A variety of policy instruments have been introduced to make endogenous research more responsive to the needs of the productive system and society at large. This is now beginning to bear fruit in some countries.

Guillermo A. Lemarchand

A young man from the Achuar Territory in Ecuador holds up a frog. There is a growing research focus on pharmacology, biodiversity and the sustainable management of natural resources in Latin America.
Photo: © *James Morgan/ Panos*

7 · Latin America

Argentina, Plurinational State of Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Bolivarian Republic of Venezuela

Guillermo A. Lemarchand

INTRODUCTION

Development slowing after a buoyant decade

Latin America consists essentially of middle-income economies[1] with very high (Argentina, Chile, Uruguay and Venezuela), high or medium levels of development. Chile has the highest GDP per capita and Honduras the lowest. Within countries, inequality is among the highest in the world, even though there has been some improvement in the past decade. According to the United Nations Economic Commission for Latin America (ECLAC), the four countries with the lowest levels of poverty are, Honduras, Brazil, Dominican Republic and Colombia (on Brazil, see Chapter 8).

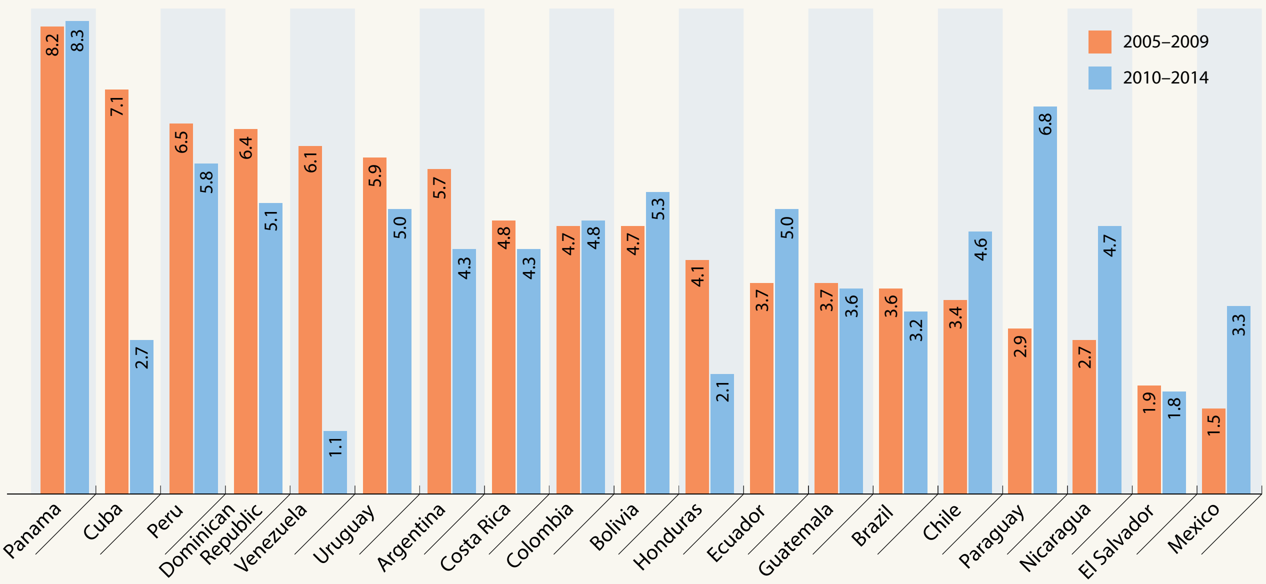
The Latin American economy grew by just 1.1% in 2014, meaning that GDP per capita actually stagnated. Preliminary figures for the first quarter of 2015 suggest an ongoing slowdown in activity since the decade-long commodities boom wound down in 2010 (see also Figure 7.1); some of the region's larger economies could even experience a contraction. While the region is expected to grow by about 0.5% on average in 2015, this masks a fairly wide variation: although South America is set to contract by 0.4%, Central American economies and Mexico are likely to expand by 2.7% (ECLAC, 2015a).

Prospects for Central America have improved, thanks to the healthy economic growth of their biggest trading partner, the USA (see Chapter 5), and lower oil prices since mid-2014. Moreover, declining prices for raw materials since the end of the commodities boom in 2010 should give countries in Central America and the Caribbean which are net importers of these products some breathing space. The Mexican economy is also dependent on North America's performance and is, thus, looking more dynamic. Present reforms in Latin America within the energy and telecommunications sectors, in particular, are expected to push up growth rates in the medium term. Meanwhile, growth forecasts are being revised downwards for those countries of South America that export raw materials. GDP is most dependent on this type of export in Venezuela, followed by Ecuador and Bolivia then Chile and Colombia.

The Andean countries of Chile, Colombia and Peru are in a comparatively enviable position but this may be short-lived, since their growth is expected to falter. Paraguay is also showing strong growth, as it recovers from a severe drought in 2012, whereas Uruguay's economy is growing at a more moderate rate.

1. Argentina and the Bolivarian Republic of Venezuela have had high inflation rates for the past few years. However, the 'official' exchange rate has remained flat, a factor which might generate some distortions in the real GDP per capita values expressed in US dollars. For a discussion of this issue, see ECLAC (2015a).

Figure 7.1: **Trends in GDP growth in Latin America, 2005–2009 and 2010–2014**



Note: Data for Cuba cover 2005–2009 and 2010–2013.

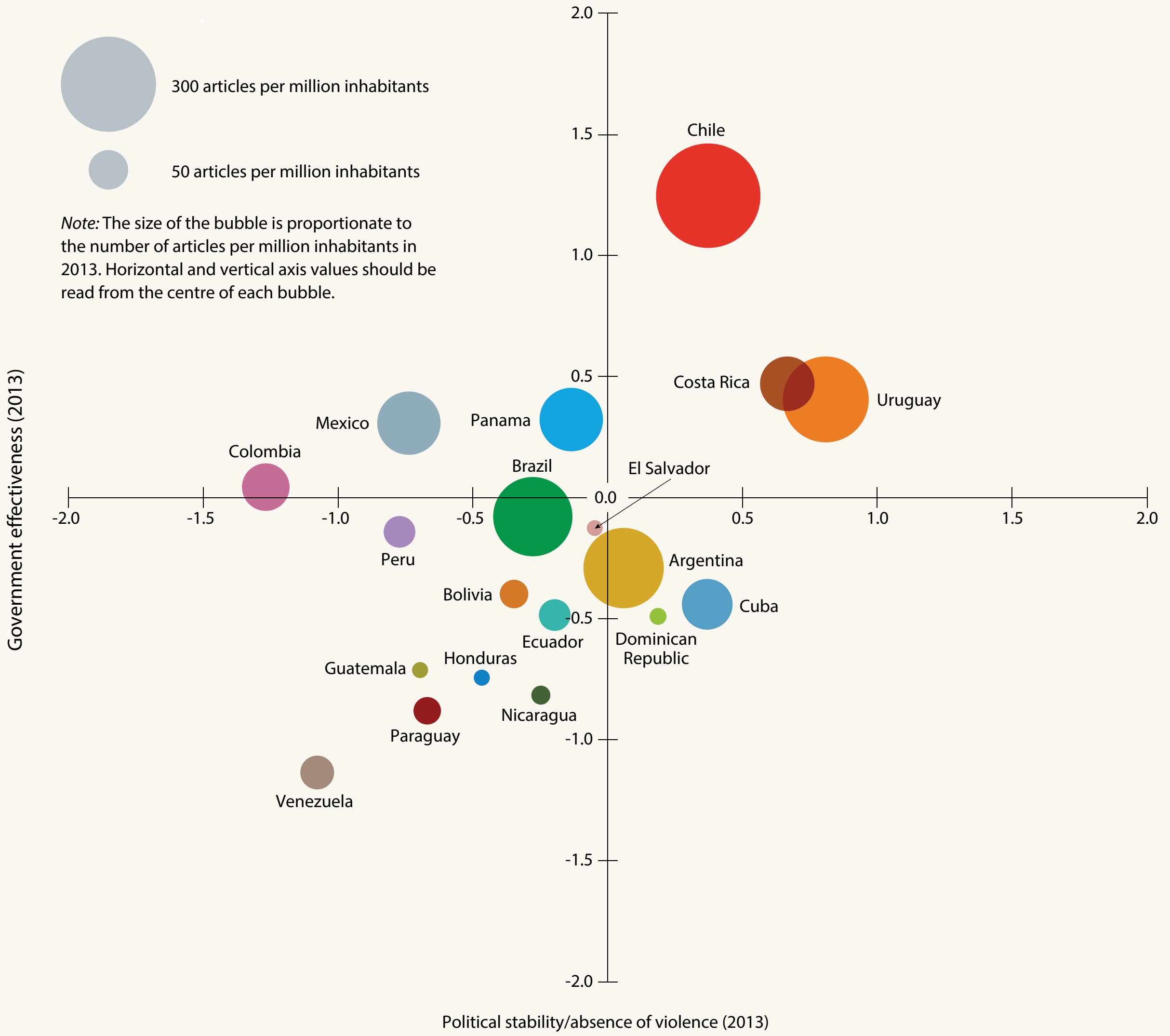
Source: World Bank's World Development Indicators, September 2015

In Venezuela, the collapse of the Brent crude price since mid-2014 has complicated an already difficult political situation but the economy is still performing vigorously. Argentina, meanwhile, is facing a debt crisis that has pitched it against private creditors in the USA; it showed almost zero growth in 2014 and this indicator may slip further in 2015. The combination of numerous administrative barriers and successive fiscal and monetary policies designed to stimulate household and business spending have engaged both Argentina and Venezuela in a spiral of high inflation levels and low foreign reserves.

On the political front, there has been some turbulence. A corruption scandal involving the Brazilian oil company Petrobras has taken a political turn (see Chapter 8). In Guatemala, President Pérez Molina resigned in September 2015 to face charges of fraud after months of street protests; such a development would have been inconceivable a few decades ago, suggesting that the rule of law has gained traction in Guatemala. The normalization of bilateral relations with the USA in 2015 should give Cuban science a considerable boost. Meanwhile, political tensions persist in Venezuela, the only country in the region to have seen its scientific publications decline between 2005 and 2014 (by 28%).

Political stability, the absence of violence, government effectiveness and the control of corruption are all vital to achieve long-term development goals and improve a country's scientific and technological performance. However, only Chile, Costa Rica and Uruguay currently have positive values for all of these governance indicators. Colombia,

Figure 7.2: **Relation between governance indicators and scientific productivity in Latin America, 2013**



Source: author, based on World Bank's Worldwide Governance Indicators; United Nations Statistics Division; and Thomson Reuters' Science Citation Index Extended

Mexico and Panama can boast of government effectiveness but not of political stability, owing to internal conflicts. Argentina, Cuba and the Dominican Republic all have positive values for political stability but are less effective when it comes to policy implementation. The remainder of countries have negative values for both indicators. It is interesting to note the high correlation between good governance and scientific productivity (Figure 7.2).

A regional union modelled on the EU

At the regional level, one of the most momentous developments in recent years has been the creation of the Union of South American Nations (UNASUR). The treaty was approved in May 2008 and entered into force in March 2011; the South American Council of Science, Technology and Innovation (COSUCTI) was established a year later within UNASUR to foster scientific co-operation.

The new regional body is modelled on the European Union (EU) and, thus, embraces the principle of the freedom of movement of people, goods, capital and services. UNASUR's 12 members[2] have plans to establish a common currency and parliament (in Cochabamba, Bolivia) and are discussing the idea of standardizing university degrees. UNASUR's headquarters are located in Quito (Ecuador) and its Bank of the South in Caracas (Venezuela). Rather than creating other new institutions, UNASUR plans to rely on existing trade blocs like the Common Market for the South (MERCOSUR) and the Andean Community.

High-tech exports drive growth in very few countries

The sectorial distribution of FDI in Latin America follows a very distinct pattern. In 2014, 18% of the region's technology-oriented FDI focused on low-tech projects, 22% on medium–low, 56% on medium–high and only 4% on high-tech projects. Investment in high technology tends to be destined for Brazil and Mexico, where much of it is captured by the automotive sector. At the other extreme, this type of technology accounts for less than 40% of FDI flows to Colombia, Panama and Peru. In Bolivia, the commodities sector receives the lion's share, especially the mining industry. In Central America and the Dominican Republic, where non-renewable natural resources are scarce and investment in *maquiladoras*[3] is not very capital-intensive, most investment goes to the services sector, which in the case of the Dominican Republic includes a competitive tourism sector. Ecuador, Colombia and especially Brazil have a more balanced distribution of FDI (ECLAC, 2015b).

2. Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay and Venezuela

3. A *maquiladora* is an export-processing zone where factories are exonerated from custom duties to enable them to assemble and transform goods using imported components, many of which are then re-exported.

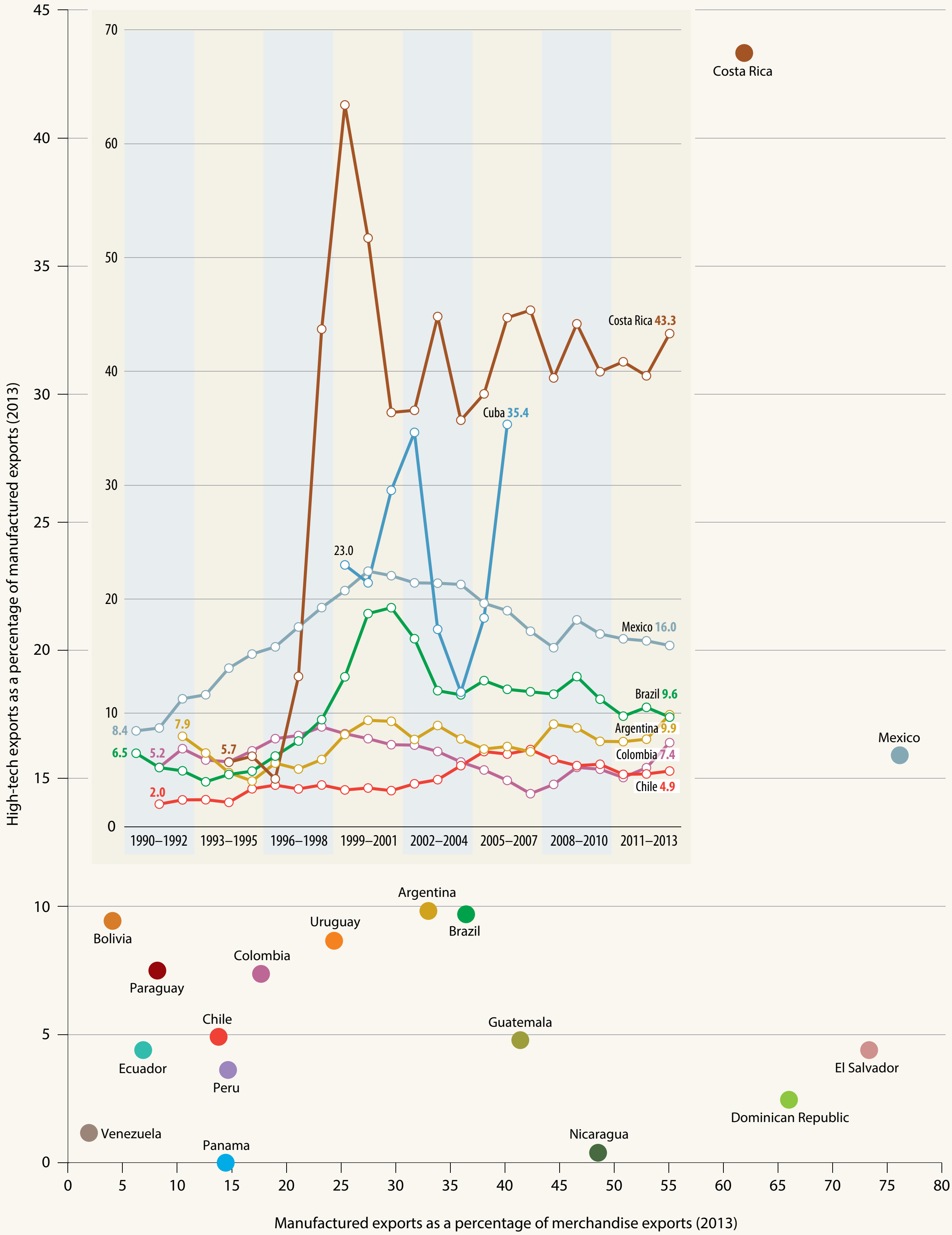
The majority of Latin American economies specialize in low technology, however, not only in terms of the content of their manufactured goods but also insofar as firms investing in an industry tend to operate at a considerable distance from the technological frontier. In addition to involving more innovation, the production and export of medium- or high-tech goods requires a higher level of physical and human capital than low-tech products or those based on natural resources.

In recent decades, the region has experienced mixed fortunes in incorporating technology into its exports. Mexico and, to a lesser extent, Central America, have achieved a radical transformation from commodities to medium- and high-tech manufactured products, thanks to special import regimes and export-oriented manufacturing. By contrast, the technological content of South American exports has not changed. This is because, on the whole, Latin America specializes in primary production.

Only in Costa Rica and, to a lesser degree, Mexico, do certain high-tech exports drive economic growth to an extent comparable with developing European economies (Figure 7.3). Moreover, there has been a decline in the high-tech component of manufactured exports from Mexico (and Brazil) since 2000. In Costa Rica, the large share of high-tech exports can be explained by the arrival of Intel, Hewlett–Packard and IBM in the late 1990s; this drove high-tech goods to a peak of 63% of manufactured exports before their share stabilized at around 45%, according to the *UNESCO Science Report 2010*. In April 2014, Intel announced that it would be relocating its microchip assembly plant in Costa Rica to Malaysia. Intel is estimated to have brought in 11% of net FDI inflows in 2000–2012 and represented 20% of Costa Rican exports in recent years. The cost to Costa Rica of the closure of Intel's production facility has been estimated at 0.3–0.4% of GDP over a 12-month period. The closure may reflect the highly competitive market for microchip assembly or the declining demand for personal computers worldwide. Although Intel wound up its assembly operations in Costa Rica with the loss of 1 500 jobs in 2014, it also added about 250 high-value jobs to the company's R&D group based in Costa Rica (Moran, 2014). Meanwhile, Hewlett Packard announced in 2013 that it would be moving 400 jobs in ICT services from its Costa Rican operations to Bangalore in India but that it would be remaining in Costa Rica.

A recent comparison with Southeast Asia has shown that the unfavourable conditions for trade in Latin America, such as time-consuming administrative procedures for exports, have discouraged export-intensive firms in the region from deeply integrating global supply chains (Ueki, 2015). Trade costs are also negatively affecting the development of internationally competitive manufacturing industries in Latin America.

Figure 7.3: **Technological intensity of Latin American exports, 2013**



Source: author, based on raw data from the World Bank accessed in July 2015

TRENDS IN STI POLICY AND GOVERNANCE

A growing public policy focus on R&D

Over the past decade, several Latin American countries have given their scientific institutions more political weight. Honduras, for example, has passed a law (2013) and related decree (2014) creating a national innovation system composed of the National Secretariat for Science, Technology and Innovation (SENACIT) and the Honduran Institute of Science, Technology and Innovation (IHCIETI), among other bodies, including a national foundation for funding STI. In 2009, Colombia passed a law defining the attributes and mandates of each individual institution within its entire national innovation system. In so doing, it followed in the footsteps of Panama (2007), Venezuela (2005), Peru (2004), Mexico (2002) and Argentina (2001).

In some cases, these new legal frameworks require that STI policies be approved by interministerial councils like the Scientific–Technological Cabinet (GACTEC) in Argentina. In other cases, STI policies may be approved by more eclectic councils bringing together the president, secretaries of state, academies of sciences and representatives of the private sector, as in the case of the Council for Scientific Research, Technological Development and Innovation (CGICDTI)[4] in Mexico. The most complex and sophisticated institutional ecosystems are found in the larger, richer economies of Argentina, Brazil, Chile and Mexico.[5]

Argentina, Brazil and Costa Rica all have Ministries of Science, Technology and Innovation. In Cuba, the Dominican Republic and Venezuela, on the other hand, the science ministry shares its mandate with higher education or the environment. Chile has a National Innovation Council and Uruguay a Ministerial Cabinet for Innovation. Several countries still have National Science and Technology Councils with policy planning attributes, as in Mexico and in Peru. Other countries have national secretaries of science and technology, such as Panama and Ecuador. In March 2013, Ecuador also created a National Council for Science and Technology (see p. 203). Some have administrative departments responsible for science and technology, like Colombia's Administrative Department for Science, Technology and Innovation (Colciencias).

A variety of sophisticated funding schemes for R&D

Over the past decade, many countries have formulated strategic plans and designed a variety of new policy instruments, including fiscal incentives, to foster innovation in the public and/or private sectors (Lemarchand, 2010; CEPAL, 2014; IDB, 2014). In Colombia, for instance, 10% of the revenue from the General Royalties System Fund (est. 2011) goes towards STI. In Peru, 25% of the royalties from the exploitation of various natural resources are allocated to the regional government where the mining took place through what are known as Canon funds (est. 2001); of these royalties, 20% is earmarked exclusively for public investment in academic research that promotes regional development through science and engineering. In Peru, 5% of the royalties from mining are allocated to universities by law (2004). A similar law adopted by Chile in 2005 allocates 20% of mining revenue to an innovation fund (IDB, 2014).

The most traditional mechanisms for promoting scientific research in Latin America are competitive grants and centres of excellence. Competitive funds may target infrastructure and the equipping of laboratories, take the form of travel grants, research grants, technological development grants or financial incentives that reward a researcher's scientific productivity. Argentina's Incentive Programme for University Teachers who conduct scientific research and the National System of Researchers (SNI) in Mexico[6] have played a fundamental role in expanding academic research. Two examples of centres of excellence are the *Programa Iniciativa Científica Milenio* in Chile and the *Centro de Excelencia en Genómica* in Colombia.

Over the past two decades, most Latin American countries have created specific funds for competitive research and innovation.[7] Most of these funds originated from a series of national loans provided by the Inter-American Development Bank (IDB). The IDB wields considerable influence over the design of national research and innovation policies by proposing specific terms of reference for how these loans should be allocated: as competitive grants, credits, scholarships, for public–private partnerships, new evaluation and assessment procedures, etc.

Cuba adopted this competitive funding model in 2014 with the creation of the Financial Science and Innovation Fund (FONCI), which promotes research and innovation in the public and business enterprise sector. This is a major breakthrough for Cuba, considering that, up until now, the bulk of the research budget for all R&D institutions, personnel and research projects has come from the public purse.

4. Consejo General de Investigación Científica, Desarrollo Tecnológico e Innovación

5. The complete organizational charts of all Latin American and Caribbean countries can be found at UNESCO's Global Observatory of STI Policy Instruments (GO→SPIN), which developed a prototype in 2010 for monitoring these national innovation systems. See: http://spin.unesco.org.uy

6. respectively the Programa de Incentivo a Docentes Investigadores (Argentina) and Sistema Nacional de Investigadores (Mexico); both programmes established a financial incentive for university teachers, according to their annual scientific productivity and their category of researcher

7. Examples are the Fondo para la Investigación Científica y Tecnológica (FONCYT) and Fondo Tecnológico Argentino (FONTAR, Argentina), Fondo de Fomento al Desarrollo Científico y Tecnológico (FONDEF, Chile), Fondo de Riesgo para la Investigación (FORINVES, Costa Rica), Fondo Financiero de Ciencia e Innovación (FONCI, Cuba), Fondo de Apoyo a la Ciencia y Tecnología (FACYT, Guatemala), Fondo Nacional de Ciencia y Tecnología (FONACYT, Paraguay), Fondo para la Innovación, Ciencia y Tecnología (FINCYT, Peru) and the Agencia Nacional de Investigación e Innovación (ANII, Uruguay)

A shift towards sectorial funding of R&D

Brazil established 14 sectorial funds between 1999 and 2002 to channel taxes[8] levied on specific state-owned companies towards fostering industrial development in key industries and services such as oil and gas, energy, space or information technology. Argentina, Mexico and Uruguay have all reoriented their policies towards this type of vertical funding, as opposed to horizontal funding which tends not to prioritize fields. Mexico adopted 11 sectorial funds in 2003 and a 12th for sustainability research in 2008. Other examples are Argentina's Sectorial Fund (FONARSEC, est. 2009) and the fund for software (FONSOFT, est. 2004), as well as the Innovagro Sectorial Fund for the Uruguayan agro-industry (est. 2008).

Brazil launched its own Inova-Agro programme in mid-2013. Inova-Agro has since become the main tool for channelling funding to the agribusiness sector disbursed by the National Bank for Economic and Social Development (BNDES), since it accounts for over 80% of the total of *circa* US$ 27 million; more than four-fifths of Inova-Agro funding targets livestock, fisheries and aquaculture.

8. For details, see the *UNESCO Science Report 2010*.

Sectorial funds are one illustration of the diversity of sophisticated policy instruments (Table 7.1) promoting research and innovation in Latin America, even if these instruments have proved more effective in some countries than others. All countries face the same challenges, however. For one thing, there is a need to link endogenous research with innovation in the productive sector – this problem was already highlighted in the *UNESCO Science Report 2010* and stems from the lack of long-term industrial policies (over decades) to promote private-sector innovation. There is also a need to design and develop more effective policy instruments to connect the demand and supply sides of national innovation systems. In addition, there is a weak culture of evaluation and oversight for scientific programmes and projects in most Latin American countries; only Argentina and Brazil can boast of having institutions that conduct strategic foresight studies, the Centre of Management and Strategic Studies (CGEE) in Brazil and the new Interdisciplinary Centre for Studies in Science, Technology and Innovation (CIECTI)[9] in Argentina, which opened in April 2015.

9. Centro de Gestão e Estudos Estratégicos (Brazil) and Centro Interdisciplinario de Estudios de Ciencia, Tecnología e Innovación (Argentina)

Table 7.1: **Inventory of operational STI policy instruments in Latin America, 2010–2015**

Country	Number of operational policy instruments by objectives and goals												
	a	b	c	d	e	f	g	h	i	j	k	l	m
Argentina	22	9	25	2	32	15	5	4	5	14	12	10	38
Bolivia	2	1	1	1	8	1	1	1	4		3	1	5
Brazil	15	10	31	6	6	15	5	5		5	8	4	27
Chile	25	12	25	6	24	17	7			6	14	6	37
Colombia	6	1	2	1	10	1		1	3	2	2	1	6
Costa Rica	2	2	10	2	23	4	3				4	4	4
Cuba					5						1		
Dominican Rep.					1								
Ecuador			5		4	2	2		4	1	1		4
El Salvador		4	2		5		9	1			6		2
Guatemala	3		6		6		2				1		4
Honduras	1		1		1		2						1
Mexico	16	9	13	5	6	14	6		3	4	6	5	19
Nicaragua	1		1									1	
Panama	5	2	14		6		3			1	1	1	4
Paraguay	8	1	6		5	4	1			3	2	5	3
Peru	10	7	12	1	6	3	5		1		1	2	6
Uruguay	13	3	11	1	13	9	2	3		3	8	4	14
Venezuela	5	1	3	2	7						2	1	2

Source: compiled by author on the basis of operational policy instruments collected by UNESCO's Montevideo office (http://spin.unesco.org.uy) and categorized using the new GO➞SPIN methodology: see UNESCO (2014) *Proposed Standard Practice for Surveys on Science, Engineering, Technology and Innovation (SETI) Policy Instruments, SETI Governing Bodies, SETI Legal Framework and Policies*

Policy instruments to:

a. strengthen production of new endogenous scientific knowledge;

b. strengthen the infrastructure of public and private research laboratories;

c. build capacity in research, innovation and strategic planning;

d. strengthen gender equality in research and innovation;

e. strengthen the social appropriation of scientific knowledge and new technologies;

f. develop strategic S&T areas;

g. strengthen science education from primary to postgraduate levels;

h. develop green technologies and technologies fostering social inclusion;

i. promote indigenous knowledge systems;

j. strengthen co-ordination, networking and integration processes in the research and innovation eco-system to promote synergies among the government, university and productive sectors;

k. strengthen the quality of technology foresight studies to: assess the potential of high-value markets; develop business plans for high-tech companies; construct and analyse long-term scenarios; and provide consulting services and strategic intelligence;

l. strengthen regional and international co-operation, networking and promotion of science and technology;

m. promote start-ups in high-tech fields and new niche products and services with high added value.

TRENDS IN HUMAN RESOURCES

Spending on tertiary education high

Many Latin American governments devote more than 1% of GDP to higher education (Figure 7.4), a level typical of developed countries. Moreover, in Chile and Colombia, there has been strong growth in both expenditure per student and in university enrolment since 2008.

Both the number of university graduates and tertiary institutions have been expanding steadily for decades. According to the UNESCO Institute for Statistics, more than 2 million bachelor's or equivalent degrees were awarded in Latin America in 2012, a 48% increase over 2004. Most of the graduates were women.[10] The rise in PhD degrees has been almost as spectacular: 44% since 2008 (23 556 in 2012). The share of PhD-holders in the general population in the more advanced countries of Latin America compares well with the figures for China, India, the Russian Federation and South Africa but not with the most developed countries (Figure 7.4).

Six out of ten graduates at the bachelor's level specialize in social sciences (Figure 7.4), compared to only about one in seven for engineering and technology. This trend contrasts starkly with that in emerging economies such as China, the Republic of Korea or Singapore, where the great majority of graduates study engineering and technology. In 1999, there was an equal share of PhD students studying social sciences and natural and exact sciences in Latin America but the region has never recovered from the strong disaffection for the latter fields witnessed at the turn of the century (Figure 7.4).

High ratios of students living abroad

Among students from the region enrolled in tertiary study abroad, there were four times as many (132 806) living in North America or Western Europe than in Latin America (33 546) in 2013 (Figure 7.4). Although the more populous countries account for the majority of these international students, some smaller countries also have large contingents, such as Ecuadorians in the USA (Figure 7.4). The highest ratios (per national population) of students living in developed countries are to be found in Ecuador, Colombia, the Dominican Republic and Panama.

Some 3 900 students of Latin American origin were awarded PhDs in science or engineering in US universities between 2008 and 2011 (NSB, 2014). Although between one-third and half typically announce their intention to stay in the USA indefinitely, the number of PhDs and postdocs returning from study abroad can rival the number trained at home, as in the case of Panama.

Many Bolivians, Colombians, Ecuadorians and Peruvians choose to study in Latin America but outside their home country. Relative to population, Bolivia still figures high on the list but is this time joined by Nicaragua, Panama and Uruguay. Cuba is one of the most popular student destinations within Latin America; the UNESCO Institute for Statistics estimates that there are around 17 000 students from other Latin American countries living in Cuba, compared to 5 000 in Brazil and around 2 000 in each of Argentina and Chile.

Schemes to strengthen knowledge networks

In light of the shortage of engineers, geologists, oceanographers, meteorologists and other specialists, Argentina, Brazil and Chile have all introduced a series of financial incentives and scholarships to attract undergraduates to these strategic fields. They have also adopted new scholarship schemes to attract foreign nationals to PhD programmes. In 2013, the Mexican National Council for Science and Technology (CONACYT) and the Organization of American States jointly created a programme offering 500 scholarships over the next five years for postgraduate education in biology, chemistry, Earth sciences, engineering, mathematics and physics, in order to facilitate graduate student exchanges within the Americas.

Another milestone has been the founding of a research institute in collaboration with UNESCO's Abdus Salam International Centre for Theoretical Physics (ICTP), the São Paulo State University and the São Paulo Research Funding Agency: the ICTP–South American Institute for Basic Research, located within the State University of São Paulo. Between 2012 and 2015, this new institute organized 22 regional graduate schools, 23 regional workshops and 18 regional mini-schools.

In recent decades, several Latin American countries have sought to strengthen knowledge networks at home by reinforcing ties with the diaspora. Those proposing the greatest variety of student scholarships and training schemes are Argentina, Brazil, Chile and Mexico. In Argentina, the Raíces Programme (*raíces* meaning 'roots') became a state policy in 2008; this programme has repatriated around 1 200 highly qualified researchers since its creation in 2003, in parallel to promoting the creation of networks of Argentinean scientists in developed countries.

Other examples are the Mexican Talent Network (*Red de Talentos Mexicanos,* est. 2005), the Bilateral Forum on Higher Education, Innovation and Research involving Mexico and the USA (FOBESII, est. 2014), Chile Global and, in Brazil, Science without Borders (see Box 8.3). Colombia, Ecuador and Uruguay have also put in place well-funded initiatives. Some schemes favour the repatriation of scientists, with a set of sophisticated mechanisms for the co-ordination of these schemes with industrial and production development policies to ease the absorption of these highly skilled people into the domestic economy. Others promote short visits (2–3 months) by experts for the purposes of teaching graduate courses.

10. The highest shares were found in Panama and Uruguay (66%), the Dominican Republic and Honduras (64%), Brazil (63%), Cuba (62%), Argentina (61%), El Salvador (60%), Colombia (57%), Chile (56%) and Mexico (54%).

Figure 7.4: **Trends in higher education in Latin America, 1996–2013**

4.47%

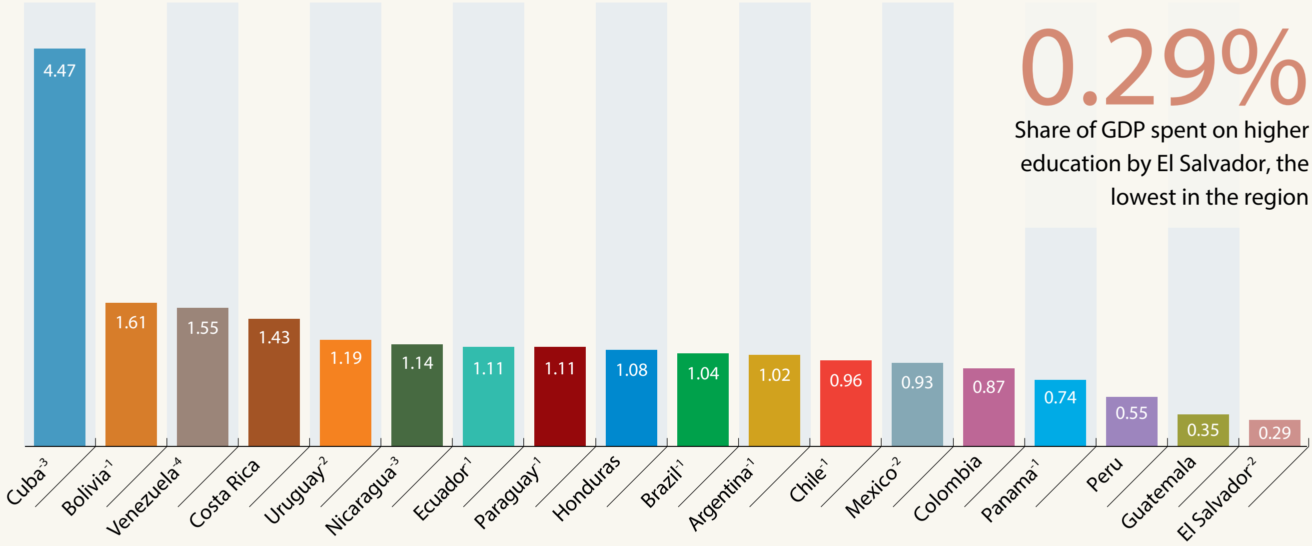
Share of GDP spent on higher education by Cuba, the highest in the region

0.29%

Share of GDP spent on higher education by El Salvador, the lowest in the region

Eleven countries devote more than 1% of GDP to higher education

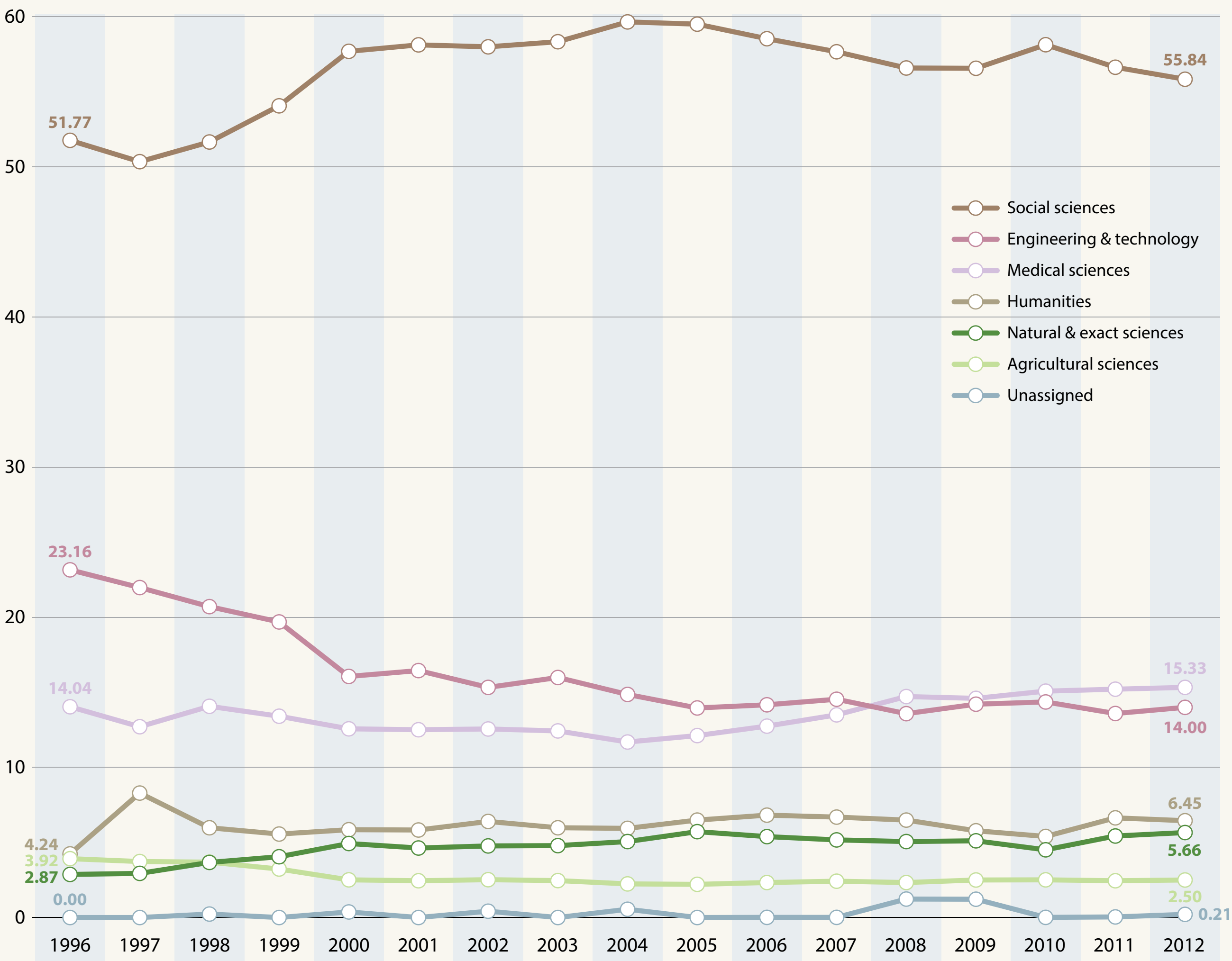
Expenditure on higher education as a share of GDP, 2013 or closest year (%)



+n/-n = data refer to *n* years before or after reference year

The great majority of first-degree graduates in Latin America study social sciences

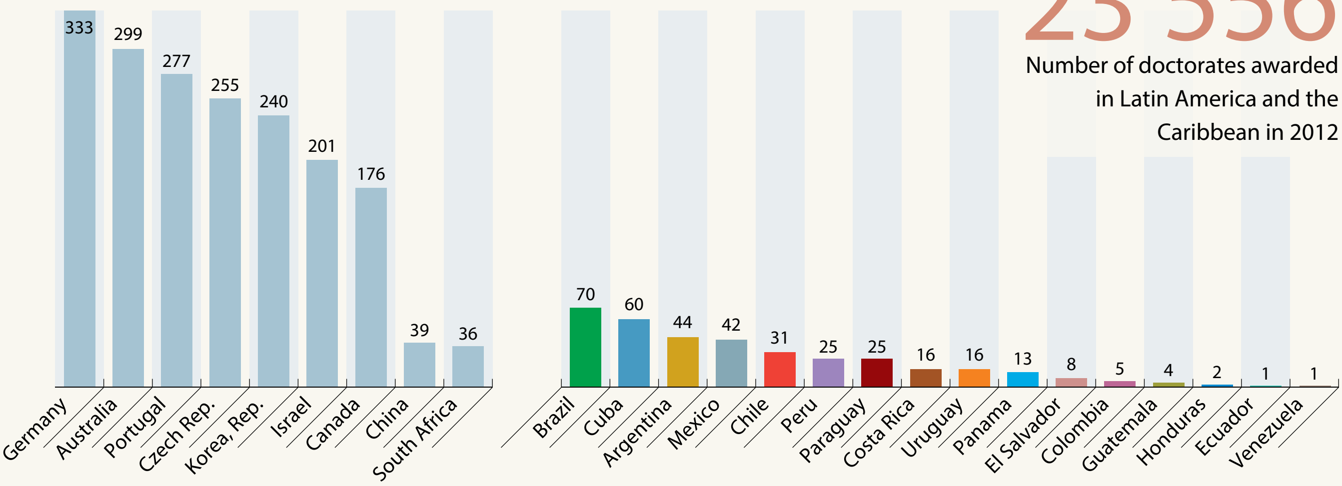
Distribution of bachelor's degrees by field of study, 1996–2012 (%)



Brazil has the most PhD graduates per million inhabitants in Latin America

PhD graduates per million inhabitants, 2012

Countries outside Latin America are given for comparison

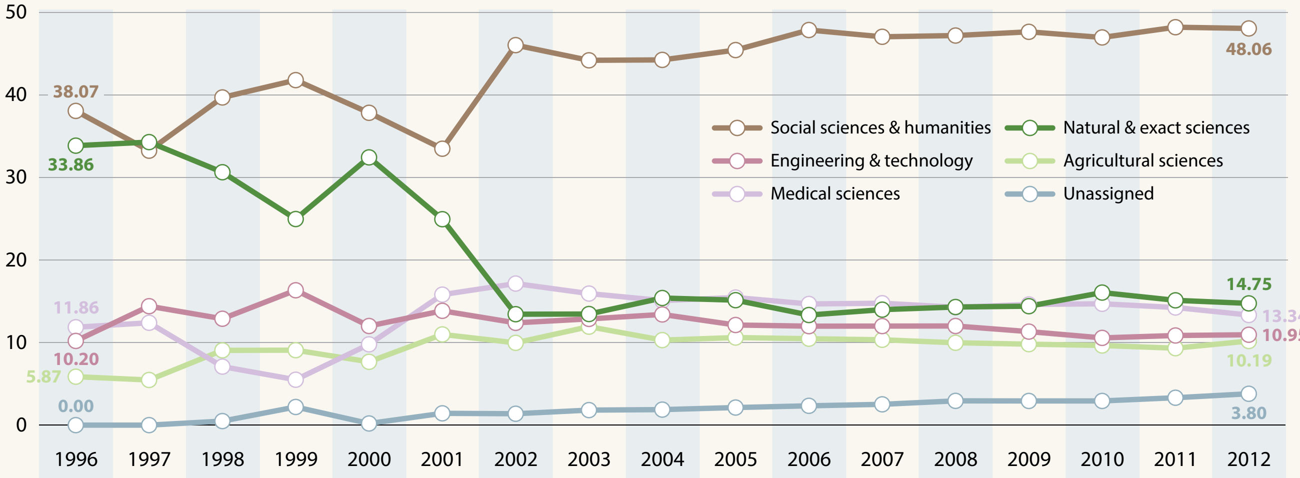


23 556

Number of doctorates awarded in Latin America and the Caribbean in 2012

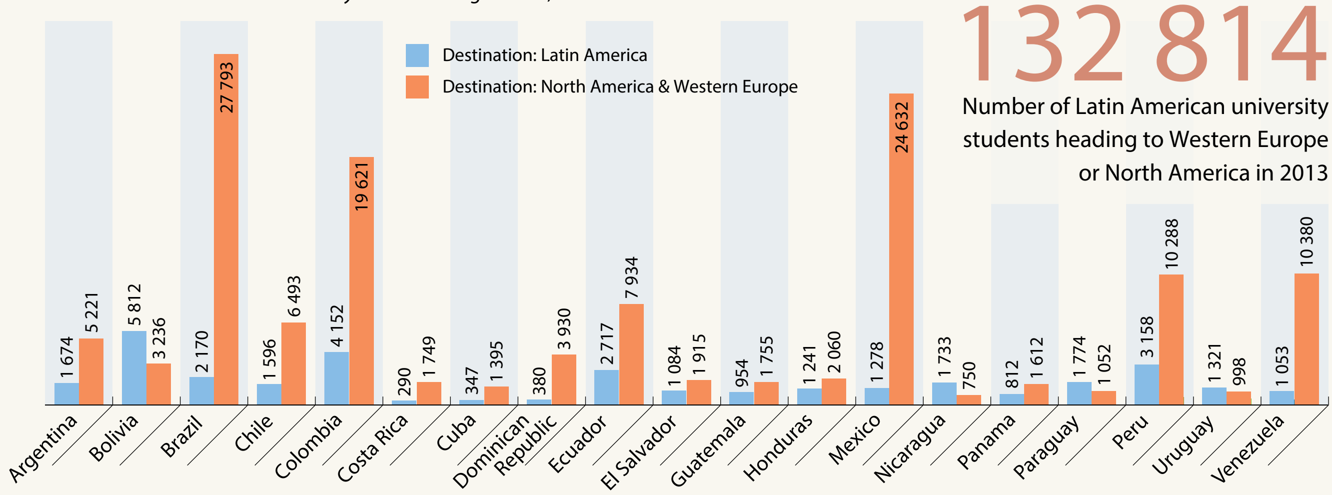
The share of PhD graduates in natural sciences has not recovered since this indicator plunged a decade ago

Distribution of PhDs in Latin America by field of study,1996–2012 (%)



Students head for Western Europe and North America more than other Latin American countries, with the exception of those from Bolivia, Nicaragua, Paraguay and Uruguay

Number of Latin American university students living abroad, 2013



132 814

Number of Latin American university students heading to Western Europe or North America in 2013

Source: For higher education spending and students living abroad: UNESCO Institute for Statistics: for graduates; RICYT database, July 2015; for PhD students per million inhabitants, estimations based on data from the UNESCO Institute for Statistics and United Nations Statistics Division

The Start-Up Chile programme (2010) takes a different approach. Its aim is to attract entrepreneurs from around the world in the hope that their presence in Chile will help transmit tacit entrepreneurial knowledge to local entrepreneurs in a way that would be impossible through traditional training and scholarship programmes (see also Box 7.1).

Most countries need more researchers

In the past few years, there has been a leap in the number of full-time equivalent (FTE) researchers in Costa Rica, Ecuador and Venezuela, whereas other countries have seen less vigorous growth (Figure 7.5). Latin American countries generally trail dynamic open economies for the number of researchers per million inhabitants, although the top two

Box 7.1: **Tenaris: a corporate university building industrial skills in-house**

Attracting and retaining talented scientists and engineers remains a big challenge for the industrial sector in Latin America. In the past two decades, top companies have been investing in the development of corporate universities around the world: Motorola, Mastercard, Toyota, Cisco, etc..

In 2005, Tenaris – a company of Argentinian origin – created the first corporate university in Latin America. Tenaris is a leading manufacturer of seamless steel pipes for the world's oil and gas industry, with facilities in nine countries that employ over 27 000 people.

Tenaris University has based its global campus in Campana (2008), Argentina, and has three other training facilities in Brazil, Italy and Mexico. The university offers employees the choice between 450 e-learning and 750 classroom courses at its Industrial Schools (for company engineers), Schools of Finance and Administration, Commercial Management, Information Technology and its Schools of Technical Studies.

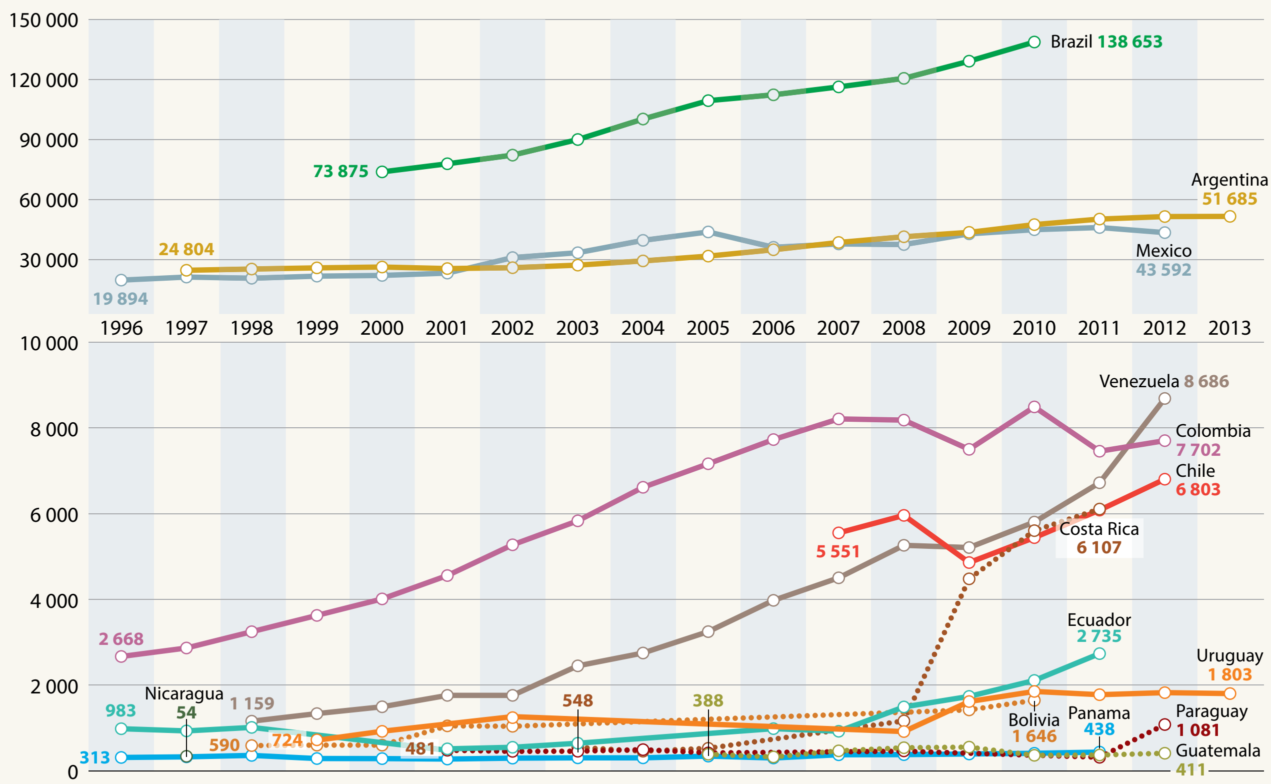
Internal experts recruited from within the company serve as the main body of instructors.

The company has compensated for the recent drop in global demand for its products by augmenting the number of hours employees spend in training. This way, employees should return to the factory floor with better skills once production picks up again.

*Argentina, Brazil, Canada, Colombia, Italy, Japan, Mexico, Romania and the USA

Source: compiled by author

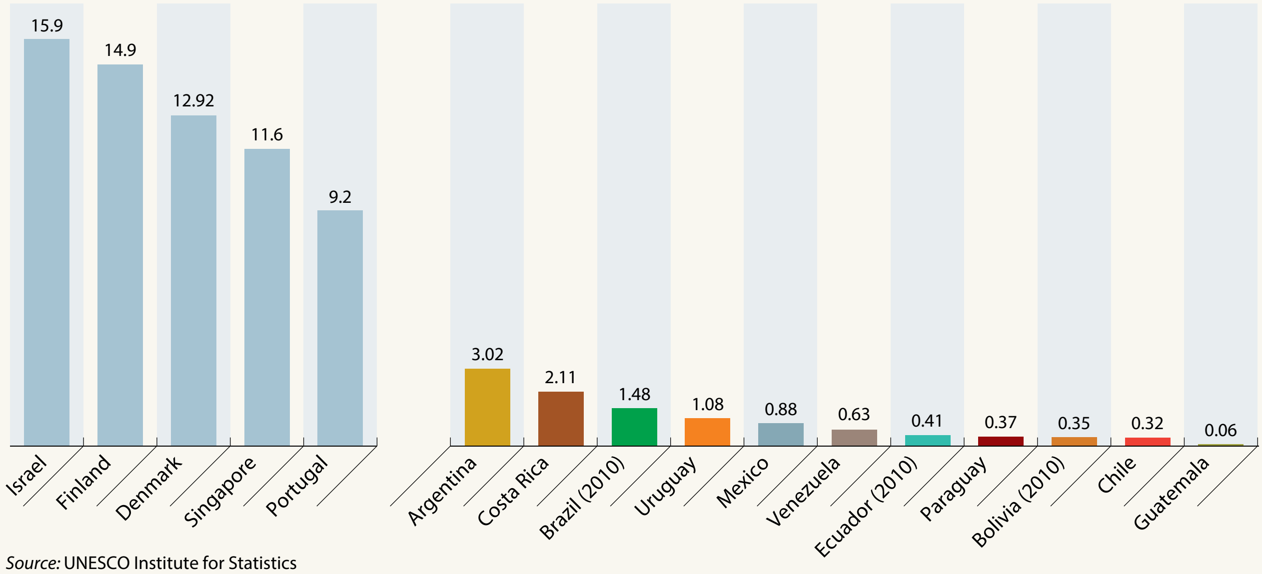
Figure 7.5: **Researchers (FTE) in Latin America, 1996–2013**



Source: UNESCO Institute for Statistics

Figure 7.6: **Researchers (FTE) in Latin America per thousand labour force, 2012**

Countries outside Latin America are given for comparison



Source: UNESCO Institute for Statistics

countries – Argentina (1 256) and Costa Rica (1 289) – both have ratios above the world average: 1 083 (see Table 1.3).

Argentina still has the most full-time equivalent (FTE) researchers per thousand labour force. Argentina's ratio is even twice that of Brazil, 3.4 times that of Mexico and almost ten times that of Chile. This said, Argentina still has a great distance to travel to catch up to developed economies (Figure 7.6).

Latin America as a region nevertheless excels for other indicators, such as for the participation of women in research (Lemarchand, 2010, pp. 56–61). A recent study has shown that Latin America also has the highest rates of female entrepreneurship and a smaller gender gap in research than other regions (IDB, 2015; see also Chapter 3). This is hardly surprising, given the explicit policy instruments promoting women in science and engineering in Latin America. The most compelling of these are the Women and Science programme in Brazil and the Postgraduate Scholarship Programme for Indigenous Women in Mexico.

TRENDS IN R&D EXPENDITURE

Countries could invest more in R&D

In 2012, gross domestic expenditure on R&D (GERD) in Latin America and the Caribbean surpassed PPP$ 54 billion (in 2012 constant dollars),[11] a 1.70% increase over 2003. Just three countries concentrate 91% of GERD: Argentina, Brazil and Mexico. Brazil is the only country with an R&D effort of more than 1% of GDP (see Chapter 8 and Figure 7.7).

GERD has remained relatively constant in Latin America over the past few decades (Lemarchand, 2010, p. 35–37). Since 2006, R&D spending has grown moderately in Argentina, Brazil and Mexico but there is no evidence to suggest that either Chile or Colombia is making a determined push to raise its own R&D intensity. Among the smaller economies, Costa Rica and Uruguay have the highest level of investment in R&D, whereas GERD seems to fluctuate in Bolivia, Cuba, Ecuador and Panama.

The public sector remains the main source of funding, particularly in Argentina, Cuba, Mexico and Paraguay. Businesses in the region contribute about 40% of R&D funding, on average (Figure 7.7), with Brazil slightly surpassing this share (see Chapter 8). The public sector still carries out the bulk of research. Six countries receive a considerable share of research funding from abroad: Chile, El Salvador, Guatemala, Panama, Paraguay and Uruguay (Figure 7.7). In the case of Chile, the high share of GERD funded from abroad (18%) relates to the activity of a cluster of European and North American astronomical observatories; in Panama, the high share (21%) is due to the presence of the Smithsonian Institution.

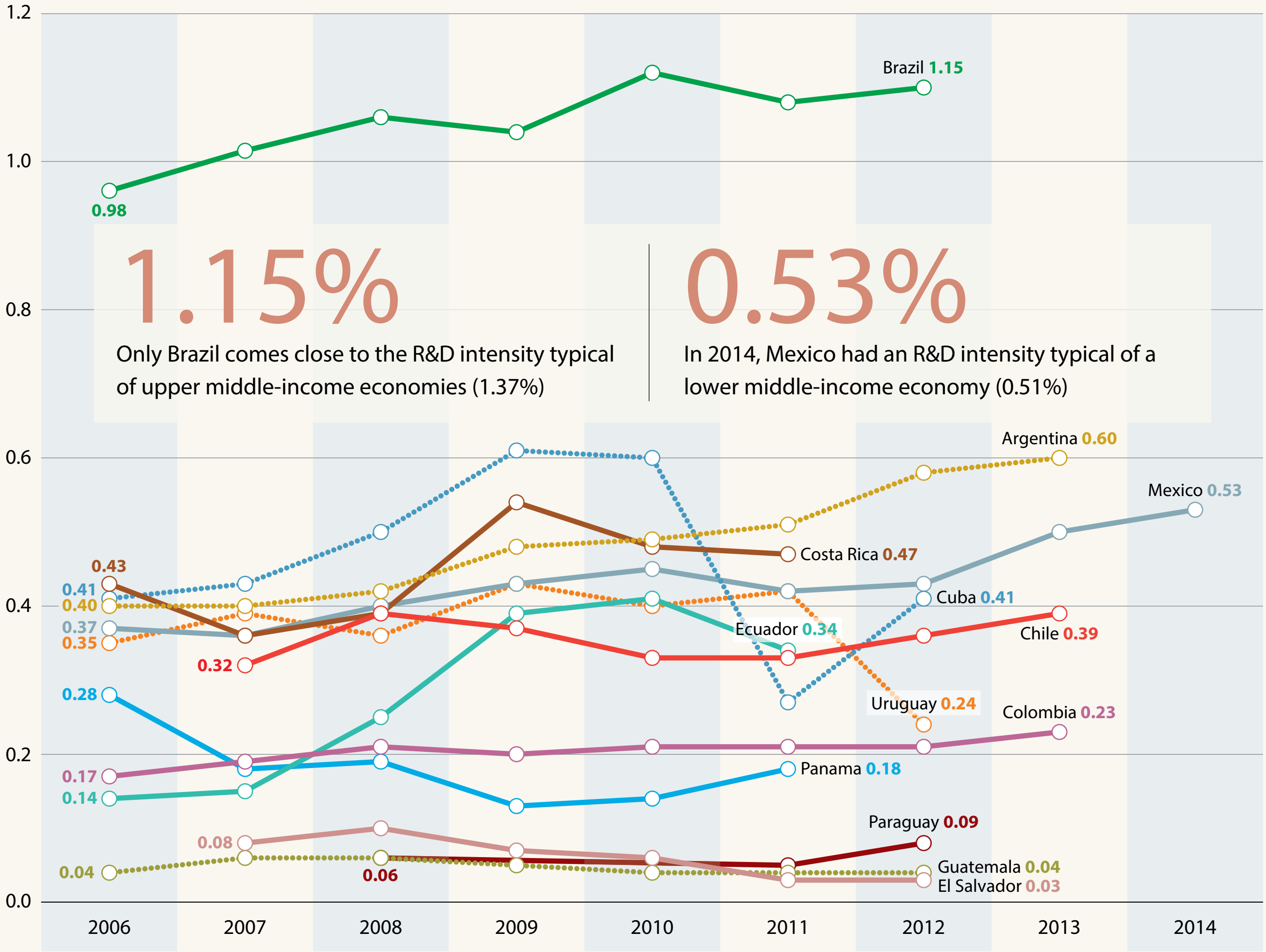
A breakdown of R&D expenditure by socio-economic objective is only available for a handful of countries. In 2012, Argentina and Chile allocated one-third of this expenditure to engineering and technology, a sizeable share for emerging economies. Both prioritized industrial and agricultural production and technology. Smaller countries prioritized agricultural production (Guatemala and Paraguay), human health (El Salvador, Guatemala and Paraguay), social structures (Ecuador), infrastructure, energy and the environment (Panama).

11. The original RICYT estimations were calculated using PPP current international dollars. In order to remove distortions caused by inflation, here, we have adjusted those values to constant PPP (2012) dollars.

Figure 7.7: **Trends in GERD in Latin America and the Caribbean, 2006–2014 (%)**

Few Latin American countries have seen a consistent rise in their R&D intensity over the past decade

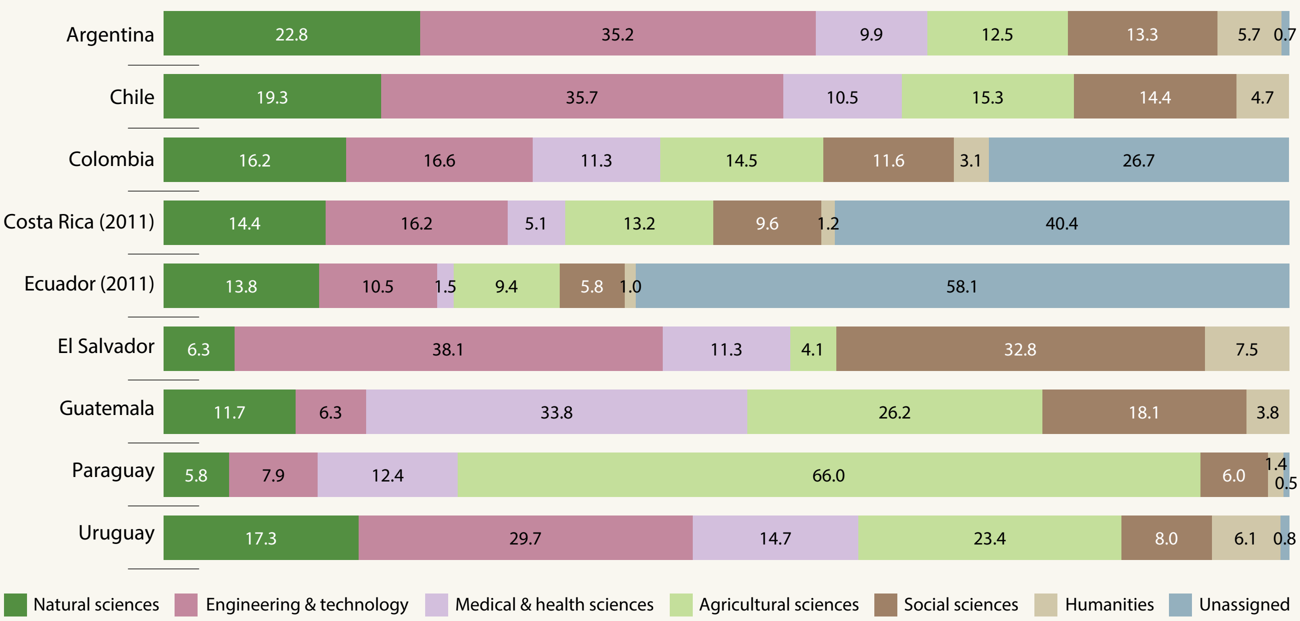
GERD as a share of GDP, 2006–2014 (%)



Note: Data are unavailable for Honduras, Nicaragua, Peru and Veneuzela. Data are only available for Bolivia for 2009 (0.15%).

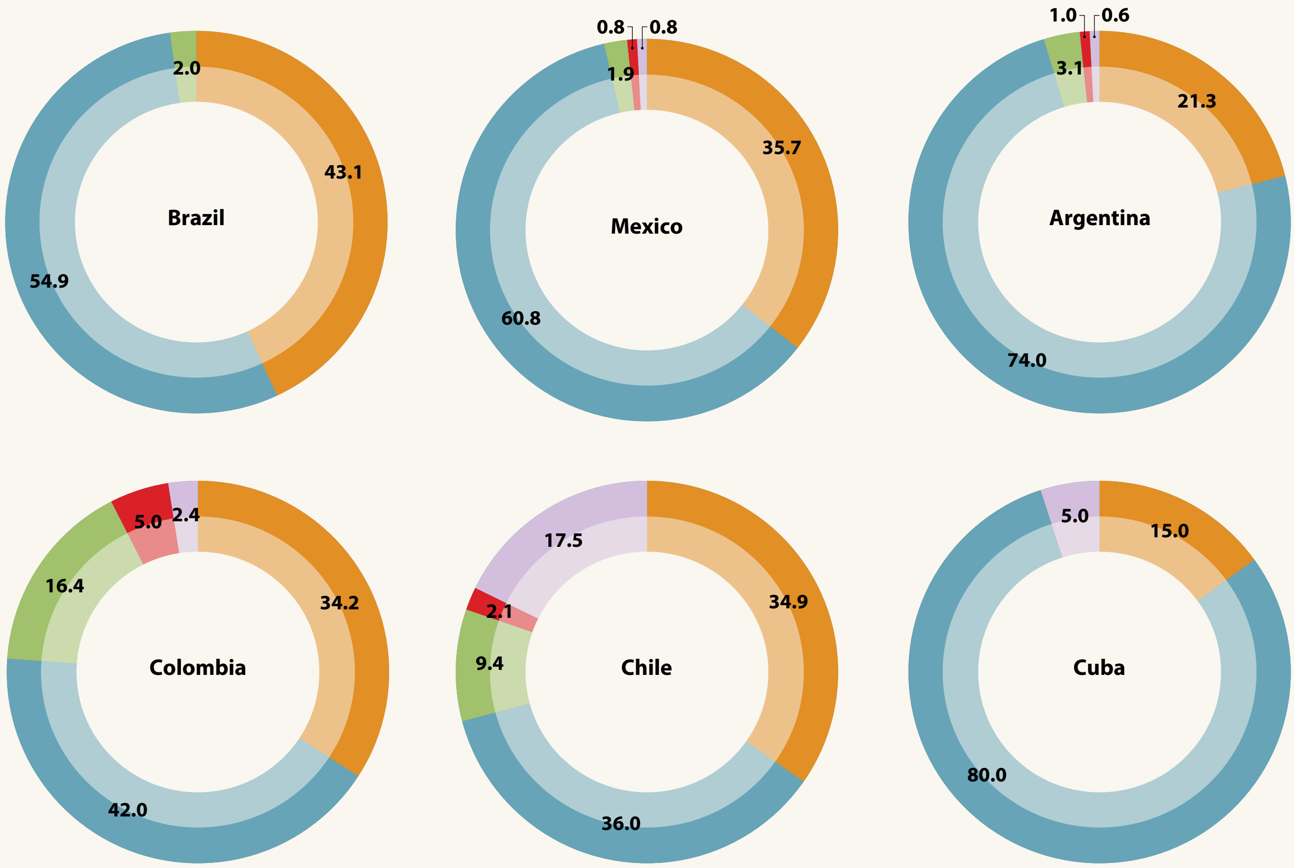
Agricultural sciences account for two-thirds of Paraguay's R&D expenditure

GERD by field of science, 2012 (%)

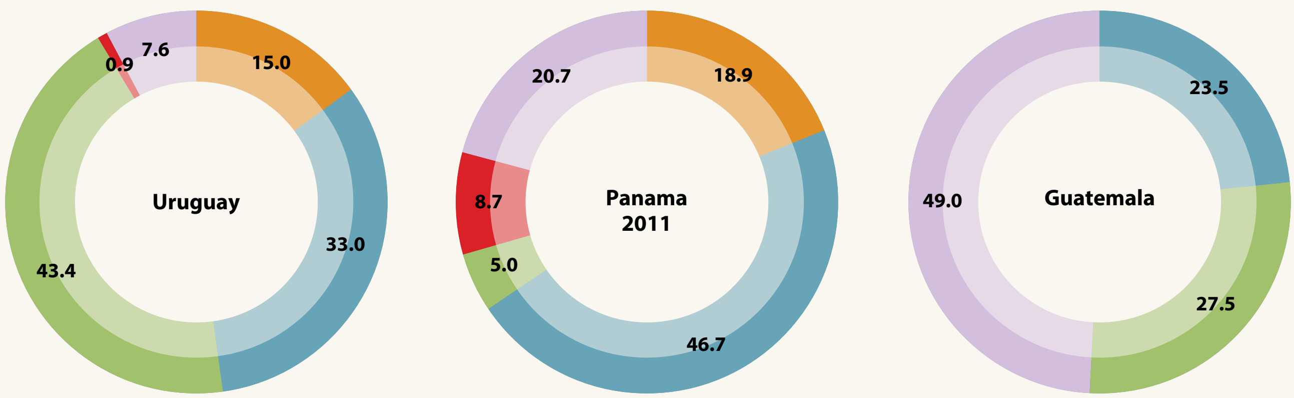


Brazil and Mexico have the highest share of business-funded R&D in Latin America

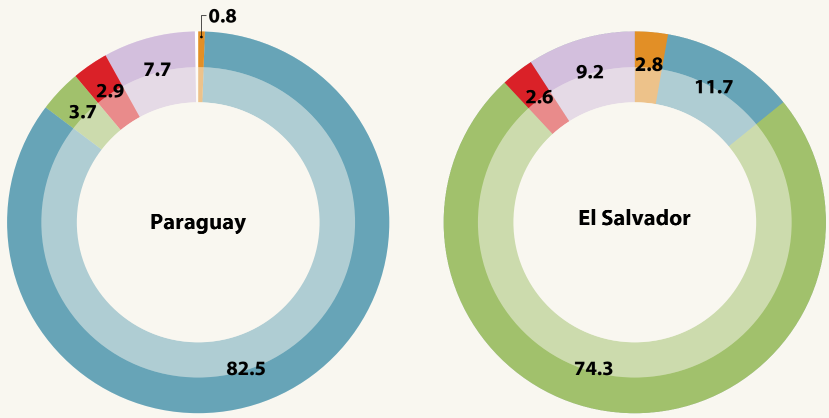
GERD by source of funds, 2012 (%), countries arranged in descending order of GERD by volume (PPP$)



Panama has the highest share of private non-profit-funded R&D, thanks largely to the presence of the Smithsonian Institution



- Business enterprise
- Government
- Higher education
- Private non-profit
- Abroad



Note: Totals may not add up to 100% due to some GERD not being classified by source.

Source: RICYT database and UNESCO Institute for Statistics, July 2015; Brazilian Ministry of Science, Technology and Innovation

TRENDS IN R&D OUTPUT

Publications rising, including those with foreign partners

The number of articles published by Latin American authors in mainstream scientific journals catalogued in the Science Citation Index Extended increased by 90% between 2005 and 2014, carrying the region's global share from 4.0% to 5.2%. Growth was fastest in Colombia (244%), Ecuador (152%), Peru (134%) and Brazil (118%) and more moderate in Argentina and Mexico (34% and 28% respectively). The overall volume of scientific Venezuelan publications actually declined by 28% (Figure 7.8).

Between 2008 and 2014, one-quarter (25%) of the region's publications focused on biological sciences, one-fifth (22%) on medical sciences, 10% on physics, 9% on chemistry and 8% each on agricultural sciences, engineering and geosciences. Of note is the relatively large share of Chilean articles in astronomy: 13% (Figure 7.8).

Despite the rise in the volume of Latin American publications, their impact on breakthrough international science remains modest. Central American papers are cited more than those from South America but this may be because the sheer volume of output from South America stifles these 'hot topics.'

It can be more telling to evaluate the impact of publications over decades rather than years. Hirsch (2005) has proposed the so-called *h*-index, which reveals the number of articles (*h*) from a given country that have received at least *h* citations. Between 1996 and 2014, the highest *h* indices were obtained by Brazil (379), Mexico (289), Argentina (273), Chile (233) and Colombia (169). Taking into account the full scientific production over this period, all Latin American countries (with the exception of Brazil, El Salvador and Mexico) rank better worldwide for their *h*-index than for the number of articles. Panama carries this trend to extremes: it ranks 103rd for the number of articles but 63rd in terms of its *h*-index.[12]

Since the early 1980s, scientific co-authorship among countries has been determined by the desire of individual scientists to give their work greater visibility (Lemarchand, 2012). This has led them to collaborate with bigger scientific networks (USA, EU, etc.). Formal co-operation agreements among countries or regions tend to have little influence over co-authorship behaviour.

Most Latin American countries have concluded a host of bilateral agreements or treaties with other economies within and beyond the region. When it comes to collaborative research, though, partners tend to be based in North America and Western Europe. Co-operation with the EU has even been stepped up since 2010 with the signing of the *Madrid Declaration* (Box 7.2).

Whereas Brazil has a copublication rate (28%) that is close to the G20 average and just under half of Mexican (45%) and Argentinian (46%) articles have foreign collaborators, this rate rises to more than 90% for the smaller countries (Figure 7.8); the latter have become so dependent on international copublishing that, in some cases, the most representative institution is based abroad.

12. The Smithsonian Institute for Tropical Research in Panama was responsible for 63% of Panama's scientific articles between 1970 and 2014. This may explain why Panama ranks so highly.

Box 7.2: **Towards a common knowledge area for Europe and Latin America**

Biregional scientific co-operation between Europe and Latin America and the Caribbean dates back to the early 1980s, when the former Commission of the European Communities and the Andean Group Secretariat signed an agreement for co-operation and established a joint commission to oversee its implementation. Later, Europe concluded similar agreements with the Central American countries and MERCOSUR.

The sixth summit between the European Union (EU) and Latin America and the Caribbean in 2010 identified new pathways for biregional co-operation in the *Madrid Declaration*, which emphasized partnership in the areas of innovation and technology for sustainable development and social inclusion.

The summit defined the long-term goal of achieving a common 'knowledge area' and agreed on a Joint Initiative for Research and Innovation. Some 17 countries are participating in a key project within this initiative entitled ALCUE Net, which runs from 2013 to 2017; this project has established a joint platform for policy-makers, research institutions and the private sector from both regions in four thematic areas: ICTs; the bio-economy; biodiversity and climate change; and renewable energies. A second project with joint calls (ERANet LAC) is implementing projects in these four areas. There were € 11 million available for the first call for project proposals (2014–2015) and a similar amount for the second call (2015–2016).

The partners are also carrying out a foresight exercise which is due to be concluded by November 2015, to build a common long-term vision for biregional co-operation.

Source: Carlos Aguirre-Bastos, National Secretariat for Science, Technology and Innovation (SENACYT), Panama

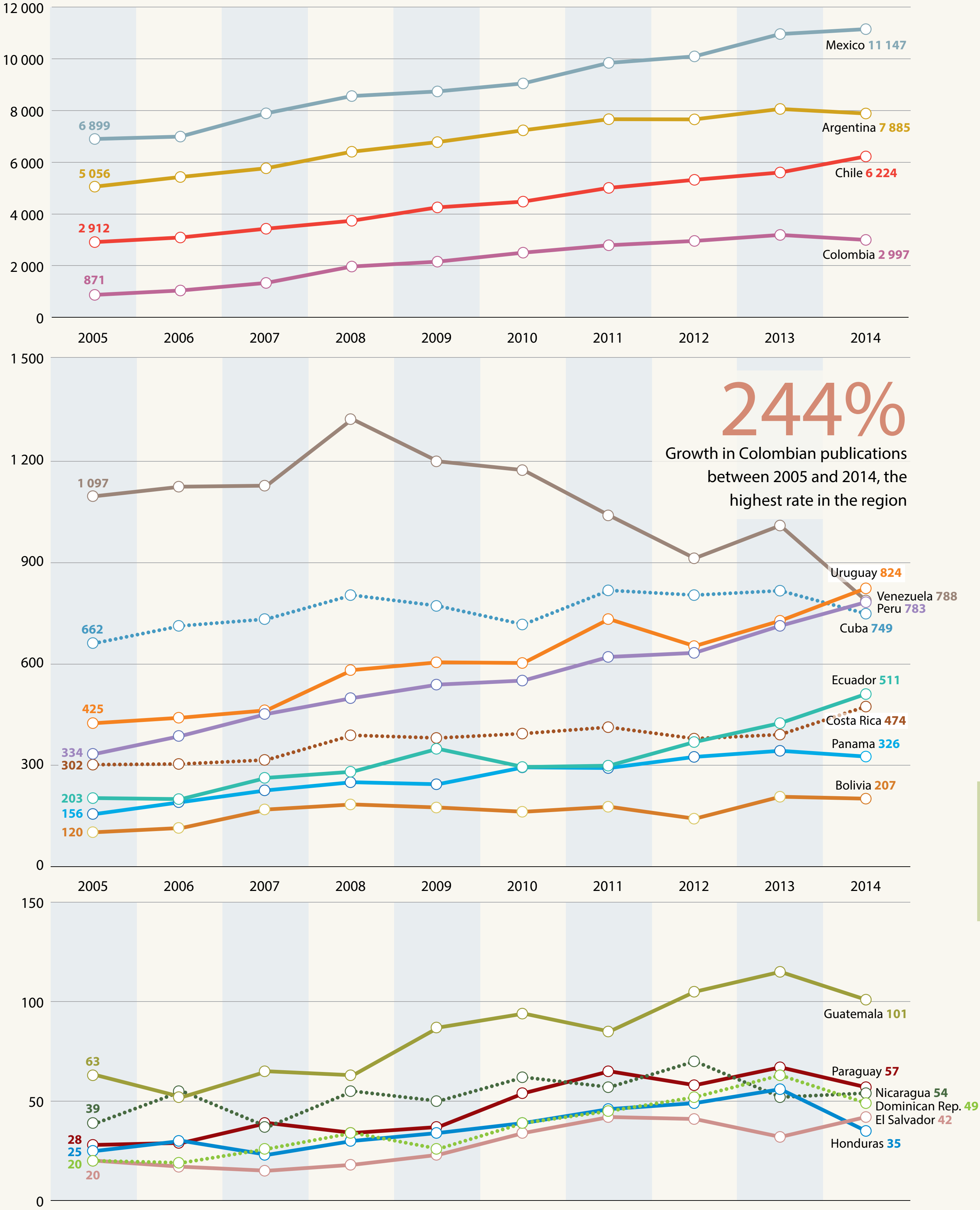
Figure 7.8: **Scientific publication trends in Latin America and the Caribbean, 2005–2014**

4.0% Latin America and the Caribbean's world share of publications in 2005

5.2% Latin American and the Caribbean's world share of publications in 2014

Strong growth in many countries

For the evolution in the volume of publications in Brazil, see Figure 8.9

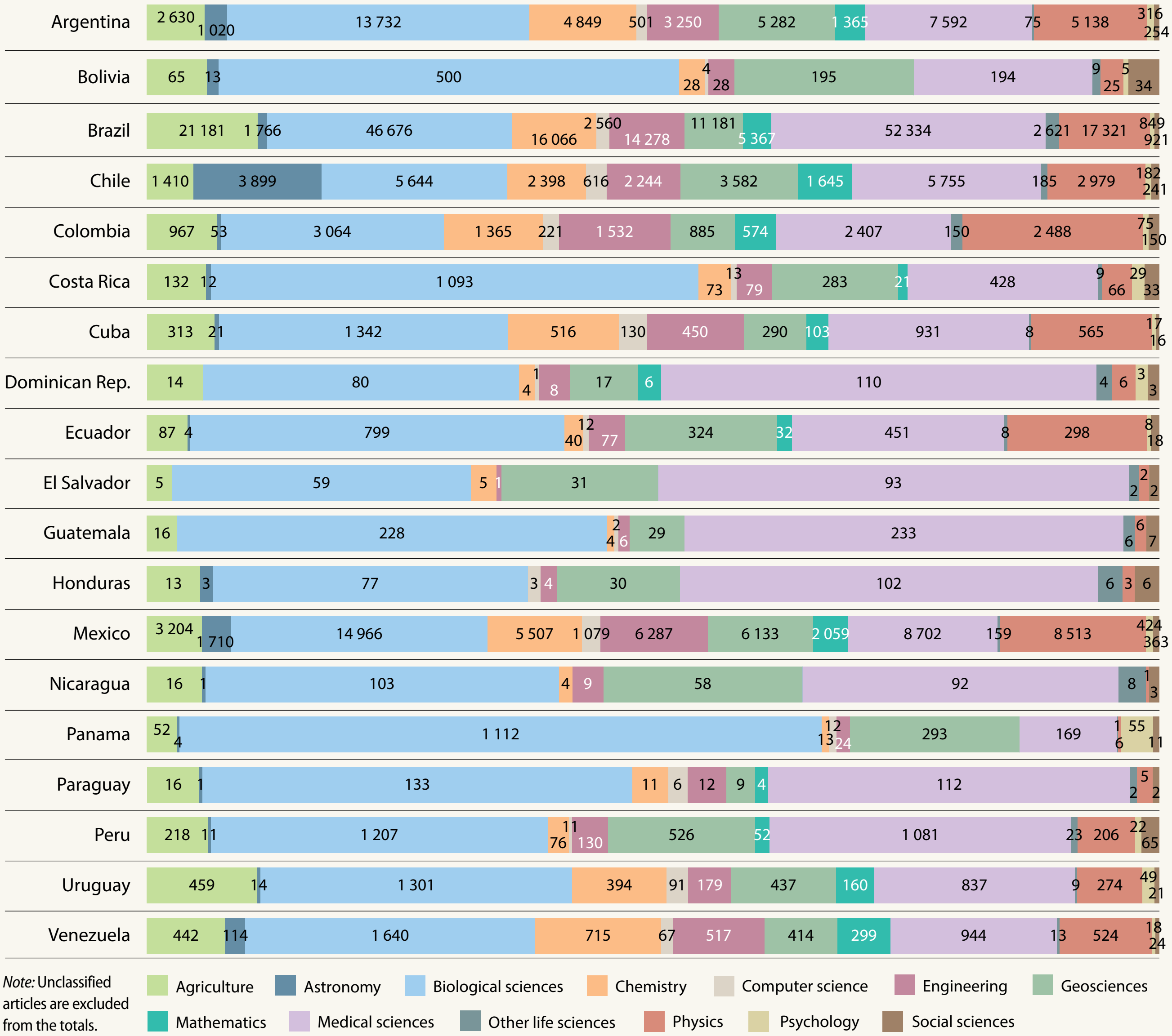


Chapter 7

Figure 7.8 *(continued)*

Life sciences dominate research in Latin America and the Caribbean

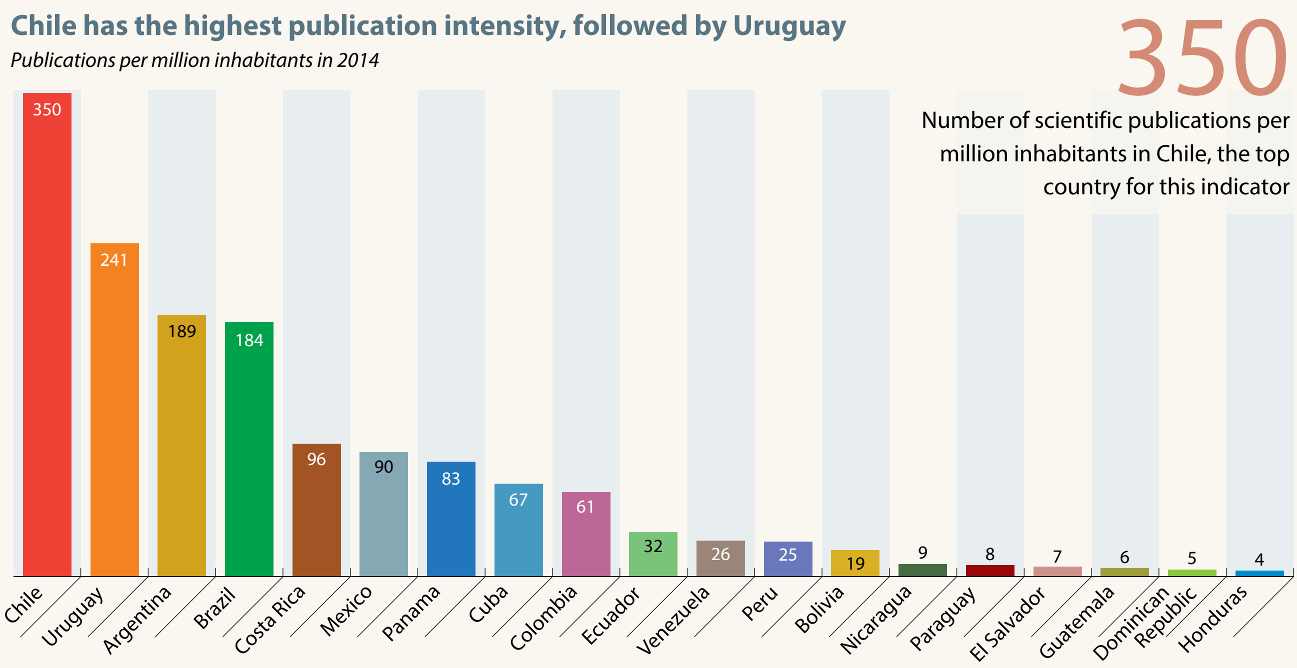
Cumulative totals by field, 2008–2014



Note: Unclassified articles are excluded from the totals.

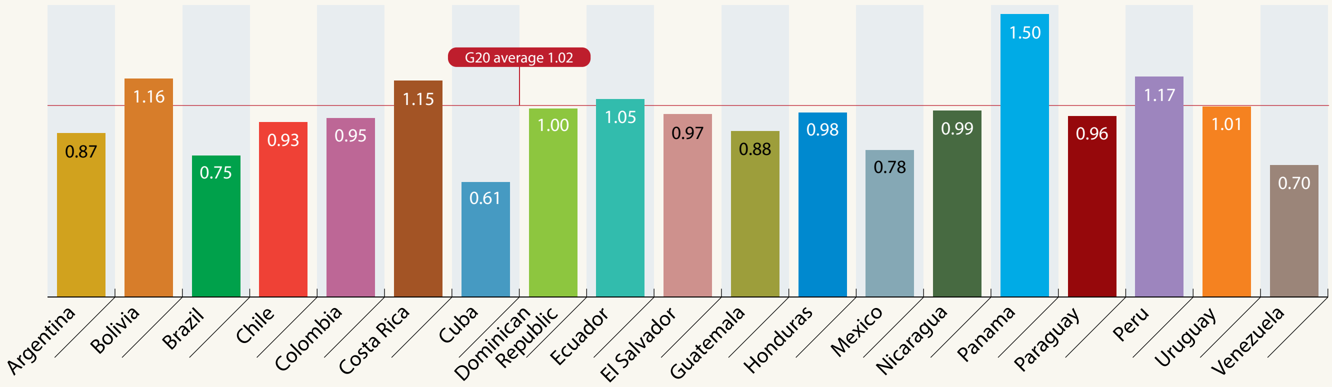
Chile has the highest publication intensity, followed by Uruguay

Publications per million inhabitants in 2014



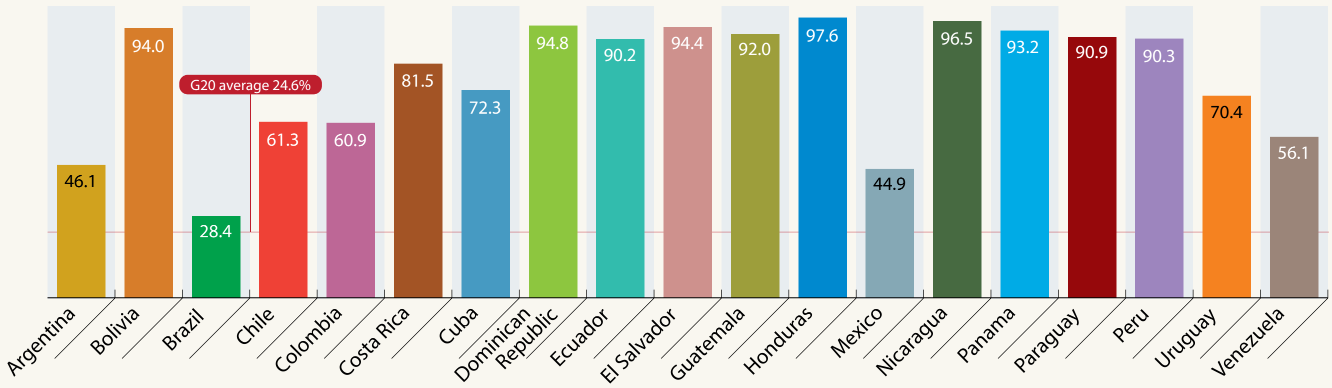
Countries with modest output have the highest average citation rate

Average citation rate for publications, 2008–2012



The majority of articles have foreign co-authors in all but Argentina, Brazil and Mexico

Share of papers with foreign co-authors, 2008–2014 (%)



The top partner for all but Cuba is the USA; Brazil is a key partner for most

Main foreign partners, 2008–2014

	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
Argentina	USA (8 000)	Spain (5 246)	Brazil (4 237)	Germany (3 285)	France (3 093)
Bolivia	USA (425)	Brazil (193)	France (192)	Spain (187)	UK (144)
Brazil	USA (24 964)	France (8 938)	UK (8 784)	Germany (8 054)	Spain (7 268)
Chile	USA (7 850)	Spain (4 475)	Germany (3 879)	France (3 562)	UK (3 443)
Colombia	USA (4 386)	Spain (3 220)	Brazil (2 555)	UK (1 943)	France (1 854)
Costa Rica	USA (1 169)	Spain (365)	Brazil (295)	Mexico (272)	France (260)
Cuba	Spain (1 235)	Mexico (806)	Brazil (771)	USA (412)	Germany (392)
Dominican Rep.	USA (168)	UK (52)	Mexico (49)	Spain (45)	Brazil (38)
Ecuador	USA (1 070)	Spain (492)	Brazil (490)	UK (475)	France (468)
El Salvador	USA (108)	Mexico (45)	Spain (38)	Guatemala (34)	Honduras (34)
Guatemala	USA (388)	Mexico (116)	Brazil (74)	UK (63)	Costa Rica (54)
Honduras	USA (179)	Mexico (58)	Brazil (42)	Argentina (41)	Colombia (40)
Mexico	USA (12 873)	Spain (6 793)	France (3 818)	UK (3 525)	Germany (3 345)
Nicaragua	USA (157)	Sweden (86)	Mexico (52)	Costa Rica (51)	Spain (48)
Panama	USA (1 155)	Germany (311)	UK (241)	Canada (195)	Brazil (188)
Paraguay	USA (142)	Brazil (113)	Argentina (88)	Spain (62)	Uruguay/Peru (36)
Peru	USA (2 035)	Brazil (719)	UK (646)	Spain (593)	France (527)
Uruguay	USA (854)	Brazil (740)	Argentina (722)	Spain (630)	France (365)
Venezuela	USA (1 417)	Spain (1 093)	France (525)	Mexico (519)	Brazil (506)

Note: Belize, Guyana and Suriname are covered in the Chapter 6 on the CARICOM countries. See also Figure 8.9 devoted solely to Brazil.

Source: Thomson Reuters' Web of Science, Science Citation Index Expanded; data treatment by Science–Metrix

For example, 50% of the articles published by at least one author from Paraguay between 2010 and 2014 and listed in the Science Citation Index Extended were co-published with the University of Buenos Aires and 31% with CONICET, both Argentinian institutions.

The most important copublication 'hub' for most Latin American countries is the USA, followed by Spain, Germany, the UK and France for the sheer number of copublications (Figure 7.8). Since the mid-1990s, intraregional co-authorship has quadrupled (Lemarchand, 2010, 2012). Over the past five years, all countries have published more than before with Latin American partners, with Brazil and Mexico often figuring among the closest collaborators (Figure 7.8).

In terms of publications per million inhabitants, Chile, Uruguay and Argentina have the highest ratios but, when it comes to articles per full-time equivalent (FTE) researcher, Panama (1.02) takes the lead, ahead of Chile (0.93), Uruguay (0.38), Brazil (0.26), Mexico (0.26) and Argentina (0.19). The high ratios for Panama and Chile probably reflect the presence of the Smithsonian Institute of Tropical Research (of US origin) in Panama and that of European and North American astronomical observatories in Chile. In both cases, some of the articles attributed to authors residing in Chile or Panama were actually written by foreign researchers, who are not counted as local research staff.

Table 7.2: **Scientific articles on indigenous knowledge systems, 1990–2014**

Articles catalogued in the Science Citation Index Extended and Social Science Citation Index

	1990–2014		2010–2014	
	Articles on indigenous knowledge	Share of national production (%)	Articles on indigenous knowledge	Share of national production (%)
USA	1 008	0.02	482	0.03
Australia	571	0.08	397	0.17
Canada	428	0.04	246	0.08
UK	425	0.02	196	0.04
Latin America				
Brazil	101	0.02	65	0.04
Mexico	98	0.05	42	0.06
Argentina	39	0.03	26	0.06
Chile	33	0.05	14	0.05
Colombia	32	0.10	19	0.12
Bolivia	26	0.80	17	1.40
Peru	22	0.23	11	0.29
Venezuela	19	0.08	4	0.08
Costa Rica	12	0.18	7	0.31
Ecuador	7	0.14	6	0.28
Guatemala	6	0.36	4	0.66
Panama	5	0.09	2	0.09
Cuba	5	0.03	3	0.07
Honduras	4	0.55	–	–
Uruguay	3	0.03	2	0.05
Nicaragua	–	–	2	0.60

Source: Estimations by author on the basis of raw Web of Science data

A growing policy interest in indigenous knowledge systems

The first scientific papers exploring the relationship between academic science and indigenous knowledge systems appeared in the early 1990s, a few years before the World Conference on Science (1999) encouraged this interaction through its *Science Agenda*. However, just 4 380 articles on indigenous knowledge were listed in the Science Citation Index Extended and Social Science Citation Index between 1990 and 2014. The principal contributors were the USA, Australia, the UK and Canada (Table 7.2). Globally, indigenous knowledge thus appears to be playing a negligible role so far in the global research agenda, even though several Latin American countries have increased their shares since 2010.

Bolivia has the one of the highest ratios of articles on indigenous knowledge (1.4%) in the region and probably the world. After the election of President Evo Morales in 2006, Bolivia attempted to organize its entire national innovation system around the indigenous concept of *good living*. The Morales government's Programme for the Protection, Recovery and Systematisation of Local and Ancestral Knowledge for Social and Productive Development has drafted a Law for the Protection of Indigenous Knowledge. Other projects within this programme include a national policy on intellectual property; mechanisms to protect strategic intellectual property; the recording of incremental knowledge; and the recovery and spread of local knowledge and ethnical knowledge through ICTs and the aforementioned law (UNESCO, 2010). The 'recovery, protection and utilization of local knowledge and technical and ancestral knowledge' is a priority of the Vice-Minister of Science and Technology. In the *National Science and Technology Plan* (2013), local and ancestral knowledge are considered to be central elements of STI policy-building. Instruments have been set in motion within this framework, including the Law on Ancestral Traditional Bolivian Medicine (2013).

In recent years, other Latin American countries have developed policy instruments to protect indigenous knowledge systems and use them in STI policy-making (Box 7.3). UNASUR has, itself, considered the promotion of indigenous knowledge systems to be one of its priorities since 2010.

Relatively modest patenting

Patenting is relatively modest in Latin America. Between one and five out of every 100 firms in any given Latin American country hold a patent, compared to between 15 and 30 in European countries (WIPO, 2015). Patenting by Latin Americans in the main developed country markets is also very low, testifying to the absence of technology-based international competitiveness.

The best way to compare patenting rates at the international level is to use the data provided by the Patent Cooperation Treaty (PCT).[13] This system makes it possible to seek patent protection for an invention simultaneously in a wide range of countries by filing a single international patent. Two of the top 10 patenting offices of destinations worldwide are located in Latin America, those of Brazil and Mexico. Within Latin America, Chile counts the greatest number of patent applications per million inhabitants (187), which is consistent with the innovation policies promoted by the Chilean Corporation for the Promotion of Production (Corporación de Fomento de la Producción de Chile, CORFO) over the past decade (Navarro, 2014). Brazil, Mexico, Chile and Argentina have the most patent applications and grants (Figure 7.9).

The top five categories for global patent applications filed under the PCT are: electrical machinery, apparatus and energy; digital communication; computer technology; measurement; and medical technology. In 2013, the patents granted in these categories in Latin America represented around 1% of the number granted to high-income economies.

13. By 2014, the PCT counted 148 contracting states. Argentina, Bolivia, Paraguay, Uruguay and Venezuela are not contracting members (WIPO, 2015).

Box 7.3: A growing policy interest in indigenous knowledge in Latin America

Bolivia is not the only Latin American country to show an interest in mainstreaming indigenous knowledge in STI policies. Peru was one of the first to draw attention to the importance of indigenous knowledge and to protect it by law, through its Protection Regime for Traditional Knowledge (2002). Projects have since been launched to promote technology transfer to rural and native communities, such as the Technological Transfer and Extension Projects (PROTEC) in 2010 or the contest run by the National Council for Science and Technology and Technological Innovation (CONCYTEC) in 2012 called From Peru to the World: Quinoa, the Food of the Future.

Ecuador's Constitution of 2008 gives the National System of Science, Technology, Innovation and Ancestral Knowledge the mandate 'to recover, fortify and empower ancestral knowledge,' making Ecuador the only country in the region to codify references to ancestral knowledge and STI at the highest level of the state. The incorporation and promotion of ancestral knowledge are, consequently, reflected in programmes run by the Ministry of Higher Education, Science and Technology, including those on Research and Innovation in Knowledge Dialogue (2013) and Traditional Knowledge and Climate Change.

Among the general objectives of Colciencias in Colombia figure the promotion and reinforcement of 'intercultural research, in agreement with the indigenous peoples, their authorities and elders, being directed towards protecting cultural diversity, biodiversity, traditional knowledge and genetic resources.' Instruments have been developed to this end, such as *A Ciencia Cierta* (2013) and Ideas for Change (2012).

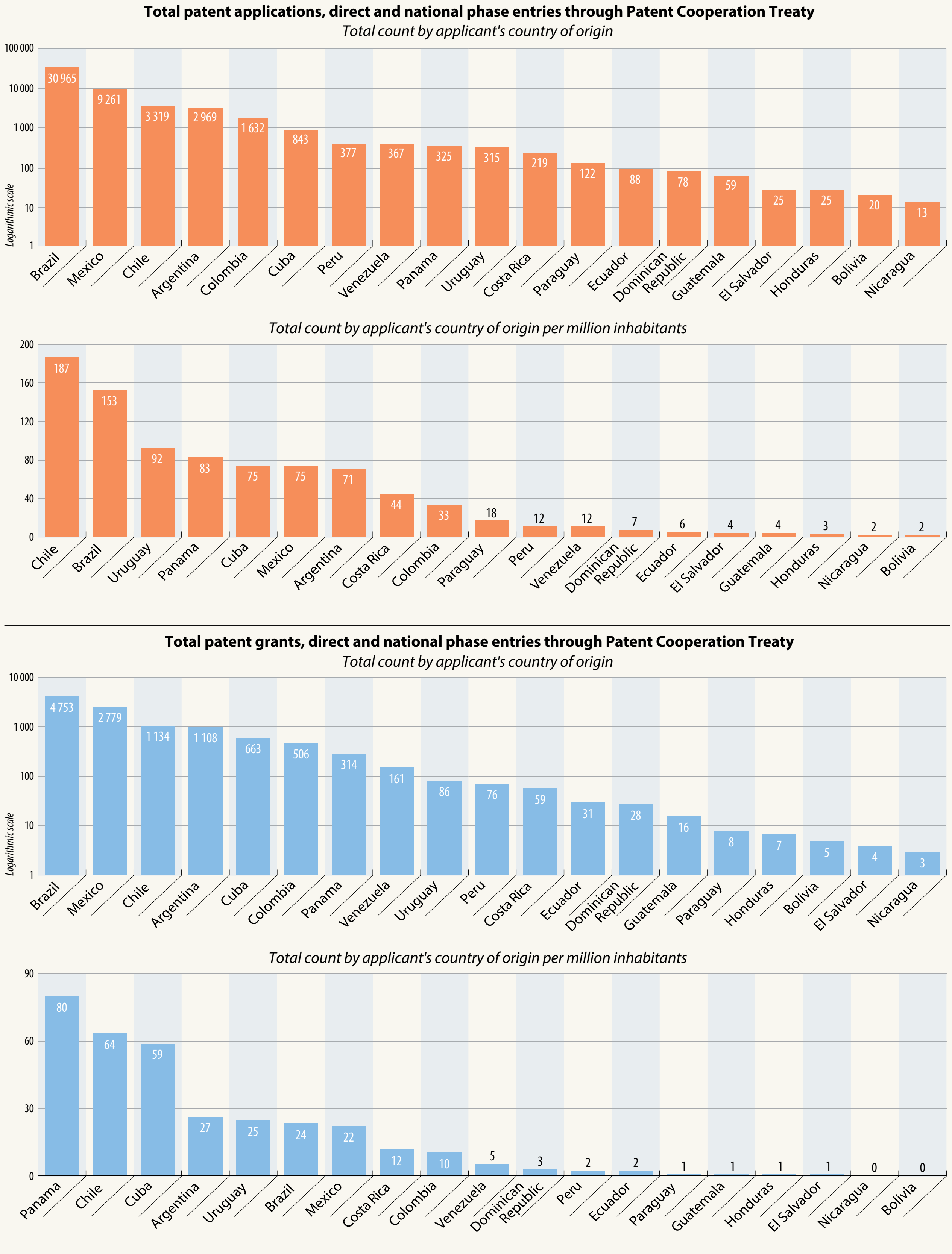
In 2013, the Mexican National Council for Science and Technology (CONACYT) stated that, within its strategic areas of growth, 'innovation will be oriented towards benefiting the less fortunate, with indigenous groups to receive special attention'. CONACYT subsequently announced a Call for Research into Indigenous and Intercultural Education and launched the Academic Strengthening Programme for Indigenous Peoples: Complementary Support for Scholarship-holding Indigenous Women. A third programme provides indigenous peoples with scholarships to pursue postgraduate study overseas.

Although indigenous knowledge is not highlighted in Argentina's national plan for STI entitled *Innovating Argentina 2020* (2013), a series of initiatives have been implemented to incorporate indigenous knowledge systems into innovation processes. Two examples are the projects on Rescuing Ancestral Technologies of Water, Land and Indigenous Farming Conservation as a Means of Adaptation to Climate Change (2009) and for the Industrialization of Fine Camelid Fibre for Social Inclusion (2013).

Last but not least, the Brazilian Ministry of Science and Technology plans to develop an approach to recording, protecting, promoting, diffusing and adding value to traditional knowledge that would not be centred exclusively on patents. In parallel, the Traditional Communities Programme – Science and Technology – is supplying indigenous villagers and communities with technology to make their lives easier.

Source: Ernesto Fernandez Polcuch and Alessandro Bello, UNESCO

Figure 7.9: **Patent applications and grants in Latin America, 2009–2013**



Source: Source: WIPO (2015)

There is a growing tendency among public research institutions to obtain patents in areas related to natural resources, such as mining and, above all, agriculture. This is true, for example of the Brazilian Agricultural Research Company (Embrapa) the National Institute for Agricultural Technology (INTA) in Argentina and the National Institute of Agricultural Research (INIA) in Uruguay.

The top four applicants in Latin America between 1995 and 2014 all came from Brazil: Whirpool SA, a subsidiary of the Whirlpool Corporation in the USA (engines, pumps, turbines), with 304 applications; Petrobrás (basic material chemistry), with 131 applications; the Federal University of Minas Gerais in Brazil (pharmaceuticals), with 115 applications, and Embraco (engines, pumps, turbines), with 115 applications (WIPO, 2015).

The quest for innovation policies that work

Innovation surveys are becoming standard practice in several Latin American countries. Since the mid-1990s, no fewer than 60 innovations surveys have been conducted in 16 countries (Table 7.3). Argentina has conducted nine surveys, for instance, Chile eight, Mexico seven and Brazil and Colombia five each (see Chapter 8 on the outcome of Brazil's most recent innovation survey). In the region, small and medium-sized enterprises (SMEs) account for 99% of all firms and generate 40–80% of jobs (ECLAC, 2015a).

Whatever companies may say in innovation surveys, businesses contribute little to R&D. This is a pity, since local industry could exploit demand for innovation to strengthen its own competitiveness. Innovation capital measures a firm's capacity to innovate and disseminate this innovation. In Latin American countries, capital stock represents just 13% of the economy, on average, less than half the OECD average (30%). More than 40% of Latin American knowledge-based capital stock comes from tertiary education (5.6% of GDP), compared to only 10% (1.3% of GDP) from R&D, the core driver of innovation.

According to Crespi *et al.* (2014), the private return on innovation in Latin America depends on the type of innovation, being larger for product innovation than for process innovation (see also Chapter 2). The same is true of spillovers, suggesting that the wedge between the private and social return on innovation could be higher in the case of product innovation, something that could guide policy for this type of innovation. The study also shows that the typical multinational firms operating in Latin America are less prone to invest locally in R&D and, consequently, less likely to innovate. Crespi and Zuniga (2010) found that, in Argentina, Chile, Colombia, Costa Rica, Panama and Uruguay, firms that invested in knowledge were capable of introducing new technologies. Firms that innovated also had greater labour productivity than those that did not. Crespi *et al.* (2014) take into account the oft-observed fact that firms in developing countries rarely undertake formal R&D on the edge of the technology curve. Rather, these firms focus on the difficult processes of acquiring and absorbing new technologies efficiently. Other national and regional studies suggest that

Table 7.3: **Percentage of manufacturing firms in Latin America engaged in innovation**
Selected countries

	Year/Period	Share of manufacturing firms that engaged in in-house R&D (%)	Share of manufacturing firms that engaged in contracted-out (external) R&D (%)	Share of manufacturing firms that acquired machinery, equipment and software (%)	Share of manufacturing firms that acquired external knowledge (%)	Share of manufacturing firms that engaged in training (%)	Share of manufacturing firms that engaged in market innovation (%)	Total number of innovation surveys conducted in country
Argentina	2007	71.9	19.3	80.4	15.1	52.3	–	9
Brazil	2009–2011	17.3	7.1	84.9	15.6	62.8	33.7	5
Colombia	2009–2010	22.4	5.8	68.6	34.6	11.8	21.4	5
Costa Rica	2010–2011	76.2	28.3	82.6	38.9	81.2	–	4
Cuba	2003–2005	9.8	41.3	90.2	36.6	22.1	83.8	2
Ecuador	2009–2011	34.8	10.6	74.5	27.0	33.7	10.6	1
El Salvador	2010–2012	41.6	6.7	–	–	–	82.7	1
Mexico	2010–2011	42.9	14.5	35.4	2.6	12.5	11.4	7
Panama	2006–2008	11.4	4.7	32.2	8.5	10.0	–	3
Uruguay	2007–2009	38.7	4.3	78.2	14.5	50.2	–	5

Note: The following countries have also conducted a series of innovation surveys in the region: Chile (8), Dominican Republic (2), Guatemala (1), Paraguay (2), Peru (3) and Venezuela (2).

Source: UNESCO Institute for Statistics; see also Chapter 2 of the present report the major challenge facing the region will be to overcome the institutional weakness of the organizations responsible for co-ordinating research and innovation policies.[14]

Brazil and, to a lesser degree, Argentina, Chile and Mexico, have all made progress towards an integrated public innovation policy by creating sectorial funds and linking industrial policy to the fund's objectives in terms of innovation. However, in most of Latin America, STI policies are rarely indexed on skills and industrial policies tend to be limited and compartmentalized (CEPAL, 2014; Crespi and Dutrénit, 2014).

In Colombia, the government uses three main mechanisms to support business investment in R&D. Firstly, under the guidance of Colciencias and other relevant government bodies, the National Development Bank provides preferential credits at below-market interest rates for projects involving innovation. Secondly, a tax incentive scheme offers exemptions of up to 175% on investment made in R&D during the taxable period. Thirdly, various government agencies provide firms with subsidies for their activities related to research and innovation.

The Peruvian National Council for Science, Technology and Technological Innovation (CONCYTEC) has been directly linked to the Presidency of the Council of Ministers since 2011; its budget soared from US$ 6.3 million to around US$ 43 million between 2012 and 2014. In parallel, new policy instruments have been launched to reduce bottlenecks in the innovation system and increase business R&D, including a 30% tax deduction on related activities since 2013 and a fund to finance credit guarantees or risk-sharing mechanisms for business through the financial system.

Mexico introduced a stimulus programme for innovation in 2009 that has three elements: INNOVAPYME (for small and medium-sized enterprises), PROINNOVA (for new and potential technologies) and INNOVATEC (for large firms). The latter operates as a grant scheme with matching funds; in 2014, the public budget amounted to U$ 295 million. The Fund for Fostering Science, Technology and Innovation at Regional Level (FORDECYT) complements this stimulus programme; the fund focuses on problem-solving projects in different regions by fostering scientific research, technological development and high-impact innovative solutions, as well as specialized training.

Other schemes target sectors in which countries have a competitive edge but could still do better. Examples are the Agriculture Technology Fund in Peru (INCAGRO-FTA) and, in Chile, the Fishing Research Fund (FIP) and Agriculture Research Fund (FIA).

Adopted in 2012, *Innovative Argentina 2020* promotes synergy in the national innovation system through the creation of clusters in 'strategic socio-productive hubs' with a high socio-economic and technological impact. The new cluster of biorefineries is one example; it groups research in bio-energy, polymers and chemical compounds. Four pilot plants have been created under agreements between public research and education institutions in the productive sector. These plants will house applied research and be used for training experts in the field. This model builds on success stories from the 1970s, such as the creation of the Chemical Engineering Pilot Plant (PLAPIQUI) within a consortium involving the National University of the South, the National Council for Scientific and Technical Research (CONICET) and the Petrochemical Pole Bahía Blanca. PLAPIQUI now produces a wealth of patents, scientific papers and PhDs theses.

The private sector has become more proactive in pushing innovation up the public policy agenda. There are a number of business councils, including the Competitiveness and Innovation Council in Chile (est. 2006) and the Private Competitiveness Council in Colombia (est. 2007) Private firms also participate forcefully in the preparation of Peru's competitiveness agenda. In addition, the private sector participates in many councils, such as in the Scientific and Technological Advisory Forum in Mexico (est. 2002) or the Advisory Commission on High Technology Foundation (CAATEC) in Costa Rica.

In parallel, a number of Latin American cities are introducing tax incentives and other mechanisms to turn themselves into innovation hubs and are starting to invest heavily in technology and innovation. Examples are Buenos Aires and Bariloche (Argentina), Belo Horizonte and Recife (Brazil), Santiago (Chile), Medellin (Colombia), Guadalajara and Monterrey (Mexico) and Montevideo (Uruguay).

A conscious use of innovation for social inclusion

Research and innovation for social inclusion can be defined as a process and an outcome which generate benefits for the disenfranchised. In recent years, this field has generated a mass of theoretical and empirical research and policy instruments (Table 7.1, item h) [Thomas *et al.*, 2012; Crespi and Dutrénit, 2014; Dutrénit and Sutz, 2014]. Most of these studies have revealed the inadequacy of local STI agendas to meet the population's needs and identified the value of using available technologies to foster social inclusion.

In 2010, Uruguay approved the first *National Strategic Plan for Science, Technology and Innovation* (PENCTI) to recognize the importance of social inclusion. In Bolivia, Colombia, Ecuador and Peru, the diagnosis of pressing problems has been aligned with national, regional and/or sectorial needs.

14. See, for example, the OECD's *Reviews of Innovation Policy in Panama* (2015), *Colombia* (2014) and *Peru* (2013), as well as the OECD's regional studies of Chile and Mexico (2013a, 2013b), or UNCTAD studies on El Salvador and Dominican Republic (UNCTAD, 2011, 2012). For regional coverage, see Crespi and Dutrénit (2014) and IDB (2014) or, for Central America as a whole, Pérez *et al.* (2012).

In particular, there has been a desire to reorient STI, traditional knowledge and know-how towards the search for solutions to national and local problems, be they related to production, social or environmental ills. (See the article by Bortagaray and Gras in Dutrénit and Crespi, 2014.)

In Colombia, Ideas for Change (2012), a Colciencias programme, is turning innovative thinking into the source of practical solutions for the poor and excluded. This offers a fresh perspective and helps spread the word that technology and innovation are not only important for firms and research institutions but also for society at large (IDB, 2014). Similar policy instruments have been implemented in Brazil by the Agency for Funding Innovation Studies and Projects (FINEP), namely the Development and Diffusion of Technologies with a High Social Impact (Prosocia) and Housing Technologies (Habitare). In Mexico, two examples are the Sectorial Fund for Research and Development related to Water and the Sectorial Research Fund for Social Development. In Uruguay, the project for Educational Connectivity of Basic Computing for Online Learning (CEIBAL) has generated a surprisingly large number of innovative technical and social solutions beyond the original one learner, one notebook programme.

Meanwhile, Peru has subsumed technology transfer in poverty alleviation programmes; these schemes have met with relative success in strengthening production chains and conglomerates. Examples are the Innovation and Competitiveness Programme for Peruvian Agriculture, the INCAGRO Project; and the network of Technological Innovation Centres (CITEs) run by the Ministry of Production. The latter two projects were implemented independently from the national innovation system: whereas INCAGRO showed impressive results, CITEs required more funding to expand its coverage and upgrade the services it offers.

GROWTH AREAS FOR R&D

Argentina and Brazil seeking space autonomy

Several Latin American countries have dedicated space agencies (Table 7.4). Taken together, they invest more than US$ 500 million per year in space programmes. In the late 1980s and 1990s, Brazil invested almost US$ 1 billion in developing space infrastructure around the National Institute of Space Research (INPE), leading to the launch of the first scientific satellite built entirely in Brazil in 1993 (SCD-1). Argentina's first scientific satellite (SAC-B) was launched in 1996 to advance the study of solar physics and astrophysics. Both countries have now achieved the critical mass of skills and infrastructure required to dominate several space technologies. Both exhibit a determination to master the complete chain of space technologies, from material sciences, engineering design, remote sensing, aperture-synthetic radars, telecommunications and image processing to propulsion technologies.

ARSAT-1, the first communication satellite built entirely in Latin America, was placed in a geostationary orbit around the Earth in October 2014. It was constructed by INVAP, a public Argentinian company, at a cost of US$ 250 million. With this feat, Argentina has become one of only ten countries to possess this technology. This is the first of a constellation of three geosynchronous satellites that will serve Argentina and other countries in the region. ARSAT-2 was launched in September 2015 from French Guyana and ARSAT-3 is due to be launched in 2017.

A new generation of scientific satellites is ready to be launched. The SAOCOM 1 and 2 Earth observation series will use remote-sensing data that incorporate a synthetic aperture radar designed and built in Argentina. The joint Argentinian–Brazilian SABIA-MAR mission will be studying ocean ecosystems, carbon cycling, marine habitats mapping, coasts and coastal hazards, inland waters and fisheries. Also under development is the new SARE series designed to expand the active remote observation of Earth through the use of microwave and optical radars. Argentina is also developing new launching technologies through the TRONADOR I and II projects.

Time for sustainability science in Latin America

In 2009, sustainable development was recognized as a priority by a series of regional fora involving ministers and other high-ranking public authorities in Latin America (UNESCO, 2010). The decision-makers acknowledged that Latin America possessed certain characteristics that required a specific research agenda for regional co-operation focusing on sustainability science.

Latin America harbours many of the world's biodiversity hotspots and the globe's largest carbon sink on land. The region counts one-third of the world's freshwater reserves and 12% of its arable land. Several countries have high potential for the use and development of clean and renewable energy sources.

The subcontinent also has one the highest rates of biodiversity loss, owing to the conversion of natural ecosystems; conservation and sustainable management of natural ecosystems is also hampered by the expansion of the agricultural frontier and problems related to land tenure and accreditation of rural properties. The Caribbean and Central America are also highly vulnerable to tropical cyclones, in particular. Coastal and watershed ecosystems are being degraded, as urban sprawl raises pollution levels and fuels demand for resources and energy (UNESCO, 2010).

Scientists are concerned about the environmental impact of Nicaragua's plans to dig a canal linking the Atlantic and Pacific Oceans that would pass through Lake Nicaragua, Central America's key freshwater reservoir. In June 2013, Nicaragua's National Assembly passed a bill granting a 50-year concession to a private firm based in Hong Kong (China).

Table 7.4: **National space agencies and main national space technology suppliers in Latin America**

Country	Institution	English name	Founded	Specialization
Argentina	Comisión Nacional de Investigaciones Espaciales (CNIE)	National Commission for Space Research	1960–1991	Propulsion systems and rocket development; projects CONDOR I & II, capacity-building
Argentina	Comisión Nacional de Actividades Espaciales (CONAE)	National Space Activities Commission	1991	Design and planning of the space programme, operation of the Cordoba Space Centre, capacity-building. Design of satellites SAC-A, SAC-B, SAC-C, SAC-D/Aquarius, SAOCOM 1 & 2, SABIA-MAR, SARE and propulsion systems TRONADOR I & II
Argentina	INVAP	Public company in nuclear and space technologies	1976	Technology design and construction of the satellites SAC-A, SAC-B, SAC-C, SAC-D/Aquarius, SAOCOM 1 & 2, SABIA-MAR, SARE, ARSAT I, II & III
Bolivia	Agencia Boliviana Espacial (ABE)	Bolivian Space Agency	2012	*Tupak Katari* (2013), a communication satellite developed in China
Brazil	Comissão Nacional de Atividades Espaciais (CNAE)	National Commission of Space Activities	1963–1971	Space propulsion studies, several rocket launchings, remote sensing analysis, capacity-building
Brazil	Agência Espacial Brasileira (AEB)	Brazilian Space Agency	1994	Design and planning of the satellites CBERS (Sino-Brazilian Earth Resources Satellite), Amazônia-1 (2015), EQUARS, MIRAX, SCD1, SCD2
Brazil	Instituto Nacional de Pesquisas Espaciais (INPE)	National Institute of Space Research	1971	Construction and technological design of the satellites SCD-1, CBERS (see AEB), Amazônia-1 (2015), EQUARS, MIRAX, Satélite Científico Lattes, Satélite GPM–Brasil, SARE, SABIA-MAIS
Colombia	Comisión Colombiana del Espacio (CCE)	Colombian Space Commission	2006	Planning for space applications
Costa Rica	Asociación Centroamericana de Aeronáutica y el Espacio (ACAE)	Central American Association for Aeronautics and Space	2010	Planning for space applications; design of a picosat satellite project (2016)
Mexico*	Agencia Espacial Mexicana (AEM)	Mexican Space Agency	2010	Planning for space research and applications
Peru	Agencia Espacial del Perú (CONIDA)	Space Agency of Peru	1974	Planning for space research and applications
Uruguay	Centro de Investigación y Difusión Aeronáutico-Espacial (CIDA-E)	Aeronautics and Space Research and Diffusion Centre	1975	Space research and popularization
Venezuela	Agencia Bolivariana para Actividades Espaciales (ABAE)	Bolivarian Agency for Space Activities	2008	Planning for space research and popularization

* In 1991, the National Autonomous University of Mexico (UNAM) started building scientific satellites. The first (UNAMSAT-1) was destroyed during the launch in 1996; UNAMSAT-B operated in orbit for one year.

Note: For details of the CBERS programme, see the chapter on Brazil in the *UNESCO Science Report 2010.*

Source: Compiled by author

As of August 2015, construction of the controversial shipping route had not yet commenced.

The complex nature of sustainable development, in which biogeophysical, economic and social processes tend to overlap, demands a transdisciplinary approach to implementing the regional research agenda (Lemarchand, 2010), combined with new financial schemes to support related R&D at the regional level and capacity-building in sustainability science (Komiyama *et al.,* 2011).

In the past two decades, the publication of scientific articles on topics related to sustainable development has grown 30% faster in Latin America than in the rest of the world. This trend underlines the growing interest in sustainability science in Latin America. However, there is currently a lack of graduate programmes in Latin America (and elsewhere) in sustainability science. In 2015, the United Nations University in Tokyo launched the world's first PhD programme in sustainability science. Universities in Latin America should also develop PhD programmes in this new interdisciplinary field.

Renewable energy could have a bright future

By early 2014, at least 19 Latin American countries had renewable energy policies and at least 14 had adopted relevant targets, mostly concerning electricity generation. Uruguay aims to generate 90% of its electricity from renewable sources by 2015. Despite having an average electrification rate of almost 95%, one of the highest among developing regions, access to energy remains a challenge: an estimated 24 million people living mainly in rural and remote areas still lack access to electricity in Latin America.

Most Latin American countries have adopted regulatory policies and fiscal incentives (Table 7.5) to drive the deployment of renewable energy. The use of public competitive bidding has gained momentum in recent years, with Brazil, El Salvador, Peru and Uruguay all issuing tenders in 2013 for more than 6.6 GW of renewable electric capacity. The more clement environment for renewable sources of energy is attracting new national and international investors.

The Brazilian government has nevertheless cut back its own commitment to energy research from 2.1% (2000) to 0.3% (2012). Renewable energy has been the primary victim of these cuts, including the bioethanol industry, as public investment has increasingly turned towards deep-sea oil and gas exploration off Brazil's southeast coast (Chapter 8).

The manufacture of 'green' technologies such as wind turbines is spreading across the region. However, differences in electricity market structures and regulations have so far hampered efforts to integrate regional electricity markets and the lack of transmission infrastructure has delayed some projects. The main obstacle is the impossibility of compensating for fluctuations in the supply of renewable energy from one country to another.

Nevertheless, the region is demonstrating unprecedented growth, with strong opportunities for further expansion. In 2014, Brazil ranked second worldwide for its hydropower capacity (89 GW) and biodiesel/ethanol fuel production, fifth for its solar water heating capacity (6.7 GW) and tenth for wind power (5.9 GW). Mexico is the world's fourth-biggest producer of geothermal power (1 GW). Both Chile and Mexico have boosted their own capacity in wind and solar energy and Uruguay has raised wind capacity per capita more than any other country. Other innovative applications are spreading, such as solar food-dryers in Mexico and Peru to process fruits and coffee. Long-term incentives for industry and technological development will be needed to guarantee that these schemes are implemented fully.

Strong growth in ICT usage...

The region uses about 5% of the world's public cloud services, less than its share of global GDP (8.3% in 2013, see Table 1.1). Nevertheless, estimated annual growth of 26.4% means that

Table 7.5: **Existing regulatory policies and fiscal incentives in Latin America for renewable energy, 2015**

Countries	Regulatory policies						Fiscal incentives and public financing				
	Feed-in tariff/ premium payment	Electric utility quota obligation/ Renewable portfolio standards	Net metering	Biofuels obligation/ mandate	Heat obligation/ mandate	Tendering	Capital subsidy, grant or rebate	Investment or tax production credits	Reduction in sales, energy, carbon, VAT or other taxes	Energy production payment	Public investment, loans or grants
Argentina	●		●	●		●	+	+	+	+	+
Brazil			●	●	●	●		+	+		+
Chile		●	●			●	+	+	+		+
Colombia			●	●				+	+		+
Costa Rica	●		●	●		●			+		
Dominican Rep.	●		●			●	+	+	+		+
Ecuador	●			●		●			+		+
El Salvador						●		+	+	+	+
Guatemala			●	●		●		+	+		
Honduras	●		●			●		+	+		
Mexico			●			●		+			+
Nicaragua	●								+		
Panama	●		●	●		●		+	+	+	
Paraguay				●					+		
Peru	●	●		●		●			+		+
Uruguay	●		●	●	●	●	+		+	+	+

Note: Data are unavailable for Bolivia, Cuba and Venezuela. VAT stands for value-added tax.

Source: REN21 (2015) *Renewables 2015: Global Status Report*, pp. 99–101. Renewable Energy Policy Network for the 21st Century: Paris these services will be adopted more quickly than in Western Europe. The strong growth forecast for cloud computing in Latin America is affirmed by the distribution of workloads among cloud data centres in the region, which is expected to grow from 0.7 million to 7.2 million workloads between 2011 and 2016, with a compound annual growth rate of 60% (ECLAC, 2015c).

However, firms in Latin America face several obstacles in adopting ICT technologies. They incur high fixed costs associated with purchasing and maintaining hardware and software and adapting it to production processes, owing to limited ICT literacy in the region (IDB, 2014). Another key problem affecting the dissemination of broadband service concerns the high rates charged for the service in relation to per-capita income. Whereas, in the EU, economy service rates are equivalent to around 0.1% of per-capita income, in Latin America, they range from 0.6% in Chile and Mexico to nearly 21% in Bolivia (CEPAL, 2015).

Over the past two decades, Costa Rica's technology sector has grown into one of Latin America's most dynamic industries. The main focus of the sector's more than 300 companies is on developing software for local and international markets. Costa Rican industry also plays an important role in manufacturing and high-tech exports, as we saw earlier, although the departure of Intel will affect this market.

Various sectorial funds and tax incentives have been designed for the software industry to improve the productivity and innovation capacity of SMEs. One successful example of competitive funds is the aforementioned FONSOFT in Argentina, another is PROSOFT in Mexico. Both funds have a diverse set of policy instruments to improve the quality of software production and foster linkages between academia and industry. These sectorial funds emphasize collaboration between public research institutions, technology transfer, extension services, export promotion and industrial development.

A study by the Inter-American Development Bank (BID, 2014) forecasts that, by 2025, Buenos Aires, Montevideo, San José, Córdoba and Santiago will be the five most important poles for the development of the ICT and software industries. By that time, business processing outsourcing is expected to employ 1.2 million people and generate sales of US$ 18.5 billion in Latin America.

... and in biotechnology

The impact of research and innovation on biotechnology in Latin America has been very well documented (Sorj *et al.* 2010, Gutman and Lavarello, 2013; RICYT, 2014). Although the bulk of progress in biotechnology has been circumscribed to a handful of research centres and corporations in developed countries, a number of public research institutions in Latin American countries have also contributed since the mid-1950s. However, the networks and nodes of these institutions are usually located in developed countries and the respective technologies are not automatically transferred. This state of affairs offers broad opportunities for local development.

Up until now, investment in biotechnology has been directed more towards higher education and creating skills in the public sector than towards R&D. This has created a fertile terrain for private firms wishing to recruit locally. As shown above, agriculture and health consume the bulk of investment in several countries. Some 25% of publications from the region concern biological sciences and 22% medical sciences (Figure 7.8). One of the most prolific institutions for patenting in pharmaceuticals is the Universidade Federal de Minas Gerais (Brazil) and, in agribusiness, one could cite Embrapa (Brazil), INTA (Argentina) and INIA (Uruguay).

A relatively modest number of enterprises specialize in technology transfer (Gutman and Lavarello, 2013; Bianchi, 2014). Figuring among the most innovative biotechnology firms in the region are: Grupo Sidus (Biosidus and Tecnoplant), Biogénesis-Bagó, Biobrás-Novo Nordik, Biomm, FK Biotecnología, BioManguinos, Vallée, Bio Innovation, Bios-Chile, Vecol and Orius.

According to the Brazilian National Confederation of Industry, the main areas for research within the Brazilian agricultural innovation system are biotechnology, bioreactors, plant- and animal- assisted reproduction, forest biotechnology, germplasm collection and conservation, plant resistance to biotic and abiotic stresses, genetically modified organisms and bioprospection. There are also a few examples of R&D contracts between public and private companies. Embrapa is carrying out research with all of the following, for instance: Monsanto (USA), BASF (Germany), DuPont (USA) and Syngenta (Switzerland). There are also R&D contracts in Brazil for seed production with non-profit organizations, such as Unipasto and Sul Pasto, and with foundations (Meridional, Triângulo, Cerrado, Bahia and Goiás).

The Biotech project is an interesting example of subregional co-operation designed to take better advantage of existing research skills to foster competitiveness in productive sectors within the MERCOSUR space.[15] The second phase, Biotech II, addresses regional projects in biotechnological innovation linked to human health (diagnosis, prevention and the development of vaccines against infectious diseases, cancer, type 2 diabetes and autoimmune diseases) and biomass production (traditional and non-traditional crops), biofuel elaboration processes and evaluation of its by-products. New criteria have been incorporated to respond to demand from participating consortia for a greater return on investment and the participation of more partners, such as from Europe.

15. See: www.biotecsur.org

COUNTRY PROFILES

UNESCO's Global Observatory of STI Policy Instruments (GO→SPIN) provides a complete description of the national innovation system for all 34 countries of Latin America and the Caribbean, with regular updates every six months.[16] Given the sheer size of the region, we summarize the most important developments since 2010 only for those countries with a population of more than 10 million. For a profile of Brazil, see Chapter 8.

ARGENTINA

Investment in STI has accelerated

Argentina has enjoyed a decade of strong growth (*circa* 6% per year until 2013) that was partly underpinned by high commodity prices. With the end of the cyclical commodities boom, however, rising subsidies and a strong currency, combined with unresolved issues from the country's 2001 debt crisis, have begun to affect trade. The Argentine economy grew by just 0.5% in 2014, as healthy public consumption (+2.8%) was offset by a 12.6% drop in imports and an 8.1% drop in exports (ECLAC, 2015a). Faced with an unemployment rate of 7.1% in the first quarter of 2015, Congress passed a bill cutting back employer contributions for micro-enterprises and payroll taxes for larger businesses that created jobs.

Between 2008 and 2013, research infrastructure expanded in Argentina as never before. Since 2007, the government has built more than 100 000 m^2 of new laboratories, with another 50 000 m^2 under construction in September 2015. Spending on R&D almost doubled between 2008 and 2013 and the number of researchers and publications progressed by 20% and 30% respectively (Figures 7.5, 7.6 and 7.8).

In 2012, the Ministry of Science, Technology and Productive Innovation (MINCYT) launched the *National Science, Technology and Innovation Plan: Innovative Argentina 2020*. The plan prioritizes the most scientifically underdeveloped regions by assigning 25% of all new posts at the National Scientific and Technological Research Council (CONICET) to these regions. The plan is organized in a matrix composed of six strategic areas (agro-industry; energy; environment and sustainable development; health; industry; and social development) and three general-purpose technologies: biotechnologies, nanotechnologies and ICTs.

The creation of the Argentine Sectorial Fund (FONARSEC) by MINCYT in 2009 accelerated the shift from horizontal to vertical policy instruments. Its mission is to establish public–private partnerships, in order to improve competitiveness in the following sectors: biotechnology, nanotechnology, ICTs, energy, health, agribusiness, social development, environment and climate change.

The establishment of the Interdisciplinary Centre for the Study of Science, Technology and Innovation (CIECTI) in 2015 should give MINCYT an enormous boost, as the ministry will henceforth be able to draw upon the findings of strategic studies and foresight exercises prepared by CIECTI when designing future policies.

More than one in ten FTE researchers in Argentina were involved in some form of international collaboration between 2007 and 2013, through a total of 1 137 research projects in other countries. In some cases, this collaboration involved Argentine researchers working with foreigners who had completed internships in Argentinian institutions as part of their postdoctoral training.

BOLIVIA

A focus on communitarian and productive research

Bolivia continues to show healthy growth: 5.4% in 2014, with projections of 4.5% in 2015 (ECLAC, 2015a). The government is promoting the industrialization of the hydrocarbons sector, as well as the extraction of natural gas and lithium, through the Investment Promotion Act (2014) and the Mining and Metallurgy Act (2014). Other projects include boosting exports of electricity to Argentina and Brazil (ECLAC, 2015a).

The government elected in 2005 has adopted a new communitarian productive model to ensure that surplus production serves the collective need, as part of the planned transition from capitalism to socialism. According to this model, the four strategic sectors capable of generating a surplus for Bolivians are identified as being hydrocarbons, mining, energy and environmental resources; rather than using this surplus to drive exports, the new model advocates using it to develop employment-generating sectors such as manufacturing, tourism, industry and agriculture.

Since 2010, the design of S&T policies has fallen under the supervision of the Ministry of Education. A series of programmes have been proposed within the *Institutional Strategic Plan 2010–2014*, including the Bolivian System of Scientific Information and Technology (SIBICYT) and the Bolivarian Innovation System. Within the plan, the Innovation, Research, Science and Technology Programme lays the groundwork for the following policy instruments:

- the conduct of communitarian and productive research at the country's public technical institutes;

16. See: http://spin.unesco.org.uy

- the creation of centres for research and innovation in textiles, leather, wood and camelids – Bolivia is thought to have the greatest number of llamas in the world;
- the development of research and innovation networks in biodiversity, food production and land and water management – some of these networks comprise more than 200 researchers from both public and private institutions distributed in various regional and national working groups; and
- the creation of a fund for STI.

CHILE

A desire to embrace the knowledge economy

Chile's economy grew by 1.9% in 2014, slowing markedly from 4.2% in 2013. An expansion of 2.5% is forecast in 2015, driven by a surge in public spending and positive developments in the external sector (ECLAC, 2015a). Chile is the major recipient of FDI in the region. In 2014 alone, it received more than US$ 22 billion. Chile has a higher proportion of private funding for education than any other OECD member country, with 40.1% of education spending coming from private sources (16.1% average for OECD countries). Chile was the highest scoring Latin American country in the PISA 2012 mathematics test but still 71 points behind the OECD average.

In Chile, it is the Office of the President of the Republic which leads the national innovation system, under the direct guidance of the National Innovation Council for Competitiveness (CNIC). The latter proposes general guidelines for the development of a *National Innovation Strategy*. The Interministerial Innovation Committee then evaluates these criteria before establishing short-, medium- and long-term national STI policies; it also monitors the implementation of the *National Innovation Strategy*.

The Ministries of Education and of the Economy play a leading role in the Interministerial Innovation Committee, their participation being channelled through the main public institutions with a focus on STI, namely, the National Commission for Scientific and Technological Research (CONICYT) and the *InnovaChile* wing of the Corporation for the Promotion of Production (CORFO). The latter[17] supports sectors with high-growth potential, through funding for SMEs and the nurturing of an early-stage seed capital industry.

The government's *Agenda for Productivity, Innovation & Economic Growth for 2014–2015* reflects the desire to move from an economy based on natural resources to one based on knowledge by diversifying the economy and supporting sectors with strong growth potential. CORFO is a key partner in this intiative.

By March 2012, the government had already modified its R&D tax credit framework to make it easier for firms to innovate. The reform abolished both the eligibility requirements for collaboration with external research centres and the requirement to invest at least 15% of the company's gross annual revenue in R&D. In a move questioned by some, the revenue from royalties levied on all mining operations was used to finance R&D cluster development in priority sectors.

In January 2015, President Michelle Bachelet established a Presidential Commission composed of 35 experts on the theme of Science for Chile. Their mandate is to elaborate a proposal as to how to foster STI and a broad scientific culture. They are considering the possibility of creating a Ministry of Science and Technology.

COLOMBIA

A greater focus on innovation

Colombia's economy grew by 4.6% in 2014. Growth projections for 2015 have been revised downwards, although they remain between 3.0% and 3.5% (ECLAC, 2015a). In June 2015, the government implemented a number of countercyclical policies known collectively as the *Productivity and Employment Stimulus Plan* to encourage investment and, thereby, limit the economic slowdown.

Colombia is preparing its entry into the OECD with the intention of adopting, adapting and implementing improved practices in a host of areas in relation to public governance, commerce, investment, fiscal issues, STI, environment, education and so on.

Colombia's innovation system is co-ordinated by the National Planning Department and the Colombian Institute for the Development of Science (Colciencias). In 2009, Colciencias was transformed into the Administrative Department for Science, Technology and Innovation with responsibility for formulating, co-ordinating, executing and implementing related public policies in line with the country's development plans and programmes.

In 2012, the government created *iNNpulsa Colombia* with the National Development Bank to support innovation and competitiveness, with a budget of US$ 138 million for the 2012–2013 period. Some 70% of Colciencias' Innovation Management Programme, on the other hand, was oriented towards micro-enterprises and SMEs (with a budget of US$ 20 million in 2013). Since 2009, Colciencias has been annually allocating US$ 0.5 million to support collaborative projects between firms and the academic sector. The General Royalties System Fund also now has a regional development focus as far as STI is concerned.

17. See www.english.corfo.cl

Between 2010 and 2014, Colciencias formulated a series of strategies for strengthening STI policies, such as *Vision 2025,* which seeks to position Colombia as one of the three most innovative countries in Latin America by 2025 and a world leader in biotechnology. The aim is for Colombia to be able to offer local, regional and global solutions to problems such as overpopulation and climate change, with a series of centres of excellence working on vector-transmitted diseases and the possibilities of interaction with other sectors: health, cosmetics, energy and farming.

Vision 2025 proposes generating 3 000 new PhDs, 1 000 annual patents and working with 11 000 companies by 2025. The programme will allocate US$ 678 million during 2011–2014, targeting researchers in the public and private sectors. In 2014, the government launched a Brain Repatriation Programme to woo 500 doctorate-holders from the diaspora over the next four years.

CUBA

Preparing incentives to attract investors

The Cuban economy grew by 1.3% in 2014 and is expected to expand by 4% in 2015. In 2014–2015, 11 priority sectors for attracting foreign capital were identified, including agrifood; general industry; renewable energy; tourism; oil and mining; construction; and the pharmaceutical and biotechnology industry (ECLAC, 2015a).

With the normalization of relations with the USA in 2015, Cuba is in the process of establishing a more attractive legal regime offering substantial fiscal incentives and guarantees for investors. Cuba is already one of the most popular destinations for Latin American university students (see p. 181).

Between 2008 and 2013, the number of Cuban scientific papers grew by 11%, even as GERD receded from 0.50% to 0.41% of GDP. In 2014, the government created the Financial Fund for Science and Innovation (FONCI) to enhance the socio-economic and environmental impact of science by boosting business innovation. This is a major breakthrough for Cuba, considering that, up until now, the bulk of R&D funding has come from the public purse.

DOMINICAN REPUBLIC

Growth restricted to economic 'enclaves'

Economic growth in the Dominican Republic has been high by regional standards, averaging 5.1% in the 12 years to 2013. However, this growth has not been accompanied by a significant reduction in poverty or inequality, contrary to trends in some other Latin American countries. Moreover, growth has been largely concentrated in what are sometimes described as economic 'enclaves' such as package tourism, export processing zones and mining, with little linkage to the broader economy.

Given the composition of sectors driving recent growth, it is not surprising that traditional indicators of industrial research intensity such as high-tech exports or patenting show little activity (Figures 7.3 and 7.9). Innovation surveys reported by UNCTAD (2012) show that the little firms invest in research comes mainly from their own treasury, suggesting weak public support and linkages with non-business actors.

Constitutional reforms adopted in January 2010 elevated the existing State Secretariat for Higher Education, Science and Technology to the rank of ministry. The Ministry for Higher Education, Science and Technology (MESCYT) has since been entrusted with developing national indicators of science and technology and with implementing a national programme to foster entrepreneurship. The ministry's *Strategic Plan for Science, Technology and Innovation 2008–2018* establishes research priorities in the following areas:

- Biotechnology;
- Basic sciences;
- Energy, with emphasis on renewable sources and biofuels;
- Software engineering and artificial intelligence;
- Innovation in processes, produce, goods and services;
- Environment and natural resources; and
- Health and food technology.

A number of key reforms recommended by UNCTAD's review of STI policy in the Dominican Republic would help coalesce public and private efforts in these priority sectors. These recommendations include a substantial increase in public investment in STI, fostering demand for STI through public procurement and the establishment of a formal status of researcher (UNCTAD, 2012).

ECUADOR

Investing in the knowledge economy of tomorrow

Ecuador's economy grew by 3.8% in 2014 but projections for 2015 have been revised downwards to 1.9%. The drop in the average price of Ecuadorian crude from US$ 96 a barrel in 2013 to US$ 84 in 2014 has meant that oil exports lost 5.7% of their value in 2014 even though their volume was up by 7% (ECLAC, 2015a).

Between 2008 and 2013, GERD tripled in PPP dollars, the number of researchers doubled (Figure 7.6) and scientific

Box 7.4: Ikiam: a university in the heart of the Amazon

The cities of Quito and Guayaquil group more than half of Ecuador's universities and polytechnics. Ikiam University (*ikiam* means 'forest' in Shuar) opened its doors in October 2014 in the heart of the Amazon. The first contingent of 150 students discovered a campus surrounded by 93 hectares of exceptional biodiversity; this protected territory will serve as an open-air laboratory for the students and researchers from Ikiam, who will be mainly studying pharmacology and the sustainable management of natural resources.

The aim is to turn Ikiam into Ecuador's first world-class university for teaching and research. All the professors hold a PhD and half are foreigners. The university offers levelling programmes to first-year students to overcome any shortcomings in their education up to the time of their admission.

In December 2013, an international workshop was organized in Misahuallí (Napo) to analyse Ikiam's future academic programme, as well as the university's organizational structure and research strategies. Ten Ecuadorian scientists participated, as well as 53 scientists from Australia, Belgium, Brazil, Canada, Germany, France, the Netherlands, South Africa, Spain, the UK, USA and Venezuela.

Source: www.conocimiento.gob.ec

output rose by 50% (Figure 7.8). In the past decade, public investment in education has quintupled from 0.85% (2001) to 4.36% (2012), one-quarter of which is devoted to higher education (1.16%). This steep rise in education funding is part of the government's wider strategy of developing a knowledge economy by reducing Ecuador's dependence on banana and oil revenue. A sweeping reform of higher education has been introduced to erect two of the pillars of any knowledge economy: quality training and research. In 2010, the Law on Higher Education established four flagship universities: Ikiam (Box 7.4), Yachay, the National University of Education and the University of the Arts. The law also introduced free education and a system of student scholarships to give a greater number of hopefuls the chance of a university education. In 2012, several private universities had to close because they did not respect the quality criteria defined by the law.

Flagship programmes put in place by the Secretariat for Higher Education, Science, Technology and Innovation (SENESCYT) include a sophisticated new system of scholarships for graduates to complete PhD programmes abroad and the construction of the City of Knowledge, modelled on similar cities in China, France, Japan, Republic of Korea and USA. Yachay (the word for knowledge in Quechua) is a planned city for technological innovation and knowledge-intensive businesses combining ideas, talent and state-of-the-art infrastructure. Together, these ingredients should be able to create a city that embodies the indigenous concept of *Buen Vivir* (good living). The city will be organized around five pillars of knowledge: life sciences, ICTs, nanoscience, energy and petro-chemistry. Yachay will host Ecuador's first University of Experimental Technological Research, which will be linked to public and private research institutes, technology transfer centres, high-tech companies and Ecuador's agricultural and agro-industrial communities, thereby becoming the first Latin American knowledge hub.

In 2013, legislation was passed certifying the status of scientific researcher and creating different categories of researchers. This normative step makes it possible to create special wages for researchers, according to their category of service.

GUATEMALA

A need to nurture its human capital

Guatemala's economy grew by 4.2% in real terms in 2014, up from 3.7% in 2013. Growth was driven by a surge in domestic demand among private consumers, in particular, along with low inflation, a rise in real wages and higher levels of bank lending to the private sector (ECLAC, 2015a).

Public spending on education has remained stable since 2006 at about 3% of GDP but only one-eighth of this goes to higher education, according to the UNESCO Institute for Statistics. Moreover, between 2008 and 2013, total expenditure on education slipped from 3.2% to 2.8% of GDP. Over this same period, GERD dropped by 40% (in PPP$) and the number of FTE researchers by 24%. Although scientific output increased by 20% (Figure 7.8), this progression is modest compared to that of other countries in the region. If we compare Guatemala with Malawi, a country with almost the same surface area and population, Guatemala's GDP is ten times that of Malawi but Malawi publishes almost three times the number of scientific articles. This suggests that Guatemala has fallen into the Sisyphus trap (see next section).

The National Council of Science and Technology (CONCYT) and State Secretariat for Science and Technology (SENACYT) now co-ordinate STI in Guatemala and are in charge of implementing policies in this area. In 2015, a National Plan for Science, Technology and Innovation to 2032 was under discussion to replace the existing plan. Guatemala disposes of a fairly wide range of funding mechanisms, including the Science and Technology Support Fund (FACYT), Science and Technology

Development Fund (FODECYT) and the Multiple Support to the National Plan Fund for Science and Technology (MULTICYT). These are complemented by the Technological Innovation Fund (FOINTEC) and the Science and Technology Emergency Activities Fund (AECYT). A grant from the Inter-American Development Bank in 2012–2013 has helped to operationalize these funds.

MEXICO

A 1% GERD/GDP target but no specific temporal horizon

Mexico, Latin America's second-largest economy after Brazil, grew by 2.1% in 2014 and is expected to do slightly better in 2015 (*circa* 2.4%), according to ECLAC. In 2014–2015, Mexico held intensive talks with EU countries with a view to opening negotiations on a new free trade agreement. According to the Mexican government, the aim is to update the agreement signed in 2000, in order to improve the access of Mexican goods and services to the European market, strengthen ties and create a transatlantic free trade area (ECLAC, 2015a).

Between 2008 and 2013, GERD (in PPP$) and scientific output progressed by 30% (Figure 7.8) and the number of FTE researchers by 20% (Figure 7.5). To improve the governance of the national innovation system, the government created the Office of Co-ordination of Science, Technology and Innovation in 2013 in the Office of the President. The same year, the National Council of Science and Technology (CONACYT) was ratified as the principal governing body for STI in Mexico.

The *National Development Plan 2013–2018* proposes making the development of STI the pillar of sustainable socio-economic growth. It also proposes a new Special Programme for Science, Technology and Innovation 2014–2018 to transform Mexico into a knowledge economy, with the normative target of reaching a 1% GERD/GDP target – but without any specific temporal horizon.

The number of doctoral programmes participating in the National Programme of Quality Postgraduate Studies increased from 427 to 527 between 2011 and 2013. In 2015, CONACYT supported around 59 000 postgraduate scholarship-holders. Mexico has been reorienting higher education programmes towards fostering entrepreneurial skills and an entrepreneurial culture. In 2014, the CONACYT Chairs Initiative planned to create 574 new positions for young researchers on a competitive basis and, in 2015, extended this programme to 225 additional new posts. Public support for research infrastructure increased tenfold between 2011 and 2013 from US$ 37 million to US$ 140 million.

As part of the drive to foster a knowledge economy, Mexico is creating or strengthening Technology Transfer Offices through its Sectorial Innovation Fund (FINNOVA) to encourage institutions that generate knowledge to establish linkages with the private sector through consulting, licensing and start-ups. In parallel, CONACYT has been stimulating business innovation through its Innovation Incentive Programme, which doubled its budget between 2009 and 2014 from US$ 223 million to US$ 500 million.

In 2013, Mexico proposed a new *National Climate Change Strategy* by raising the energy efficiency target by 5% for the national oil company, PEMEX, increasing the efficiency of transmission and distribution lines by 2% and the thermal efficiency of fuel oil-fired thermoelectric plants by 2%. The aim is to use endogenous research and a new sectorial fund known as CONACYT-SENER to reach these targets; the latter fund supports problem-solving in the areas of energy efficiency, renewable energy and 'clean and green' technologies.

To promote regional development, the government established the Institutional Fund for the Regional Development of Science, Technology and Innovation (FORDECYT) in 2009 to complement the existing Mixed Funds (FOMIX). FORDECYT receives both national (CONACYT) and state funds to promote R&D at the state and municipal levels. The new contribution ratio scheme for these two funding sources is respectively 3:1. The funds mobilized only amounted to US$ 14 million in 2013.

PERU

A new fund for innovation

The Peruvian economy grew by 2.4% in 2014 and is expected to progress by 3.6% in 2015, driven by a surge in mining output and, to a lesser extent, by higher public spending and the monetary stimulus created by lower interest rates and the increased availability of credit (ECLAC, 2015a).

GERD has been estimated at just 0.12% GDP (see the article by J. Kuramoto in Crespi and Dutrénit, 2014). Research and innovation policies in Peru are co-ordinated by the National Council of Science, Technology and Technological Innovation (CONCYTEC). Since 2013, CONCYTEC has been functioning in the orbit of the Presidency of the Council of Ministries. CONCYTEC's operational budget soared between 2012 and 2014 from US$ 6.3 million to US$ 110 million.

The *National Plan for Science, Technology and* Innovation 2006–2021 focuses on the following:

- Obtaining research results focused on the needs of the productive sector;
- Increasing the number of qualified researchers and professionals;
- Improving the quality of research centres;
- Rationalizing STI networking and system information; and

- Strengthening the governance of the national innovation system.

In 2013, the government created the Framework Fund for Innovation, Science and Technology (FOMITEC), allocating *circa* US$ 280 million for the design and implementation of financial and economic instruments fostering the development of research and innovation for competitiveness. The National Fund for Scientific and Technological Research and Technological Innovation (FONDECYT) received US$ 85 million in 2014, an increase over the previous year.

The government has introduced a scholarship programme for PhD candidates wishing to study abroad (*circa* US$ 20 million) and those planning to study at local universities (US$ 10 million).

VENEZUELA

Scientific output down

In 2014, the Venezuelan economy contracted by 4% with a double-digit inflation rate (ECLAC, 2015a). The number of FTE researchers increased by 65% between 2008 and 2013, the highest growth rate in the region. Scientific output has actually decreased by 28% over the past decade, however (Figure 7.8).

In 2010, a reform of the regulatory decree for the Organic Law for Science, Technology and Innovation (LOCTI) established that industrial and business sectors with higher revenues should pay a special tax to finance laboratories and research centres. The government prioritized a number of thematic areas to which these resources should be allocated: food and agriculture; energy; public safety; housing and urbanism; and public health. Plans for areas related to climate change and biological diversity have been developed and are being directed by the Ministry of the Environment.

After a series of ministerial reforms in 2015, the Popular Power Ministry for University Education, Science and Technology was made responsible for co-ordinating STI policy.

The online publication *Piel-Latinoamericana* reports that 1 100 out of the 1 800 doctors who graduated from medical school in Venezuela in 2013 have since left the country. Although precise numbers are unavailable, according to the President of the Venezuelan Academy of Physical, Mathematical and Natural Sciences, many researchers have emigrated in the past decade, most of them scientists and engineers, after becoming disillusioned with government policies. This is another example of the Sisyphus trap (see next section).

Table 7.6: **Institutions in Latin America and the Caribbean with the most scientific publications, 2010–2014**
Spanish-speaking countries of more than 10 million inhabitants

Argentina	CONICET (51.5%)	University of Buenos Aires (26.6%)	National University of La Plata (13.1%)	National University of Cordoba (8.3%)	National University of Mar del Plata (4.3%)
Bolivia	Major University of San Andres (25.2%)	Major University San Simon (10.7%)	Autonomous University Rene Moreno (2.6%)	National Historical Museum Noel Kempff Mercado (2.2%)	Bolivarian Catholic University San Pablo (1.5%)
Chile	University of Chile (25.4%)	Pontifical Catholic University of Chile (21.9%)	University of Conception (12.3%)	Pontifical Catholic University of Valparaiso (7.5%)	Austral University of Chile (6%)
Colombia	National University of Colombia (26.7%)	University of Antioquia (14.6%)	University of the Andes (11.9%)	University Valle (7.8%)	Pontifical University Javeriana (4.6%)
Cuba	University of Habana (23.4%)	Central University Marta Abreau las Villas (5.5%)	Genetic Engineering and Biotechnology Centre (5%)	University Oriente (4.9%)	Tropical Medicine Inst. Pedro Kouri (4%)
Dominican Republic	National University Pedro Henriquez Ureña (8%)	Santo Domingo Technological Institute (6%)	Ministry of Agriculture (4%)	Pontifical Catholic University Mother and Teacher (3%)	General Hospital Plaza Salud (3%)
Ecuador	San Francisco de Quito University (15.0%)	Pontifical Catholic University of Ecuador (11%)	Technical University of Loja (6.0%)	Polytechnic National School (5.4%)	University of Cuenca (3.7%)
Guatemala	University of the Valle (24.4%)	General Hospital San Juan de Dios (3.0%),	San Carlos University (2.5%)	Ministry of Public Health and Social Assistance (2.0%)	
Mexico	National Autonomous University of Mexico (26.2%)	National Polytechnic Institute of Mexico (17.3%)	Metropolitan Autonomous University of Mexico (5%)	Autonomous University of Puebla (2.1%)	Autonomous University of San Luis Potosi (2.9%)
Peru	University Cayetano Heredia (21.6%)	National University of San Marcos (10.3%)	Pontifical Catholic University of Peru (7.5%)	International Potato Centre (3.6%)	National Agrarian Univ. La Molina (2.5%)
Venezuela	Central University of Venezuela (23%)	IVIC (15.1%)	Simon Bolivar University (14.2%)	University of the Andes (13.3%)	Zulia University (11.1%)

Source: compiled by author from Thomson Reuters' Web of Science, Science Citation Index Expanded

CONCLUSION

Escaping the Sisyphus trap

According to ancient Greek mythology, Sisyphus was the craftiest of men but his chronic deceitfulness infuriated the gods, who ended up punishing him by compelling him to roll a boulder up a hill, only to watch it roll back down time and time again – forever. Francisco Sagasti (2004) made astute use of the Sisyphus metaphor to describe the recurrent difficulties developing countries face in creating endogenous research and innovation.

The history of STI policies in Latin America can be likened to the Sisyphus trap. Recurrent economic and political crises since the 1960s have had a direct impact on the design and performance of STI policies for both the supply and demand sides. The lack of continuity of long-term public policies and poor public governance in the majority of countries are largely to blame for the lack of appropriate STI policies in recent decades. How often has a new party or group come to power in a Latin American country and immediately set about putting a new set of rules and policies in place? Like Sisyphus, the national innovation system sees the original policy roll back down the hill, as the country takes a new policy direction. 'As the scientific and technological hills to climb will continue to proliferate – making Sisyphus' tasks even more daunting – it is also essential to devise ways of keeping the rock on the top of the hill…'(Sagasti, 2004).

Since the structural adjustments of the 1990s, a new generation of STI policy instruments has emerged that has profoundly transformed the institutional ecosystem, legal framework and incentives for research and innovation. In some countries, this has been beneficial. Why then has the gap between Latin America and the developed world not narrowed? This is because the region has failed to overcome the following challenges.

Firstly, Latin American economies do not focus on the type of manufacturing that lends itself to science-based innovation. Manufactured goods represent less than 30% of exports from most Latin American economies and, with the notable exception of Costa Rica and to a lesser extent Mexico, high-tech goods represent less than 10% of manufactured exports. With the exception of Brazil, GERD remains well below 1% and business contributes one-third, at best. These ratios have hardly changed for decades, even as many other developing countries have moved on. On average, R&D intensity in the private enterprise sector (expressed as a percentage of sales) is less than 0.4%, well below the averages for Europe (1.61%) or the OECD (1.89%) [IDB, 2014]. A recent Argentinian study showed that R&D expenditure as a percentage of sales over 2010–2012 amounted to just 0.16% for small firms, 0.15% for medium-sized firms and 0.28% for large firms (MINCYT, 2015). The stock of innovation capital is far lower in Latin America (13% of GDP) than in OECD countries (30% of GDP). Furthermore, in Latin America, this stock is mainly comprised of tertiary education, compared to R&D expenditure in the OECD countries (ECLAC, 2015c).

Secondly, the paltry investment in R&D partly reflects the insufficient number of researchers. Although the situation has improved in Argentina, Brazil, Chile, Costa Rica and Mexico, numbers remain low in relative terms. The shortage of trained personnel restricts innovation, especially that done in SMEs. Some 36% of companies operating in the formal economy struggle to find a properly trained workforce, compared to a global average of 21% per country and an OECD average of 15%. Latin American companies are three times more likely than South Asian firms and 13 times more likely than Asian–Pacific firms to face serious operational problems owing to a shortage of human capital (ECLAC, 2015b).

Thirdly, the education system is not geared to addressing the shortage of S&T personnel. Although the number of tertiary institutions and graduates has been rising, their numbers remain low in relative terms and insufficiently focused on science and engineering. The shares of bachelor's and PhD graduates against the major six fields of knowledge (Figure 7.4) show an important structural weakness. More than 60% of bachelor's graduates and 45% of PhDs obtained their corresponding degrees in social sciences and humanities. Moreover, only a small proportion of scientific researchers work in the business sector in Latin America (24%), compared to the OECD average (59%). In Argentina, Brazil, Chile, Colombia and Mexico, there is a lack of engineering graduates in the private sector.

Last but not least, patenting behaviour confirms that Latin American economies are not seeking technology-based competitiveness. The number of patents granted per million inhabitants between 2009 and 2013 was highest in Panama, Chile, Cuba and Argentina but generally very low across the region. Patent applications by Latin Americans over the same period in the top technological fields[18] accounted for just 1% of those filed in high-income economies in these same fields.

In the past decade, Argentina, Chile, Mexico and Uruguay have followed Brazil's example by initiating a shift from horizontal to vertical funding mechanisms like sectorial funds. In so doing, they have given a strategic boost to those economic sectors that require innovation to increase productivity, such as agriculture, energy and ICTs. In tandem, they are implementing specific policies and putting incentive mechanisms in place to foster strategic technologies such as biotechnologies, nanotechnologies, space technologies and biofuels. This strategy is beginning to pay off.

18. namely, electrical machinery, apparatus, energy, digital communication, computer technology, measurement and medical technology

A second group of countries are adopting a variety of funding mechanisms to foster greater endogenous research and innovation: Guatemala, Panama, Paraguay and Peru. Others are promoting competitiveness through specific programmes, such as the Dominican Republic and El Salvador.

In sum, in order to escape the Sisyphus trap, Latin American countries need to address the following challenges:

- Improve governance: political stability, government effectiveness, control of corruption;
- Design long-term public policies that extend beyond a single term of government;
- Involve a greater range of stakeholders in the formulation, co-ordination and harmonization of STI policies to connect the demand and supply sides of national innovation systems better;
- Promote regional integration mechanisms to share the costs of R&D, in order to be in a position to address the regional sustainability science agenda;
- Modify the organizational culture, in order to rationalize the institutional ecosystem responsible for formulating, monitoring and evaluating STI policies and policy instruments; and
- Create institutions to promote foresight and prospective studies to guide the decision-making process.

Step-by-step, Latin America has been consolidating its scientific research system and boosting its share in global publications, which rose from 4.9% to 5.2% between 2008 and 2014. A variety of policy instruments have been introduced to make endogenous R&D more responsive to the needs of the productive system and society at large. This is now beginning to bear fruit in some countries – but the road ahead remains long for Latin America.

KEY TARGETS FOR LATIN AMERICAN COUNTRIES

- Mexico's *National Development Plan 2013–2018* proposes raising GERD to 1% of GDP but gives no target year;
- Uruguay aims to generate 90% of its electricity from renewable sources by 2015.

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Guillermo A. Lemarchand (b. 1963: Argentina) is an astrophysicist and science policy specialist. In 2000, he was made a Full Academician of the International Academy of Astronautics (Paris). He co-chaired the Advisory Board of the Commission of Science and Technology of the Argentinean Parliament (2002–2005). Since 2008, he has been working as a science policy consultant for UNESCO, for which he has designed and developed the Global Observatory of STI Policy Instruments (GO➞SPIN).

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