Measures of Science Technology in Ecuador

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4 January 2009

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1. Introduction

One of the structural problems in Latin-American has been the lower innovative capacity and lower generation of economically exploitable knowledge. This phenomenon has been produced by the absence of government's incentives and strategies in order to be competitive inside the Knowledge Based Economy. More concretely, political, institutional and social factors have contributed negatively within this reality. As a consequence, the knowledge generation in this region is insufficient not only to satisfy its necessities but also to be competitive in the global context.

At difference, the developing regions have recognized the significance impact of Science and Technology (S&T) and Education in their sustainable growth. In the Latin-American context, this analysis requires robust indicators that help to evidence the causes of this problematic. In this respect, the absence of harmonized politics and common variables that allows studying the evolution of S&T in the Latin-American region is the main limitation for this analysis. Based on that, this report brings an exploratory analysis that allows identifying the critical factors and the possible solutions of this S&T problematic. In parallel, the case of the National Innovation System implanted in Ecuador is presented and evaluated.

2. R&D in Ecuador

2.1 Ecuador Profile

Officially, Ecuador is namely Republic of Ecuador. The government system is a Representative Democratic Republic. The current president is Rafael Correa. This country is localized in South America and bordered by Colombia (north), Peru (east and south), and the Pacific Ocean (west). Also, this country includes the Galápagos Islands localized in the Pacific Ocean. Thus, Ecuador straddles the Equator, from which it takes its name. It has an area of 256,371 km2 and its capital city is Quito. Other relevant characteristics are summarized in the next table. By several years, the economy of Ecuador has been supported by the exportation of primary products such as petroleum, banana, shrimp, and flowers. In this respect it is important to mention that the industrial products that are exported do not have a highest technological component. At the same time, other contributors for the economy have been the ecotourism and the transferences of money from immigrants.

Tabla 1: Ecuador Profile

Capital	Quito
Official Languages	Spanish, Quechua
Government	Presidential Republic
Independence	From Spain May 24, 1822
Population (2007 estimations)	13,755,680 (65th)
GDP (2006 estimations per capita)	$4,776 (111th)
Currency	U.S. dollar[1] (USD)

2.2 Science & Technology in Ecuador

The history of Science & Technology in Ecuador started in 1950. Since this date, several actions have been focused on developing an adequate infrastructure. This allows establishing plans and mechanisms in order to promote the Science and Technology in Ecuador (see Table 2). Actually, the National Innovation System of Ecuador was developed by the Secretaria Nacional de Ciencia y Tecnología – SENACYT- (National Science and Technology Department).

Tabla 2: History of Science & Technology in Ecuador

50`s - 70's	80's	90's	00's
• Establishment of the Ecuadorian Foundation of Advancement of Science	• Restructuration of the National Council for Science and Technology	• First National Plan for Science and Technology. The main lines are: • Scientific research • Training • Innovation	• Mechanisms to evaluate such as Integral System for the Monitoring and Evaluation of Competitiveness
• Creation of the National Council for Science and Technology	• R&D legislation	• R&D Plan 1996-2000	• Human Development Plan 2007-2010

The National Innovation System of Ecuador is an initiative that was encouraged by the government within the strategic lines implemented on the Human Development Plan 2007-2010. The main aim of this system is the investment in science and technology in order to contribute to the economic and social development (SENACYT, 2007). At the same time, this legislation promotes the collaboration among government, university and industry in order to achieve the objectives defined. Concretely, the main actions are associated with:

- The promotion of human, social, and productive development
- The diffusion of science, technology and innovation
- The transversally and convergence
- The reinforcement of the system
- The sustainable funding

In this context, the priority economic sectors are associated with the sustainable agriculture; the environment and sustainable development; the industrial and productive reinforcement; the renewable energy alternatives; the information and communication technologies; the biotechnology; and other scientific research areas. In this process, the main agents involved in the promotion of science and technology have been the universities and government. The Table 3 shows the actions developed by each institution in several areas such as agriculture, environmental, physics, chemistry, biology, electronics, mechanics, and other sciences.

Table 3: Institution participating in S&T activities

Universities	Autonomous National Institute of Pecuary Researches	Agro-forestry, agro-pecuary and agro-industrial sectors.
	National Polytechnic School	Engineering
	Army Polytechnic School	Physics, chemistry, Microbiology, Environmental, and geo-physics areas.
	Superior Polytechnic School of Chimborazo	Electronics and Mechanics Sciences
	Superior Polytechnic School of Litoral	Anthropology, Economics, Coastal Studies, Informatics and Robotics.
	University of Cuenca	Microbiology & hydraulic
	Technical University of Machala	Agro-pecuary
	University of Azuay	Environmental, Economics, and Linking Projects.
	International University of Ecuador	Mechanics.
	Equinoctial Technological University	Technology Transfer.
	Private Technical University of Loja	Research and Technology Transfer, Extension and Services Centre
	Catholic University of Santiago Guayaquil	Research and Development System (SINDE).
	Latin American Faculty of Social Sciences, Ecuador	Technological Impact studies.
Government Institutions	Forest Ecuadorian, Natural and Wildlife Areas Institute	Local biodiversity
	National Institute of Energy	Energy.
	Meteorology National Institute	Meteorology and Hydrology.
	"Charles Darwin" Research Station	Research and Marine conservation.
	Fishing National Institute	Economic, technological, and biological researches on fisheries.
	National Centre of Aquaculture and Marine Researches	Aquiculture.
	Ecuadorian Institute of Standardization	Metrology and Standardization.

Source: REICYT http://reicyt.org.ec/

2.3 Science & Technology Measures in Ecuador

A. Science and Technology Inputs

Human capital: Population employed in R&D activities by degree: With respect to human resources, the most recent information available only allows for the establishment of certain statistics regarding people holding a PhD and, in general, those people involved in R&D activities. It can be seen that the number of people holding a postgraduate degree has increased during the course of the last year. Nevertheless, the number of scientists for every one thousand people forming part of the Economically Active Population (PEA – Spanish acronym) is less than one. This would indicate that the training of scientists and professionals to the postgraduate level is a task that is still pending for Ecuador.

Table 4: Human Capital – R&D Workers

	2001		2002		2003	
	Pop.	**%**	**Pop.**	**%**	**Pop.**	**%**
Bachelor	446	68,8	451	64,8	548	64,9
Master	141	21,8	167	24	208	24,62
PhD	60	9,3	77	11,1	88	10,41
Total	648	100	696	100	845	100

Source: FUNDACYT-REICYT-SENACYT

Science and Technology Expenditure (Thousands USD$): As can be observed in the following table, spending on S&T and R&D activities is low and, furthermore, rather than increasing over time the figures have dropped dramatically over the last three years. Paradoxically, the National S&T+I Plan 1996-2001 announced that the country had managed to strengthen the capacity of scientific research and technological development agents through the provision of physical infrastructure and the formation of new researchers holding Masters Degrees and PhDs.

Table 5: Science and Technology Expenditures

	1996	1997	1998	1999	2000	2001	2002	2003
S&T USD	33030	45414	43049	24196	26274	21201	22315	24777
R&D USD	15920	15844	15011	-	-	12583	15841	18621
R&D/GDP	0,086	0,08	0,076	-	-	0,06	0,07	0,07

Source: FUNDACYT-REICYT-SENACYT

Expenditure on S&T Activities and GDP by Sector (%): The information acquired concerning S&T spending is very limited and the lack of participation of the production sector in this area, and in fact its diminishing participation, is clearly evident. The highest level of participation is that of public institutions, followed by private non-profit organizations and then universities. Nevertheless, towards the year 2000, this tendency is reversed and the academic sector participates far more, rising to 45.8%. This reflects the intention to improve infrastructure and human resources within Ecuador's academic sector. However, spending on S&T as a percentage of GDP remains at the same level as when it started, despite having peaked in 1997 and 1998.

Table 6: Expenditures on S&T Activities by Sector

	1996	1997	1998	1999	2000	2001	2002	2003
Universities	23,6	21,7	25,9	23,2	45,8	-	-	-
Enterprises	5,7	4,4	5	-	-	-	-	-
Non lucrative organizations	34,9	34,5	31,1	19,5	20,7	-	-	-
Public Institutions	35,9	39,4	38	57,2	33,6	-	-	-
Total	100	100	100	100	100	-	-	-
S&T/GDP (%)	0,18	0,23	0,22	0,19	0,19	-	-	-

Source: FUNDACYT-REICYT-SENACYT

S&T Expenditure by Field (Thousands USD$): In relation to the scientific fields, the greatest contribution of research can be observed in engineering and agricultural sciences. This is consistent with the experience of the SENACYT- FUNDACYT in its training component where the majority of beneficiaries applied for the areas of engineering, industrial processes, natural resources and the environment.

Table 7: Expenditures on S&T Activities by Field

	2001		2002		2003	
	USD$	%	USD$	USD$	%	USD$
Exacts &Naturals	3,146	25	3,057	19,3	4,469	24
Engineering & Technology	4,027	32	5,148	32,5	6,089	32,7
Medical	0,802	6,4	1,156	7,3	1,62	8,7
Agriculture	3,309	26,3	4,8	30,3	4,73	25,4
Social	1,145	9,1	1,584	10	1,657	8,9
Humanities	0,96	0,8	0,79	0,5	71	0,48
Total	12,583	100	15,841	100	18,621	100

Source: FUNDACYT-REICYT-SENACYT

B. Science and Technology Outputs

Patents Granted to Residents: The following table shows the low number of applications submitted for patents by resident scientists and of patents subsequently granted.

Table 8: Patents Granted to Residents

	2001		2002		2003	
	Demanded	Granted	Demanded	Demanded	Granted	Demanded
Exacts &naturals	0	1	0	1	0	0
Engineering & Technology	0	0	1	1	1	2
Agriculture	0	0	3	0	8	1
Social	0	0	0	0	1	1
Total	0	1	4	2	10	4

Source: FUNDACYT-REICYT-SENACYT

Patents Granted to Residents and Non-residents: The data compared between residents and non-resident scientists from 1996 to 2001 evidenced considerable differences. In other words, the majority of the patents have been granted by non-residents.

Table 9: Patents Granted to Residents and No Residents

	1996	1997	1998	1999	2000	2001	2002	2003
Residents	7	5	18	-	7	5	-	-
No residents	129	362	291	-	32	21	-	-
Total	136	367	309	-	39	26	-	-

Source: FUNDACYT-REICYT-SENACYT

Personnel Involved in R&D According to Gender of Researchers: No information could be obtained concerning the career of researchers, their distribution by field or institution. However, in relation to gender distribution in R&D activities, the following table demonstrates the enormous difference in participation between men and women. The number of women participating is far below half the number of men for the three years analyzed, although the rhythm of growth for women is greater than that for men over the course of the last year.

Table 10: Personnel Involved in R&D According to Gender of Researchers

	2001		2002		2003	
	Pop.	%	Pop.	%	Pop.	%
Female	157	24,2	160	23,1	241	28,52
Male	491	75,87	535	76,9	603	71,36
Total	648	100	696	100	845	100

Source: FUNDACYT-REICYT-SENACYT

Scientific Publications by scientific area: in this case, was so difficult to find information about the publications in Ecuador. However, Segarra and Carrión (2006) present the case of ESPOL University where we can obtain evidence about this measure. As we can see, 2003-2004 was a productive period for this university with 132 papers. In this respect, 55% percent of these publications were developed by ESPOL's researchers and 45% in collaboration with national and international organisms. The most relevant area of investigation in this university is associated with technological and alimentary areas.

Table 11: Scientific Publications by scientific area:

2003-2004	Papers	Congress
Escuela Superior Politécnica del Litoral, ESPOL	132	
Escuela Politécnica del Ejército, ESPE	63	1
Hospital Metropolitano	24	
Escuela Politécnica Nacional, EPN	6	16
Hospital Luís Vernaza	19	
Universidad Técnica de Ambato	18	
Universidad Central del Ecuador	16	
Hospital Alcívar	14	
Universidad San Francisco de Quito	5	8
Universidad de Cuenca	10	

Source: Segarra and Carrión (2006)

Quality Research: the Indicators provided by the ISIWeb-Knowledge measure the quality research by fields, number of papers, and citation ratio. If we compare the Ecuadorian data with USA, we can see that the main research subjects are related with Immnunology and Engineering (See Table 12). In general terms, these statists show the low effectiveness of policy and science strategies in Ecuador.

Table 12: Essential Science Indicators January 1, 1998-April 30, 2008

	Papers EC	Citation EC	C/P EC	C/P USA
Clinical Medicine	300	2,228	7.43	15.60
Physics	198	1,941	9.80	12.15
Environment/Ecology	173	1,790	10.35	11.53
Plant & Animal Science	352	1,418	4.03	8.57
Geosciences	110	1,016	9.24	11.79
Biology & Biochemistry	50	620	12.40	21.84
Neuroscience & Behavior	108	540	5.00	22.35
Immunology	**23**	**511**	**22.22**	**25.14**
Molecular Biology & Genetics	23	334	14.52	31.91
Agricultural Sciences	58	280	4.83	7.74
Engineering	**41**	**270**	**6.59**	**5.02**
Social Sciences, General	42	137	3.26	
Multidisciplinary	3	22	7.33	9.81
All Fields*	**1,588**	**11.730**	**7.39**	**13.76**

Source: ISIWEB-Knowledge

2.4 Analysis of Science & Technology: Ecuador vs. Latin-American Countries

The Case of Ecuador corroborates the relevance of some factors involved in the evolution of its R&D strategy. These factors are associated with (see Annex 1):

- The R&D Expenditure/GDP is one of the most important variables inside the Knowledge Creation Indicator in developing countries like Ireland (1,24%) and Spain (1,12%). In Ecuador, the R&D strategy evidenced a lower expenditure in science and technology activities. One explanation could be associated that the financial recourses are used to cover social necessities.

- The patents applications not only evidenced a value added but also the possible commercialization of this new knowledge. In this line, Ireland has a higher score (42,45) that corroborate the importance of this intellectual property outputs for the economic development. In Ecuador this capacity is extremely lower only 0,22 pat./Mill. People.

3. Final Comments

At the legislative level interesting proposals exist concerning decentralization and the offering of stimuli for the generation of S&T and R&D capabilities. It was not possible to obtain information concerning infrastructure and the performance of institutions at the regional level. In this panorama, Ecuador would be considerate such a weak country because the majority of its indicators evidenced the deficiencies of its R&D Strategy.

In this perspective, the country needs strong measures focused on promoting the innovation such as a real alternative to economic and social development. Particularly, the evidenced corroborate that a lower investment in activities generated lower technological and innovative outputs (patents and technological value added). At the same time, other weaknesses can be observed on poor links with the production sector, low levels of funding for S&T activities, a lack of incentives for attracting the participation of numerous agents, a reduced number of researchers and people with PhDs.

Therefore, it is required that all educational-governmental-industrial spheres work together in order to develop and implement strategies that allows reinforcing its fragile economy. A clear example is the National Innovation System that tries to bring the structures and elements required in this process. In this sense, it is important to know the experience of other countries that have experimented this process. But the most relevant effect of this paper is not identifying the deficiencies even thought understanding that the education, collaboration, and resources are other necessities that need to be covered globally. In this idea, this problematic is not only of the Latin-American countries but also is a global problem that require the collaboration and help of strong countries.

4. References

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Annex 1: S&T Latin-American Indicators

	AR	BO	BR	CH	CO	CR	DO	EC	EL	GT	GU	HA	HO	JA	MX	PN	PY	PE	UY	VE	NI	LA	IR	ES	US	JP
INPUTS-Human Capital																										
Science and Engineering Enrolment Ratio (%), 2006	19,02		15,89	28,18	35,59	23,34			23,45	18,77	14,29		23,09		31,34	20,47						24,15	22,56	29,84	15,59	19,49
Researchers in R&D / Mil. People, 2006	768,04	120,07	462,06	832,74	127,08	425,26		50,18					65,13		331,46	97,46	85,52		375,39	206,51		309,70	2.681,11	2.528,97	4.628,20	5.300,49
Gross Secondary Enrollment, 2006	85,58	88,50	105,65	90,79	82,23	79,20	69,07	64,66	64,82	51,12			67,26	87,06	84,68	70,21	66,65	92,42	106,94	74,44	66,49	81,11	111,64	118,08	94,12	101,56
Employment in M. and H-tech manufacturing (% workforce)	23,50	28,20	21,00	23,00	18,80	21,60	21,10	21,20	23,70	20,00	22,60	10,70	20,90	17,70	25,70	17,20	15,80	23,80	21,90	19,80	18,00	20,84	27,80	29,70	20,60	27,90
INPUT - Expenditure																										
Total Expenditure for S&T as % of GDP, 2006	0,44	0,28	0,91	0,68		0,37		0,06					0,05	0,07	0,41	0,24	0,08	0,15	0,26	0,25	0,05	0,28	1,24	1,12	2,68	3,18
Private Sector Spending on S&T (1-7), 2007	2,90	2,40	3,80	3,30	3,10	4,00	2,70	2,60	2,70	3,20	2,80		2,70	3,50	3,10	3,00	2,20	3,10	2,80	3,00	2,40	2,98	4,80	3,40	5,80	5,80
ICT Expenditure as % of GDP, 2006	6,90	4,90	6,40	5,20	8,00	7,30		3,00					4,60	9,70	3,30	8,20		5,90	7,80	3,70		6,06	4,20	3,60	8,70	7,90
OUTPUT - Patents																										
Patents Granted by USPTO / Mil. People, avg 2002-2006	1,40	0,02	0,75	0,93	0,24	2,54	0,07	0,22	0,24	0,15	0,00	0,00	0,12	0,46	0,95	0,45	0,00	0,15	0,41	0,89	0,04	0,90	42,45	8,04	324,12	278,03
Total Royalty Payments and receipts(US$/pop.) 2006	1,76	0,21	0,55	3,36	0,25	0,12	0,00	0,00	0,35	0,01	47,12	0,00	0,00	4,78	0,83	0,00	33,24	0,06	0,02	0,00	0,00	4,32	141,64	21,17	207,54	157,53
Firm-Level Technology Absorption (1-7), 2007	4,20	3,20	4,90	5,20	4,20	4,90	4,80	3,80	4,40	4,80	3,70		4,20	4,90	4,40	5,00	3,40	4,30	4,20	4,60	3,50	4,37	5,50	4,80	6,10	6,20
OUTPUT – Application																										
Prof. and Tech. Workers as % of Labor Force, 2004	21,29	15,04	13,28	10,81	12,62	21,55		15,88	10,64				8,31	26,03	15,74			17,79	16,35	10,92		15,81	23,58	23,17	20,32	14,54
Scientific and Technical Journal Articles / Mil. People, 2005	78,92	4,05	52,93	95,67	8,90	24,26	0,70	1,65	0,00	1,28	5,44	0,12	1,81	17,09	37,85	12,79	0,76	4,88	61,71	20,09	1,59	21,40	509,73	422,51	692,46	434,14

Notes: AR: Argentina; BO: Bolivia; BR: Brazil; CH: Chile; CO: Colombia; CR: Costa Rica; DO: Dominican Republic; EC: Ecuador; EL: El Salvador; GT: Guatemala; GU: Guyana; HA: Haiti; HO: Honduras; JA: Jamaica; MX: Mexico; NI: Nicaragua; PA: Panama; PY: Paraguay; PE: Peru; UY: Uruguay; VE: Venezuela RB; LA: Latin America; IR: Ireland; ES: Spain; US: United States; JP: Japan.
Source: World Bank, 2008