] )</td>
<td>( [0.012] )</td>
<td>( [0.011] )</td>
<td>( [0.006] )</td>
<td>( [0.005] )</td>
<td>( [0.012] )</td>
<td></td>
</tr>
<tr>
<td>Ln (Total Population)</td>
<td>Pop ( _{t-1} )</td>
<td>-0.822</td>
<td>0.457</td>
<td>-2.456</td>
<td>-2.086</td>
<td>-3.748</td>
</tr>
<tr>
<td>( Pop_{t-2} )</td>
<td>-0.822</td>
<td>0.457</td>
<td>-2.456</td>
<td>-2.086</td>
<td>-3.748</td>
<td>-2.451</td>
</tr>
<tr>
<td>Ln (per capita real GDP)</td>
<td>pcGDP ( _{t-1} )</td>
<td>0.509***</td>
<td>0.551***</td>
<td>-0.099</td>
<td>0.085</td>
<td>-0.025</td>
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<td>Ln (Population Density)</td>
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<td>0.039 ([0.172])</td>
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<td>-0.412 ([3.381])</td>
<td>-0.273 ([0.547])</td>
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<td>0.722 ([0.828])</td>
<td>-1.181** ([0.536])</td>
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<td>0.377**</td>
<td>-0.034</td>
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</table>

**Note:** All regressions refer to the entire panel of 118 countries observed from 1960 to 1999. Data are in 5 years average. GMM estimators are used. Robust standard errors are reported in "(#)". The GMM one-step estimates are computed with Huber-White SE, while the two-step uses the Windmeijer bias-corrected two-step robust VCE. * significant at 10%; ** significant at 5%; *** significant at 1%. For the Wald test, we report the results obtained under the assumption of homoskedasticity in the error terms. For the Sargan Test we report the results computed over the two-step regression and the p-value referring to the null hypothesis of instrument validity. The values reported for the AB2-test refer to the second order autocorrelation of the residuals of the first differenced equation. The constant (i.e. the overall time trend) is included because some of the series are found to be stationary with a deterministic trend.

**Source:** Author's own calculations.
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<th>Power</th>
<th>Roads and Railways</th>
<th>Infrastructure Aggregate Indicator</th>
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**Note:** *p < 0.1, **p < 0.05, ***p < 0.01.
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**Note:** All regressions refer to all countries with low and middle income observed from 1960 to 1999. Data are in 5 years average. GMM estimators are used. Robust standard errors are reported in “(#).” The GMM one-step estimates are computed with Huber-White SE, while the two-step uses the Windmeijer bias-corrected two-step robust VCE. * significant at 10%; ** significant at 5%; *** significant at 1%. For the Wald test, we report the results obtained under the assumption of homoskedasticity in the error terms. For the Sargan Test we report the results computed over the two-step regression and the p-value referring to the null hypothesis of instrument validity. The values reported for the AB2-test refer to the second order autocorrelation of the residuals of the first differenced equation. The constant (i.e. the overall time trend) is included because some of the series are found to be stationary with a deterministic trend.

**Source:** Author's own calculations.
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<td>637</td>
<td>0 to 1</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Roads &amp; Railways</td>
<td>-390.9560</td>
<td>(0.000)</td>
<td>91</td>
<td>577</td>
<td>0 to 1</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Roads &amp; Railways Quality</td>
<td>-15.7462</td>
<td>(0.000)</td>
<td>93</td>
<td>605</td>
<td>0 to 1</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Infrastructures Ind.</td>
<td>-10.4070</td>
<td>(0.000)</td>
<td>96</td>
<td>613</td>
<td>0 to 1</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Infrastructure Quality Ind.</td>
<td>-4.2658</td>
<td>(0.000)</td>
<td>67</td>
<td>313</td>
<td>0 to 1</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: The null hypothesis $H_0$ assumes the presence of an individual unit root process. The result indicates the presence of a unit root if the test fails to reject the null of absence of a unit root for any individual cross-section. Probabilities are computed assuming asymptotic normality. P-values of the standardized t-bar correspond to the asymptotic values of the lower tail. Source: Author's own calculations.
APPENDIX 2

GRAPH 1

INFRASTRUCTURAL GAP
(computed on the aggregate index of infrastructural stock)

Source: Author's own calculation.
Graph 2

TELECOMMUNICATION SECTOR GAP
(in terms of N. of phone lines/1,000 inhabitants)

MAIN PHONE LINES
(N. phone lines/1,000 inhabitants)

Source: Author's own calculation.
Graph 3

POWER SECTOR GAP
(in terms of N. of produced and distributed GW/1,000 inhabitants)

Source: Author's own calculation.
GRAPH 4

TRANSPORT SECTOR GAP
(in terms of road km /km²)

Source: Author's own calculation.


