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Educational policies to promote the knowledge economy and the technological development in Ecuador

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Abstract

The objective of this research is to define educational policies to promote the knowledge economy and technological development. For this, the objective is to determine the existing conditions for the development of the knowledge economy in Ecuador, and the connection with the business structure (public and private) to promote the country in technological development, so that higher education comply with the principle of relevance. To analyze the theoretical perspectives with the empirical results, two models were made that cover the evolution of the knowledge economy. The main results show that when investment in education is greater, the knowledge economy grows and is reflected in exports with a higher technological level. For the Ecuadorian case, it is recommended to carry out an educational reform and increase investment in education, and in science and technology, that promotes technological development.

1. Introduction

Ecuador is a developing middle-income country with an educational offer that must be linked to the productive structure through the definition of public policies where the state has a strong intervention. The fact of having a primary export productive structure defines the importance of developing the knowledge economy to promote not only productive development but also technological development, since the knowledge economy "is an economy in which the creation, distribution and use of knowledge it is the greatest driver of growth, wealth and employment" (Heng, et al: 2002, p. 9). In this regard, in the Organic Law of Higher Education -LOES-, the Council of Higher Education (2010) in article 107 established as a principle of relevance the following:

"The principle of relevance is that higher education responds to the expectations and needs of society, to national planning, and to the development regime, to the prospect of global scientific, humanistic and technological development, and to cultural diversity. For this, the higher education institutions will articulate their teaching offer of research and activities of connection with the society, to the academic demand, to the needs of local, regional and national development, to the innovation and diversification of professors and academic degrees, to local, regional and national occupational market trends, local, provincial and regional demographic trends; to the link with the current and potential productive structure of the province and the region, and to the national science and technology policies" (p. 43).

For Tünnermann (2000) higher education must be oriented towards policies that respond to social relevance; Although the demands of the economy and the labor sector must be considered, it is also imperative to broaden its attention to the challenges of society as a whole. On the other hand, according to Taccari (2007), education achieves quality when it is articulated with people's conditions (defined by the author as relevance), and with development challenges (defined by the author as relevance). Finally, for Hamid, Álvarez and Torres (2017), relevance studies must consider: i) needs of the work environment; ii) need; iii) influence of educational training; iv) relationship between curriculum and environment. Therefore, the first objective of this research is to determine the existing conditions for the development of the knowledge economy in Ecuador, and the connection with the business structure (public and private) to promote the country in technological development. So, higher education complies with the principle of relevance. Therefore, the first research question is what are the existing conditions for the development of the knowledge economy in Ecuador, and the connection with the business structure (public and private) to promote the country in technological development?

The answer is given later by demonstrating the link between education and the productive structure and technological development, based on educational policies that arise from economic policies of greater spending and fundamentally greater public investment.

In addition, it should be considered as a condition for the development of the knowledge economy, that a production that goes hand in hand with greater human capital (education) generates technological improvements that are reflected in greater competitiveness as a result of exports with the incorporation of greater technological level, but the following tables show the opposite. The share of exports with high technological intensity has been decreasing since 2017 as a result of lower public investment in education, while imports with high technological intensity have increased since 2017, after imports had been decreasing since 2013 as a consequence of greater exports with high technological intensity, that is, as of 2017, imports with high technological intensity have been increasing, unlike exports with the incorporation of high technology, which have been decreasing since 2017.

Table 1. Share of exports according to technological intensity, percentage, 2013-2022.

Years	Low technology	Medium Technology	High technology
2013	1,92%	2,35%	0,48%
2014	1,96%	2,11%	0,64%
2015	1,62%	1,76%	0,91%
2016	1,42%	1,37%	0,90%
2017	1,44%	1,25%	0,79%
2018	1,50%	1,62%	0,53%
2019	1,43%	1,35%	0,51%

2020	1,26%	1,37%	0,38%
2021	2,00%	1,61%	0,46%
2022	1,79%	1,78%	0,69%

Source: *Central Bank of Ecuador. Elaboration: Authors.*

Table 2. Share of imports according to technological intensity, percentage, 2013-2022.

Years	Low technology	Medium Technology	High technology
2013	10,74%	35,03%	14,57%
2014	10,44%	35,01%	14,98%
2015	9,11%	28,16%	12,18%
2016	6,66%	21,18%	9,96%
2017	8,42%	27,24%	10,49%
2018	9,46%	31,15%	11,39%
2019	9,13%	30,53%	11,05%
2020	7,23%	22,46%	10,78%
2021	9,62%	30,51%	13,48%
2022	11,42%	36,97%	13,54%

Source: *Central Bank of Ecuador. Elaboration: Authors.*

The result, as of 2017, the trade deficit with the incorporation of high technology presents the same dynamics, after reducing between 2013 and 2017, it begins to increase as of 2017, which is generating loss in the development of the economy of the country. knowledge, as shown below.

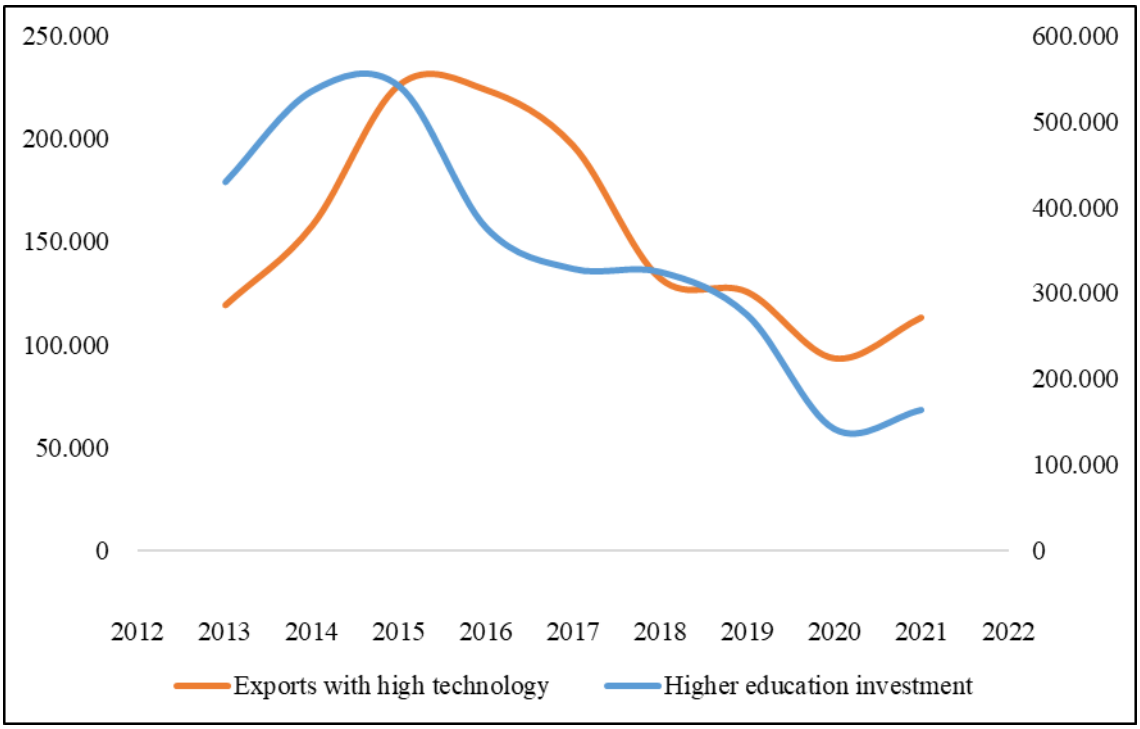
Table 3. Trade deficit according to technological intensity, thousands of dollars, 2013-2022.

Years	Low technology	Medium Technology	High technology
2013	-2.290.681	-8.444.278	-3.635.929
2014	-2.205.673	-8.496.692	-3.700.734
2015	-1.946.121	-6.818.396	-2.911.408
2016	-1.365.558	-5.118.788	-2.342.202
2017	-1.812.176	-6.709.296	-2.506.855
2018	-2.067.318	-7.624.954	-2.801.844
2019	-2.000.051	-7.530.051	-2.722.050
2020	-1.550.768	-5.449.050	-2.683.174

2021	-1.982.000	-7.463.719	-3.359.566
2022	-2.499.389	-9.083.624	-3.317.664

Source: *Central Bank of Ecuador. Elaboration: Authors.*

In addition, it can be seen in the following graph that the relationship between public investment and higher education is closely related, the higher the investment in higher education, the higher the export with the incorporation of high technology, or the lower the investment in higher education, the lower the export with the incorporation of high technology.



Graph 1. Investment in higher education and exports with the incorporation of high technology, 2013-2021, thousands of dollars.

Source: *Central Bank of Ecuador. Elaboration: Authors.*

2. Literature Review

Saenz de Miera (1998) points out that over time Universities have become "knowledge factories"; and in the current century the relevance, social responsibility and accountability on the part of the Universities is essential to face the current process of globalization where the knowledge society and the knowledge economy is linked to technological development, that is, new forms of knowledge production in a globalized world. David and Forey (2002, p. 1) point out "that knowledge has always occupied the central place of economic growth and the progressive elevation of social welfare. The ability to invent and innovate, that is, to create new knowledge and new ideas that later materialize in products, procedures and organizations, has historically fueled development.

According to Edward Steinmueller (2015) the knowledge-based economy makes a big difference between the conduct of economic life and the organization existing in companies, since the economy of a country also depends on the success of companies based on the effectiveness have to generate and use knowledge.

"Although scientific and technological knowledge is of key importance, knowledge about how to organize and manage economic activities, especially those involving the application of new scientific and technological perspectives, is also a crucial determinant of economic performance. In short, knowledge contributes to the economy by sustaining productivity increases, the formation and growth of new industries, and the organizational changes necessary to effectively apply new knowledge." (p. 2).

In this sense, the knowledge economy has become a factor of competitiveness and development because one of its characteristics is to allow the more systematic exploitation of knowledge with the use of new technologies to create wealth (Brinkley, 2006: 6). In addition, as the OECD (2004: 9) points out, "the role of knowledge (compared to natural resources, capital and low-skilled labor) has become more important. Although the pace

may differ, all OECD economies are moving towards a “knowledge-based economy”, and economic success is increasingly based on the effective use of intangible assets such as knowledge, skills and innovative potential as the key resource for competitive advantage (Dahlman et al, 2005). Therefore, the term *knowledge economy* is used to describe this emerging economic structure.

According to Dahlman and Andersson (2000, p. 5) "a knowledge-based economy is one in which knowledge (codified and tacit) is created, acquired, transmitted and used more effectively by companies, organizations, individuals and communities for a further economic and social development. However, the preamble to the knowledge economy is the "learning economy" in which the result of the teaching-learning process, the cognitive process, results in the information acquired and obtained; and all information transmission, analysis and retention translates into intelligence. Therefore, in any learning process, the use of technology-based tools develops human knowledge and intelligence, as part of a social process in which skills and abilities are part of that conjunction in economic success. as they point out Reig Martinez et al (2017: 61).

“The role of human knowledge as a transcendental factor in explaining the growth capacity of modern economies is widely recognized today. Investments in knowledge make it possible to improve the productivity of the other factors that contribute to production, and allow their transformation into new products and the use of new production processes. Knowledge, or more simply ideas, constitutes a resource characterized by increasing returns in its use, which gives it a determining role as a key to long-term economic development.”

The greatest successes of knowledge-based economies, where public investment in education has high levels such as in Finland, Sweden, South Korea, Singapore, among others, have been based on obtaining a highly qualified labor force with a class business that uses and adapts knowledge in an economic system where the state stimulates and fosters the creation of knowledge through distributive economic policies in a framework of high access to information and communication technologies that streamlines the exchange of information within a national innovation system. In the case of Ecuador, as part of this process of creating innovation and technological development, Yachay was the Emblematic University to achieve the knowledge economy, however, the policies of structural adjustment and reduction of the state (austericide) did not not only that they have minimized the size and role of the state, but they have minimized the innovative role of Yachay, which is destined to disappear as a result of these structural adjustment policies.

Therefore, "education, as a central and core element of knowledge-based economies, affects both the supply and demand of innovation processes, since a trained labor and business force will be in a better position to create, adopt, and transform technologies." , while an educated population will generate a demand for new and better products" (Del Valle et al, 2005), and hence the importance of the existence of a national innovation system as a "network of public and private institutions that finance and they carry out research and development, translate the results of these investigations into commercial innovations and carry out the processes of diffusion of new technologies” (Mowery & Oxley, 1995; p. 68)

Despite the difficulties in measuring knowledge, Steedman (2001) defines four fundamental categories are:

1. Creation of knowledge

2. Acquisition/transfer of knowledge

3. Dissemination of knowledge

4. Application of knowledge

And these categories have been defined with proxy variables, as Heng et al (2002) determined.

Table 4. Indicators and variables to be measured in different phases of knowledge

Proxy Indicator	Variables to measure
Knowledge creation	
I&D spending as a percentage of GDP	I&D intensity in the economy
Researchers per capita	Availability of human resources necessary to carry out R&D activities
Patents per capita or Academic publications	Quality of scientific creation
Acquisition and transfer of knowledge	
Percentage of imports with technological content	Content of technological knowledge included (embedded) in the imports
Number of central and regional offices of companies in the country	Number of companies with specialized knowledge established by multinational and regional companies
Number of companies in the knowledge-intensive services sector	Services provided to knowledge-intensive industries, promotion of the creative process and the acquisition and transfer of knowledge by activities
Dissemination of knowledge	
Spending on information and communication technologies (ICT´s)	Intensity of information and communication resources and infrastructure available for the transfer and dissemination of knowledge
Internet access costs as a percentage of GDP per capita	Accessibility of ICT services as a determinant of use
Percentage of labor force with secondary education	Linguistic and technological skills necessary to make use of ICT´s
Application of knowledge	
Percentage of labor force with higher education	Ability of the workforce to search, process and use relevant information
Percentage of knowledge workers in the labor force	Number of jobs that require and promote the application of knowledge
Rank of business conduct (entrepreneurship) according to the world competitiveness yearbook	Capacity of the economy to create new business models that promote the creation, acquisition, dissemination and application of new ideas and processes

Source: *Heng et al (2002).*

In addition, the existence of intangible assets in the generation of knowledge based on capital must be considered, which is not only for companies that are in the service sector or on the technology frontier. Knowledge-based economies have different degrees of success, and this depends on how resources are directed towards companies that have great growth potential and have greater R&D or innovation processes. As Andrews and Criscuolo (20013: 22) point out, "the proper functioning of the product, labor and capital markets, and the reduction of the costs for companies to experiment with new ideas, and even to fail, constitute a pillar essential to ensure that difficulties in reallocating productive resources do not hinder the development of the knowledge economy".

Undoubtedly, the knowledge economy implies that companies reduce their costs in innovation processes, reduce their costs in resource allocation, and hence how important the role of the state. If the state allocates more public investment to higher education, companies would have a more trained workforce and would not have to spend/invest in obtaining knowledge. If the state intervened in the financial market and reduced the spread (see Varela, 2017, 2021), that is, a higher passive interest rate to generate more deposits and with it more credit, and reduce active interest rates, since there are more Deposits can allocate greater credits, this would reduce the financial costs of companies and easier access to credit that will not only be for production processes, but also for R&D processes. If the state provided cheaper energy to companies, cheaper services, the costs of companies would be reduced. If the state gave tax incentives to smaller companies, they could direct those resources towards R&D processes. If the state will carry out a tax reform of progressive taxation for companies, where the smaller ones would have a lower tax effort, they could allocate these resources to R&D processes (see Varela and Salazar, 2022). If the state develops more complexes for the generation of knowledge and innovation for technology transfer, for example the Yachay University, the costs of access to technology for companies would be lower. That is, the state is fundamental in the development of the knowledge economy and technological development, and the result would be a successful economy with a diversified productive structure (see Varela, 2018).

The evidence of the knowledge economy is extensive, but it is worth considering what Del Valle et al (2005: 62) said:

"The complexity of the treatment of knowledge within the framework of a theory of production has led economists to develop simplifications that allow its management. Among them is reducing the production of knowledge to the generation of research and development (R&D), an activity for which abundant statistical information is available today. But in reality, the analysis of the R&D undertaken by companies, universities and other specialized private and public centers is a relatively small part of the set of activities related to the production of knowledge. In fact, any activity related to the production or use of a good or service can contribute to the production of knowledge, for example through learning by doing."

Marquina and Rozga (2015) point out that the greatest experience in the generation of knowledge occurred in the Sicilio Valley in California when, with state support, there was the greatest increase in high-tech ventures. In this process, the intervention of the state generated the result of "post-industrial cities" where the state with the collaboration of the Universities and the industry:

"Design strategies that would give a boost to the dynamics of knowledge in cities and megalopolitan regions and thus increase the value of their economy and the possibilities of a greater economic spillover that would translate into an improvement in the living conditions of the urban population. Since then, experiences of cities began to be systematized that emphasized the importance of knowledge as a basis for development at the dawn of the 21st century" (p. 12).

Regarding what was said above, Richard Knight (1995: 13) underlined:

"In post-industrial society knowledge had become the fundamental force that was restructuring cities. He argued that knowledge-based development requires attention to the extent that societies prosper towards knowledge-based organizational models and, therefore, cities play a strategic role since the greatest resources of both knowledge and equipment are concentrated in them (universities and public and private research centers) as well as intellectual capital".

Hence the link between the role of the state and knowledge determines a system of capitals of knowledge cities.

Table 5. Taxonomy of the capital system of knowledge cities

Type of capital	Indicators and dimensions
Capital Aim	1. Referential: identity, responsibility 2. Articulation: integration and cohesion; equity; legality; financing
Human Capital	1. On an individual basis: ethnic diversity, health, education, socio-economic level. 2. Collectively based: living cultures (languages, religions, customs, clothing, food, celebrations and rituals 3. Evolving capacities: diversity, tolerance, participation
Instrumental Capital	1. Tangible: geography, environment; infrastructure (basic service networks, land use planning, equipment, etc.) 2. Intangible or symbolic: public institutions, procedures, government system, political powers; commercial institutions, civil society organizations; physical and digital information platforms; memory physical and digital collective.

Source: *Carrillo (2002, 2004).*

Similarly, in this state-knowledge link, development measurement indices have been developed.

Table 6. Indicators for the construction of the index for measuring the development of Regional Knowledge Economies

Indicator	Measurement index
Education Subsystem	SE1- Average years of school education
	SE2- Percentage of population with higher education
Research and Development Subsystem	SID1 – Researchers at the SNI
	SID2 – Patent application
Productive-Innovative Subsystem	SPI1 – Number of technology-based companies
	SPI2 – Companies that have applied for patents
Dissemination and Promotion Subsystem	SDP1 – I&D dissemination and promotion centers
	SDP2 – Number of users of dissemination and promotion centers
Financing Subsystem	SF1 – Number of financial supports for I&D
	SF2 – Amount of financial support for I&D
Information Infrastructure Subsystem	SI1 – Percentage of households with a computer
	SI1 – Percentage of population with Internet access

Source: *Rozga, 2010*

Vilaseca et al (2002) in a study for the spanish economy, in which they analyze technological development, that is, the penetration of digital technologies in the activity of economic agents, and its structural evolution, that is, the economic dynamics of the transformation process sector, which is the information and communication technology sector, conclude as follows:

"The development of the demand for goods and services resulting from the economic application of information and communication technologies is much more advanced than the development of the offer, represented by the indicator of economic development of the ICT sector. This conclusion is even more relevant when comparing the dynamics between ICT demand and supply in the group of less developed countries. In fact, we can close this section by stating that, in countries like Spain, with regard to the development of the information society, society as a whole is clearly more advanced than the business sector, as has been observed in the analysis of the indicator related to the economic development of the ICT sector." (p. 33).

Pérez, Hernández and Mendoza (2018), in a study for Mexico, detect public policy problems directed towards supply or market failures, the misdirection of tax incentives, trade opening as the main element in the knowledge economy as a dimension of the preconditions of development, and the lack of a culture of innovation associated with deficient levels of schooling prevent "promoting, extending and generalizing the knowledge economy." (p.9) and conclude that:

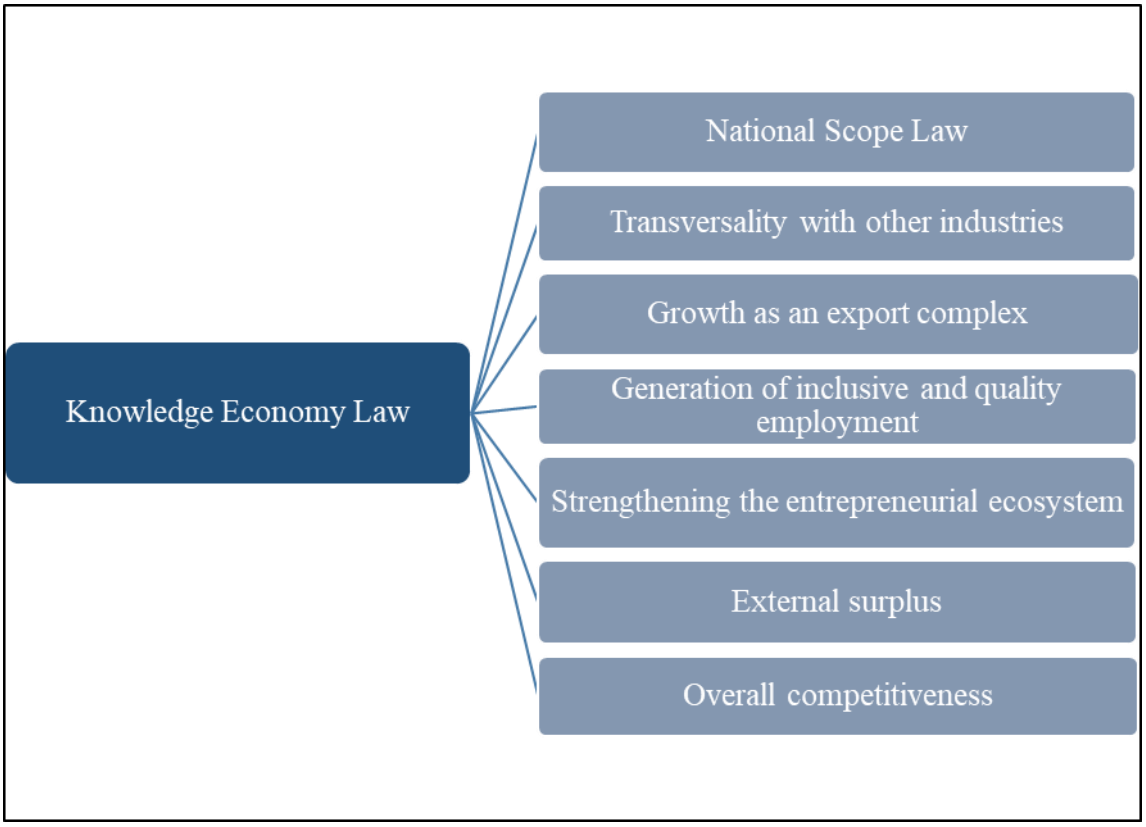
"There are priority challenges in the dimension of the preconditions for development, which implies that this is a problem that has a certain social endorsement, because both experts, analysts and society; they perceive failures that have to do with macroeconomic stability, economic incentives and the institutional regime, the degree of commercial openness, the labor market, social or cultural factors and the policy of CTI itself. Therefore, in order to intensify the knowledge economy, the quality of the environment in which economic, scientific and technological activities take place should initially be ensured." (p. 1).

The knowledge economy has been widely discussed in various organizations and countries, including Argentina, where the development of productive transformation strategies linked to the knowledge economy have been defined. Paula Szenkman, Secretariat for Productive Transformation, announced that Argentina is working on a new law to promote the knowledge economy. "The knowledge economy will allow us to increase productivity across the entire economy." For this, "we are working on a new framework of incentives for these activities, as well as instruments for the development of talent, the reduction of export costs and the reinvestment of profits towards innovation." (https://conexionintal.iadb.org/2018/10/31/hacia-una-economia-del-conocimiento/).

In the development of strategies linked to knowledge and the digital economy, in all its aspects, from the opportunities offered by electronic commerce, to the challenges of regulating data exchange. We are experiencing a very accelerated exponential change that requires rethinking the current production models and structures. Progress is being made towards "hybrid processes that combine the physical and the digital, biology with knowledge, human intelligence with artificial intelligence". (Gustavo Beliz, Director of INTAL-IDB).

Rodrigo Filgueira, Project Coordinator of the Inter-American Center for the Development of Knowledge in Vocational Training (Cinterfor) of the ILO has pointed out "Creativity, communication, critical thinking and problem solving are some of the most frequent, it is necessary modify educational systems and pedagogical practices to develop these skills. What we propose is a teaching based on research and the realization of projects. We must encourage ourselves to innovate in curricular designs". (https://conexionintal.iadb.org/2018/10/31/hacia-una-economia-del-conocimiento/).

The Secretariat of Productive Transformation of Argentina has defined the importance of the Knowledge Economy through a Law: "The knowledge economy is vital for the growth of Argentina. They are the industries and services that would make it possible to take a leap in the country's development, which will transversally increase productivity and job creation throughout the economy" (Paula Szenkman, Secretariat for Productive Transformation).



Graph 2. Knowledge Economy Law, Argentina.

Source: Secretary of Productive Transformation of Argentina.

Finally, it can be pointed out that the knowledge economy is made up of those productive activities that are characterized by the intensive use of technology and that require highly qualified human capital, and represents sectors with enormous development potential for future generations. It requires a promotion regime in: Software, computer and digital services; audiovisual production and post-production; biotechnology, neurotechnology and genetic engineering; geological and prospecting services; aerospace and satellite industry; professional export services; nanotechnology and nanoscience; artificial intelligence, robotics (IOT), internet of things. For all these reasons, the role of the state with a view to the future requires different productive strategies, which, on the one hand, in developing countries and with a primary exporting structure, demand to diversify the productive structure based on the implementation of supply and demand policies. aggregate (see Varela, 2021) to move towards an economy of knowledge and technological development.

3. Methodology and Results

A balanced panel data model was made using the process for the adequate selection of evaluators in short panel data, proposed by Cameron and Trivedi (2009), and Álvarez, Perdomo, Morales and Urrego (2013). In such a way that, it starts by identifying if there is unobserved heterogeneity due to the presence of constant terms in time that vary between observed units. In the event that this component exists, the model can be estimated with fixed effects and/or random effects.

In subsequent calculations, X represents the model regressors, α is the model constant, and Ɛ is the terminal error of the model. If alpha represents an unobservable variable in the model that varies between individuals, but not over time, since it is constant and is related to the regressors, a fixed effects model should be used, while if it is not related to the regressors it can be considered as randomness and applying the random effects model. Therefore, there is also a discussion about the endogeneity of the X variables, where when there is evidence that random effects prevail, it can be approximated that the regressors are related to the error term.

The Ordinary Least Squares (OLS) model is presented in equation [I] where there is a single constant for all the observed units and their respective times. In this case, the estimators are consistent if the appropriate model is the random effects model. In this type of model, a different specification can be considered depending on the behavior of the errors, for example, an autoregressive process of order one (AR1) has the following error specification [II].

The random effects (EA) model assumes that the time-invariant component of the error can be treated as random and is not related to the regressors, it presents a specification where each observed unit has a different intercept [III]. On the other hand, the fixed effects (EF) model eliminates unobserved individual effects through the calculation of means, it is consistent despite the existence of endogeneity with the time-invariant component of the error, the specification of the model [IV] includes v_i as a binary variable that holds the difference between the observed units fixed.

$$y_{it} = \alpha + \beta_k X'_{it} + u_{it} \quad [I]$$

$$u_{it} = \rho_1 u_{it-1} + \epsilon_{it} \quad [II]$$

$$y_{it} = \alpha_i + \beta_k X'_{it} + u_{it}\ , \alpha_i = \alpha + e_{it} \quad [III]$$

$$y_{it} = v_i + \beta_k X'_{it} + u_{it} \quad [IV]$$

In the analysis of panel data, the variability of the dependent variable can be captured by the variability within [V] of the regressors (given for the same unit observed in several periods of time) and/or by the variability between [VI] of the regressors (it occurs between the units observed at one time). The combination of both variations is called overall [VII]. It should be noted that, according to (Baltagi, 2005, p.200), the between estimator tends to estimate long-term relationships, while the within estimator tends to estimate short-term relationships. Collaterally, Kennedy (2008, p. 287) indicates that if there were only observations in cross-section, the OLS regression produces long-term estimators, on the contrary, if there were a unit observed in several periods of time, effects would be estimated. Short-term.

$$S_w^2 = \frac{1}{NT-1}\sum_i \sum_t (x_{it} - \bar{x_i} + \bar{x})^2 \quad [V]$$

$$S_B^2 = \frac{1}{N-1}\sum_i (\bar{x_i} - \bar{x})^2 \quad [VI]$$

$$S_O^2 = \frac{1}{NT-1}\sum_i \sum_t (x_{it} - \bar{x})^2 \quad [VII]$$

To quantify the relationship between public spending on education and economic growth in Ecuador, it is proposed to estimate a panel data model at the provincial level with annual information. For which information from different databases was collected and estimated as shown in the following table. The specification of the model considers the incorporation of variables carried out by previous studies such as Cerquera et al (2022), Alataş and Çakir (2016), Ngepah et al (2021) and Odhiambo (2020). In this sense, the variable of interest is public spending on education controlled for demographic and business factors.

Table 7. Databases used for the econometric model

Entity	Base number	Variables	Notes
Central Bank of Ecuador	1	Gross value added by province	Provincial accounts were used to address economic growth through the variation of the provincial gross value added of all economic activities.
World Bank	2	Public spending on education. GDP at current prices, national currency.	Public spending on education was obtained by multiplying: the indicator of the % of public spending with respect to GDP by Ecuador's GDP.

Entity	Base number	Variables	Notes
National Institute of Statistics and Censuses	2	Population estimated by province. Total, hospital discharges by province.	The total provincial population that was estimated for the death tabulations was used. Likewise, the total number of hospital discharges was used as a proxy variable for the health of the population in each province.
Superintendence of Companies	12	Average registered employment. Average income tax caused.	The databases of the Ranking of companies of the Superintendence of Companies were used to estimate the indicators considering legal persons in active status.

Source: Central Bank of Ecuador, World Bank, National Institute of Statistics and Censuses, Superintendence of Companies. Elaboration: Authors.

The estimated model has the following specification, where the determinants of the growth rate of the provincial gross added value are analyzed. It should be noted that growth rates and variations were used so that the series are stationary and avoid making spurious regression errors when correlating trends of the variables.

$$tvab_{it} = \alpha + \beta_1 tedu_t + \beta_2 dpob_{it} + \beta_3 \text{tegr}_{it} + \beta_4 tigad_{it} + \beta_5 demp_{it} + \beta_6 dirc_{it-1} + u_{it}$$

Where:

i =1, …, 23 (provinces of Ecuador, Galapagos not included)

t = 2013, 2014, …, 2019

$tedu$ = Growth rate of public spending on education

$dpob$ = Population variation

tegr= Growth rate of hospital discharges

tigad= Growth rate of investment by decentralized autonomous governments

demp= Variation of average employment of active companies

$dirc$= Variation of income tax caused by active companies. Notice that the subscript indicates that the variable is from one year earlier.

$\alpha =$ Model constant

$u =$ Model error

The following table presents the results of different tests applied to the model. As a summary, the OLS model prevails over EA or EF. In addition, the EA model prevails over EF. It is necessary to correct problems of heteroskedasticity and first order autocorrelation. The typical contemporaneous correlation of models that have cities, provinces or countries as observed units, in this case is not a critical factor if a high confidence level is considered for the estimates.

Table 9. Results of the tests carried out on the model

Test	Null hypothesis of the test	Statistical probability	Interpretation
Ramsey test	The model does not omit variables	0,1185	There is no evidence to reject the hypothesis that the model does not omit variables, with at least 99% confidence.
Wooldridge test	The model has no first-order autocorrelation	0,000	The hypothesis that the model has no first-order autocorrelation is rejected.
Wald test	The model presents a constant variance of errors	0,000	The hypothesis is rejected, therefore, due to heteroscedasticity problems, it is necessary to estimate with robust errors or with cluster errors.
Breusch and Pagan test	There is no time-invariant component, but it is different for each province in the model. If it exists, it can lead to endogeneity problems	1,0000	There is no evidence to reject the hypothesis that there is no unobservable component that produces heteroskedasticity. OLS model prevails before EA or EF.
Hausman test	There is no systematic difference between the EA and EF estimates	0,6474	There is no evidence to reject the hypothesis, therefore, the EA model prevails over EF.
Contemporaneous correlation test	There is contemporaneous cross-sectional independence in the errors	0.0248	The hypothesis is rejected at 95% confidence; therefore, it is necessary to use a Discoll-Kraay estimation.
Harris-Tzavalis unit root test corrected for small bases	The panel contains unit roots in each of the regressors	Not applicable	The hypothesis is rejected for all the regressors. Therefore, the variables of the model are stationary.
Variance inflation factor	Not applicable	Not applicable	All regressors have an inflation factor of less than 2%. Likewise, weak correlations between the regressors are evident.

Source: Central Bank of Ecuador, World Bank, National Institute of Statistics and Censuses, Superintendence of Companies. Elaboration: Authors.

The following table presents the results of the different estimated models. It is observed that the sign of each of the variables is the same in all the regressions; likewise, the coefficient of the variable of interest presents relatively robust results for all estimations. In such a way that, given a unitary increase in the growth rate of public spending on education, it is expected that on average the growth rate of the provincial gross added value will increase by 0.2 units.

The population variation of each province has a positive effect on economic growth, while an increase in the growth rate of hospital discharges has a negative effect. Intuitively, it would be expected that with more hospital discharges, a sicker population could be had, and therefore with a lower contribution to final production.

It is possible to observe that the investment of the decentralized autonomous governments (GADs) contributes positively to the provincial economic growth. Also, as expected, a higher average number of total workers per company is positively correlated with higher growth. Finally, the average income tax incurred for the previous period has a positive sign, but it is not statistically significant in all the estimated models.

Table 8. Results of the econometric model, dependent variable growth rate of gross provincial added value

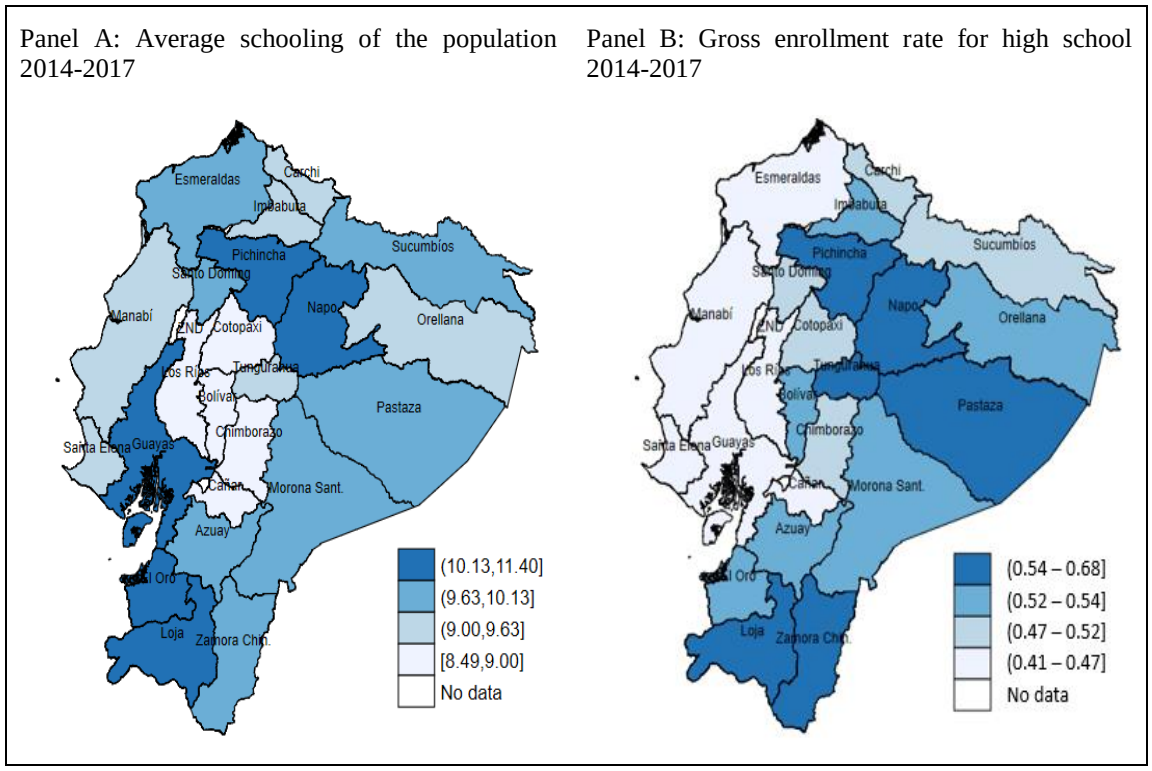
Variable	MCO	AR1	EA	EF	DK
tedu: Growth rate of public spending on education	0.209***	0.237***	0.209***	0.181**	0.209**
dpob: Population variation of the province	4.26e-07**	5.55e-07***	4.26e-07**	28.9e-07	4.26e-07
tegr: Hospital discharge growth rate	-0.348**	-0.276**	-0.348**	-0.300**	-0.348**
tigad: Provincial GADs investment growth rate	0.001*	0.016***	0.001*	0.002***	0.001
demp: Variation of the average employment of the companies	0.027*	0.029*	0.027*	0.028*	0.027***
dirc: Variation of the average income tax caused by the companies one year before	6.87e-07	4.42e-07*	6.87e-07*	6.89e-07	6.87e-07
Model constant	0.021**	0.017**	0.021***	-0.286	0.021***
N	161	161	161	161	161
r2	0.1232			0.1299	0.1232
r2_o			0.1232	0.0088	
r2_b			0.1517	0.0599	
r2_w			0.1215	0.1299	

*p-value <0.15, ** p-value <0.05, *** p-value <0.01. *Source: Central Bank of Ecuador, World Bank, National Institute of Statistics and Censuses, Superintendence of Companies. Elaboration: Authors.*

4. Educational policies to promote the knowledge economy and technological development

Educational policies aimed at promoting the knowledge economy in Ecuador must consider the territorial dynamics in terms of secondary education, tertiary education, schooling, employment and production. In such a way that heat maps were prepared with relevant indicators for the discussion of potential policies. It should be noted that the study covers a pre-pandemic stage, especially due to the comparability of information at the time of presenting the results in terms of averages, which are not affected by the impact of the pandemic.

Certain provinces of the Sierra and Amazon region of Ecuador have a higher gross enrollment rate for high school studies, which, in turn, have high levels of average schooling in their population. This phenomenon is less marked in the Amazonian provinces, in this sense, it is to be expected that the new generations are preparing more (in formal school education) compared to past generations. In addition, it should be noted that, in the Coastal region, several provinces have a population that has a high level of schooling, however, the gross enrollment rate is low. Note that this may be due to the estimate made since the numerator of the indicator includes the population between 18 and 19 years of age, who may have already graduated from high school.

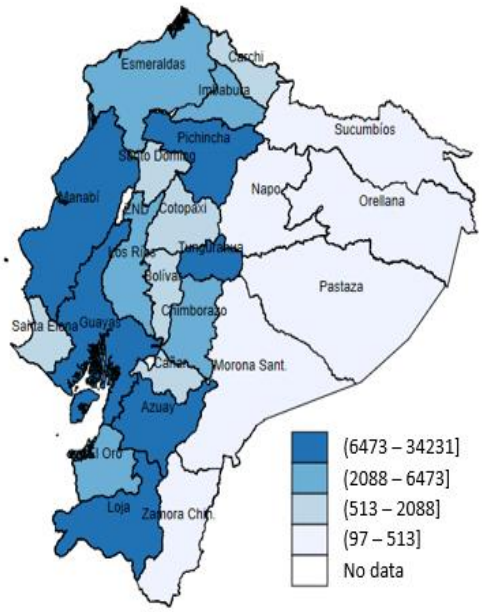


Graph 3. Maps of average schooling and high school gross enrollment rate by provinces of Ecuador

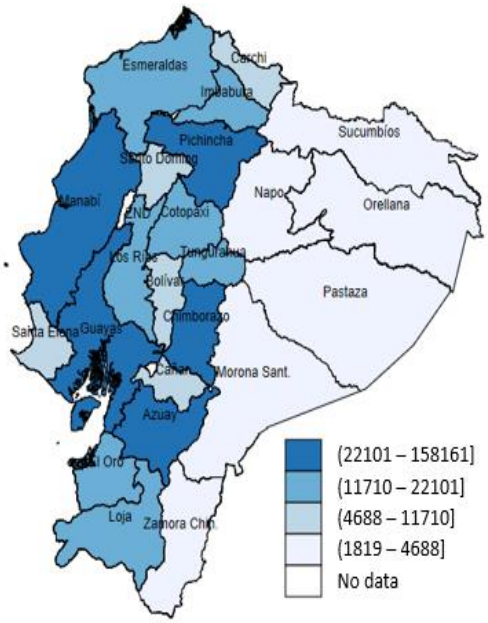
Note: The average schooling was calculated from the INEC methodological file, the indicator covers the population older than or equal to 24 years. The gross enrollment rate was calculated from the records of the Master File of Educational Institutions, the denominator of this indicator was calculated with the estimated population between 15 and 19 years of age. Source: Central Bank of Ecuador, National Institute of Statistics and Censuses. Elaboration: Authors

In the following heat maps, a strong relationship is identified between the provinces that have a greater number of titles registered annually, and those that have a greater number of enrolled students. It is clear, the lag of students and degrees in the entire Amazon region of Ecuador, this is linked to the tertiary level academic offer offered in said territories. It is also important to mention that, of the total number of students enrolled in the period analyzed, on average close to 42% studied careers in the field of knowledge related to administration, social sciences, journalism and law. While, on average, 15% studied engineering, industry and construction; 4% in services; and, 1% in information technologies. A similar case occurs with the enrollments in the field of study of the technical and technological institutes, where the majority were studying administrative careers. To a certain extent, this is related to the academic offer of universities and technological institutes, where 36% of the offer (measured percentage of the total careers offered in 2021) is in fields related to administration, social sciences, journalism and law.

Panel A: Annual average titles registered 2013-2019



Panel B: Average students enrolled in third grade level 2015-2019

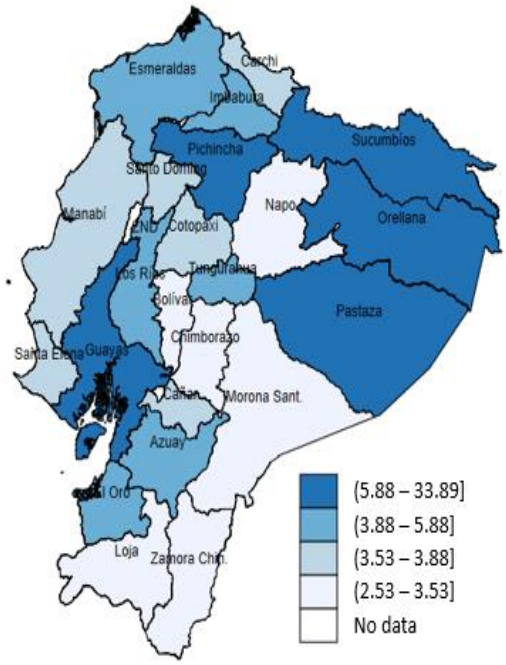


Graph 4. Maps of the total registered titles and total number of students enrolled in third-level degree courses by provinces of Ecuador

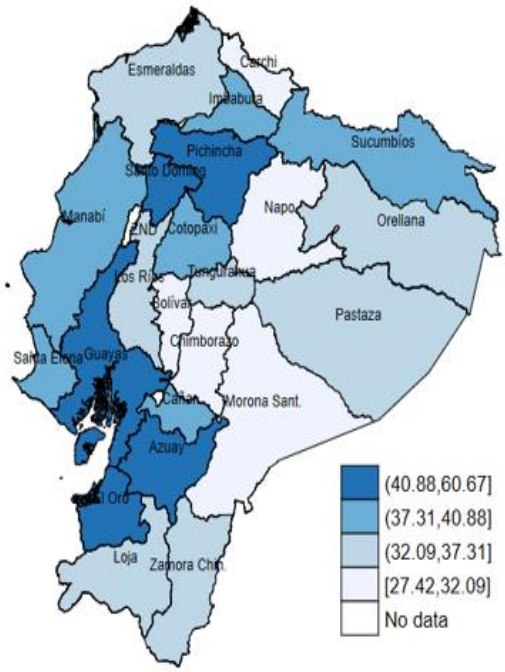
Source: National Secretariat of Higher Education, Science, Technology and Innovation. Elaboration: Authors.

In terms of production, several of the Amazonian territories that present the lowest prevalence of students and registered third-level degrees have a high gross added value. This is due to the extractive activities carried out in the Ecuadorian Amazon, where professionals who are trained in other provinces work. In turn, it may imply that in such territories a part of the wealth generated is sent to large cities via salaries (without considering that the largest surplus is taken by companies dedicated to the exploitation of natural resources). Finally, a certain pattern of relationship with schooling and adequate employment is observed, territories where the population has a high level of education are associated with territories with better working conditions.

Panel A: Average Gross Value Added per capita of all industries 2013-2019



Panel B: Average adequate employment divided by the economically active population 2013-2017



Graph 5. Maps of the total registered titles and total students enrolled in third-level degree courses by provinces of Ecuador

Source: Central Bank of Ecuador, National Institute of Statistics and Censuses. Elaboration: Authors.

Consequently, according to the literature review, analysis of the descriptive statistics of variables that allow contextualizing the problem and results of the econometric model, educational policies to promote the knowledge economy and technological development in Ecuador should be focused on:

- Promote school enrollment at all educational levels: school, college and tertiary level. Mitigating the potential risks that can be found according to each territory (coverage, violence, child labor, among others).
- Promote the offer of third-level careers with a high technological component, ensuring that the careers comply with the principles of relevance and achieve employability of students in the short term.
- Invest in tertiary education infrastructure in territories where there is currently a limited supply, and that has characteristics for the project(s) to be successful (scholarship programs, infrastructure construction in places where population density justifies the creation of institutions large or small, etc.).
- Establish research and cooperation agreements between universities and technological institutes and public and private sector companies. For the creation and application of knowledge.
- Give incentives to legal persons in the field of innovation. As well as creating environments for cooperation between industries and consolidation of value chains.

5. Conclusions

Investment in higher education is important for the country to develop exports that incorporate high technology in the long term. Evidence was found that, at the territorial level, a higher growth rate of public spending on education is associated with a higher growth rate of the economy. In such a way that, in the face of reductions in public spending, as has been seen since 2019, growth is affected in the short term, and in the long term it is committed to the technological development of the country.

The indicators of imports and exports according to technological level indicate that Ecuador is an importer of products with a high technology component, but its exports do not reach similar levels. One way to change this is through the development of human capital (education), however, there are territorial barriers (measured by education, enrollment rate and registered titles) and barriers due to the academic offer of universities and

technical and technological institutes. Therefore, it is necessary to rethink the priorities in terms of preparing future generations, taking into account the country's own territorial dynamics.

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