SOCIAL AND ECONOMIC INFRASTRUCTURE AND ITS RELATIONSHIP WITH REGIONAL ECONOMIC GROWTH IN ECUADOR

Ronny Correa-Quezada
Universidad Técnica Particular de Loja (UTPL), Loja, Ecuador

Tania Paola Torres-Gutiérrez
Universidad Técnica Particular de Loja (UTPL), Loja, Ecuador

José Álvarez-García♣
Departamento de Economía Financiera y Contabilidad, Instituto Universitario de Investigación para el Desarrollo Territorial Sostenible (INTERRA), Universidad de Extremadura, Cáceres, España

María de la Cruz del Río-Rama
Business Management and Marketing Department, Faculty of Business Sciences and Tourism, University of Vigo, Ourense, Spain

ABSTRACT

In the literature on growth, infrastructure, in addition to other factors, is identified as a determining element in the growth of regions from a long-term perspective. However, there are few studies where the unit of analysis is disaggregated down to the regional level. Therefore, this research aims to explore the importance of infrastructure (social and economic) in the economic growth of Ecuador´s provinces. The methodology used leads to the calculation of a Global Productive Infrastructure Index (GPII) composed of two categories: Social Productive Infrastructure (SIP), and Economic Productive Infrastructure (EPI) (Hansen, 1965). In addition, econometric estimates are made of the relationship between infrastructure and economic growth, the latter measured by the Gross Added Value of each province. The results of the empirical models used indicate that the economic productive infrastructure is essential for the economic growth of Ecuador´s provinces. It is made up of energy infrastructure, transport infrastructure and communications infrastructure, of which the last two are the most representative and affect growth directly. In terms of the disaggregation of indices, it is observed that, in general, the provinces with the highest economic and global index and, therefore, the highest growth are the provinces of Pichincha, Azuay and Guayas.

Keywords: Social infrastructure, economic infrastructure, economic growth, regional growth, global productive infrastructure index, ecuador.

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♣ Corresponding author: Departamento de Economía Financiera y Contabilidad, Instituto Universitario de Investigación para el Desarrollo Territorial Sostenible (INTERRA), Universidad de Extremadura, Cáceres, España. Email: pepealvarez@unex.es

1. INTRODUCTION

Infrastructure is relevant for economic growth, particularly in developing countries, where according to the Inter-American Development Bank [IDB] (2015) infrastructure contributes to expanding markets, increasing private investment and lowering production costs, in a context of efficient spending on this item. However, the countries of Latin America generally exhibit a high scarcity of infrastructure, which suggests that the economies of the region have been functioning almost solely with a historical stock of infrastructure that limits the possibilities of achieving periods of sustained growth (Lardé, 2016).

Growth is a substantial issue in Ecuador because there are regional economic divergences, that is, marked differences between growth and productivity in states and regions (Fuentes, 2007). In this line, Mendieta Muñoz et al. (2015) explain the spatial regional heterogeneity in the country in terms of the productive structure, defining as winning provinces those that have benefited from better opportunities than the other provinces in terms of infrastructure, airports, access to education, quality of the educational system. and performance of the industry and institutional environment.

For their part, Correa-Quezada et al. (2018:1) state that "*Regional inequalities in Ecuador's economic development processes are clearly revealed through a number of situations and conditions such as an economic and population concentration in certain provinces, disparities in per capita GDP, household income, access to public services, schooling, significant gaps in the provision of infrastructure, as well as the marginalisation and poverty of a considerable number of people in the population*."

The reduction of such inequalities requires promoting regional growth through three elements: natural resources, in whose endowment individuals can hardly interfere; human resources (job supply, training, discipline, motivation, etc.) and capital formation (machinery, factories, facilities, etc.). Added to these are the elements of government responsibility, such as education, public safety, legislation and infrastructure, the latter being a key element in production processes and in improving the quality of life of individuals (Aschauer, 1990).

From this perspective of analysis, the positioning of infrastructure in the objectives of sustainable development entails a greater responsibility of public policies in advancing towards higher levels of quality investment required to improve the quality of life of the population. Hence, the motivation and contribution of this work is to specify the role played by investment in social and economic productive infrastructure in the growth of Ecuador, and briefly discuss the implications of the investment patterns made, an approach that does not exist in the country. Our results indicate that the productive economic infrastructure, in particular the transport infrastructure and the communications infrastructure, is essential for the economic growth of the provinces in Ecuador.

Following Barajas and Gutiérrez (2012) in a study conducted for the northern states of Mexico, this paper adapts the sequence and methodology for the case of Ecuador´s provinces. Firstly, a Global Productive Infrastructure Index (GPII) is calculated, composed of two categories: Social Productive Infrastructure (SPI) and Economic Productive Infrastructure (EPI) (Hansen, 1965); and secondly, some econometric estimations of the relationship between infrastructure and economic growth are developed, the latter measured by the Gross Value Added of each province, which is the unit of territorial analysis of interest. The calculation of indicators allows for the identification of heterogeneous results regarding the factors or elements that condition the economic growth of the respective provinces of Ecuador, which is assumed to occur due to the specific characteristics of each province; while it is evident that the economic productive infrastructure is a determining factor for regional growth, the social productive infrastructure is not.

This paper is structured as follows. After a brief contextualization of the topic and the objective of research, in the second section, a review of the literature on the impact of state infrastructure on growth and productivity is presented. The third section presents the methodology used, describes the indices and variables to be used, and the regression models to be validated are proposed. The fourth section presents the results, and the last section presents the final conclusions of the research.

2. STATE INFRASTRUCTURE AND ITS IMPACT ON GROWTH AND PRODUCTIVITY

The analysis of the relationship between growth and infrastructure is of ancient date in the economic literature. Rostow (1961) in a pioneering work postulated that the development of infrastructure networks (specifically, transport networks) was an essential precondition for economic development, which was later corroborated by Taaffe et al. (1973). In the works of these authors, the stock of public infrastructure conditioned the pace of the aggregate growth of the economy, so they proceeded to evaluate the direct impact of the former on the latter (Rozas & Sánchez, 2004). For his part, for Barro (1990), public and infrastructure spending is considered one of the elements that generates endogenous growth. Infrastructure facilitates the circulation of information, goods and people, which in turn leads to improved productivity of companies in the regions.

The first attempts to measure the impact of investment in infrastructure works and services on economic growth emerged strongly in the late 1980s at the global and Latin American level. In Argentina, two studies were carried out at the metropolitan level on the impact of additional creation and infrastructure improvements. Eberts (1986) measured the effect on industrial added value, and Denno (1988) measured the effect on the industrial product, obtaining elasticities that fluctuated between 0.16 and 0.26 in the first study; and 0.31 in the second study (Rozas & Sánchez, 2004).

For its part, the work of Aschauer (1990) is considered the most relevant worldwide on the impact of infrastructure on the economy because it focused on a set of forty-eight states in the USA, highlighting the following premises: 1) Public capital exerts a positive and significant effect on private production and factor productivity, the composition of this capital is important as the so-called productive infrastructures are those that show a closer relationship with productivity, with public capital allocated to health, education or general services being less relevant (Alastuey & Echavarren, 2008). It is noteworthy that the results of Aschauer's model are questioned by Munnell (1992), Tatom (1993), and Gramlich (1994) because they show high elasticities and are derived from equations with methodological and econometric limitations.

Another study that observed the positive effect that infrastructure has on economic growth or productivity was that of Ford and Porter (1991), who found that the average elasticity of infrastructure on total factor productivity is 45% for the countries of the Organization for Economic Co-operation and Development (OECD).

Likewise, Easterly and Rebelo (1993), when correlating data for 28 countries (Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Denmark, Finland, France, Germany, Greece, Italy, Japan, Mexico, Holland, New Zealand, Norway, Peru, Portugal, Spain, Sweden, Switzerland, United Kingdom, Uruguay, United States, and Venezuela), indicate among other issues, that investment in transport and communication is constantly correlated with growth and that the coefficient (impact) of public investment on the growth of the economy is 0.4.

Para Estados Unidos de Norteamérica se realizaron varios estudios cuyos hallazgos señalan: (1) that a fall in public investment causes a decrease in productivity (Tatom, 1993); (2) that public spending is a determinant of the differences in growth between states (Hulten & Schwab, 1991); and (3) that investment in infrastructure has a positive effect on cost reduction in the manufacturing sector (Nadiri & Mamuneas, 1994). For this country, Pereira (2000) finds that public investment has a positive effect on private production. Investment in basic infrastructure in electricity and gas facilities, transit systems and airfields, as well as in sewerage and water supply systems shows the highest rates of return, 16.1% and 9.7%, respectively. Meanwhile, investment in education, hospitals and other public services generates a return of less than 9%.

In Sweden, Berndt and Hansson (1992), when assessing and measuring the contribution of public infrastructure capital to private-sector production and productivity growth conclude that increases in public infrastructure capital, all other things being equal, reduce private sector costs, thereby increasing productivity. On the other hand, for Chinese provinces, Démurger (2001) points out that investments in transport and communication contribute more to growth than investment in education.

Calderón and Servén (2004) empirically assess the impact of infrastructure development on economic growth and income distribution, using a set of panel data covering more than 100 countries for the period 1960-2000. These researchers find that growth is positively affected by the stock of infrastructure assets, and that income inequality decreases with a higher quantity and quality of infrastructure. They also state that these two combined results suggest that infrastructure development can be highly effective in combating poverty.

For its part, Pradhan et al. (2015) analyse the causal relationships between information and communications technology (ICT) infrastructure and economic and financial growth in Asian countries. By using panel cointegration techniques, these authors observe short-term and long-term causal links between ICT infrastructure and economic growth, and between ICT infrastructure and financial development. Similar conclusions are reached by other authors in different countries (Madden & Savage, 1998; Dutta, 2001; Chakraborty & Nandi, 2003; Chu et al., 2005; Pradhan et al., 2014).

Yılmaz and Çetin (2017) use a set of instrumental variables comprising 29 developing countries between 1990 and 2014 and through a dynamic panel model show that infrastructure has a positive and significant impact on growth; however, this impact is smaller than predicted by previous studies on this cause-effect relationship.

Recently, Novitasari et al. (2020) investigates the impact of infrastructure development on economic growth in Indonesia, using as the unit of analysis all regencies and cities in three provinces, namely West Java, DKI Jakarta and Banten, chosen for their strong connection between activities. economy and infrastructure. The findings suggest that the infrastructure indicators used have positive and negative impacts on economic growth indicators. The infrastructure indicators with positive impacts on the GDP share are the length of roads, the number of hospitals and the level of service in waste management, while the infrastructure indicator that negatively affects the GDP share is the percentage of running water.

Zhang et al. (2021) analyze the relationship between the construction of different types of public infrastructure and regional economic growth using statistical data from the Yangtze River Economic Zone with 131 cities between 2003 to 2016 with a spatial approach. The results show that different types of capital stock in public infrastructure have different spatial effects on regional economic growth. The energy infrastructure capital stock significantly promotes global economic growth in the order of 0.515. The capital stock of the transport infrastructure significantly stimulates the local economic growth and inhibits the growth of the adjacent areas in the order of 0.0670. The capital stock of water-related infrastructure restricts local economic growth and promotes economic growth in adjacent areas. These findings indicate that increasing investment in public infrastructure development in the Yangtze River Economic Zone remains an effective measure to promote regional economic growth.

Singh (2021) assesses the disparities between districts in social infrastructure (SI) and physical infrastructure (PI) and accordingly attempts to examine the impact of SI and PI. on economic growth in Punjab, India in two moments 2004-2005 and 2016-2017. For this purpose, the author calculates a social infrastructure index (SII) and a physical infrastructure index (PII) both at the district level that encapsulate 12 and 10 indicators, respectively, using principal component analysis. The study findings revealed that PI acts as a critical catalyst to accelerate economic growth, while SI does not demonstrate any significant association with economic growth in Punjab. Furthermore, it is noted that there are widespread disparities between districts in the development of SI and IP with most districts showing a bleak picture of infrastructure development in Punjab.

In contrast, another group of studies find that infrastructure is not significant in the economy (Holtz-Eakin, 1994; Evans & Karras, 1994; García-Milá et al., 1996). On the other hand, when Bougheas et al. (2000) take Romer's endogenous growth model (1987) as a reference, they agree that infrastructure can promote specialization and long-term growth, although its effect on the latter is not monotonous (not serial or with defined patterns), reflecting its resource costs, and that the degree of specialization is positively correlated with the core infrastructure. Crescenzi and Rodríguez-Pose (2012) analyse the contribution of the provision of transport infrastructure, represented by regional motorways, to regional growth in the European Union between 1990 and 2004. Their findings are that infrastructure provision is a limited indicator of economic growth and that regional growth in the EU is rooted in a combination of an adequate “social filter”, a good innovative capacity, both in the region and in the neighboring areas, and in the region's ability to attract migration.

The review and synthesis of the current literature on “infrastructure and growth by determining sources of variation in empirical results” lead Elburz et al. (2017) to conclude that studies using data from the United States are more likely to record a negative impact of public infrastructure on regional growth. They also found that the type of infrastructure, the research methodology, the time period, the type of infrastructure measure, and the geographic scale affect the results of the primary studies. Likewise, they indicate that studies that take into account interregional, interstate, and interprovincial relations are more likely to find negative effects, which gives an idea of the indirect effects of these investments. Taking into account the works cited above and others such as Sánchez-Robles (1998), Canning (1999), Röller & Waverman (2001), Esfahani & Ramirez (2003), it is observed that the data used in the investigations are aggregated data.

Likewise, by reviewing the literature (64 documents between 1989 and 2007) on infrastructure and development, Straub (2008) concludes that this type of study should take microeconomic and economic geography orientations into account, in addition to macroeconomic approaches. He also indicates that the main effort should focus on the microeconomic side, through a strategy to collect data from household and business surveys on aspects including access, quality and costs of services. Furthermore, he suggests that at the macro level, research should move away from a long series of contributions whose aim has been to estimate the link between production or growth and aggregate infrastructure indicators (public capital or physical indicators); and, rather, focus on how aspects related to the political, institutional and regulatory environment have affected the provision and efficiency of services in different sectors.

In terms of public policies in recent years in Latin America, State participation in development processes emerged as an important element, particularly to improve the opportunities of territories or regions that show clear economic and social disadvantages. Among the public policies implemented in the continent, the most widespread is investment in infrastructure, mainly in roads, electricity, and drinking water (Aguirre, 2016). In this region, greater availability and quality of infrastructure have a significant impact, accelerating growth and reducing inequality (Calderón & Sérven, 2004).

In this context, González et al. (2007), when addressing the effects of infrastructure on productivity and growth, suggest three recommendations for Latin American countries: (1) The region needs to invest more and better in infrastructure, as countries in the region spend less than 2% of GDP on infrastructure. 3% to 6% is required to keep up with other countries such as China or Korea. However, the temptation to build "white elephants" should be avoided, new investments should focus on increasing productivity and competitiveness without neglecting the social part. In this regard, Latin American countries need to establish institutions capable of carrying out adequate planning and cost-benefit analysis; and monitoring and assessment. (2) Latin America needs to group infrastructure investments by adopting policies aimed at improving the efficiency of logistics service providers. This is related to the absence of public policies, poor quality infrastructure and unreliable service providers. (3) Latin American countries need to adopt policies to improve trade facilitation.

Cipoletta Tomassian (2009) points out that infrastructure integration at the regional level is a key issue for boosting growth and achieving higher levels of development in the region. That is why Latin America and the Caribbean require the development and strengthening of formulas that allow them to function as an integrated space. It is in this sense that it is essential to have a physical infrastructure that connects the countries of the region, linking their routes by roads, railways and river and maritime transport, as well as integrating their different forms of energy and telecommunications. Latin American and Caribbean Economic System [SELA] (2011) determines that in Latin America, there is a positive relationship between the development of physical infrastructure, economic growth and social well-being. Thus, it can also be assumed that underdevelopment is directly related to a poor and insufficient infrastructure. Investments in the infrastructure sector and its related services generate three types of effects: (1) they contribute to the formation of the Gross Domestic Product, through transport services, telecommunications, the supply of drinking water and electricity, and sanitation; (2) they generate externalities on production and investment, accelerating long-term growth; and (3) they influence the productivity of the rest of the economy within the different production processes and at the business level.

Cárdenas et al. (2006) make public policy recommendations for Colombia in order to solve institutional problems in the infrastructure sector (availability of public resources, sectoral planning, intergovernmental relations and the political environment). Urrunaga and Aparicio (2012) analyse the importance of infrastructure for economic growth for the 24 regions of Peru in the period 1980-2009. These authors confirm that public service infrastructures (roads, electricity and telecommunications) are relevant to explain the transitional differences in the regional product, in line with neoclassical exogenous growth theories. On the other hand, they find evidence supporting the presence of significant differences in the impact of different infrastructures on the per capita product of each region. Previously, Vásquez & Bendezu (2008) found that road infrastructure has a significant impact on the growth of Peru´s regions, but, in turn, could generate adverse effects on regional inequality.

In Mexico, according to Berman et al. (2012), public spending on infrastructure is not primarily responsible for the change in economic activity, i.e., it is not responsible for economic growth in the country. Recently, Zepeda-Ortega et al. (2019) observed a positive density-road-production relationship for municipal regions in Mexico. These authors show that roads have their greatest effects on regional gross production from manufacturing activities and retail trade, while they have no significant influence on agriculture, livestock, fishing and mining.

In the case of Ecuador, although efforts have been made to measure the importance of infrastructure, they have focused on housing, transport and education, as well as its role in economic concentration and regional inequalities, but to date there has not been a study that comprehensively covers infrastructure. In this direction, Vilema (2010) argues that Ecuador´s road infrastructure is extensive; however, lack of maintenance has led to its deterioration over time. Other infrastructures such as railways, air and waterways have undergone the same fate as roads. This author also mentions that there is a significant difference between Ecuador´s infrastructure and that of Asian countries, especially in terms of technology levels and quality of services.

Along these lines, Ponce (2013) analyses the evolution of housing and basic infrastructure in Ecuador, comparing information from the 1990 and 2001 Censuses. In this study, the Multivariate Index of Basic Infrastructure is used to investigate the differences between cantons and provinces in terms of the provision of basic infrastructure and to determine the different levels of development, based on the following variables: 1. Percentage of Households that have water (public network), 2. Percentage of Households that have a sewage system (public network), 3. Percentage of Households with a rubbish collection system (by garbage cart), 4. Percentage of Households with electricity service (public network). The paper concludes that Ecuador did not experience significant improvements in terms of housing ownership and quality during the 1990s. The situation is worrying if one considers that for example, in the 21st century, one out of every five homes still has dirt floors. In terms of cantons, strong disparities can be seen in the contrast between the provincial capitals, which are better equipped with basic infrastructure, and the rest of the cantons.

Acosta (2010) proposes a general equilibrium model of a two-sector economy, whose main objective was to find implications of public infrastructure on private performance. In Ecuador, strategic sectors were selected, where public investment is prioritized. For these sectors, the same productivity coefficient of infrastructure investment is estimated, obtaining a result of 0.1330, which is very similar to the result obtained for the two-sector economy, 0.1319. Therefore, public investment in strategic value-generating sectors one year before the National Plan for Good Living is insufficient, showing low effective elasticity of public infrastructure. The model assesses the social profitability of public investment in basic sanitation infrastructure, productive support, energy, agriculture, transport and telecommunications.

From a spatial perspective, public spending in the country under the so-called “import substitution industrialization” development model generated a series of biases. Investment in infrastructure, especially in two cities, resulted in a greater concentration of employment and income. In this way, industrial conurbation and infrastructure generated cumulative effects of economic and demographic growth in certain urban areas (Quito and Guayaquil), which an issue that remains to this day (Correa, 2016; Correa-Quezada & Bonilla, 2018). Following this line of research, Torres-Gutiérrez et al. (2019), in a study on agglomeration economies, suggest that in Ecuador´s cities it is necessary to strengthen diversified local productive structures as a source of innovation and economic growth. To this end, public and political intervention must ensure an adequate infrastructure, as well as the proper functioning of transport and communication. Meanwhile, on the social side, in Ecuador, significant gaps in the provision of public infrastructure have led to precarious conditions and poverty traps in a considerable number of municipalities in the country (Correa-Quezada et al., 2018).

Recently, Flores Chamba et al. (2019), by correlating convergence and public spending in Ecuador, aimed to determine the effect of increased public spending on physical infrastructure and education on the improvement of productive conditions and the process of disparity reduction (convergence) at the regional level in Ecuador between 2001 and 2015. The findings show the existence of a "slight" process of per capita convergence and productivity, although with a significant level of territorial "segregation". It is also observed that public investment during this period did not increase the productivity of small and medium-sized provinces significantly, severely conditioning the sustainability of the process of reducing disparities at the regional level. Finally (Correa-Quezada et al., 2019), when determining the basic explanatory factors of growth using a *bottom-up* spatial econometric methodology, in which they consider territorial, sectoral and institutional aspects, it was observed that the road density per square kilometre of municipalities is not a determinant of economic growth.

3. METHODOLOGY

The study carried out by Barajas and Gutiérrez (2012) for the northern states of Mexico is taken as a methodological reference for two reasons; The first is the availability for Ecuador of data and indicators used by these authors; the second corresponds to the similarity that the authors find between Ecuador and Mexico when comparing the contribution of social and economic infrastructures in the regional growth of these countries.

Also, the sequence and methodology are adapted for the case of the Ecuadorian provinces. Firstly, a Global Productive Infrastructure Index (GPII) is calculated, composed of two categories: Social Productive Infrastructure (SPI) and Economic Productive Infrastructure (EPI) (Hansen, 1965). Secondly, considering that the population (number of inhabitants) can affect the results, more reliable indicators are obtained when using the indices in per capita terms. Table 1 shows the components and variables of the indices, as well as the sources of information used in this paper, dating from 2010 and calculated for the 24 provinces of Ecuador.

Table 1: Indices, Sub-indices, Variables and Sources of Information

	INDEX	Sub-Index	Variables	Source (Year)
Global Productive Infrastructure Index (GPII)	Social Productive Infrastructure (SPI)		Number of Schools per capita	Statistics from the Ministry of Education (2019)
			Number of Teachers per capita	Statistics from the Ministry of Education (2019)
			Number of Students (Sum of students from preschool, primary, secondary, basic education, baccalaureate, post-baccalaureate, higher and postgraduate) per capita	Population and Housing Census, INEC (2010a)
	Economic Productive Infrastructure (EPI)	Energy Infrastructure (Ie)	Percentage of homes that receive water through the Public Network	Population and Housing Census, INEC (2010a)
			Number of luminaires per capita	Statistics of the Ecuadorian Electricity Sector, CONELEC (2011)
			Kilogrammes of LPG Consumed by province. (LPG demand by province) per capita	Mixed Economy Company, LOJAGAS (2013)
		Transport Infrastructure (It)	Total Length of Roads per Km2 of province surface	Ministry of Transport and Public Works, GEOPLADES (2014)
			Number of Cargo Trucks per capita	Statistics of land transport, INEC (2010b)
			Number of9 Airports per capita	Statistics of the Civil Aviation Directorate of Ecuador (2011)
			Number of passengers admitted per capita	Statistics of air transport, INEC (2010c)
			Charge inputs and outputs (tonnes) per capita	Statistics of air transport, INEC (2010c)
			Maritime movement of ships (units) per capita	Statistics of air transport, INEC (2010c)
			Maritime cargo movement (tonnes) per capita	Statistics of air transport, (2010c)
		Communications Infrastructure (Ic)	Number of Post Offices per capita	Statistics of the National Mail Company (2010)

	Internet Users by Province through Fixed Access per capita	Statistics of the National Telecommunications Corporation, ARCOTEL (2019)
	Fixed telephone service subscribers per capita	Statistics of the National Telecommunications Corporation, ARCOTEL (2019)
	Radio bases by provinces per capita	Statistics of the National Telecommunications Corporation, ARCOTEL (2019)

Source: Authors' own data.

Following Barajas and Gutiérrez (2012), in order to homogenise the different types of data and their respective measurements, a normalisation was used, converting the variables into dimensionless magnitudes as a percentage with respect to the maximum value of each variable. Thus, indices ranging from 0 to 100 were obtained, where 100 represents the municipality with the highest infrastructure provision according to the variable that is being taken as a reference. Thus, one-dimensional and comparable values within the region are obtained. Formally, the calculation would be:

$$S_{j,r} = \left(\frac{a_{j,r}}{a_{MAX,r}}\right) * 100$$

Where:
$a_{j,r}$ = infrastructure equipment for each variable *j* in region *r*.
$a_{MAX,r}$= measure of the region with the maximum value.
$S_{j,r}$ = standardised indicator for region *r* and variable *j*.

Finally, for the aggregation of the indices, Biehl's Synthetic Indicators method was used (Biehl, 1988, cited by Cancelo de la Torre & Uriz Tomé, 1994). This index is based on the assumption that lower endowments in one category can be compensated by higher endowments in some other category. The aggregation is done with arithmetic means when the endowments are considered as substitutes and with geometric means when they are not (Fuentes & Mendoza, 2003, cited by Barajas & Gutiérrez, 2012).

Each category is then constructed with an arithmetic mean as follows:

$$I_{i,r} = \left(\frac{1}{n}\right) * \sum S_{j,r}$$

Where:
$I_{i,r}$ = category indicator in region *r*.
$S_{j,r}$ = Subcategory indicator which is included in the category.

The categories are added with a geometric mean, since they are irreplaceable. The formulation is as follows:

$$IG_r = \sqrt[n]{\prod_{i}^{n} I_{i,r}}$$

Where:
IG_r= Global infrastructure indicator in region r.
$I_{i,r}$ = Category indicator in region r.

Specifically, the calculation formulas for the different indices are described below:

$$SPI = \text{(Number of Schools pc}_S + \text{Number of Teachers pc}_S + \text{Number of Studentspc}_S)/3$$

$$Ie = \text{(Percentage of homes that receive water through the PN}_S + \text{Number of luminaires pc}_S + \text{Kg of LPG Consumed by province}_S)/3$$

$$It = \text{(Total Length of Roads per Km2 of province surface}_S + \text{Number of Cargo Trucks pc}_S + \text{Number of Airports pc}_S + \text{Number of passengers admitted}_S + \text{Charge inputs and outputs (tonnes) pc}_S + \text{Maritime movement of ships (units) pc}_S + \text{Maritime cargo movement of ships (tonnes) pc}_S)/7$$

$$Ic = \text{(Number of Post Offices pc}_S + \text{Internet Users by Province through Fixed Access pc}_S + \text{Fixed telephone service subscribers per capita pc}_S + \text{Radio bases by provinces per capitad}_S)/4$$

$$EPI = (\text{Ie} + \text{It} * \text{Ic})/3$$

$$GPII_r = \sqrt[4]{SPI * Ie * It * Ic}$$

Next, in order to know the relationship between infrastructure and economic growth, it is necessary to perform econometric regressions that relate the Gross Value Added per capita as a dependent variable, for which the inputs of a basic production function were considered; with capital and population as independent control variables and the chosen infrastructure variables (GPII, SPI, EPI).

The models assume a relationship of type:
(1) $ln\, Y_i = \alpha + \beta_2 lnK_i + u_i$
(2) $ln\, Y_i = \alpha + \beta_2 lnK_i + \beta_3 lnPT_i + u_i$
(3) $ln\, Y_i = \alpha + \beta_2 lnK_i + \beta_3 lnPT_i + \beta_4 lnGPII + +u_i$
(4) $ln\, Y_i = \alpha + \beta_2\, lnK_i + \beta_3 lnPT_i + \beta_4 lnIEPI + u_i$
(5) $ln\, Y_i = \alpha + \beta_2 lnK_i + \beta_3 lnPT_i + \beta_4 lnSPI + u_i$
(6) $ln\, Y_i = \alpha + \beta_2 lnK_i + \beta_3 lnPT_i + \beta_4 lnEPI + \beta_5 lnSPI + u_i$

Where:
$ln\ Y_i$ = logarithm of provincial Gross Value Added per capita
lnK_i = logarithm of Subscribed Capital of the companies in each province
$lnPT_i$= total Provincial Population logarithm
$lnGPII$ = logarithm of the provincial Global Productive Infrastructure Index
$lnEPI$ = logarithm of the provincial Economic Productive Index
$lnSPI$ = logarithm of the provincial Social Productive Index

4. RESULTS

4.1. Index

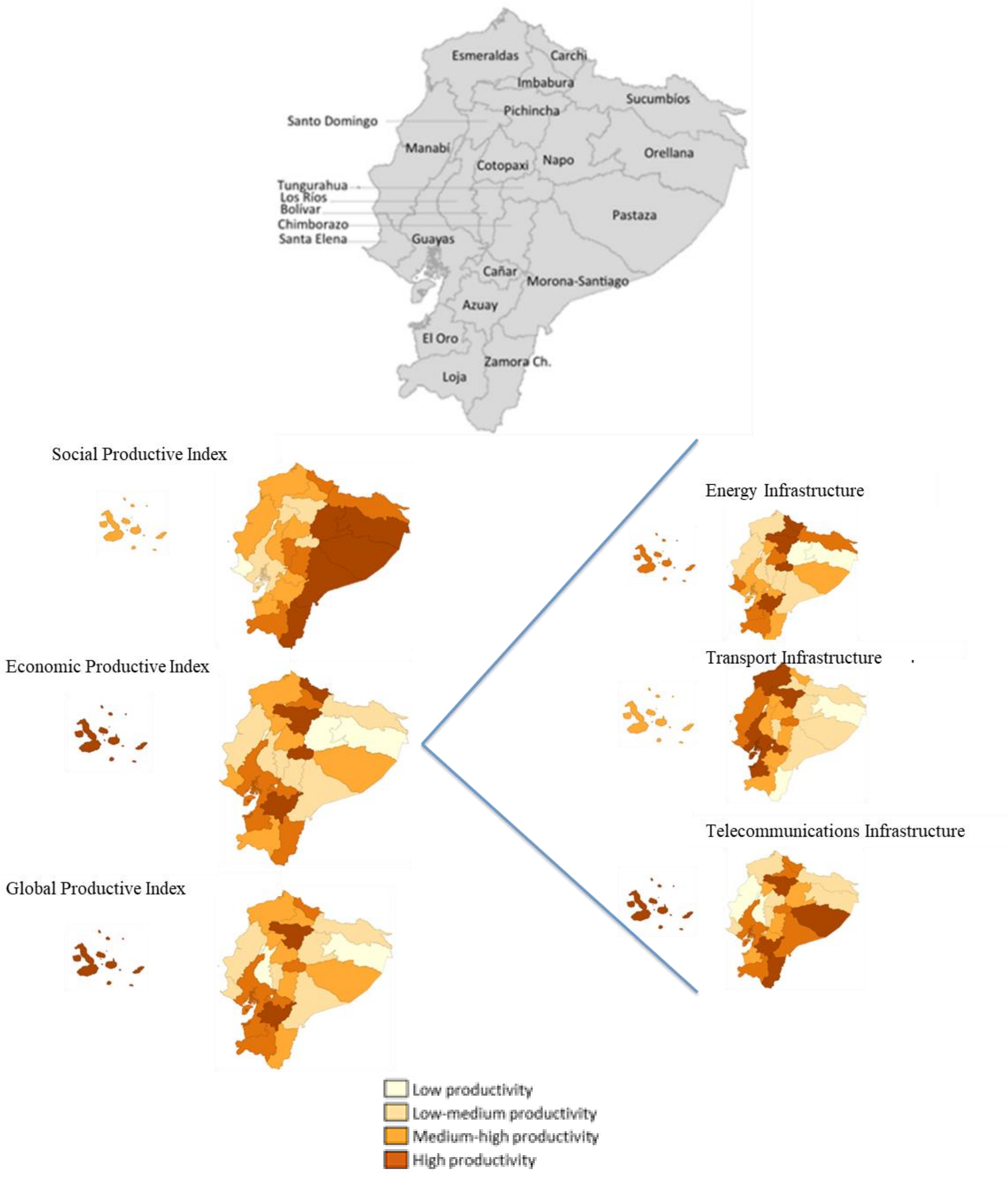
Regarding the indices obtained, it was possible to establish that the province of Pichincha has the highest Global Productive Infrastructure Index, followed by Galapagos and then Azuay, while the provinces with the lowest global indices are Orellana and Los Ríos. Table 2 shows the infrastructure indices calculated at the provincial level.

Table 2: Infrastructure Indices

Provinces	**(SPI)**	**Sub-Indices**			**(EPI)**	**(GPII)**
		Energy Infrastructure (Ie)	**Transport Infrastructure (It)**	**Communications Infrastructure (Ic)**		
Azuay	61	86	16	51	51	45
Bolívar	78	54	12	16	27	30
Cañar	67	62	29	19	37	39
Carchi	69	83	18	22	41	39
Cotopaxi	61	64	18	18	33	33
Chimborazo	72	55	17	20	31	34
El Oro	61	70	30	19	40	40
Esmeraldas	64	48	38	12	32	34
Guayas	56	58	32	26	38	40
Imbabura	61	76	10	25	37	33
Loja	76	63	16	21	33	35
Los Ríos	62	49	17	6	24	24
Manabí	67	54	19	10	27	29
Morona Santiago	86	49	9	22	26	30
Napo	86	43	7	20	22	26
Pastaza	98	62	7	31	33	34
Pichincha	58	78	40	53	58	56
Tungurahua	60	76	21	27	42	40
Zamora Chinchipe	88	59	6	39	34	33
Galápagos	65	72	18	62	51	48
Sucumbíos	75	69	10	13	30	28
Orellana	79	41	5	13	19	21
Santo Domingo	56	58	18	19	32	32
Santa Elena	53	64	20	14	32	31

***Source*:** Authors' own data.
Note: SPI: Social Productive Index, EPI: Economic Productive Index, GPII: Global Productive Infraestructure Index.

Graph 1: Social Productive Index (SPI)



Finally, regarding the Economic Productive Index, the provinces with the lowest index are Orellana, Napo, Los Ríos and Bolívar. In contrast, Pichincha and Azuay have the highest EPI, followed by Galapagos, a situation which is assumed to occur in the provinces that have airports, with maritime cargo, passengers of this type of transport, which favours them to a large extent.

4.2. Estimations

Table 3 shows the first estimations in the order mentioned, the inclusion of the IGP as a factor that affects production indirectly, i.e., in a linear estimation.

Several estimations were made to test the significance of each of the variables included in the model. In the first estimation, the subscribed capital of the companies registered in Ecuador was used as a proxy variable of the capital factor, which has significance at 5%, i.e., the growth of Ecuador´s provinces is directly related to the growth of subscribed capital, or, in other words, to the creation of new companies. In the second equation, the labour variable is added, using the total population, which is also significant, although negative (inverse relationship), so the higher the population, the higher the growth is, but there are other factors that could determine the growth of the economies of Ecuadorian regions. In this model, capital continues to be a determining factor.

Table 3: Logarithmic Estimation of the Variables

	(1) $ln\,Y_i$	(2) $ln\,Y_i$	(3) $ln\,Y_i$	(4) $ln\,Y_i$	(5) $ln\,Y_i$	(6) $ln\,Y_i$
lnK_i	0.0929^{***}	0.194^{***}	0.133^{***}	0.124^{***}	0.179^{***}	0.119^{***}
	(4.46)	(6.87)	(5.38)	(4.53)	(5.30)	(3.95)
$lnPT_i$		-0.262^{***}	-0.182^{**}	-0.163^{**}	-0.261^{***}	-0.164^{**}
		(-4.29)	(-3.79)	(-3.13)	(-4.23)	(-3.08)
$lnGPII$			0.703^{***}			
			(4.41)			
$lnEPI$				0.609^{***}		0.600^{***}
				(4.11)		(3.91)
$lnSPI$					-0.275	-0.111
					(-0.78)	(-0.41)
cons	-0.665	0.752	-1.593^{*}	-1.315^{*}	2.172	-0.710
	(-1.66)	(1.69)	(-2.56)	(-2.17)	(1.16)	(-0.44)
N	24	24	24	24	24	24
adj. R^2	0.451	0.693	0.837	0.825	0.688	0.818

Note: *t* statistics in brackets, * $p < 0.1$*, $p < 0.05$**, $p < 0.01$***.

In the third equation, the Global Infrastructure Index is incorporated into the equation, and it can be seen that this index is significant, which shows the importance of infrastructure, both social and economic, which means that the better the infrastructure, the higher the production. Similarly, when the Economic Infrastructure index is added to the equation, it is found that it is significant and positive in relation to economic growth. This fact indicates that the greater the economic infrastructure (which includes the subcategories of energy, transport and communications infrastructure), the higher the production. Therefore, the provinces that are better equipped with infrastructure are the provinces that most produce and contribute to the country's growth. Regarding the control variables used, capital and labour, they remain significant in the model.

In the fifth estimation, the Social Productive Index is included, which is negative and not significant. Therefore, in this case, social infrastructure does not favour a higher provincial production. As for the factors, labour and capital are significant. Finally, in estimation six, a contrast is made between the EPI and the SPI. The analysis of both indices together with the control variables shows that the EPI variable is significant and positive, while the capital variable continues to be significant. Regarding labour, the inverse relationship with respect to production confirms the above, a larger population does not favour production, and the conditions and endowments of social infrastructure do not determine a dynamism in the economy of the provinces.

In this context, it has firstly been proven that the Economic Productive Infrastructure (EPI) has an impact on regional growth, but the Social Productive Infrastructure (SPI) does not. However, the EPI is in turn made up of three infrastructure sub-indices (energy, transport and communications), so in order to determine with specificity which of these factors have the greatest impact on growth, we proceeded to estimate regression models in which the control variables, the Social Productive Infrastructure and three indices that make up the Economic Infrastructure interact. Consequently, the models and variables used were:

(7) $ln\, Y_i = \alpha + \beta_2\, lnK_i + \beta_3 lnPT_i + \beta_4 lnSPI + \beta_5 lnIe + u_i$
(8) $ln\, Y_i = \alpha + \beta_2\, lnK_i + \beta_3 lnPT_i + \beta_4 lnSPI + \beta_5 lnIe + \beta_6 lnIt + u_i$
(9) $ln\, Y_i = \alpha + \beta_2\, lnK_i + \beta_3 lnPT_i + \beta_4 lnSPI + \beta_5 lnIe + \beta_6 lnIt + \beta_7 lnIc + u_i$

Where:
$ln\, Y_i$ = logarithm of provincial Gross Value Added per capi
lnK_i = logarithm of Subscribed Capital of the companies in each province
$lnPT_i$= Total Provincial Population logarithm
$lnSPI$ = Provincial Social Productive Index logarithm
$lnIe$ = provincial energy index logarithm
$lnIt$ = Provincial transport index logarithm
$lnIc$ = Provincial communications index logarithm

Table 4: Estimation

	(7) $ln\, Y_i$	(8) $ln\, Y_i$	(9) $ln\, Y_i$
lnK_i	0.162^{***}	0.161^{***}	0.120^{***}
	(4.53)	(4.87)	(4.08)
$lnPT_i$	-0.227^{**}	-0.255^{***}	-0.178^{**}
	(-3.46)	(-4.09)	(-3.24)
$lnGPII$	-0.173	0.225	-0.194
	(-0.49)	(0.59)	(-0.59)
$lnSPI$	0.304	0.264	-0.106
	(1.36)	(1.27)	(-0.53)
$lnIe$	0.304	0.264	-0.106
	(1.36)	(1.27)	(-0.53)
$lnIt$		0.205	0.178^{*}
		(2.03)	(2.19)
$lnIc$			0.253^{**}
			(3.31)
cons	0.393	-1.313	1.096
	(0.17)	(-0.58)	(0.56)
N	24	24	24
adj. R^2	0.700	0.742	0.834

Note: *t* statistics in brackets, * $p < 0.1$*, $p < 0.05$**, $p < 0.01$***.

Finally, the last estimation of the model is shown in table 4. It was performed with capital, labour, the subcategories of Energy Infrastructure Ie, Transport Infrastructure It and Telecommunications Infrastructure It, obtaining that only the Ic is significant at 5% and positive; Ie is not significant; while It is positively related to growth and is significant at 10%. Labour similarly has a negative relationship, and capital is positively related to growth and affects it.

5. DISCUSSION AND CONCLUSIONS

This study is relevant because it provides data, elements and conclusions that contribute to the literature, which focuses on the relationship between infrastructure and growth, in a context of positioning of infrastructure in the objectives of sustainable development that entails a greater responsibility of public policies in advancing towards higher levels of quality investment required to improve the quality of life of the population. Likewise, it leads to establish that it is necessary to carry out studies at the regional level since the macro and national figures can hide errors about the behavior of the variables in the different regions of the country, from which the analysis can be approached from the perspective of the regional disparities regarding the endowment of infrastructure in terms of the productive structure that is not very diversified, the lag in the effort and performance of innovation and the high concentration of income and wealth.

The calculation of indicators allows for the identification of heterogeneous results regarding the factors or elements that condition economic growth in the respective provinces of Ecuador, which is thought to occur due to the specific characteristics of each province. In general terms, Social Productive Infrastructure (according to the variables used) is not a determinant for regional growth. However, there is evidence that the endowment of Economic Productive Infrastructure positively affects economic growth in the provinces of Ecuador, with an elasticity of 0.6.

The results found do in fact confirm that transport and telecommunications infrastructure are determining elements of provincial growth in Ecuador, while the influence of Energy Infrastructure is not significant according to the evidence. Such results are consistent with those obtained by Easterly and Rebelo (1993), Pradhan et al. (2015) and Démurger (2001). In particular, regarding studies for Latin America, they correspond to SELA (2011), Urrunaga and Aparicio (2012) for Peru and Zepeda-Ortega et al. (2019) in Mexico. In all of them, a positive causal relationship is demonstrated empirically between growth and economic productive infrastructure, specifically, transport and communications. As for the social productive infrastructure, there are no previous studies to make a comparison with.

The implications of these findings focus on the field of public policies. In fact, "few public policies generate greater consensus in Latin America and the Caribbean than the need to invest more in infrastructure" (Cavallo et al., 2020). However, public investment in infrastructure in the region is low compared for example with China; i.e., 2.08% of GDP in the region on average between 2015 and 2019 according to IDB data, compared to 6.3% of GDP between 2010 and 2014 in the Asian country. In Ecuador, between 2015 and 2019, the average investment was 2.4% of GDP, divided between 1.1% in water economic infrastructure; 0.2% in energy; 1.1% in transport and 0% in telecommunications.

Faced with this reality, the alternative for governments is to improve policies and practices in order to enhance the efficiency of investments in infrastructure, since it was estimated that "corruption, insufficient competition and poor supervision generate inefficiencies in public investment that represent 35% of such investment or, in aggregate terms, 0.65% of the region's GDP" Cavallo et al. (2020). Along these lines, the authors highlight the importance of a planned investment that integrates: (1) social and environmental dimensions, (2) public-private partnerships PPPs as a strategy to attract private investment, (3) the need to improve efficiency of the infrastructure project cycle and its maintenance, (4) counteracting corruption through legislative and institutional reforms, civil society initiatives and the adoption of international standards of transparency and governance; and, (5) the adoption and promotion of disruptive technologies.

Among the main limitations of this study were the difficulty in accessing public investment data at the sectoral and provincial levels, as they are not available, which made it necessary to resort to proxy variables. Another obstacle was the cut-off of the data (only one year´s data available), which does not allow for robust estimations and panel estimations, in order to have a better understanding of the subject.

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