Science, Technology and Innovation in Argentina

A profile of issues and practices

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Abstract: *This paper profiles strengths and weaknesses of Argentina's national innovation system in order to identify efficacious policies. Argentina has established strong institutions at the national level for science and technology oversight and support. Yet, unrealized potential remains for adopting a coherent approach to research and development, particularly for reinforcing public-private partnerships. Comparative data reveal that Argentina underinvests in R&D. Notably, private sector involvement in R&D is very low by international standards. In part, this can be attributed to the prevalence of small and medium-size enterprises with few innovative sales. Moreover, Argentina's national innovation system is marked by weak linkages between private companies, universities and Government research institutions. Public-private collaboration is only common in regard to the financing of research. Another weakness of the innovation system is the lack of R&D personnel with advanced degrees. Strengthening graduate education, boosting private sector R&D and fostering linkages would be important first steps in building a globally competitive Argentine national innovation system.*

[1] The following persons have provided helpful comments and suggestions to earlier versions of this paper: Carlos Abeledo, former president of CONICET; José Joaquín Brunner, director of Fundación Chile's educational program; Daniel Chudnovsky, professor at Universidad de San Andrés in Argentina; Jesko S. Hentschel, human development country sector leader for Argentina, Chile, Paraguay and Uruguay in the World Bank; Lauritz B. Holm-Nielsen, lead education and S&T specialist in the World Bank; and Eduardo Velez Bustillo, human development sector manager for the Latin America and the Caribbean region in the World Bank.

Acronyms

ACCIF	Average country citation impact factor
ANLIS	Administration for Health Laboratories and Institutes
ANPCyT	National Agency for the Promoting of Science and Technology
CICYT	Inter-agency Council on Science and Technology
CNEA	Atomic Energy Commission
CoFeCYT	Federal Council for Science and Technology
CONICET	National Council for Scientific and Technological Research
FDI	Foreign Direct Investment
FONCYT	Fondo para la Investigación Científica y Tecnológica
FONTAR	Fondo Tecnológico Argentino
FTE	Full-time equivalent
GACTEC	Cabinet for Science and Technology
INDEC	Instituto Nacional de Estadística y Censos de la Republica Argentina
INTA	Institute of Agricultural Technology
INTI	Institute of Industrial Technology
IP	Intellectual property
MEST	Ministry of Education, Science & Technology
OECD	Organization for Economic Co-operation and Development
PTC	Polo Tecnólogica Constituyentes
R&D	Research and development
RICyT	Red de Indicadores de Ciencia y Tecnología
SECyT	Department for Science, Technology and Productive Innovation
SME	Small and Medium-sized Enterprises
ST&I	Science, technology and innovation
WDI	World Development Indicators

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INTRODUCTION

Economic growth is to a large extent driven by innovation. The ability to create knowledge and innovate is essential for gains in productivity and global competitiveness. Therefore, countries are paying increasing attention to their science and research capacity as well as to the mechanisms through which research results can be turned into business. The Newly Industrialized Economies—South Korea, Singapore and Taiwan—have demonstrated that R&D investments do not reward only countries that are already technologically advanced but can successfully alter the development path also for less advanced economies.

Argentina is no exception in this trend. Investments in knowledge production—advanced education, technology diffusion, and research—hold considerable promise for placing Argentina on the path to sustainable growth. However, there are a number of challenges that would need to be overcome. Notably, private sector investments in R&D are low, business opportunities are lost due to weak public-private linkages and the stock of highly skilled researchers is insufficient to meet future needs. Nonetheless, there is reason for optimism. Actions have been taken on several fronts to strengthen Argentina's national innovation system. Particularly promising are initiatives to stimulate excellence in research and increase innovation in small and medium size enterprises (SMEs).

This paper profiles of strengths and weaknesses of Argentina's national innovation system in order to identify potentially efficacious government innovation politics. The analysis draws on a wide range of sources and data made available by the Argentine government and international institutions. The paper is structured according to a flow model, tracing inputs, activities and outputs. Part I introduces the structure of Argentina's science, technology and innovation (ST&I) system. Part II analyzes the inputs for innovation by assessing public and private investments in R&D, the availability of advanced human capital and access to venture capital. Part III focuses on the nature of R&D activities by analyzing processes and collaborative patterns in knowledge production and dissemination in Argentina. Finally, Part IV analyzes the output of Argentina's R&D efforts and its impact in the global research community.

PART I – CONTEXT AND FRAMEWORK FOR ARGENTINA'S ST&I SYSTEM

Public sector involvement in ST&I has traditionally been justified based on market failures associated with R&D activities. Such failures have their origin in the difficulties tied to ensuring the non-excludability of knowledge, which implies that private actors face weak incentives to engage in research and development. This section examines how Argentina has addressed this challenge by establishing structures for public sector oversight and support for ST&I and creating a legal framework conducive to innovation.

The structure of the Argentine ST&I system

Governing agencies. The adoption of Law 25.467 on Science, Technology and Innovation in 2001 played an important role in giving legal status and assigning responsibilities to key players in the Argentine ST&I system. The historic evolution had created a system with several overlaps and ambiguity concerning duties and powers.

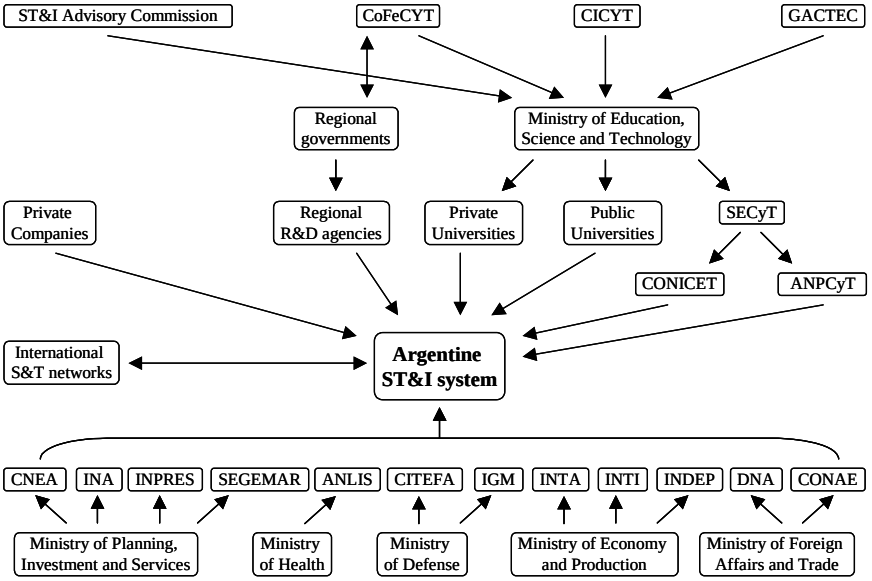
Created in 1996, the Cabinet for Science and Technology (GACTEC) is composed of ministers of economy, health, foreign relations, defense and planning and is chaired by the chief of cabinet. GACTEC is responsible for formulating and updating the national plan for ST&I and preparing the annual budget for research activities sponsored by the federal government. GACTEC was created to tackle cross-sectoral problems and coordinate science and technology policy with sectoral policies. Nonetheless, GACTEC reportedly only meets sporadically and hitherto has not played the foreseen prominent role in the Argentine ST&I system (Decibe et al. 2003 and Chudnovsky 1999).

A number of advisory entities have been established to provide input to GACTEC and the national plan for ST&I. The Federal Council for Science and Technology (CoFeCYT)—made up of representatives from the 23 provinces and the city of Buenos Aires—is responsible for promoting a balanced development of research activities in Argentina. The Inter-agency Council on Science and Technology (CICYT) is composed of high-ranking officials from public research institutes and national universities as well as invited representatives from industry and private universities. At the core of CICYT's responsibilities is the authority to optimize the use of resources by promoting synergies and cooperation between programs and projects in Argentina's ST&I system. Finally, the National ST&I Advisory Commission comprises renowned personalities from various public and private organizations. The commission gives independent advise to GACTEC in the design and implementation of the national plan for ST&I.

The responsibilities for coordinating and monitoring ST&I policies fall under the Ministry of Education, Science and Technology. Its department for Science, Technology and Productive Innovation (SECyT) acts as the executive secretariat of GACTEC. SECyT's responsibilities include the articulation and implementation of the national plan for ST&I, legislation on science and technology, allocation of budgeted resources to executing institutions and the maintenance of statistics on research and innovation.

Implementing agencies. In 1996, the Government decided to set up a National Agency for the Promotion of Science and Technology (ANPCyT) under the auspices of SECyT with the exclusive role of financing research. ANPCyT was intended to strengthen public-private linkages and coordinate S&T programs by centralizing decision-making. Although aiming to streamline Argentina's ST&I system, it has so far made little progress in enhancing coherence and reducing overlaps (Dahlman et al. 2003).

Graph 1. Graphical overview of Argentina's science, technology and innovation system



ANPCyT administers two funds: FONCYT and FONTAR. Inspired by practices from the OECD, FONCYT uses competitive funds to subsidize research activities carried out by groups of researchers working in public or private non-profit institutions. Between 1997-2001, FONCYT allocated around 150 million US$ to about 2,400 research projects (Decibe et al. 2003). FONTAR finances technological innovation and modernization projects designed to improve the competitiveness of Argentina's private sector. The beneficiaries of FONTAR are innovative companies—particularly SMEs—or non-profit institutions that provide technical assistance to the private sector (see Part III and Chudnovsky 1999).

The National Council for Scientific and Technological Research (CONICET) was created in 1958 to promote and conduct research. CONICET played a key role in establishing research as a formal career in Argentina. Headed by a board composed of public and private stakeholders in the Argentine ST&I system, CONICET executes policies and strategies formulated by SECyT. CONICET finances 93 research institutes and six research centers. In addition, it administers scholarships for researchers and finances cooperation between foreign and Argentine scientists. Approximately 80 percent of the research financed by CONICET falls within the fields of biology, physics, chemistry and engineering (Decibe et al. 2003). CONICET was recently subjected to an in-depth external evaluation. One of the criticisms that emerged was the lack of strategic direction and the large number of entities within the institution, which fail to profit from scale and synergies due to insufficient coordination (World Bank 2003).

A significant part of research in Argentina is conducted by scientists in Argentina's 37 public universities. Private companies and to a lesser degree private universities also sponsor and execute research activities. In addition, the Argentine government administers and finances a number of sector research institutes and laboratories. The most prestigious include the Atomic Energy Commission (CNEA), the Administration for Health Laboratories and Institutes (ANLIS), the Institute of Agricultural Technology (INTA) and the Institute of Industrial Technology (INTI).

A national vision for ST&I. The Argentine ST&I system is of high complexity. Diversity of institutional ownership, funding and programs has contributed to a somewhat disjoined and fragmented system divided among institutions with weak links between them (Dahlman et al. 2003). Significant unrealized potential remains for adopting a coherent approach to R&D that reinforces linkages to the private sector and participation in international knowledge networks.

In order to formulate a long-term vision and addressing systemic shortcomings, the Argentine government approved a national multi-year science and technology plan in 1997. Multi-year planning contrasted with the "laissez faire" approach, which had been in force for most of the 1990s in regard to ST&I policies (Chudnovsky 1999). The plan formally adopted the concept of a national innovation system and launched initiatives aimed at stimulating private sector R&D and public research of high quality and relevance (SECyT 1997).

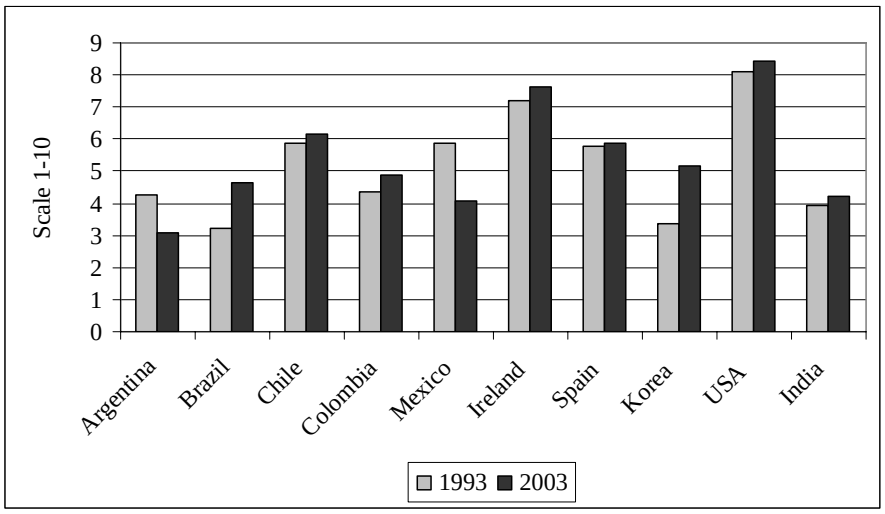
The focus of the first ST&I plan has been reinforced by subsequent plans. The National Plan for 2005 reorients public resources towards programs with an expected impact on the productive sector. The plan also calls for an increased focus on research undertaken by networks or consortia with the aim of promoting cooperation between private companies and public R&D institutions. Perhaps most prominently, the plan sets the goal of increasing investments, public and private, in R&D to one percent of GDP by 2015. Drawing on a loan from the Inter-American Development Bank, a number of new initiatives will be financed. These initiatives include the upgrading of research laboratories, scholarships for young researchers and technological upgrading of Argentine companies.

Legal framework

Weak intellectual property rights regime. The legal framework should ideally provide enterprises with a strong incentive to undertake R&D and commercialize innovations. Few private investors would invest in R&D activities in a situation where everybody benefits and few carry the cost. Strong intellectual property right (IPR) regimes are therefore a key component of promoting R&D activities in any society since they allow innovators to receive a return on their investment.

Argentina officially adheres to most treaties and international agreements on intellectual property rights. However, some elements of the enforcement regime are still at variance with Argentina's international obligations. Particularly copyright protection remains a problem. The Argentine Government has made few efforts to impose criminal penalties in commercial piracy cases and stop counterfeit importation. Bottlenecks in the judicial system have caused substantial delays in the completion of criminal and civil infringement cases. As a consequence, losses by the Argentine software industry to illegal copying were estimated at US$140 million in 2001 (Dahlman et al. 2003). In addition, inadequate patent protection notably in regard to pharmaceuticals has been a controversial bilateral issue with the United States in the past.

Graph 2. Protection of intellectual property rights, 1993 and 2003



Source: IMD, 2001; IMD & WEF, 1993
Note: 1993 data reflect whether "intellectual property is adequately protected in your country".
2003 data reflect the degree to which "patent and copyright protection is enforced in your country".

Graph 2 reveals a low perceived protection of intellectual property rights in Argentina compared to other middle- and high-income countries. Moreover, the situation appears to be worsening. Between 1993 and 2003 Argentina's score dropped considerably, which goes against the trend in other countries in the region. Notably, neighboring Brazil substantially improved its IPR protection in the same period.

Business climate. Operating permits and licenses and a cumbersome labor and social security system exert a heavy financial and administrative burden on companies in Argentina. Particularly, SMEs have difficulties conforming to all the requirements. For smaller companies the estimated costs of compliance with tax and labor regulations are estimated to about 4 percent of monthly turnover (Dahlman et al. 2003).

Table 1. Business registration red tape and ease of doing business, 2003

Country/region	Business registration		Percentage agreeing that ease of doing business is a competitive advantage
	No. of steps	No. of business days	
Argentina	12	71	35 %
Chile	12	78	73 %
Colombia	17	55	49 %
Mexico	15	112	41 %
Venezuela	15	124	17 %
LAC average	14	93	44 %
Europe average	9	60	60 %
United States	4	7	84 %

Source: De Ferranti et al. 2003 and IMD 2003

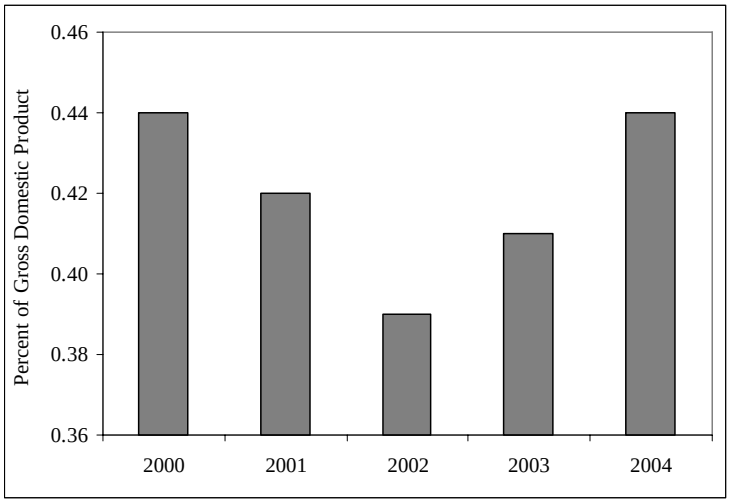
Registering a business requires the completion of 12 steps and an average processing time of 71 business days in Argentina (Table 1). This is less than the time and effort required in other countries in the region, but well above the average in Europe and the United States. Only 35 percent of respondents agree that ease of doing business is a competitive advantage of Argentina, which should be contracted with an average 44 and 60 percent in Latin America and Europe, respectively.

PART II - INPUTS INTO ARGENTINA'S NATIONAL INNOVATION SYSTEM

Financial resources

Low aggregate R&D expenditure. An effective innovation system presupposes the availability of sufficient resources. Aggregate spending on R&D—public and private—is relatively low in Argentina when measured by international standards. In 2004 Argentine expenditures for R&D represented 0.44 percent of GDP, equivalent to the level of investment prior to the crisis (Graph 3). In contrast, Chile and Brazil allocated 0.61 and 0.97 percent, respectively, of their GDP to R&D in 2003 (RICYT 2005). Argentina falls even further behind when compared to countries with high performance in innovation such as Korea, United States and Finland, which on average spend around 3 percent of GDP on R&D (OECD 2002).

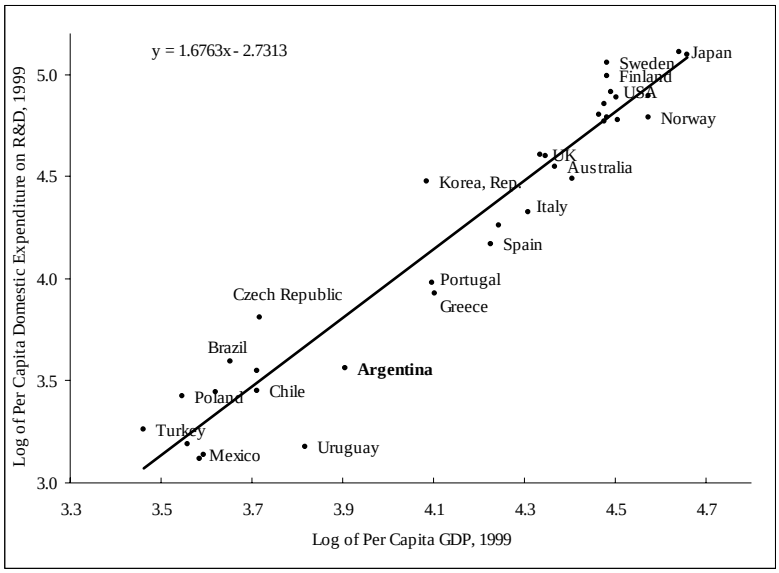
Graph 3. Aggregate Argentine R&D expenditure relative to GDP, 2000-2004



Source: SECyT 2005

To measure Argentina's R&D spending relative to its level of income, Graph 4 compiles data on R&D expenditure and GDP per capita in 1999 for a sample of 36 countries. The trend line corresponds to the predicted log of R&D per capita domestic expenditure when a linear regression is performed on the log of per capita GDP. The analysis revels that Argentina not only tails leading economies in terms of R&D spending, but also features a significantly lower aggregate level of R&D expenditures than expected based on its level of income. Argentina's expected R&D spending level is 0.81 percent of GDP, considerable above the actual 1999 level of investment.

Graph 4. Investments in R&D relative to GDP per capita, 1999



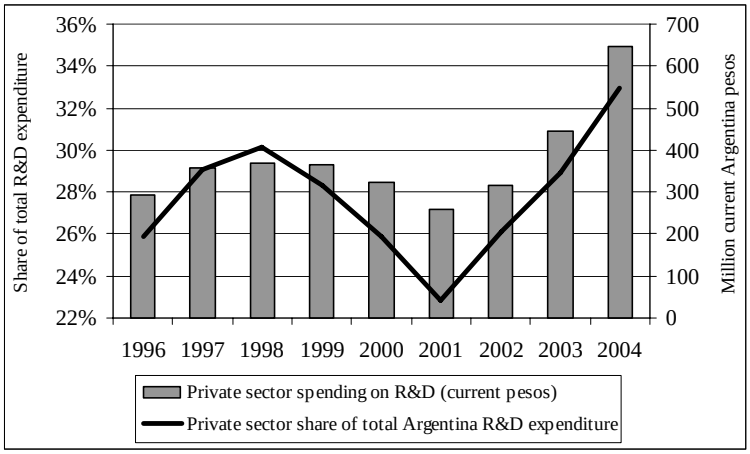
Note: Some country names have been omitted to make the graph more legible.
Source: Author's calculation based on data from OECD 2002, RICYT 2004 and WDI 2003

Additional investment is not a sole prerequisite for strengthening the Argentine national innovation system. Considerable unrealized potential remains for improving performance by addressing problems of low quality, eliminating overlapping structures and enhancing the relevance of public research for society and the productive sector. Hence, the effective use of existing R&D spending is equally important to making additional resources available for research.

Limited private sector R&D. Active involvement by the private sector in R&D is essential to building an advanced S&T capacity. No country has undergone a successful technological transition without a significant contribution from industry. Argentina demonstrates a very high dependence on the public sector for R&D funding. Government agencies and public universities accounted for more than two-thirds of R&D financing and implementation in 2004.

The private sector finances about 33 percent of all R&D activities in Argentina, a share, which is significantly lower than that of the private sector in Brazil (38 percent), Korea (72 percent) and the United States (68 percent). However, the trend is encouraging. From a low point in 2001, the Argentine private sector has significantly expanded its investments and share of R&D expenditure (Graph 5).

Graph 5. Private sector R&D spending, 1996-2004



Source: SECyT 2005

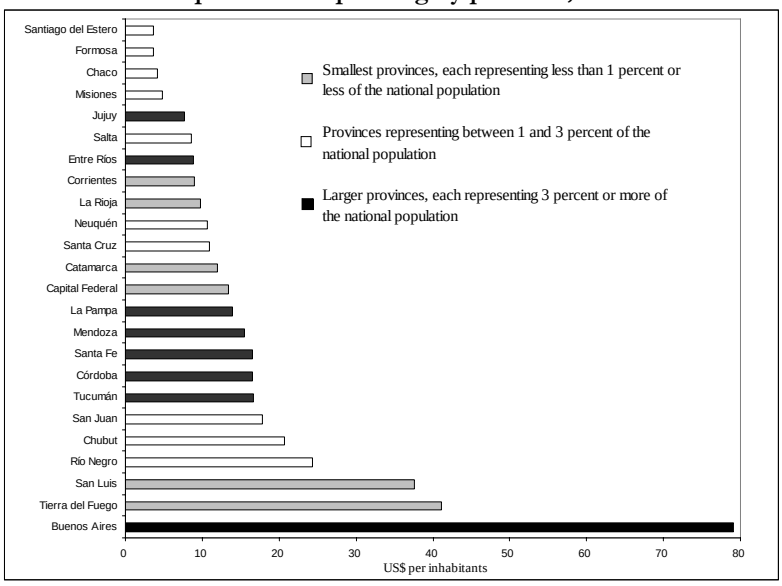
Research in Argentina is heavily dominated by public universities. In 2004, private universities accounted for only 2 percent of total R&D expenditures. The low levels of R&D in private universities primarily reflect a strong focus on instruction and relatively few researchers among the faculty (SECyT 2003a). In addition, the high percentage of part-time teachers places private institutions in a weak position to carry out research.

Provincial disparities. Argentina not only shows a significant technology gap with leading economies, it also features substantial technological disparities between its regions. Evidence suggests that economic liberalization and pressure from more dynamic entrants from the exterior have hurt regional economics more than metropolitan centers (Dahlman et al. 2003).

Inter-regional disparities are exacerbated by a lack of institutions for national technology diffusion and weak efforts by the federal government to promote R&D activities outside the capital area (PER 2003). The creation of the Federal Council for Science and Technology (CoFeCYT) is a positive development, but the council has so far not assumed a prominent role in formulating national S&T policies (SECyT 2003a).

Geographical imbalances are evident in the distribution of federal R&D expenditures. In 2004, the *City of Buenos Aires* and the provinces of *Buenos Aires*, *Santa Fe* and *Córdoba* received 63 percent of all public expenditures on R&D (SECyT 2005). In addition, they employed 44 percent of all Argentine researchers. The concentration of R&D activities is an obstacle to regional adaptation of technology and provides a weak basis for economic growth beyond the capital area.

Graph 6. R&D spending by province, 2004

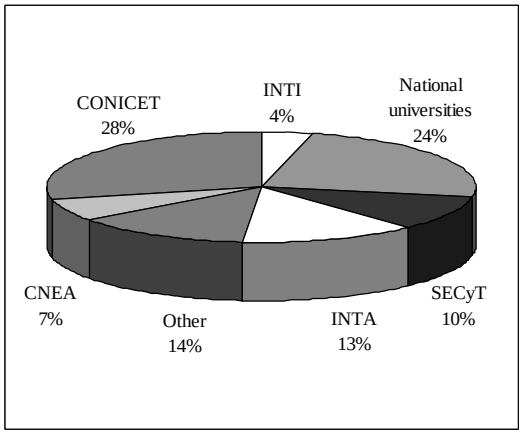


Source: Author's calculation based on data from SECyT 2005 and INDEC 2003

In 2004, spending on R&D ranged from US$79 per inhabitants in the Greater Buenos Aires area to US$4 in the province of Santiago del Estero (Graph 6). The most and the least populated provinces received the greatest support for R&D relative to their population (on average US$22 and US$20 per inhabitants, respectively) whereas federal R&D spending in provinces representing between 1.1 and 2.9 percent of the population was much lower (on average US$11 per inhabitants). Hence, the data suggest that federal programs have been somewhat successful in supporting the least populated provinces while making less progress in stimulating R&D in the more populous provinces in the north and center of Argentina.

Executers of research. About 72 percent of the national budget for R&D is concentrated in public universities and three organizations: CONICET, the National Institute of Agro-industrial Technology (INTA) and the National Atomic Energy Commission (CNEA) (Graph 7). CONICET plays a leading role in government research, managing almost a third of government R&D spending. The competitive funds administered by SECyT made up a mere 10 percent in 2003.

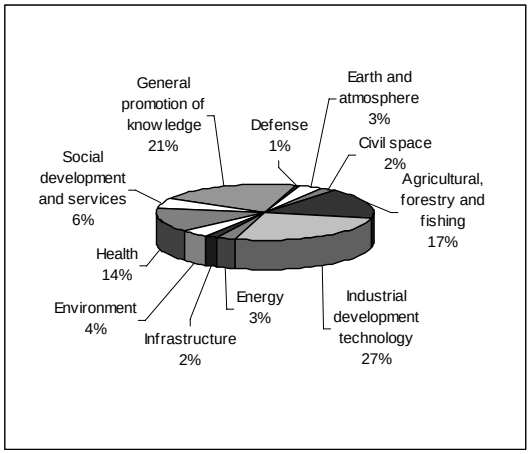
Graph 7. Relative public expenditure for R&D by recipient, 2003



Source: SECyT 2003a

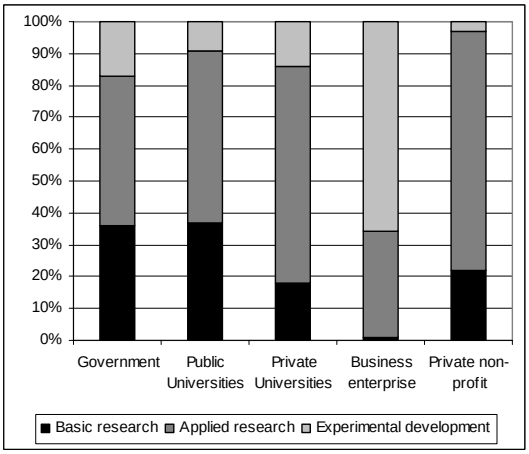
Socioeconomic purpose of R&D. In line with some of the country's key exports, the bulk of Argentine research is targeted at industrial production and agriculture (Graph 8). Other significant areas of research are health, social development and energy.

Graph 8. Expenditure on R&D by socioeconomic purpose, 2002



Source: RICYT 2005

Graph 9. Expenditure on R&D by type of research, 2002



Source: SECyT 2005

The heavy dependence on the public sector for R&D funding is associated with a high focus on basic research in Argentina (Graph 9). With the exception of private companies, low priority is given to experimental development, which is a key component in the commercialization of research. Roughly 26 percent of R&D expenditure was dedicated to experimental development in Argentina in 2002, while the corresponding percentage for the United States and Spain was 61 and 43, respectively (RICYT 2005).

Human capital

Skills for the knowledge economy. Highly skilled human capital is a key element in developing a competitive ST&I system. It is human ingenuity and entrepreneurship that forms the backbone of the knowledge economy. Consequently, most efforts to fund a strong ST&I system and upgrade the technological infrastructure would be in vain if such efforts were not complemented by an adequate stock of human capital. Also, new technologies have particularly increased the productivity of educated workers. Formal education and skills upgrading are therefore expected to have a larger effect on growth than before (De Ferranti et al. 2003).

Educational attainment in Argentina is high by regional standards. The mean educational attainment of the Argentine population aged 25 years and older is 8.5 years, well above Brazil, Chile and Mexico (Table 2). A relatively high percentage of the Argentine population has engaged in some secondary or tertiary education. These strengths place Argentina in a comparatively favorable position to embrace the knowledge economy. However, a significant proportion of the population does not hold adequate foundational skills. 'Some primary education' represents the highest educational attainment for almost 50 percent of all Argentines.

Table 2. Educational attainment in selected countries, 2002

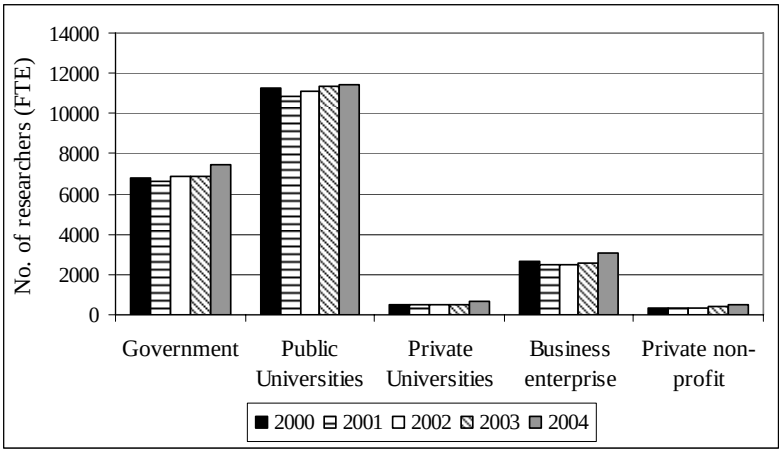
		Fraction of the adult population (25 or older)			
	Years of schooling	No school	Some primary	Some secondary	Some tertiary
Latin America	5.8	17.9	50.1	20.3	11.8
Argentina	**8.5**	**5.8**	**49.6**	**24.9**	**19.7**
Australia	10.6	2.2	24.4	43.6	29.8
Brazil	4.6	21.3	56.8	13.5	8.4
Chile	7.9	5.3	42.9	36.0	15.8
Finland	10.1	0.4	29.2	47.3	23.2
Mexico	6.7	12.4	47.3	29.0	11.3

Source: De Ferranti et al. 2003

The returns to higher education, both complete and incomplete university, have increased substantially in recent years, with university now exhibiting the highest returns of all education levels. Between 1998 and 2002, the return to complete university education rose from approximately 9 to 14 percent. Rising returns to tertiary education—in a situation with large increases in supply—suggest that demand for skilled labor exceeds supply in Argentina (Patrinos and Vegas 2005).

Low stock of researchers. Measured in full time equivalent, Argentina employed about 23,000 researchers, 6,300 research assistants with fellowships, and 13,000 supporting and technical staff in 2004. Public universities and the government research institutions employ most researchers (Graph 10).

Graph 10. Argentine researchers in full time equivalent by sector, 2000-2004



Source: SECyT 2005

Argentina is at a disadvantage compared to OECD benchmarks. In 2004, Argentina featured 1.7 researchers per 1000 people in the workforce. The corresponding number for the United States and France was 9.0 and 6.9 respectively (WDI 2003). Yet, Argentina compares well in the region in relative terms. For example, Brazil and Mexico feature only 0.8 and 0.7 researchers per 1000 people in the workforce, respectively.

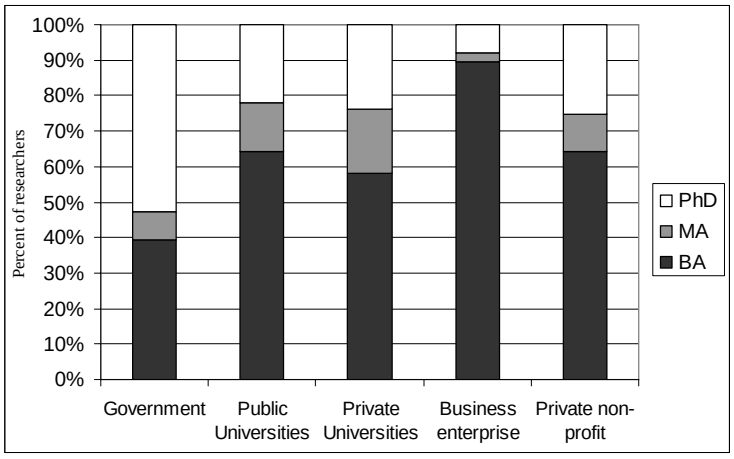
Few privately employed researchers. Only 13 percent of researchers in Argentina are employed by the private sector. Measured in full time equivalent, private companies employed about 3,100 researchers, 600 research assistants and 2,900 supporting staff in 2004. The low number of researchers in industry has negative bearing on the ability of Argentine firms to produce and apply new knowledge. Human capital is particularly important as a transmitter of tacit

knowledge and as a facilitator of knowledge networks (De Ferranti et al. 2003). Hence, transmitting research results to the private sector and the commercialization of innovations hinge on an adequate stock of advanced human capital in Argentina's private sector.

Low performance and skills among researchers. Argentina is the only country in the Latin American region which features several Nobel prizewinners. While some researchers and research groups have won worldwide recognition for their contributions, problems of scanty developed scientific disciplines and low performance of researchers are widespread. The number of papers published per researcher in Argentina is low by international comparison (see part IV).

Involvement in cutting-edge research is hampered by a low number of Argentine researchers holding advanced university degrees. A startling 67 percent of Argentine researchers hold a bachelors degree as their highest qualification (Graph 11). Only 25 percent of researchers have a doctoral degree, and in private companies this share is no more than 9 percent.

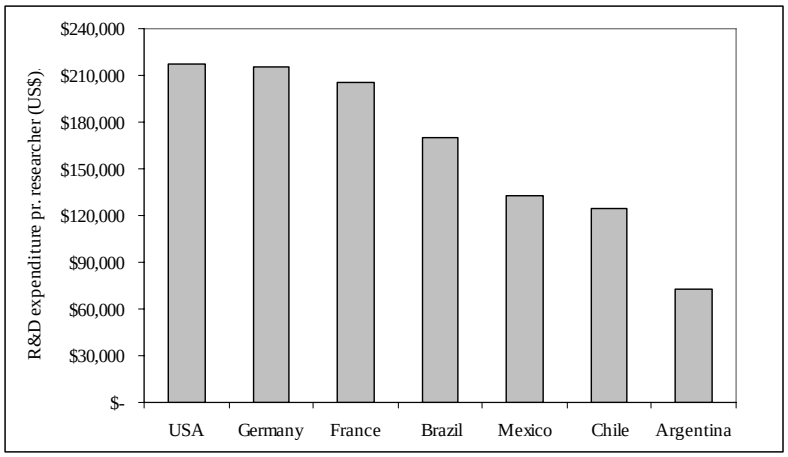
Graph 11. Researchers by educational attainment and sector, 2004



Source: SECyT 2003

Argentine researchers are alarmingly under-funded. Expenditure per researcher is only a fraction of the equivalent spending in other Latin American countries, let alone more developed nations (Graph 12). Lack of adequate funding is an obstacle to the execution of world class research in Argentina and have negative implications for Argentina's ability to attract and retain qualified researchers.

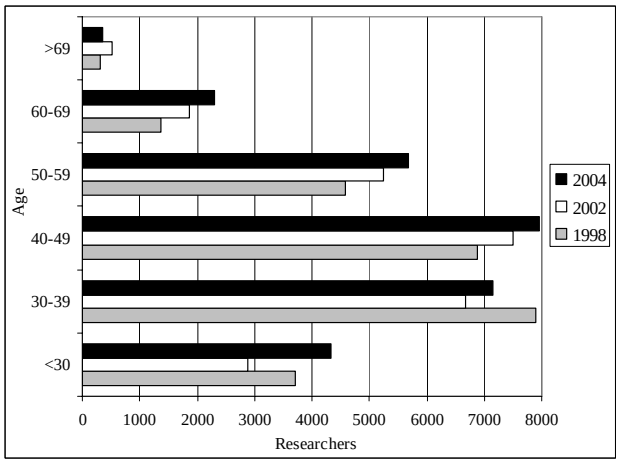
Graph 12. R&D expenditure per researcher (2004 or latest available)



Source: SECyT 2005

Evidence suggests that progress has been made in recent years in attracting greater numbers of young researchers, particularly below the age of 30 (Graph 13). However, in relative terms the proportion of researchers below the age of 40 fell from 43 to 39 percent between 1998 and 2004. Reportedly, a rising average age of researchers is particularly an issue in institutes under the supervision of CONICET where the majority of the research staff is 50 years or more (Decibe et al. 2003). Hence, ensuring an influx of young researchers that rise beyond current trends would be essential to strengthening Argentina's science base and, notably, increasing the number of researchers working for private companies.

Graph 13. Age distribution of Argentine researchers, 1998, 2002 and 2004



Source: SECyT 2005

Weak graduate education. Argentina is currently in a weak position to replace retiring researchers and expand the stock of advanced human capital. The production of research-trained scientists and engineers is very low due to little enrollment in these areas. In public universities, students at the graduate level constitute only 4 percent of the student body (MEST 2002). The problem is aggravated by a low availability of scholarships and loans for graduate studies, making it economically difficult to complete advanced studies and engage in post-doctoral research. Also, a lack of adequate employment opportunities for PhD graduates, particularly in industry, provides few incentives to enroll in advanced education in the hard sciences.

Little progress has been made in reorienting graduate education to produce and disseminate knowledge with a social and economic impact. Some faculties, including engineering and biochemistry, have established some linkages with the private sector. However, Argentine higher education remains inward-focused with activities largely disconnected from the needs of the industry and the economy at large (Holm-Nielsen et al. 2004). As Graph 11 revealed most doctoral graduates remain in the public sector working either for government research institutions or public universities.

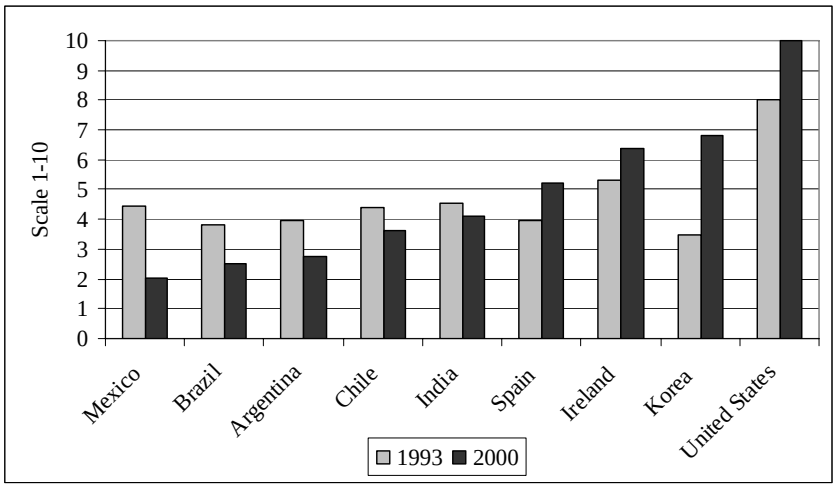
Brain drain. Argentina's access to innovative and entrepreneurial human capital is largely dependent on the ability to retain and attract researchers. Evidence suggests that the crisis spurred an outflow of highly qualified Argentines towards Europe and the United States. Especially young researchers and university graduates reportedly leave or intent to leave Argentina permanently (Albornoz 2002).

Migration of talented individuals can, in part, be attributed to the lack of opportunities for young researchers in Argentina. Inadequate research infrastructure, low resources per researchers and weak linkages between research institutions and the private sector are some of the reasons for researchers to seek challenges overseas (Thorn and Holm-Nielsen 2005). Hence, determined action to create opportunities for knowledge workers and technologists is key to improving Argentina's competitiveness. For nationals that cannot be retained, it would be important to reinforce current diaspora initiatives, making use of expatriate knowledge and creating opportunities for technology transfer by strengthening linkages to skilled nationals living abroad.

Venture capital

Lack of risk capital. In common with its Latin American neighbors, Argentina does not feature a mature system for venture and seed capital. In terms of perceived availability of venture capital, Argentina compares relatively well with Mexico and Brazil but falls behind economies such as Chile, India and Spain (Graph 14). The situation appears to have worsened between 1993 and 2000.

Graph 14. Perceived availability of venture capital, 1993 and 2000



Source: IMD 2000
Note: The data reflect to what degree: "Venture capital is easily available for business development". The data have been normalized on a scale from 1 to 10.

Only a small fraction of foreign direct investments during the 1990s was directed to young small and medium-size enterprises and new science-based firms. Foreign capital was focused on technology upgrading and expansion of businesses in general and to a lesser degree on the financing of R&D-driven new ideas. Although some entrepreneurial finance was available during the 1990s, an institutionalized venture capital activity did not develop (Pereiro 2001).

To stimulate investment in venture capital funds, the Argentine government has recently developed a framework that provides fiscal incentives for the creation of funds for risk capital. To be eligible for support, such funds must be targeted at R&D projects developed by young SMEs, or to the creation of new firms in the area of science, technology and innovation (World Bank 2003). It is too early to assess the impact of this initiative on the creation of knowledge-based companies. Nonetheless, a venture capital culture is unlikely to emerge in Argentina without a strong participation by the private financial sector.

PART III – INNOVATION PROCESSES AND COLLABORATIVE PATTERNS

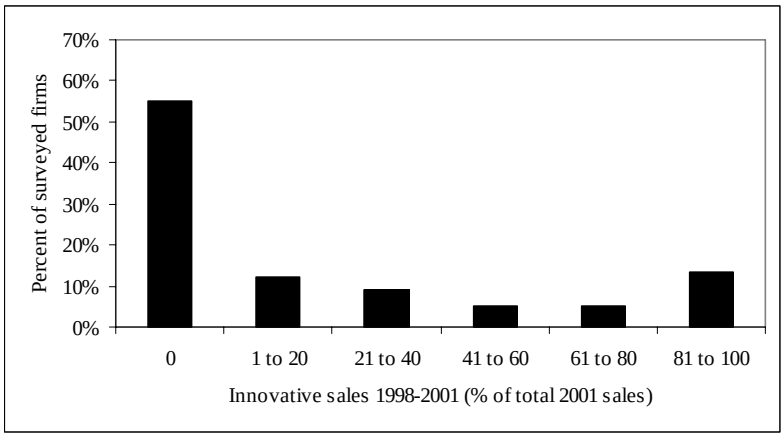
Private sector R&D activities

Low private sector knowledge absorption capacity. The incorporation of knowledge and technology in private sector production is low in Argentina. A predominance of agriculture and natural resource based exports has not nurtured an innovative culture (Decibe et al. 2003).

Small and medium-size enterprises form the bulk of Argentina's economy, accounting for 61 percent of production and close to 80 percent of private sector employment. These companies have little tradition for employing people with advanced degrees, let alone researchers (Dahlman et al. 2003). Hence, the flow of innovative ideas and tacit knowledge into Argentine companies is low.

Argentine innovators. In 2002 a national innovation survey was carried out in Argentina. More than 1200 companies participated, providing a unique opportunity to analyze private sector innovation (SECyT 2003).

Graph 15. Innovative firms, 1998-2001



Source: SECyT 2003a

Graph 15 shows the distribution of firms by different levels of innovative sales in the 1998-2001 period relative to total 2001 sales. The graph reveals that most Argentine companies are not innovators. More than 50 percent of surveyed companies featured no innovative sales between 1998 and 2001. For most other companies, innovative sales—revenue arising from significantly changed or entirely new products—comprised a small share of their total sales. In the three years under review, only 13 percent of Argentine companies displayed a level of innovative sales above 80 percent of their 2001 turnover.

Table 3. Proportion of companies with at least one innovative sale by company size and ownership

		Size			Total
		Large	Medium	Small	(ownership)
Ownership	Domestic	74%	47%	40%	**42%**
	Foreign	78%	57%	51%	**58%**
	Total (size)	**76%**	**51%**	**41%**	

Source: SECyT 2003a and Chudnovsky et al. 2003
Note: N=1243 firms. Firms are classified as small, medium or large if their total sales average in 1998-2001 is less than 25 million pesos, between 25-100 million or more than 100 million, respectively.

Large enterprises are the most innovative in Argentina. Table 3 shows the percentage of firms that had at least one innovative sale in the 1998-2001 period differentiated by company size and ownership. 76 percent of large companies participating in the survey are innovators. This share is only 41 percent for small companies. Another important finding is the overrepresentation of foreign firms among innovators. For all firm sizes, foreign owned firms are more innovative than domestic firms. Overall, 42 percent of surveyed domestic firms feature innovative sales, where the share is 58 percent for foreign owned companies.

Government initiatives to boost private sector R&D. The Argentine government has launched a number of programs in recent years targeted at promoting private sector R&D activities, particularly in domestic SMEs. A prominent example is the Technological Advisors Program

under FONTAR, which aims to overcome the isolation and limited innovative capability of small firms. The program funds, in part, technology advisors who assist groups of entrepreneurs in identifying business constraints and opportunities and connect them with suitable partners in the innovation system. The subsidy enables businesses to bring high-qualified engineers into their staff. At the same time, the program offers employment opportunities for young engineers to work in industry from the beginning of their professional career (Chudnovsky 1999).

Another example is the FONTAR Seed Fund Program designed to helps firms upgrade their innovative capacity. The program has several lines, which include resources for developing business plans, building in-house R&D capacity, preparing technology blueprints and modernizing products and processes. In 2000, 14 percent of all proposals received financing. Close to 80 percent of the beneficiaries were SMEs (Dahlman et al. 2003).

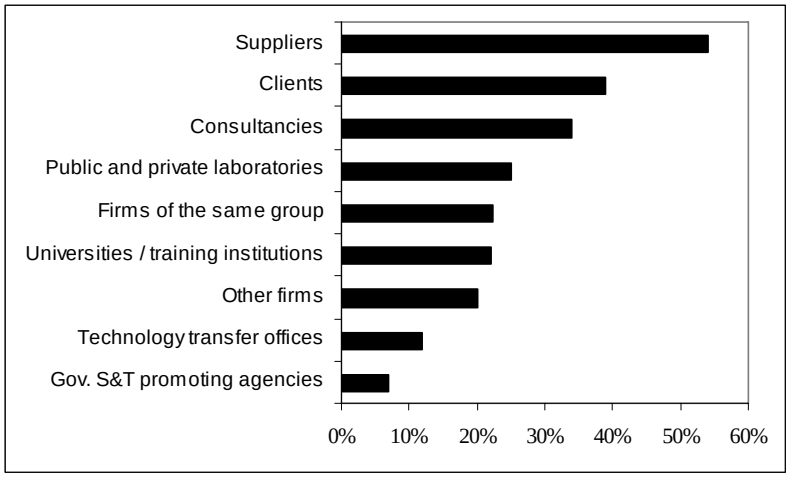
The Argentine government has operated a program of tax credits for R&D activities since 1997. This program allows Argentine companies to deduct a maximum of 50 percent of their R&D expenditure. Project applications are reviewed by ANPCyT, which determines expenditures eligible for the tax credit. Each year the Argentine government sets a ceiling for the aggregate amount that can be spend under the program. In 1998 and 1999, tax credits amounting to US$38.7 million were authorized, which reportedly fell considerably short of the demand by industry (SECyT 2003a).

These initiatives are important steps towards providing a conducive framework for firms to strengthen their R&D capacity. Nonetheless, the impact of the programs is limited due to their narrow coverage and scope. The 2004 national budget only allocated roughly 2 percent of total public S&T funds to FONTAR initiatives (SECyT 2003a). A stronger focus on promoting private sector innovation, by increasing the relative weight given to industrial outreach in public S&T programs, would be key in meeting the government's objective of increasing investments in R&D to one percent of GDP by 2015.

Research cooperation

Collaborative patterns of Argentine innovators. Data from the 2002 national innovation survey show that innovative firms are much more likely than non-innovators to connect with other agents in the national innovation system. The most important external partners for firms involved in R&D are suppliers, clients and consultancies (Graph 16). Universities and training institutions, public and private laboratories, technology transfer offices and particularly government S&T promoting agencies are much less the partner of choice for private innovators in Argentina.

Graph 16. External R&D partners for Argentine innovators



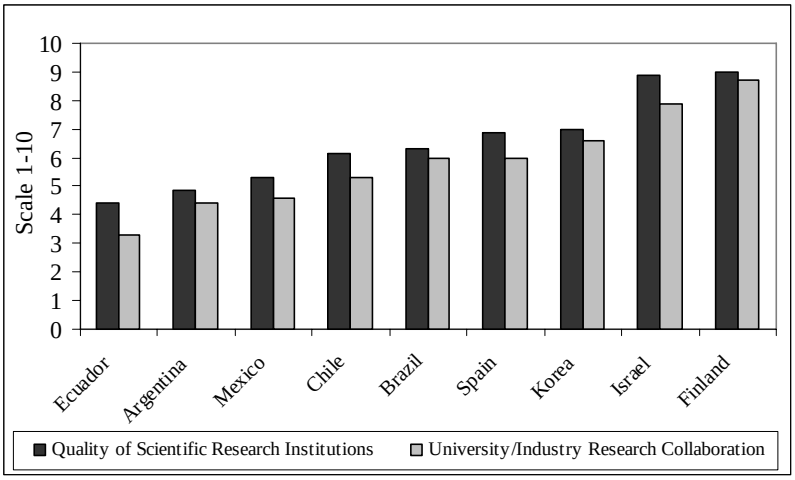
Source: SECyT 2003b

The type of linkages between innovators and external partners varies considerably. Research partnerships are primarily formed with suppliers, public and private laboratories and other companies. Suppliers and consultancies are the main sources of technical assistance and most training collaboration involves consultancies and universities. Cooperation with government institutions is only considerable in regard to the financing of research (SECyT 2003b).

Public research inadequately geared to a business time scale. The relatively weak R&D linkages between companies and public research institutions stem, in part, from problems of low quality and relevance of publicly subsidized research. Surveys indicate that Argentine public research institutions and universities are not sufficiently responsive to the needs of industry, emphasizing academics over commercial applications in their research orientation. Nonetheless, over the last ten years there are isolated examples of Argentine universities working with industry and several universities have recently appointed personnel responsible for promoting collaboration with external partners (Dahlman et al. 2003 and Chudnovsky 1999).

Graph 17 suggests the existence of a link between the quality of research and university-industry research cooperation. On both variables, Argentina receives a low score and tails countries in the region such as Mexico, Chile and Brazil.

Graph 17. Perceived university/industry research collaboration and quality of public research



Source: WEF 2002

Note: The data reflect to what degree: (1) Scientific research institutions, such as university and government laboratories, are best in their field and (2) in R&D activity, business collaboration with local universities is intensive and ongoing. The data have been normalized on a scale from 1 to 10.

In addition to real or perceived low quality, cooperation is hampered by lack of incentives for public researchers in Argentina to link and address private sector knowledge needs. Reward structures generally do not recognize the value of non-academic collaboration and bureaucratic rigidities make inter-sectoral mobility and the establishment of public-private partnerships cumbersome and costly. In addition, ambiguous intellectual property rights for publicly employed researchers lower the expected private return to transmitting innovations to industry (De Ferranti et al. 2003).

Government initiatives to promote collaboration in research. A positive development is a recent step by CONICET to facilitate researchers' awareness of private sector needs. CONICET now formally recognizes the position of 'researcher in industry'. The initiative paves the way for research staff to work full time in private companies for a limited period of time in order to contribute to innovation and training activities. The firm is required to contribute a substantial percentage to the researcher's salary. CONICET researchers are granted credit in placement and promotion for their participation in these type of activities and are allowed to collect at least one-third of the benefits obtained from patenting or sale of their innovations (World Bank 2003).

International linkages in research. Over the past 15 years international research collaboration has grown worldwide, with researchers and academics in both industrial and developing countries co-authoring research articles, participating in international conferences and working abroad. Argentine researchers are no exception. Table 4 shows that between 1996 and 1999 the number of Argentine international co-authored articles—a good estimator of substantive research cooperation—grew almost 400 percent. With 1,120 international co-authored articles Argentina compares well with neighboring Chile but falls behind Brazil and Mexico. Korea provides an interesting benchmark. Through a targeted internationalization strategy, Korea has improved itself from a level of co-authored articles below Argentina in 1996 to almost twice the Argentine number in 1999.

Table 4. International linkages in research

	Internationally co-authored articles			International scholars in the United States		
	1996	1999	Change	2000	2001	Change
Argentina	234	1120	379%	638	837	31%
Brazil	594	2501	321%	1315	1493	14%
Chile	214	659	208%	243	229	-6%
Colombia	64	256	300%	404	514	27%
Korea	193	2016	945%	5830	7143	23%
Mexico	310	1418	357%	898	1068	19%
Spain	911	5569	511%	1706	1822	7%

Source: NSF 2002 and Chin 2003

As a proxy for international mobility, Table 4 also includes the number of international scholars teaching in U.S. universities for a sample of countries. Argentina saw a high growth of scholars working in the United States between 2000 and 2001. This growth may, in part, be attributable to the economic crisis (see discussion of brain drain in Part II). However, numbers above Chile and Colombia is also evidence that Argentine scholars are relatively well connected and respected internationally.

International connectivity of private sector R&D. Research cooperation between Argentina's private sector and research institutions abroad is essential to ensure a flow of ideas and technology into Argentina directly applicable in industry. Data show that company size is a key determinant of private sector cross-national research activities. In the group of Argentine companies featuring innovative sales, 93 percent of large enterprises have established international linkages. This proportion should be contrasted with a corresponding 48 percent among SMEs (SECyT 2003a). A low degree of international connectivity is consistent with the identified need for SMEs to improve their knowledge absorption capacity.

Argentine companies cooperate mostly with research institutions and companies in the European Union and the United States. Ties with research efforts in other Latin American countries are much less frequent, amounting to only a quarter of international contacts (SECyT 2003b). Given the geographical proximity and few language barriers, Argentine companies appear to have unrealized potential for establishing research partnerships with other companies in the region. Increased regional cooperation may provide Argentine industry access to cutting-edge research and an extended team of research personnel at a relative low cost to the individual company.

Argentine ST&I Clusters

Clusters strengthen national innovation systems. Innovation clusters are critical for industrial and economic development in Argentina. Clusters are locally based subsystems of national innovation systems comprised of firms, research centers, universities, suppliers and investors working together in close physical proximity to design and commercialize new technologies, products and enterprises (Porter 1998). Clustering enables firms, especially SMEs, to grow and upgrade more easily. Examples such as Silicon Valley and Route 128 in the United States show that SMEs may even become players in world markets if a high degree of inter-firm specialization and proximity to other firms—performing complementary functions—offset the disadvantages of being small (Bortagaray 2000). Hence, clustering is one way of improving the innovation capacity of Argentine SMEs.

Argentina's private is sector generally not organized to create economies of scale and scope for innovation and competitiveness through clustering. Collaborative efforts among Argentine companies and with domestic research institutes are far and between. Some of the key problems are an adverse investment climate and lack of tradition for collaboration and knowledge sharing. Currently, no mature enterprise clusters exist in Argentina. Nonetheless, there are examples of 'proto-clusters' that potentially could develop into engines of regional development and economic growth in Argentina. In the city of Rafaela, for example, dairy farmers systematically collaborate and exchange information on technical, managerial and financial matters of their production. As a result, productivity has increased, prompting dairy farmers throughout the Pampa to form similar groupings. Other emerging clusters can be found in petrol-chemical processing (Bahia Blanca) and wine production (Mendoza). Transforming such subsystems into mature clusters will depend on incentives for producers to tap into local supply chains, fostering linkages to domestic input suppliers and service providers. The government could speed up this process by being a source of start-up funding and strengthening the interface between companies, universities and public laboratories.

Polo Tecnólogica Constituyentes. A publicly led attempt to stimulate cross-sectoral collaboration in Argentina is the Polo Tecnólogica Constituyentes (PTC) in Buenos Aires. The PCT is made up of several public research institutions including the National Institute of Industrial Technology (INTI), the Atomic Energy Commission (CNEA), the Armed Forces Scientific and Technical Research Center (CITEFA) and the National University of San Martín. The purpose of the collaboration is to disseminate knowledge among members and transfer technology by building partnerships with the private sector. Industry outreach activities include a program to stimulate new technology-based enterprises, provide courses in entrepreneurship and offer of technical assistance. The PCT also emphasizes collaboration with research clusters and science institutions around the world (Cassin 2001).

Despite a potential for stimulating clustering, progress to date has been slow due to several weaknesses in the institutional design. The PCT remains a mainly supply-driven organization centered on public research institutions attempting to find commercial applications and customers for their work. Low private sector commitment is evident in the PCT's almost exclusive dependence on public funding. Also, the PCT is not yet sufficiently focused in its activities to reach a critical mass of knowledge and researchers in specific scientific sub-fields (Bortagaray 2000).

Approaches to promoting clusters and cooperation. Several OECD countries have kick-started clusters by supporting cooperative research among universities, government laboratories and private companies. The Australian collaborative research program requires public and private agents to formulate and execute joint research projects. To obtain funding, participating companies must make substantial financial commitments. The program has been successful in involving a large group of SMEs in research that lack the technical and financial resources to conduct cutting-edge research on their own (ARC 2001).

Hence, building on international good practice may help Argentina strengthen its national innovation system by bring new thrust to inter-sectoral cooperation and clustering. The primary goal should be to engage the private sector with a view to strengthening its capacity for R&D.

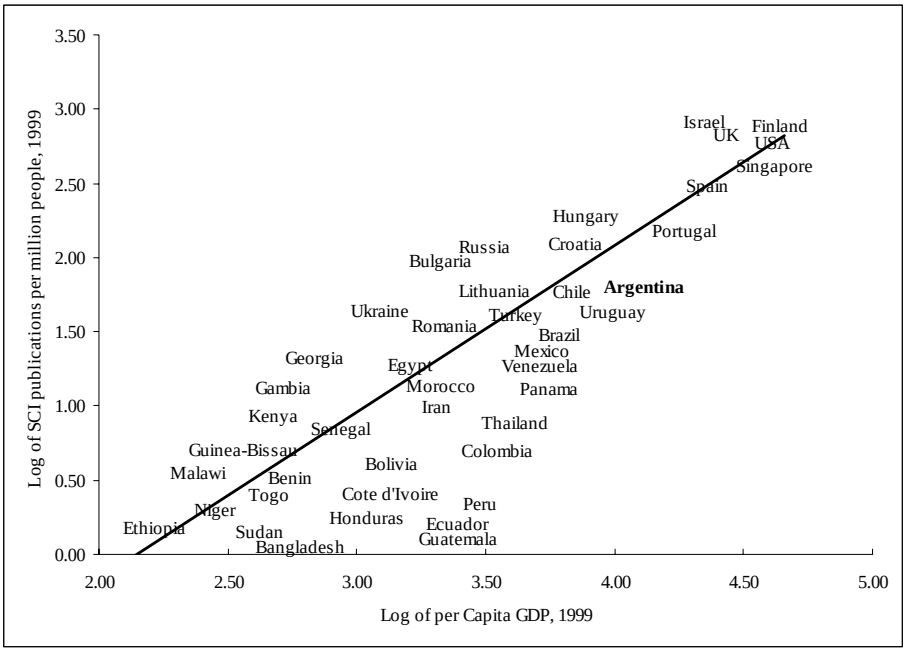
PART IV – SCIENTIFIC OUTPUT IN ARGENTINA

This section overviews Argentina's scientific output based on key indicators. These measurements, however, do not provide a complete account of knowledge production and innovation in Argentina. Patenting, for example, is only one component of a business strategy for successful innovation. Many technology advances are in the form of changes to processes or products that are not captured in traditional statistics. Hence, the results below should be interpreted with this in mind.

Publications

Lower than expected total number of Argentine publications. In 2003, Argentine researchers published roughly 5,600 articles in international scientific journals (SECyT 2005). Graph 18 shows the size of this production relative to Argentina's level of income for a sample of 123 countries. The estimated trend line reflects the expected log of SCI publications per million people when a linear regression is performed on the log of per capita GDP. The data indicate that Argentina performs slightly below what is expected based on its level of income.

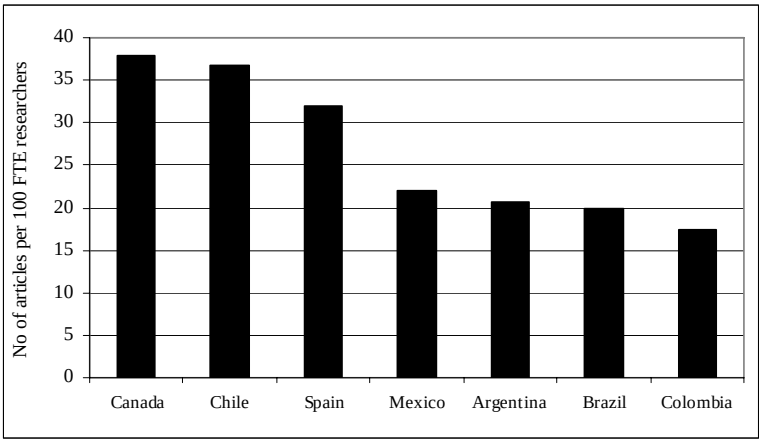
Graph 18. Publications per million people relative to GDP per capita, 1999



Note: Some country names have been omitted to make the graph more legible
Source: Author's calculation based on data from NSF 2002 and WDI 2003

Low publication productivity of Argentine researchers. To assess the productivity of Argentine researchers, Graph 19 shows the annual SCI publications relative to the number of full-time equivalent (FTE) researchers for a sample of seven countries. Argentina features about 21 articles per 100 FTE researchers. This ratio is equivalent to each researcher in Argentina publishing an article every five years, which is low by international standards. In the region, Mexico and notably Chile feature publication productivity levels above the level for Argentina. Canadian researchers publish about twice as often as their Argentine colleagues.

Graph 19. Scientific articles per 100 FTE researchers, 2004 or latest available



Source: RICYT 2005
Note: Based on publications registered in SCI search

The low efficiency of Argentine researchers is not surprising given the considerable under-funding of research in Argentina, few young researchers and the low number of researchers holding advanced degrees (Graph 11 and 12).

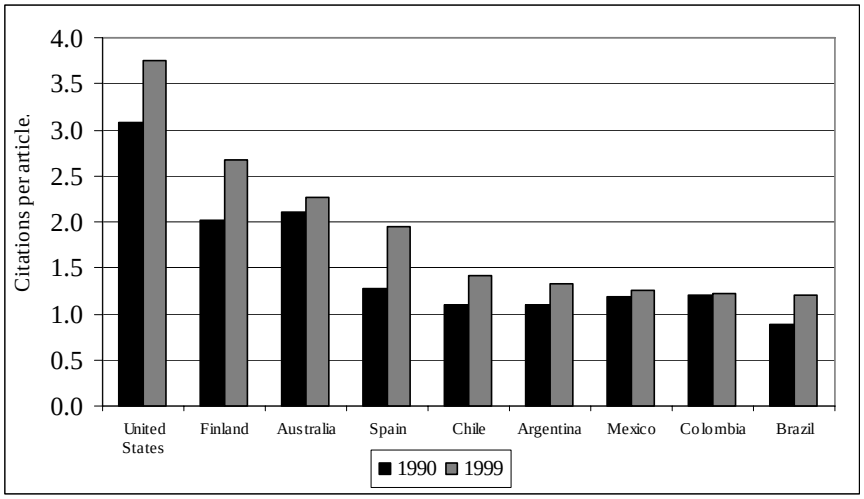
Low impact of publications. Relying solely on publications as an indicator of scientific output may be misleading since no account is taken of their impact in the scientific community. Yet, measuring the quality and relevance of scientific output is inherently difficult. Direct quantitative measures do not exist, making it necessary to identify reliable and valid proxies. In this context, citation data are used as a proxy of scientific impact. Calculating the average country citation impact factor (ACCIF) allows assessment of aggregate citation impact per country. ACCIF is defined as the ratio obtained from dividing citations received in one year by papers published in the two previous years. By allowing for a time lag and using two years as a reference, it is presumed that a rough match is made between articles and citations (Thorn and Blom 2003)[2].

Argentina's ACCIF improved slightly between 1990 and 1999 from an average 1.1 to 1.3 citations per publication (Graph 20). In 1999, Argentina compared relatively well with other countries in Latin America. Only Chilean scientists were cited more than their Argentine counterparts. Yet, Argentina performed considerably below countries such as Australia, Finland and particularly the United States, suggesting a gap in the quality of scientific output between Latin America and high-income OECD countries.

Spain provides an interesting example. From a similar number of citations per publication in 1990, Spain featured an ACCIF approximately 70 percent above Argentina's score in 1999. Hence, Spanish researchers illustrate the possibility of substantially improving the quality and relevance of scientific outputs in less than a decade.

[2] For a discussion of shortcomings necessary to take into account when interpreting ACCIF results see Walter 2003 and Hecht 1998.

Graph 20. Average country citation impact factor, 1990 and 1999



Source: Author's calculation based on data from NSF 2002

Patenting

Patent statistics are among the most widely used indicators of innovation capacity. They are presumed to reflect the relevance and commercial application of research results.

Few Argentine patent applications. In 2004, 4,602 patent applications were filed in Argentina. Out of those applications only 14 percent were filed by residents in the country. In relative terms, residents filed 18 patent applications per million people in Argentina in 2004. This figure is quite low when compared to Brazil (45), Spain (59), Canada (128), Australia (420) and Germany (576) (RICYT 2005). Argentine residents also take out a very low number of patents abroad. In 1999 Argentine nationals filed 96 patent applications in the United States. The comparable number for Brazil and Mexico was 186 and 147, respectively (NSF 2002).

Industry patenting. Among all companies participating in the 2002 national innovation survey, only 6 percent obtained a patent in the 1998-2001 period. Consistent with findings on innovative sales, large enterprises obtained the most patents. Large enterprises obtained on average 0.18 patents per year while the corresponding number for small companies was 0.03 (Table 5). Medium-size companies compared well to large enterprises with an annual average of 0.16 patents obtained. However, the data reveal that patenting is limited to only 8 percent of medium-size companies while 14 percent of surveyed large companies obtained a patent between 1998 and 2001. Hence, only a small number of medium-size companies were relatively successful in protecting their innovations with patents.

Table 5. Patenting by company size, yearly average 1998-2001

	Large	Medium	Small	Total
Proportion of surveyed companies obtaining a patent between 1998 and 2001	14%	8%	5%	6%
Total annual no. of patents obtained	19	45	41	105
Average no. of patents obtained per surveyed company	0.18	0.16	0.03	0.06

Source: SECyT 2003a

Note: Firms are classified as small, medium or large if their total sales average in 1998-2001 is less than 25 million pesos, between 25-100 million or more than 100 million, respectively.

Tentative explanations for low level of patenting. The low involvement of Argentines in patenting is a reflection of deficiencies in the national innovation system. Notably, low private sector R&D capacity and weak linkages between public scientific institutions and industry have a toll on Argentina's ability to commercialize research. Weak intellectual property protection and enforcement in Argentina also lower returns to obtaining patent rights (see part I). In the 2002 innovation survey, 14 percent of companies list weak IP protection as a main obstacle for innovation (SECyT 2003a). Moreover, few support programs—public and private—exist in Argentina to help industry obtain patent rights and other intellectual property protection. In OECD countries, such programs usually entail the establishment of tech-transfer offices and initiatives to increase awareness among producers of the value of patenting (OECD 2003).

SUMMERY OF FINDINGS

This paper profiled strengths and weaknesses of Argentina's national innovation system in order to identify efficacious government innovation politics. The paper relied on a flow model, tracing inputs, activity and outputs of Argentina's ST&I system. The analysis showed that Argentina has established strong institutions at the national level for S&T oversight and support. However, fragmentation and overlaps persist and potential remains for reorienting public research toward the needs of the economy.

Argentina under-invests in R&D. Comparative data revealed that Argentina features a significantly lower aggregate R&D spending than expected based on its level of income. Fulfilling the government's goal of increasing investments in R&D to one percent of GDP by 2015 will only be feasible with a sharp rise in private sector R&D spending. Moreover, attaining this goal would depend on achievements made in expanding Argentina's stock of advanced human capital. Less than a third of Argentine researchers hold a doctoral degree. Hence, it should be a high priority to strengthen graduate education in the hard sciences and engineering.

Equally important are initiatives to boost the number of researchers employed by the private sector. Less than one-fifth of Argentine researchers work in private companies. The low number of researchers in industry has negative implications for the private sector's capacity to undertake and commercialize research. This is partly reflected in the 2002 national innovation survey which showed that most Argentine companies are not innovators. Low knowledge absorptive capacity is particularly a problem in small, domestically owned companies. Hence, strengthening private sector innovation and technological upgrading, particularly among SMEs, would be essential to restore long-term economic growth in Argentina.

Cooperation and interaction between the stakeholders of the Argentine innovation system leave much to be desired. Although on the rise, partnerships and joint ventures are not regarded as crucial drivers for growth by firms and academia. Government institutions are generally not the partner of choice for private innovators in Argentina and cooperation with the public sector is only considerable in regard to the financing of research. Data suggested that reasons for insufficient public-private cooperation in R&D include quality problems in public research institutions and low responsiveness among public researchers to the needs of industry. Hence, it would be important to sustain recent efforts to foster linkages by financing collaborative research and stimulating cross-sectoral mobility of researchers.

Placing Argentina on the path to sustainable growth will depend on clear articulation of policies to address identified weaknesses in the Argentine ST&I system. Given the financial constraints of both the private and public sector, the main focus should be on redeploying and prioritizing initiatives. Placing an emphasis on quality and results-oriented research, strengthening graduate education and boosting private sector R&D would be important first steps in building a globally competitive Argentine national innovation system.

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