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Research and development in Central America: panorama and prospects for international cooperation

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Abstract This article examines the state of scientific research and development in Central America, highlighting the potential contribution of international partners. It separates Central America from the larger region of Latin America and the Caribbean to underscore its differences and how these affect scientific and technological capacities, priorities and possibilities. Using primarily data from the Ibero-American Network of Science and Technology Indicators and the United Nations Educational, Cultural and Scientific Organization Institute for Statistics, current research and development trends in the region are explored, as defined by international Frascati norms, and juxtaposed against broader scientific and technological parameters. Challenges within this environment include educational quality and completion rates; low public and private funding of scientific research; lack of institutionalization; limited understanding of the potential returns associated with research; and the fact that the region operates almost entirely in Spanish, limiting opportunities for global publication and exchange. In addition to national efforts, collaborative international initiatives that appear to be yielding dividends against these obstacles are multinational and intergovernmental supported research training and monitoring partnerships; cross-border university- and research institute-led programs; and international joint publishing projects.

Keywords Central America · Research · Development · Science · Technology

Introduction

This article examines the status of and prospects for scientific research and development in Central America, emphasizing the potential contribution of international partners. It separates Central America from the larger region of Latin America and the Caribbean, within

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which it is usually placed, highlighting some of its elemental differences and how these affect scientific and technological capacities, priorities and possibilities.

Using primary and secondary data from the Ibero-American Network of Science and Technology Indicators (RICYT) and the United Nations Educational, Cultural and Scientific Organization (UNESCO) Institute for Statistics (UIS), the article explores current research and development trends in the region, as defined by international Frascati norms, and juxtaposes these against broader initiatives related to scientific and technological activity. It examines the inherent obstacles to both scientific research and publishing faced by academics in Central America, reviews some of the more promising programs underway to advance regional research capacity, and concludes with recommendations for future development.

This study is of potential interest not only for Central America but also for other developing countries and regions that share similar characteristics. Increasingly, the developing world is being separated into three groups: larger, more populace and productive emerging economies (such as China, India, Brazil and Russia); extremely poor and troubled countries that continue to receive the bulk of international assistance (such as Haiti, Zimbabwe, Niger and Afghanistan); and all the rest: mostly middle-income nations that are growing but often not highly resourced or productive in relative terms. International attention tends to focus on the first two groups of countries. This effort focuses attention on the third, the countries that may not yet benefit from the large trade gains seen in the emerging economies but that no longer qualify for significant donor aid. It is critical for these countries to cultivate scientific and technological resources to advance national development goals. Better understanding how Central America can propel this effort adds to the broader knowledge base on how smaller, middle-income developing countries in comparable circumstances may progress as well.

Regional overview

Central America is generally grouped together with the rest of Latin America and the Caribbean, but the region actually forms its own sub-continent with a rather different combination of characteristics. Thus, especially for issues related to scientific research and development, Central America merits examination on its own for a more complete assessment of its particular situation, resources, challenges and prospects.

Geographically, Central America is the isthmian corridor connecting North and South America. It consists of seven countries—Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama—bordered by Mexico to the north, Colombia to the south, the Pacific Ocean to the west and the Caribbean Sea to the east. It encompasses an area of over 500,000 square km and a population of over 40 million. Politically, the region has been independent of colonial rule for over 200 years. It has transitioned in the past half-century from primarily autocratic rule to democratically elected governments, though governing structures and processes differ significantly by country. Spanish is the official language everywhere except Belize, where English is the national language and Spanish is the predominant second language.

Economically, all of Central America is technically "middle income" according to World Bank classification, but this categorization covers a wide breadth. It includes lower middle income performers such as Nicaragua with annual GDP per capita of around $1,000 and upper middle income performers such as Costa Rica and Panama with annual GDP per capita of over $7,000 (Table 1). Economic structures vary, but there is a tendency toward

Table 1 Central America—selected economic statistics

Country	Population (millions)	GDP ($US billions)	GDP per capita ($US)	Agriculture (% GDP)	Industry (% GDP)	Services (% GDP)
Belize	0.3	1.4	4,064	12	23	65
Costa Rica	4.7	35.8	7,691	7	26	67
El Salvador	6.2	21.2	3,426	13	27	60
Guatemala	14.4	41.2	2,862	13	19	68
Honduras	7.6	15.4	2,026	13	27	61
Nicaragua	5.8	6.6	1,132	21	30	49
Panama	3.5	26.7	7,589	5	17	78
CA (average)		21.2	4,113	12	24	64

Source World Bank, World Development Indicators (2011a)

reliance on commodities and natural resource extraction, especially for the poorer countries. In recent decades, efforts have been made to diversify economies, mainly through development of tourism, transport, finance and other services, and increase international trade.

Developmentally speaking, if Central America were a single country it would have close to half its population living in poverty but with a life expectancy of 74 years. It would be relatively free, but show considerable income inequality and perform around the global average for human development, government effectiveness and environmental management (Table 2). This consolidated data, however, masks certain profound similarities and differences.

Poverty remains high (over 40 %) across the region in spite of the economic gains of past years, though it is lower in Costa Rica (24 %) and worse in Guatemala and Honduras (51 and 60 %, respectively). Income inequality also runs high throughout Central America, as in all of Latin America and the Caribbean. This is reflected in Gini index ratings of over 50 for nearly every country, indicating that resources are concentrated in the hands of a relative few.

Other development statistics show more divergence. In the United Nations Development Programme human development rankings, for example, Costa Rica and Panama appear in roughly the top third of all countries worldwide, whereas Guatemala, Honduras and Nicaragua appear near the bottom third. Freedom ratings measuring civil liberties and political rights show similar tendencies with Belize, Costa Rica and Panama coming out as very free societies and Guatemala, Honduras and Nicaragua demonstrably less so. Likewise with government effectiveness: according to World Bank evaluations, Costa Rica and Panama perform above the 60th percentile worldwide, while Nicaragua is in the 15th percentile (Table 2).

The most variability is shown with environmental management. In the Yale Environmental Performance Index (Emerson et al. 2012), Costa Rica ranks number 5 of 132 countries for sustainably and professionally managing its natural resources, whereas most of the rest fall into the lower half of all countries evaluated (Table 2). This is noteworthy since Central America possesses significant biological diversity and richness; the region makes up only 1 % of the earth's surface but accounts for 7 % of global biodiversity (CATHALAC 2008). Also, because of its geographic location and climactic conditions, it

Table 2 Central America—selected development statistics

Country	Poverty (% of pop.)	Life expectancy (years)	Gini index	Human development ranking (out of 187)	EPI ranking (out of 132)	Freedom rating	Government effectiveness (percentile)
Belize	33.5	76	59.6	93	–	1.5	39.7
Costa Rica	24.2	79	50.3	69	5	1.0	64.6
El Salvador	37.8	72	46.9	105	75	2.5	56.0
Guatemala	51.0	71	53.7	131	76	4.0	28.2
Honduras	60.0	73	57.7	121	71	4.0	30.1
Nicaragua	46.2	73	52.3	129	35	4.0	15.8
Panama	32.7	76	52.3	58	39	1.5	60.3
CA (average)	40.8	74	53.3	101	50	2.5	42.1

The UNDP Human Development Index (HDI) combines normalized measures of life expectancy, educational attainment, and GDP per capita for countries worldwide to serve as a standard means of quantifying and comparing development levels. The Gini coefficient is a measure of statistical dispersion commonly used to quantify inequality of income. A low Gini coefficient indicates a more equal distribution, with 0 corresponding to perfect equality, while higher Gini coefficients indicate more unequal distribution, with 1 corresponding to perfect inequality. The Environmental Performance Index (Emerson et al. 2012) produced by Yale and Columbia universities rates and ranks 132 countries worldwide on their ability to (1) reduce environmental stresses to human health and (2) promote ecosystem vitality and sound natural resource management. Freedom House, a recognized independent NGO dedicated to the monitoring of democratic freedoms, publishes the *Freedom in the World* annual survey of political rights and civil liberties, which are ranked by country on a scale of 1 (high) to 7 (low). This contributes to the overall ranking of a country as *Free* (1–2.5), *Partly Free* (3–5) or *Not Free* (5.5–7). Among the World Bank's Worldwide Governance Indicators is one that concentrates on government effectiveness. It provides aggregate measures that combine data from a variety of sources on governments' administrative ability to produce an indicator reflecting the percentile rating of each country

Sources World Bank (2011b) (poverty and government effectiveness); UNDP (2011) (Gini and Human Development indices); Freedom House (2011); and Yale and Columbia Universities (2012) (environmental performance)

is highly vulnerable to natural disasters (IDB 2010). Therefore, custodianship and study of environmental resources are important for the entire region, particularly with regard to R&D.

In terms of education, Central America is in questionable condition (Table 3). With the exception of Costa Rica, public spending on education is relatively low compared with the OECD average of around 5 % of GDP (OECD 2011). More important, however, are the results achieved. Progress has been made over the past decades with primary education coverage and completion rates are now at or over 90 % for most of the region. Literacy rates have improved as well. Secondary coverage, though, is less universal. The region overall enrolls less than three-fourths of the secondary age cohort, with completion rates far below that. Interestingly, tertiary gross enrollment is relatively high at roughly 25 %, though estimated completion rates are half that. Tertiary attendance has improved steadily over the last 20 years because of increased public and private degree offers and labor market compensation incentives.

Beyond coverage, access and completion rates, the issue of quality remains contentious. Numerous sources point to serious problems throughout Central America (with the possible exception of Costa Rica) regarding the degree of learning occurring at every level.

Table 3 Central America—selected education statistics

Country	Literacy (% of adults)	Primary completion (% of age group)	Secondary enrollment (% gross)	Tertiary enrollment (% gross)	Public spending on education (% of GDP)
Belize	70	105	75	21	5.7
Costa Rica	96	96	100	–	6.3
El Salvador	84	93	63	23	3.6
Guatemala	74	84	59	18	3.2
Honduras	84	99	73	19	–
Nicaragua	78	81	69	–	–
Panama	94	97	74	45	3.8
CA (average)	83	94	73	25	4.5

Source World Bank, World Development Indicators (2011a)

These difficulties include poor teacher training, lack of national monitoring and evaluation mechanisms, outdated curricula, and minimal quality assurance systems (PREAL 2003, 2007; UNESCO 2007). The problems are exacerbated by the relative lack of national resources in each country dedicated to educational development and the region's middle-income development status, which makes for diminishing international assistance.

R&D panorama

This section turns attention to Central America's progress on scientific research and development (R&D). Countries are reviewed individually and collectively and advances are studied relative to both regional activity and to what is being done elsewhere.

Definitions, parameters and measurement

To clarify what is being examined, it is necessary to employ global standards to insure uniformity of terminology, measurement and methods. The most relevant reference for this is the *Frascati Manual*, a document that sets forth the methodology for collecting statistics on worldwide R&D activity. Originally developed and published by the Organization for Economic Cooperation and Development (OECD) in Frascati, Italy in 1963, it has been repeatedly revised throughout the years. The manual gives fundamental definitions for basic, applied and experimental research, general fields and sub-categories into which science should be subdivided; and measures for R&D related resources.[1] It is also helpful

[1] The *Frascati Manual* is clear about what classifies as R&D for international measurement. The UNESCO Institute for Statistics (UIS) paraphrases the Frascati definition as follows: R&D comprises creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of humanity, culture and society, and the use of this stock of knowledge to devise new applications. The term R&D covers three activities:

- Basic research—experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
- Applied research—also original investigation undertaken in order to acquire new knowledge; it is, however, directed primarily towards a specific practical aim or objective.

for understanding the role of science and technology in the economic development of both industrialized and developing countries. Since the Frascati definitions have become internationally accepted, they serve to establish a common language and taxonomy for science and technology policy making.

Because the *Frascati Manual*—along with subsequent publications now referred to collectively as the "Frascati family" of references—was originally developed by industrialized countries for their own R&D tracking and monitoring, it presents a number of limitations for application to developing country R&D efforts (Arber et al. 2008; Gaillard 2010; UIS 2010a). These include difficulties with centralized data capture, separation of R&D from other scientific and technological activity, accurate recording of scientific personnel, and documentation of relevant publication and citations, among other issues (Gaillard 2010).

In response to these impediments, UIS and the OECD Working Party of National Experts on Science and Technology Indicators (NESTI) prepared the *Frascati Manual* annex, released in early 2012. The annex provides recommendations to developing country practitioners on how to apply the *Frascati Manual* to their particular circumstances so that measurement both serves national development needs and ensures international comparability of data. It maintains the standard definition of R&D but takes into consideration relevant issues for developing countries and offers suggestions for minimizing complexity and expense in the collection of the corresponding survey data (UIS 2012; OECD 2012).

Based on the Frascati definition of R&D, smaller developing countries such as those in Central America are likely to have little to report. The set of activities that makes more sense to track for these countries is the broader category of all scientific and technological (S&T) activity, which is described in this framework as all "…systematic activities which are closely concerned with the generation, advancement, dissemination and application of scientific and technical knowledge in all fields of science and technology. These include such activities as R&D, scientific and technological education and training (STET), and scientific and technological services (STS)"[2] (UIS 2010a, b).

These classifications go beyond the stricter definition for R&D and are more likely to capture the majority of scientific activities and expenditures for smaller developing countries. UIS has begun to warehouse this type of data from countries worldwide and works actively with counterpart institutions in developing regions to create materials for training professionals and institutionalizing practices that insure consistent and timely national data collection.

Essential inputs for capturing data worldwide include not only the efforts of the OECD and UNESCO, but also those of regional and sub-regional networks and institutions that assist with data collection, categorization and compilation. For Latin America and the

Footnote 1 continued

- Experimental development—systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed (UIS 2010b).

[2] Scientific and technological education and training (STET) includes all activities related to specialized non-university higher education and training, higher education and training that leads to a university degree, post-graduate training, and organized lifelong training for scientists and engineers. Scientific and technological services (STS) include those activities concerned with research and experimental development and those that contribute to the generation, dissemination and application of scientific and technical knowledge (UIS 2010a, b).

Caribbean, the critical body in this regard is the Ibero-American Network for Science and Technology Indicators (or RICYT as it is known for its acronym in Spanish). RICYT was established in 1995 by all countries of the Americas, Spain and Portugal through the Ibero-American Programme for Science, Technology and Development (CYTED) and the Organization of American States (OAS). Its central purpose is to promote the development of instruments for measuring and analyzing S&T activity in Ibero-America. It aims to do this within a framework of international cooperation and is closely tied to UNESCO, the Inter-American Development Bank, the UN Economic Commission for Latin America and the Caribbean (ECLAC), and various regional development organizations. RICYT activities include the design and dissemination of indicators for S&T measurement; organization of regional and international meetings; training on S&T indicators and statistics; indicator database management; and publication and dissemination of related literature throughout the region (RICYT 2012). Since its inception, RICYT has been instrumental in pulling together a more complete overview of S&T and R&D activity in Latin America and the Caribbean. From that data, a clearer picture of Central American S&T trends also emerges.[3]

General statistics

Three regions dominate global R&D: North America (35.1 %), Europe (25.7 %) and Asia (34.4 %). Latin America and the Caribbean (2.5 %), Africa (0.9 %) and Oceania (1.3 %) contribute less than 5 % of worldwide research, with the portion attributable to Latin America and the Caribbean actually diminishing in recent years. Within Latin America and the Caribbean, over 90 % of R&D is carried out in four countries: Brazil (53.8 %), Mexico (26.1 %), Argentina (6.2 %) and Chile (5.9 %). Central America makes up about 1 % of the R&D in Latin America and the Caribbean, or 0.025 % of global research (Arber et al. 2008, RICYT 2012). Examined from this perspective, R&D in Central America hardly seems worthy of study. Nevertheless, once we review additional S&T data for Central America, new patterns appear that are relevant for the region and possibly for other developing regions.

Publication data, as presented in the Science Citation Index (SCI),[4] reflects the data presented above on global R&D expenditure. Citing SCI data, RICYT shows the United States accounting for about 28 % of scientific publishing, while Ibero-America (Spain, Portugal and Latin America and the Caribbean) accounts for around 8 %. Latin America and the Caribbean is responsible for only 4 % of major science publication and Central America alone barely appears on the global scale (RICYT 2009). Language has much to do with these figures as SCI journals are predominantly in English. Within Central America, Costa Rica and Panama publish most. Central American productivity is 3.97 articles per 100,000 inhabitants, less than 40 % of Latin America and the Caribbean's 10.13 and 3 % of the United States' 127.47 publications per 100,000 inhabitants. Costa Rica and Panama, however, post figures near those for Latin America overall (Table 4).

[3] It is important to note that consistent data in many S&T categories is still not available for Belize, Nicaragua and Honduras. Therefore, regional generalizations rely primarily on concrete figures from Costa Rica, El Salvador, Guatemala and Panama and estimates from the rest.

[4] The Science Citation Index (SCI) was established by the Institute for Scientific Information in 1960 and is now a part of Thomson Reuters. Its expanded version covers over 6,500 of the world's leading science and technology journals. The multidisciplinary database provides information for identifying frequently cited articles by author and publisher. Thomson Reuters' separate Social Sciences Citation Index offers a similar service for close to 2,500 social sciences journals (Thomson Reuters 2012).

Table 4 Number of SCI publications—Central America, by country, 2009

	Number of SCI publications	Percentage of global total	SCI publications per 100,000 inhabitants
Costa Rica	433	–	9.62
El Salvador	45	–	0.61
Guatemala	99	–	0.91
Honduras	54	–	0.68
Nicaragua	73	–	1.27
Panama	364	–	10.70
Central America	1,068	0.07	3.97
Latin America and Caribbean	61,853	4.36	10.13
United States	391,950	27.64	127.47

Source Calculations based on indicator data from RICYT (2012)

Unlike its industrialized counterparts, Central American S&T is primarily (nearly 70 %) funded by government, and to some degree international sources (20 %), as opposed to business. This in itself represents a limitation as most Central American governments are often struggling to budget adequately for basic health and education investments, much less for S&T. International funding sources can help augment national S&T and R&D budgets, especially in specific areas such as agriculture, environment and health. In fact, international organizations already do more in this regard than is reflected in the national statistics because of the way in which accounting practice and publishing credit affect reporting and ownership.

Another major difference with Central America compared to more industrialized areas is the nature of R&D undertaken. Almost two-thirds of Central American R&D is applied research, with the rest split between basic and experimental. In the United States, experimental research accounts for 60 % of R&D efforts, with the rest split between basic and applied. In Spain, the division is more evenly distributed: 42 % is applied, 36 % experimental and 22 % basic research. It is logical and strategic that developing countries with less to invest will opt for higher concentrations of applied research from which gains may be realized more quickly. This trend is fairly consistent with developing countries in other regions as well (UIS 2012).

The fields of study most predominant in Central American S&T tend to coincide with areas that are important to the countries' national development plans and priorities: environment, health and social sciences (Table 4). Other areas, however, that also figure heavily into national plans and priorities seem to be underrepresented. Relatively little S&T is dedicated to agriculture, industry and infrastructural development, for example—all of which are key to development efforts. Regarding a couple of the Table 4 outliers: Panama invests considerably more than the rest of Central America in energy because of its interest in developing its hydroelectric power base; and the over-weighted "other" category results from Costa Rica's lack of detailed breakdowns. Overall, the Central American S&T trends presented in Table 4 are in sharp contrast to many industrialized nation R&D budgets, the United States' in particular, which are more weighted toward defense (Table 5).

Table 5 S&T activity by field application, percentage of total, 2009 or latest data

	Exploitation of the earth/ infrastructure	Environment	Health	Energy	Agriculture	Industry	Social relations	Other
Costa Rica	2	5	4	1	7	2	7	73
El Salvador	4	19	14	3	4	15	39	3
Guatemala	2	14	39	1	17	3	21	4
Panama	7	27	8	20	1	10	5	20
CA (average)	4	16	16	6	7	8	18	25

Source Calculations based on indicator data from RICYT (2012)

Obstacles

The obstacles for Central American countries to developing rigorous and consistent national S&T systems are multi-layered. As noted above, education is one of the initial impediments as it directly impacts development of necessary S&T human capital at every level. Though the region, on average, shows tertiary enrollment of 25 % (Table 3), this figure has grown in recent years with the proliferation of private for-profit universities, many of which offer courses of questionable quality. Also, little data on completion is available. Informal estimates put completion rates at around half or less of enrollment figures. Though there are some in the region with Master's and PhD degrees, reliable statistics on graduate degree holders for most Central American countries are either non-existent or incomplete. Moreover, at least 10–15 % of Central American higher education degree holders migrate out of the region in search of better employment. Often these are among the best-trained professionals and researchers (Holm-Nielsen et al. 2005).

Added to this, educational quality tends to be quite low. Central American countries score at the bottom of international standardized comparisons, seldom have established national standardized testing, and are just beginning to implement quality control mechanisms and entities for higher education. Another constraining factor for R&D human resource development is that Central American university research training, with some exceptions, is inclined more toward theory than practical application. Frascati Manual principles are not in widespread use and rigorous R&D design and implementation is limited. What often passes for research is little more than information gathering or investigative reporting.

Further frustrating attempts to develop and promote R&D in Central America is lack of funding. Though countries in the region are middle-income by World Bank categorization, they are small and GDP figures are low by global standards. As most of these countries still have difficulty complying with even necessary social welfare investments, R&D is often seen as a luxury. Policymakers are also often uninformed about the potential returns associated with research-oriented investments and less inclined to prioritize such expenditures. As a consequence, Central America has among the lowest R&D investment rates worldwide relative to percentage of GDP. Without sufficient funding, it is difficult to develop sustainable R&D programming.

Because of inadequate efforts and expenditures on scientific activity, Central American publishing on S&T is limited as well. Publishing in international journals is made more

difficult by the language barrier, as the majority of recognized scientific journals are in English, and by regional researchers' lack of familiarity with and integration of Frascati methodology. Minimal efforts to promote higher education integration with US and European institutions and international higher education and research associations have kept the region somewhat isolated and out of the S&T mainstream, though this is slowly beginning to change.

Future prospects

National organizational scenarios

All countries in Central America have passed legislation within the last decade or so that establishes a national council for developing science and technology. And all except Belize have established some centralized entity to deal with the implementation and oversight of S&T (see Appendix). The most sophisticated of these is Costa Rica's Ministry of Science and Technology (MICIT), which began as a government program in 1986 and through subsequent legislation, regulation and funding evolved to become a full ministry. It has developed systems for strategic planning, indicator monitoring through regular survey administration, awarding of research grants, policymaking, and a full portfolio of scientific programs and projects. Costa Rica's university system is also stronger than those in the rest of the region so the national trained human resource base is more professional as well.

Panama and Guatemala are moving in a similar direction, each with its own national secretariat for science and technology, but both countries are behind Costa Rica. Their structures and mechanisms for indicator monitoring, planning and programming are not as complete. El Salvador, Honduras and Nicaragua have passed similar national council legislation, but have not established or developed the complementary independent S&T agencies to the extent that they can assume the corresponding S&T functions so have not progressed as significantly.

For examining these different levels of progress on S&T activity, Arber et al. (2008) propose a general framework for analyzing and grouping Latin American countries (or any developing countries) according to three sets of parameters—socioeconomic development, R&D systems capacities, and S&T statistical systems. From this framework, three categories of countries emerge:

- Group A: countries with consolidated R&D systems and developed S&T statistics systems;
- Group B: countries with consolidated R&D systems and less developed S&T statistics systems; and
- Group C: countries with incipient R&D systems and S&T statistical systems.

Group A countries tend to be emerging economies such as Brazil, Mexico, Chile and Argentina that are relatively developed socioeconomically, have well established, stable and reliable R&D and statistical monitoring systems, and consistently apply Frascati Manual principles throughout. Central America has no Group A countries. Group B countries show some R&D, but with a limited history of both research and S&T statistics gathering. Application of Frascati methods is also weak in these countries and they will not often have developed legal and organizational frameworks for institutionalizing the administration of R&D/S&T surveys. Arber et al. (2008) include Costa Rica and Panama

in the Group B category.[5] Group C countries may be starting to collect S&T indicators but likely through secondary sources and estimates rather than surveys or direct input; the data will not cover all relevant sectors and will not meet Frascati Manual standards. Additionally, the S&T systems generally rely on a few government and university institutions with little or no business sector participation. Resources for S&T, policy and management will be considerably limited. Arber et al. (2008) include the rest of Central America—El Salvador, Guatemala, Honduras and Nicaragua—in this category.

Group A countries tend to be upper-middle income, Group B countries tend to be middle income, and Group C countries tend to be lower-middle income. Thus, a socio-economic correlation appears between national per capita income levels and S&T advancement. In many of these developing systems, the public and private institutions involved in S&T are few and not well connected or coordinated. If there is high dependence on international funding for S&T, there may be increased opportunity for knowledge transfer but also increased instability with research efforts. In contrast with these developing systems, industrialized countries with strong national S&T bases tend to have a critical mass of established, well-endowed (in terms of both human and financial resources) higher education and research institutions, along with robust national S&T governance systems (Arber et al. 2008).

For the Group B Central American countries, Costa Rica and Panama (and also Guatemala to some degree), the primary issue for strengthening future S&T capacity is the consolidation and institutionalization of S&T activity, funding and monitoring. This implies national prioritization of the following: (1) better strategic linking of the national S&T entities' projects with national development goals; (2) allocation of additional public (and possibly international) funding to pursue strategic S&T activity; (3) more consistent and widespread training in *Frascati Manual* principles—both for research design and implementation and S&T indicator monitoring; and (4) implementation of programs and mechanisms to insure continuous S&T indicator survey monitoring across sectors and research activity that extends beyond a single government administration. This last point is critical as a major problem for institutionalization in Central America has been the lack of programming continuity from one governing period to the next.

Group C national priorities are similar except that first and foremost, these countries must establish a solid national entity (secretariat, department or similar body) to complement national council policymaking. And these entities must be staffed with trained professionals. Without this commitment of more stable financial and human resources, no fundamental base exists upon which to build.

Promising international programs and resources

Alongside the national efforts to boost S&T activity and indicator monitoring, regional and international organizations play an increasingly important role in this process. To the extent that Central American countries can tap into joint endeavors involving countries, institutions and researchers with advanced knowledge and scientific experience, opportunities for knowledge transfer improve significantly. These joint programs may take many different forms; this article examines several types of collaborative international S&T activity that appear to be enjoying some success in the region: (1) multinational and

[5] Panama's own S&T higher education and research systems are still rather weak compared to Costa Rica's so its inclusion in Group B may reflect the presence in the country of international research institutions, such as the Smithsonian Tropical Research Institute, which account for roughly 20 % of all S&T activity.

intergovernmental supported S&T training and monitoring partnerships; (2) cross-border university- or research institute-led programs; and (3) international joint publishing initiatives.

The multinational and intergovernmental supported partnership typically involves the creation of a regional program, network or institution that is supported, at least in part, financially and technically, by a multinational and/or an intergovernmental organization. The prime example of this in Latin America is the RICYT network referred to earlier. Based in Argentina and supported by the Organization of Ibero-American States (OIS) and the Spanish Agency for International Development Cooperation (AECID), RICYT has had considerable impact on consolidation of S&T indicators and statistics for the entire Latin America and Caribbean region. With its close ties to UNESCO and UIS, its observer role in the OECD committee of National Experts on Science and Technology Indicators (NESTI), and its links to regional development organizations and scientific bodies, it is well positioned to serve as S&T liaison and promoter for the region.

More could be made of this positioning to benefit Central America by increasing joint programming through the Commission for Scientific and Technological Development of Central America and Panama (CTCAP). CTCAP is another official intergovernmental body established within the regional Central American Integration System (SICA) for promoting S&T, but its existence is more nominal than functional. With more resourcing and better coordination with RICYT, additional training specific to Central America's S&T needs could be collaboratively developed and implemented. Done consistently, this type of effort would help further countries' research and monitoring in line with international Frascati principles. RICYT could also assist CTCAP to take on an archival function for Central America with regard to documenting and databasing ongoing S&T activity. This would serve to facilitate access to information, collaboration and replication of successful projects.

A number of bilateral initiatives also strive to advance S&T training in Central America in a similar way with individual academic partners. The Enhancing Scientific Cooperation between the European Union and Central America (ENLACE) is one such program designed to stimulate regional R&D through direct connection with European higher education and research institutes. IBEROEKA, run by the Ibero-American Program of Science and Technology for Development to promote entrepreneurial technological cooperation, is another example that has benefitted several Central American countries. And the United States Agency for International Development (USAID), along with its affiliate, Higher Education for Development (HED), has sponsored numerous programs of this kind. When these programs reach the level of producing joint research proposals and projects, their potential for knowledge transfer is considerably enhanced. Unfortunately, most bilateral projects have a fixed lifespan, making sustainability a challenge. And they do not generally allow for centralized archival of related documentation, making it difficult to access and utilize the resulting lessons learned for future projects. The more permanently established structures, with both multinational and regional intergovernmental involvement, such as RICYT and its counterparts, offer more potential for longer-term S&T development, especially if adequate funding can be maintained.

International universities and research institutes are also leading cross-border initiatives in the region that contribute considerably to Central American S&T capacity development. An example of this is the Tropical Agricultural Research and Higher Education Center (CATIE, for its acronym in Spanish) in Costa Rica. Established in 1946 through the Inter-American Institute of Cooperation on Agriculture (IICA) and now supported by the World Bank, various government donors and other international funding sources, CATIE is a

regional research and education center for Latin America and the Caribbean that concentrates on agriculture and natural resource management. It has graduated over 2,000 students, runs more than 100 research projects in 17 countries, and employs professors and researchers from 25 countries. CATIE publishes widely in Spanish and English, and has developed joint programs with top universities and institutes throughout the hemisphere. Similar examples to CATIE include the US Smithsonian Tropical Research Institute (STRI) based in Panama, the United Nations University for Peace (UPEACE) in Costa Rica, the United Nations Pan-American Health Organization (PAHO) Institute of Nutrition of Central America and Panama (INCAP) in Guatemala, and the Latin American School of Social Sciences (FLACSO) with various campuses throughout the region.

STRI began in 1923 and developed into a fully operational research center with major library and laboratory resources, field stations, resident staff of over 35 international scientists, and a global network of tropical research institutions and professionals. It sponsors numerous fellowship programs for students and visiting scientists from countries around the region and the world. UPEACE, established in 1980 by the UN, offers a range of Master's degree programs and shorter courses related to peace, security, governance and sustainable development. It also pursues a number of research projects, houses the UN international Human Rights Centre and publishes a peer-reviewed, open-access academic journal. INCAP, founded by PAHO in 1949, is a specialized clinical and epidemiological research and education center that focuses on nutrition and food security issues for Central America. It receives funding from various international organizations and has developed joint programming with the UN University, numerous prestigious US academic institutions, including Harvard, Johns Hopkins and Cornell, and various Latin American universities. FLACSO, created in 1957 with support from UNESCO, is an institution that offers graduate degrees and training in different fields of the social sciences. It engages in social science research, publishing and consulting activity and has become a respected academic source and partner for countries throughout Central and South America. To date, FLACSO has awarded degrees to over 5,000 students, published hundreds of articles, and participated in countless research and consulting projects. FLACSO is based in Argentina and has permanent satellite academic operations in Costa Rica and Guatemala, along with projects and programs in El Salvador and Panama (FLACSO 2012).

CATIE, STRI, UPEACE, INCAP and FLACSO all strive to create regional hubs in Central America for specialized knowledge generation, education, research and innovation in areas that are critical to regional development. To the extent these hubs can draw on international R&D capacity and funding at the same time as they incorporate regional actors and students, opportunities for knowledge transfer will continue to advance.

Regional and international publishing initiatives are the third medium examined in this article that serve to further collective Central American S&T efforts and also present platforms for academic networking and exchange. All of the cross-border university and research institute-led initiatives mentioned previously—CATIE, STRI, UPEACE, INCAP and FLACSO—contribute to this effort with regular journals, reports, manuals and other publications. CATIE, STRI, UPEACE and INCAP have a more international reach as a result of working in both English and Spanish, whereas FLACSO works principally in Spanish and is more regional.

Some of the international organizations (particularly USAID and various of the UN agencies) have tried to promote various thematic bilingual (English and Spanish) journal publications in the region over the years, but for the most part, these have not been permanently enduring. Since 1992, the Mexican Association for International Education (Asociación Mexicana para la Educación Internacional) has produced a bilingual annual

publication, *Educación Global/Global Education*, devoted to the internationalization of higher education within the context of globalization and international cooperation. It is directed toward researchers, academics, students and specialists worldwide and seeks to promote research, publication and exchange on higher education internationalization across regions. This type of effort has broader potential for connecting academia in Latin America, including Central America, with the rest of the world. More of this type of publishing initiative across sectors would be welcome for propelling S&T development in Central America and beyond.

A final area that bears mentioning for its potential to promote publishing by and for Central American institutions and individuals is that of international co-authorship, joint publication between Central American academics and those of other regions, usually in the US or Europe. Lemarchand (2010) discusses the exponential returns made possible by this type of effort, noting that once universities and professors in different countries have worked jointly on research and publications, the tendency for this to replicate between additional members of the academic communities of the countries involved is significantly (even quadratically) increased. This produces a domino effect of collaboration that portends enormous dividends, particularly for developing countries and regions. Within Central America, Costa Rica has been most diligent and successful with this (Lemarchand 2010).

Conclusion

The challenges to Central American S&T capacity development are many. Educational quality, coverage and completion rates are issues at every level. Less than adequate educational outcomes are combined with relatively low public funding of S&T across the region, little complementary financing by the private sector, a lack of institutionalization, and limited understanding at the policymaking level of the potential returns associated with S&T investment. Additionally, the region operates almost entirely in Spanish—even at the highest academic levels—which, in effect, limits opportunities for publication and exchange with the rest of the world. These obstacles all act to impede progress, yet the circumstantial positioning of countries in Central America—not large or rich enough to be producing sufficient S&T innovation on their own and not poor enough to qualify for donor aid—demands that these nations work to improve their S&T capacity as a means to advancing their development objectives. Failing to do so could prove costly.

Common development priorities throughout Central America include environmental risk management, better health and education service delivery, generation of more productive and sustainable employment opportunities, and the professionalization of government systems. Thematically, concentrating S&T investment and activity around these larger priorities—preferably at the regional level to create hub-like economies of scale and subsequently at the national levels focusing on the relevant sub-topics associated with these larger priorities—is critical. Technically, better monitoring of ongoing S&T efforts in line with global standards and improved training in *Frascati Manual* principles for research and publishing are essential first steps—as are the establishment, professionalization and adequate funding of independent national S&T entities.

Joint applied research projects and programming with international institutions play an important role in advancing these efforts. Among some of the collaborative international initiatives that appear to be yielding dividends are (1) multinational and intergovernmental supported training and monitoring partnerships such as RICYT; (2) cross-border university- and research institute-led programs such as CATIE, STRI, UPEACE, INCAP and FLACSO;

and (3) joint publishing initiatives, particularly those centered around international co-authorship. Resources and models exist and potential development partners are out there. Central America, collectively and at its individual national levels, needs to improve its monitoring methods for better knowledge of ongoing activity, strategically target S&T capacities to develop, link its development priorities with S&T capacity building, allocate the necessary resources and better utilize international partners and expertise to accomplishing this objective.

How can the universities of Central America—especially the major public institutions in each country—become more instrumental in this process of bringing tertiary education and research in the region to a higher level? Even with their limited resources, a productive first step would be the alignment of graduate studies curricula with research methods that are more reflective of the Frascati principles used elsewhere as the global benchmark. This would better prepare faculty and students to seek out and participate in international research partnerships. In addition to propelling professional academic learning, this type of exchange could give universities more leverage with national governments for increasing S&T/R&D budgets and would set the stage for more and better joint work and international publishing. University strengthening of English language skills would also serve to promote these goals.

The to-do list for developing Central American S&T and R&D capacity is rather long and daunting for actors at all levels. Still, progress is being made and must be nurtured and furthered as quickly as possible. If this collection of small, middle-income countries can begin to make better use of scientific and technological resources everywhere to advance its development, then not only will Central America stand to benefit but also the region will serve as a model for similarly small and struggling middle-income developing countries in other regions of the world as well.

Appendix

See Table 6.

Table 6 Central American national science and technology entities, by country, 2012

Country	Entity	URL
Costa Rica	*Ministerio de Ciencia y Tecnologia (MICIT)* Ministry of Science and Technology	http://www.micit.go.cr/
El Salvador	*Consejo Nacional de Ciencia y Tecnologia (CONACYT)* National Council for Science and Technology	http://www.conacyt.gob.sv/
Guatemala	*Consejo Nacional de Ciencia y Tecnologia (CONCYT)* National Council for Science and Technology *Secretaria Nacional de Ciencia y Tecnologia (SENACYT)* National Secretariat for Science and Technology	http://www.concyt.gob.gt/
Honduras	*Consejo Hondureño de Ciencia y Tecnologia e Innovación (COHCIT)* Honduran Council for Science, Technology and Innovation	http://www.cohcit.gob.hn
Nicaragua	*Consejo Nicaraguense de Ciencia y Tecnologia (CONICYT)* Nicaraguan Council for Science and Technology	http://www.conicyt.gob.ni/
Panama	*Secretaria Nacional de Ciencia, Tecnologia e Innovacion (SENACYT)* National Secretariat for Science, Technology and Innovation	http://www.senacyt.gob.pa/

Belize recently established a Prime Minister's Council of Science Advisers but no national organizational entity to date, and is, therefore, not included

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