FINAL VERSION

PUBLIC/PRIVATE RESEARCH AND DEVELOPMENT AND INNOVATINESS IN PERU: AN OVERVIEW Relative to Other Latin American Countries

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Lima, February 2004

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PUBLIC/PRIVATE RESEARCH AND DEVELOPMENT AND INNOVATINESS IN PERU: An Overview Relative to Other Latin American Countries

1. Introduction

Latin American countries have struggled macroeconomic instability characterised with irregular and dramatic economic cycles. During the 1980s populist macroeconomic policies and dreadful management of deficit financing have destroyed every economic mechanism for resource allocation. Policymakers have focused in financing unsustainable economic growth. With the aim to accelerate economic recovery expansive fiscal and credit policies have been carried out and currencies have been overvalued. This has increased the vulnerability of the economic system and has sunk Latin American countries into deep crisis.

Peru has been affected by this economic and political environment causing a deep economic crisis during the 1980s. Macroeconomic instability destroyed the economic system. Mechanisms for resource allocation were truncated causing an unbalance between financial and physical investment. The existing environment motivated this and the firms' very short-term scope. Additionally, market demand was reduced due to the market contraction. This had negative effects on the firms' innovation activities, even though in Peru they are only limited to the incorporation and adaptation of new equipment. The economy's installed capacity became obsolete thus; the competitiveness of most industries diminished and, with the adverse conditions for exporting, complete industrial branches almost disappeared.

The crisis also affected the public sector. Public institutions experienced budget cuts that undermined their performance. Science and technology (S&T) institutions, including universities, were the most damaged; their function was perceived as non-priority. Human capital from these institutions fled to the private sector or migrated to other countries. Furthermore, the scarce links from these institutions with the private sector finally disappeared as the economic conditions hindered all demand for scientific and technological services.

The Peruvian economic reforms in the 1990s stabilised the economy and provided a good climate for private and foreign investment, which was enhanced by the government's commitment to privatisation. This provoked a modernisation of those industries in which the capture of rents was possible, such as mining, telecommunications and energy generation. As no special incentives were provided for manufacturing, traditional industrial branches remained depressed. Internal demand was weak and the firms' diminished competitiveness impeded their access to foreign markets.

Thus, the situation of S&T institutions did not change after the economic reforms. Foreign firms that invested in attractive industry branches imported all capital equipment and knowledge-intensive services, as a result, all technological services these firms required were imported. On the other hand, the limited growth of other industry branches hampered the generation of domestic science and technological services.

This paper will try to answer several questions with respect to R&D strategies and will explore within other country experiences, how poor countries like Peru can maximize its benefits from R&D expenditures. The paper is divided in eight sections including this introduction. The second section is a brief overview of the policy debate in developing countries, the linkages between private sector and innovation are shown as well as the importance of an adequate institutional framework.

The third section is a macro overview of the situation of innovation in Peru and Latin America. This macro overview allows understanding the ways in which knowledge is produced, communicated and applied to development problems. It also permits to investigate the policy and institutional frameworks that govern this process. In section four the potentiality to innovate is analysed and it is concluded that information technology indicators are a good predictor for innovation. Section five, introduces the concept of the Technological Innovation System (TIS) as a useful tool to understand the different technological and growth performance among countries. This section also highlights the main features and shortcomings of the Peruvian TIS.

Section six descends to the micro level and analyses the impact over firm performance of investment in research and development in the Peruvian case. In this sense, the difference in performance variables are analysed between firms with and without expenditures in research and development as a way to prove, that although there is a reduced level of investment in innovation in this country it has a real impact over the production process and therefore, over firm performance.

The next two sections present the case studies that help to further analyse the ways in which the Peruvian TIS respond to the generation, adoption and diffusion of specific technologies in the mining and agricultural sectors. They also show the roles that the public and private sectors took in these processes.

Finally, several possible alternatives based on previous experiences are evaluated as potential alternatives to be applied in countries like Peru. Research on high-technology industries has demonstrated the importance of geographically local "knowledge spillovers" by building specific links between university scientists and firms. An analysis of the existence and potentiality of innovation clusters and spillovers between universities and firms is carried out as a way to show that an increase in the innovation rate within firms increases the positive externalities from innovation. Additionally, alternatives as public private partnerships and investment funds are studied.

2. Policy Debate in Developing Countries

Typical S&T research in developing countries was focused on providing overviews of the sector's situation (Erber, 1999; Vargas, 1999). Lately, there has been some efforts to analyse the changes occurred in the S&T apparatus or to analyse the behaviour of the actors engaged in S&T activities (Arocena and Sutz, 2000).

In industrialised countries, where there is a prevalence of private firms in R&D and innovation activities, there is a large body of research based on innovation surveys. These surveys have a neo-Schumpeterian approach to innovation; they consider technological opportunities and the firm's knowledge base and capabilities (Pianta and Sirilli, 1998). Most of these surveys follow the guidelines of the Oslo Manual, a comprehensive handbook on the measurement of technological innovation (OECD, 1997).

The information collected in these surveys made possible the studies about the impacts of S&T inputs and outputs in firm's performance, the assessment of other variables in determining firm's innovativeness and the different patterns of innovation expenditures across sectors. Regarding the impact of other variables on innovation, Pianta and Sirilli (1998) suggest that R&D is a limited fraction of the innovation expenditure while factors like investment in machinery and equipment and design represent the largest part of the firms' financial efforts for innovation.

Also, there have been efforts to measure the impact of technological opportunities on R&D intensity. Estimates of technological opportunities were based on patent-based technology opportunity classes (Jaffe and Trajtenberg, 1998) and on an index of "closeness to science" (Klevorick et al 1987).

Another stream of studies assess the impacts of S&T inputs on outputs and firms' performance (Griliches, 1980, 1988, 1990; Mansfield, 1983). These studies are usually based on a total factor productivity approach, in which productivity growth can be explained by a number of standard inputs and the technology investment variable. The focus is to figure out if innovation contributes to the explanation of differences in productivity growth among firms, when controlling the variable of observable factors relevant to firm performance (Lööf et al, 2001).

Also, research on high-technology industries has demonstrated the importance of geographically local knowledge spillovers because they build specific links between university scientists and firms (Torero, 1998). All these kind of studies have seldom been performed in Latin America because of lack of information.

Current policy debates in Latin America about S&T are related to the recognition that economic reforms performed in the 1990s have not led to increasing levels of industrialisation and neither to the upgrading of the existing industry branches; therefore, posing doubts about the effectiveness of “neutral” policies. Although most countries in the region still adhere to the idea of letting market forces work and only intervene when market failures arise, there are some examples of direct support to specific industries in countries such as Brazil (i.e. incentive for local purchases of capital goods). As an extension, measures focused on creating systematic linkages among firms, universities and technological institutions, or to generating National Innovation Systems (NIS), have superseded implicit S&T policies.

This shift of policy options is reflected in the documents of multilateral organisations such as the World Bank, which promoted the Washington Consensus and now recognise that knowledge and technical progress are the main force behind productivity growth and, therefore, behind competitiveness. The World Bank even implicitly recognises that Latin American countries have returned to a natural resource specialisation and recommends the use of incentives for R&D and NIS as a way to overcome the resource curse trap (Ferrati et al, 2002).

Although there is a wide battery of policies to promote R&D and NIS, the challenge is that these do not work in isolation, they require a systemic approach that include both “horizontal” and “targeted” policies as well as the setting of national priorities and the generation of non-market mechanisms (Lall and Teubal, 1998).

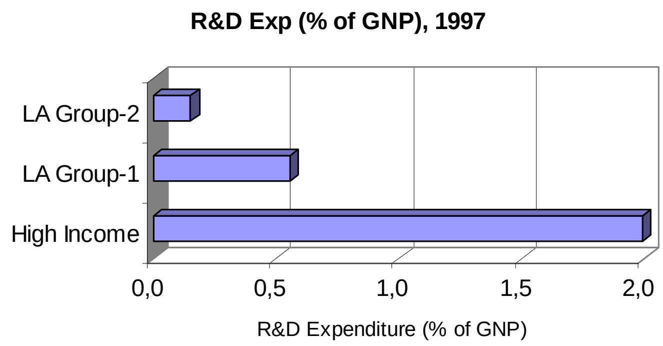
Again, innovation surveys can provide valuable information about the pertinence, focus and effectiveness of policy tools. For example, Pianta and Sirilli (1998) found that innovation incentives provided by the Italian government have been biased towards the largest firms in high tech sectors and they appear to be relevant for them. However, the vast majority of Italian innovating firms are of smaller size and policy tools hardly seem to adequate to their needs.

3. A Macro Overview: Where does Peru and Latin America stand in Innovativeness and Research and Development?

Latin America is a latecomer in recognising the importance of Research and Development and Innovation. **Graph 1** presents R&D expenditures of three groups of countries, low-income Latin American countries, lower and middle-income Latin American countries, and high-income OECD countries. It is clear that Latin American and specially the poorer Latin American countries expend a lot less in R&D than high-income countries.

The US expends in R&D approximately 2.67% of its GNP, i.e. its investment is around US$ 247,000 million of dollars, Canada invests around 1.5% of its GNP, i.e. US$ 12,744 millions of dollars. On the contrary, levels of expenditure for bigger Latin American countries (Argentina, Brazil and Mexico), are less than 1% of their GNP, and are less than 0.1% of the GNP for the smaller countries. Specifically for Peru, the expenditure in R&D only represents 0.08% of its GNP.

Graph 1



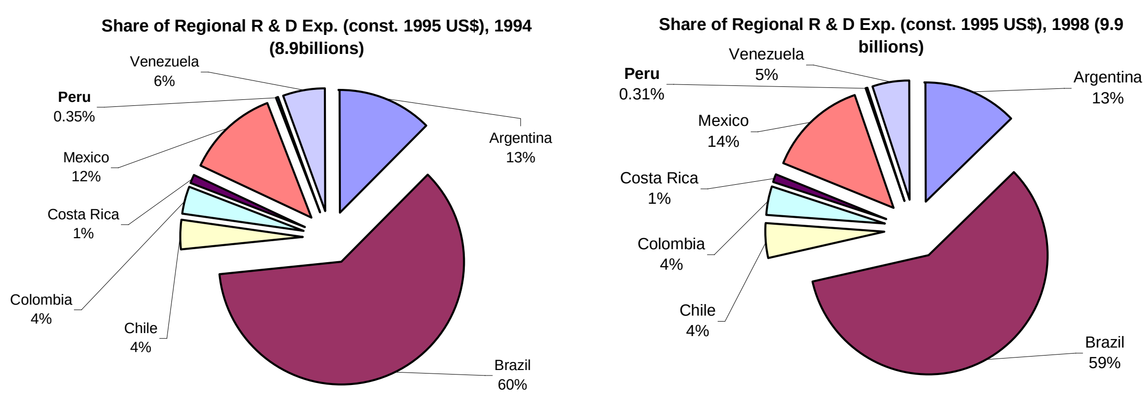
Notes: Countries included in each category are: High Income: Norway, Germany, Austria, United States, France, Finland, Canada, Italy and Spain.; LA Group-1: Argentina, Brazil, Chile, Mexico, Costa Rica, Peru and Colombia; LA Group-2: El Salvador, Ecuador, Bolivia, and Nicaragua.

Source: Ricyt 1990-1999 and WDI 2002

Even more, when the share of R&D expenditures within Latin American countries in **Graph 2** is analysed, Brazil, Mexico and Argentina concentrate more than 85% of R&D expenditures in the region. According to the figures, Brazil has the highest share while Peru has the least share. Peru has spent US$31 millions in R&D, which is around 5% of Brazil's expenditure and 0.35% of the total expenditure in the region.

Available figures[1] report that R&D expenditures in Peru decreased from US$118.63 million in 1980 (Arregui and Torero, 1991) to US$ 41.679 million in 1999 (CONCYTEC, 2001). This sharp reduction mainly reflects the shrinking of the R&D budgets of public institutions, which decreased in more than 40% between 1981 and 1985 and continue to decrease in the late 1980s (Agenda: PERU, 2000).

Graph 2



Source: RICYT (Indicadores Ricyt 1990-99).

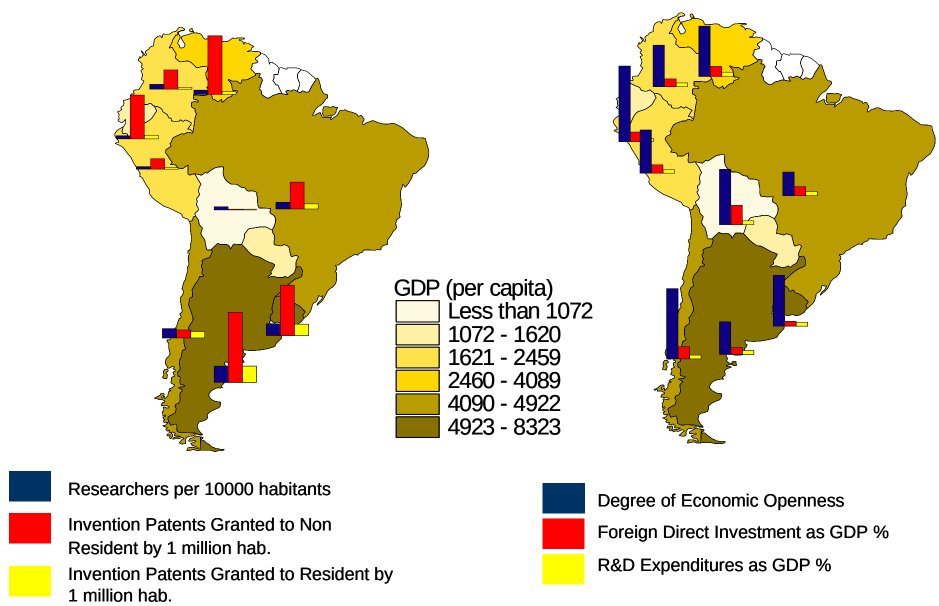
Map 1 tries to summarize the most important innovation indicators for the latest year with available data. These indicators are R&D expenditures, researcher per 10,000 habitants,

[1] These figures should be treated as mere references because there is not a clear description of the methodologies deployed to get them.

invention patents granted to non-residents and residents, foreign direct investment, degree of openness and R&D expenditures by US multinational and affiliated companies. Additionally, the countries are shaded according to their level of gross domestic product per capita (GDP). Similarly to what was found previously, it is clear that Brazil, Argentina, and Chile are the countries with the major innovation activity in the region. Also, they are the countries with the higher GDP compared to countries with less innovation activity. Again, it is striking how Peru ranks in practically all the indicators, as the country with the lowest innovation activity.

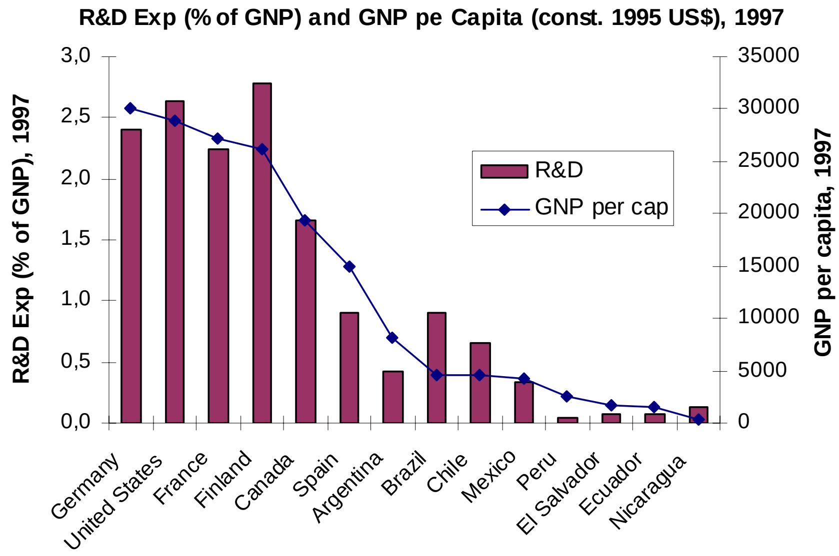
Map 1

Science and Technology Indicators in Peru and other Latin American Countries



In **Graph 3**, the left vertical axis shows the R&D expenditure as a percent of GNP and the right vertical axis shows the GNP per capita. It is evident from the figure that there is a strong positive relationship between R&D expenditure and GNP per capita. Though the direction of the relation cannot be derived from the figure, one can find that the higher the R&D the higher the per capita income and vice versa.

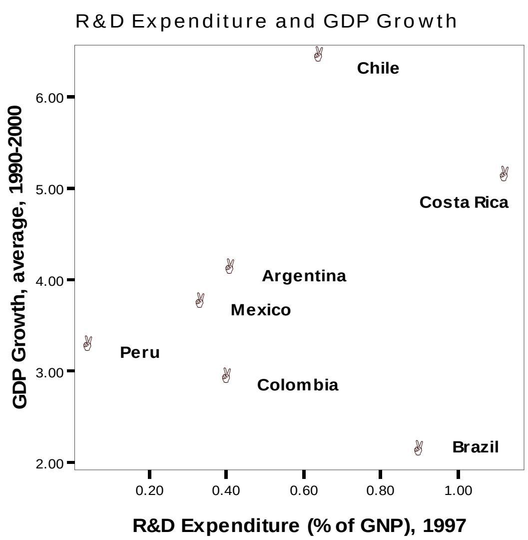
Graph 3



Source: Ricyt 1990-1999 and WDI 2002.

With respect to GDP growth, **Graph 4** shows that if Brazil is excluded from the sample, there is a clear positive relationship between R&D expenditure and GDP growth.

Graph 4
R&D and GDP Growth



Data Source: Ricyt and WDI 2002.

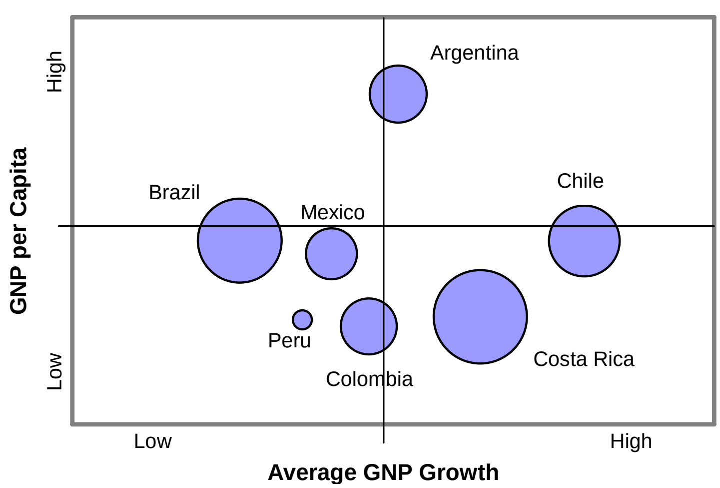
Similarly, **Graph 5** tries to combine, GNP growth with GNP per capita and R&D expenditures. The graph is divided in four quadrants identifying countries with high and low GNP per capita and their corresponding GNP growth. In this sense Peru, Mexico and Colombia are identified as countries with low GNP per capita and low GNP growth, while

Costa Rica is identified as a country with low GNP per capita but with a high GNP growth. Finally, the size of the circle reflects the amount or R&D expenditures as a percent of the country GNP. From the graph, it can be seen that countries with very little expenditure in R&D such as Peru, Colombia and Mexico are countries with low GNP per capita and low growth, while countries like Chile with high levels of expenditures in R&D are characterised specially by high GNP growth with the exception of Brazil. This country has the highest R&D expenditures according to its high GNP per capita but it has a low GNP growth.

When analyzing the composition of the share of R&D expenditures by source, the industrialized countries, for instance USA, Canada and Spain, show that the highest share of R&D expenditure comes from the private sector (see **Graph 6** and **Table 1**).

In Peru, government has remained a dominant source of R&D expenditure. Although, in the later years there has been a change in the composition of R&D expenditures. By 1980, firms only contributed with 2.2% (Arregui and Torero, 1991), while by 1999, the participation of firms was 42%, universities 30%, and research institutions only 28% (CONCYTEC, 2001). It is also important to note that firms contributed with 20% of the basic research budget, 47% of the applied research one and 89% of the development expenditures (CONCYTEC, 2001)[2].

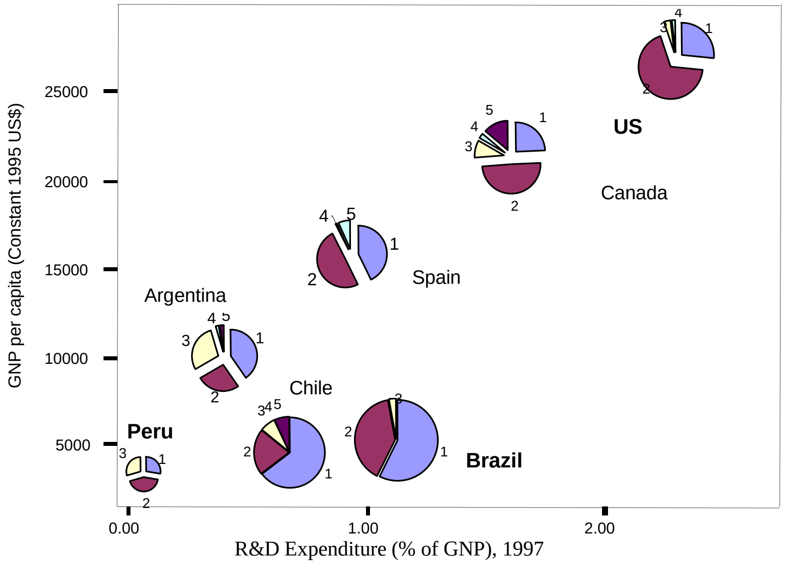
Graph 5
R&D Expenditures (% GNP), GNP Per Capita (1997) and GNP Average Growth



Data Source: Ricyt and WDI 2002.

[2] Although the figures shown are official, they may not be accurate. The figures come from the survey elaborated by CONCYTEC, which has several shortcomings such as a not well defined sample and the different ideas that firms may have from the different concepts used in the survey.

Graph 6
GNP per capita and R&D by Source



Notes: Here, 1: Government, 2: Private Sector, 3: Universities, 4: Not for profit, and 5: Foreign firms.
Source: Ricyt and NSF 2000 (pocket data book).

Table 1
Distribution by Source of R&D Expenditures

	Government	Private Sector	Universities	Not for Profit	Foreign
Core Group					
Argentina, 1999	40.4	26.0	29.1	1.9	2.6
Brazil 1996	57.2	40.0	2.8	0.0	0.0
Chile, 1999	64.3	21.5	7.3	0.0	6.8
Colombia, 1997	70.0	13.0	14.0	3.0	0.0
Costa Rica, 1996	53.4	17.4	14.8	4.5	9.9
Mexico, 1997	71.1	16.9	8.6	0.9	2.5
Peru, 1999	27.8	42.3	29.8		n.a
Venezuela, 1997	31.5	44.8	23.7	0.0	0.0
Developed Countries					
Canada, 1999	24.4	49.2	9.8	2.8	13.8
Spain, 1998	42.7	49.8	0.0	0.8	6.7
Portugal, 1997	68.2	21.2	1.5	2.9	6.1
Other Latin American Countries					
Bolivia, 1999	24.0	20.0	30.0	16.0	10.0
Ecuador, 1998	90.6	0.0	0.0	0.5	8.9
El Salvador, 1998	51.9	1.2	13.2	10.4	23.4
Uruguay, 1999	9.4	35.6	47.1	0.0	7.9

For Argentina, Peru and Venezuela, data is for S&T.
For Peru, the first figure is for government and not for profit sector together.
Source: Ricyt.

4. Measuring Potentiality to Innovate

Warner (2000) constructed an index, called the economic creativity index, in which he tried to bring together under one measure several important aspects of innovation and technology transfer and diffusion; with the institutions that facilitate innovation and diffusion. This index is an average of two indices: the technology transfer index and the start-up index.

The technology transfer index is based on survey questions that try to capture pure innovation activity and international technology transfer. Since countries can get technology either by producing it or by importing it, Warner measures an overall technology index after scaling both components in similar units. The key idea, as mentioned by Warner, is that countries get credit on the technology index for either innovation or technology transfer. What is important is that the country participates with the newest technologies and innovations; it does not matter if it designs the innovation itself.

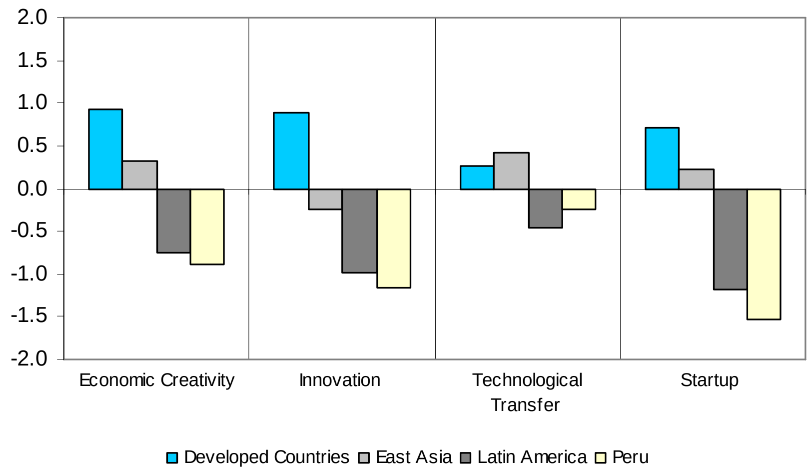
The ability to revote firms or ease for starting new enterprises is captured through an index of start-ups. The index is an average of two parts. Whether financing is available and whether it is easy to start a new business. The former is measured by averaging responses to two questions: whether venture capital is available for risk taking entrepreneurs, and whether it is easy to get a loan with a good business plan but little collateral. The latter has to do with the firm capability of renovating technologies according to the institutional framework.

The economic creativity index falls in a range from –2 to +2. The average index of economic creativity for the industrial countries is 0.92, whereas the index for developing economies is –0.19. The gap is observed in all sub-categories involved in the economic creativity index, although it is more significant in the case of innovation (0.89 for industrial countries vs. –0.57 for developing countries). The economic creativity index for East Asia is 0.32, whereas the creativity index of Latin America is –0.75.

As mentioned by Chong (2001), most Latin American countries, with the bare exception of Chile, Brazil, and Mexico rank low in terms of economic creativity. Innovation plays a major role in the economic creativity index of most of the developed economies. While the top economies show high levels in innovation, the performance of Latin America is poor, all countries display negative scores (i.e. below the world average). Costa Rica and Chile are the Latin American leaders in this category, whereas Bolivia, El Salvador, Peru[3] and Ecuador are the poorest performers in terms of innovation. Unlike Latin America, not all the countries of East Asia register negative scores: Singapore and Taiwan have remarkable positions (see **Graph 7** and **8**).

[3] Peru is ranked in position 54 of 59 countries for which the index was constructed

Graph 7
Economic Creativity and its Components

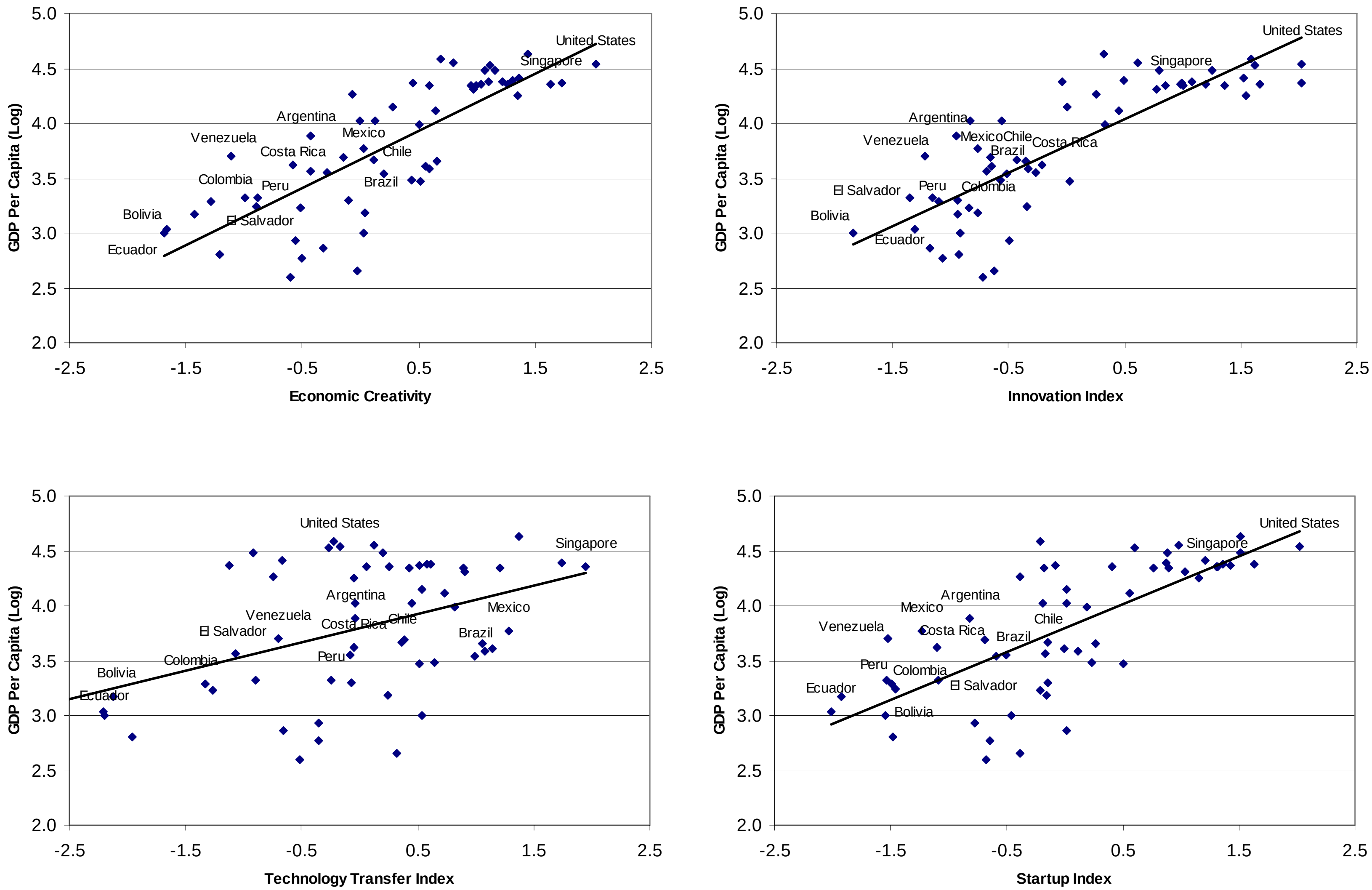


Note: The regional classification came from World Bank (2001)

While innovation is the major force behind economic creativity in industrial countries, technological transfer plays a more important role in the developing world and in Latin America in particular, as shown in **Graph 7**. Specifically, Peru moves from position 54 out of 59 in the innovation index to position 40 in the technology transfer index. However, the overall scores for Latin America are both negative for innovation and for technology transfer.

This implies that there is a lack of ability to renovate technologies in the region, either by developing them or by assimilating those developed by others. Again Peru is ranked in position 54 of 59 countries for which the index was constructed. This is different to what happens in East Asia, where despite the innovation index is negative (although less than the one of Latin America) the technology transfer score is positive. This confirms the idea that in East Asia technological adaptations of existing technologies have played a key role in the economic creativity process in the region. This is an important experience from where Latin American countries can learn.

Graph 8: Economic Creativity Index and GDP per Capita



Economic creativity and innovation depends not only on the ability to renovate technologies, but also on the ability of firms to renovate them, which is captured by the ease of starting new enterprises or what Warner calls the start-up index. The ranking of Latin American Countries fall far from developed countries in an even worst situation than in the innovation index as shown in **Graph 7**, being lower the ranking for Peru. There are several reasons behind this result. Latin American Countries are characterized by inappropriate and very expensive regulations to create firms, tight labour regulation codes, lack of credit, shallowness of capital markets and lack of adequate infrastructure. Even more, there is a lack of adequate institutional capital (adequate protection of property rights, independent judiciary system, and strong regulatory institutions) which impact negatively on the ability to start-up new firms[4].

4.1 Evaluating the Robustness in Innovation Indicators

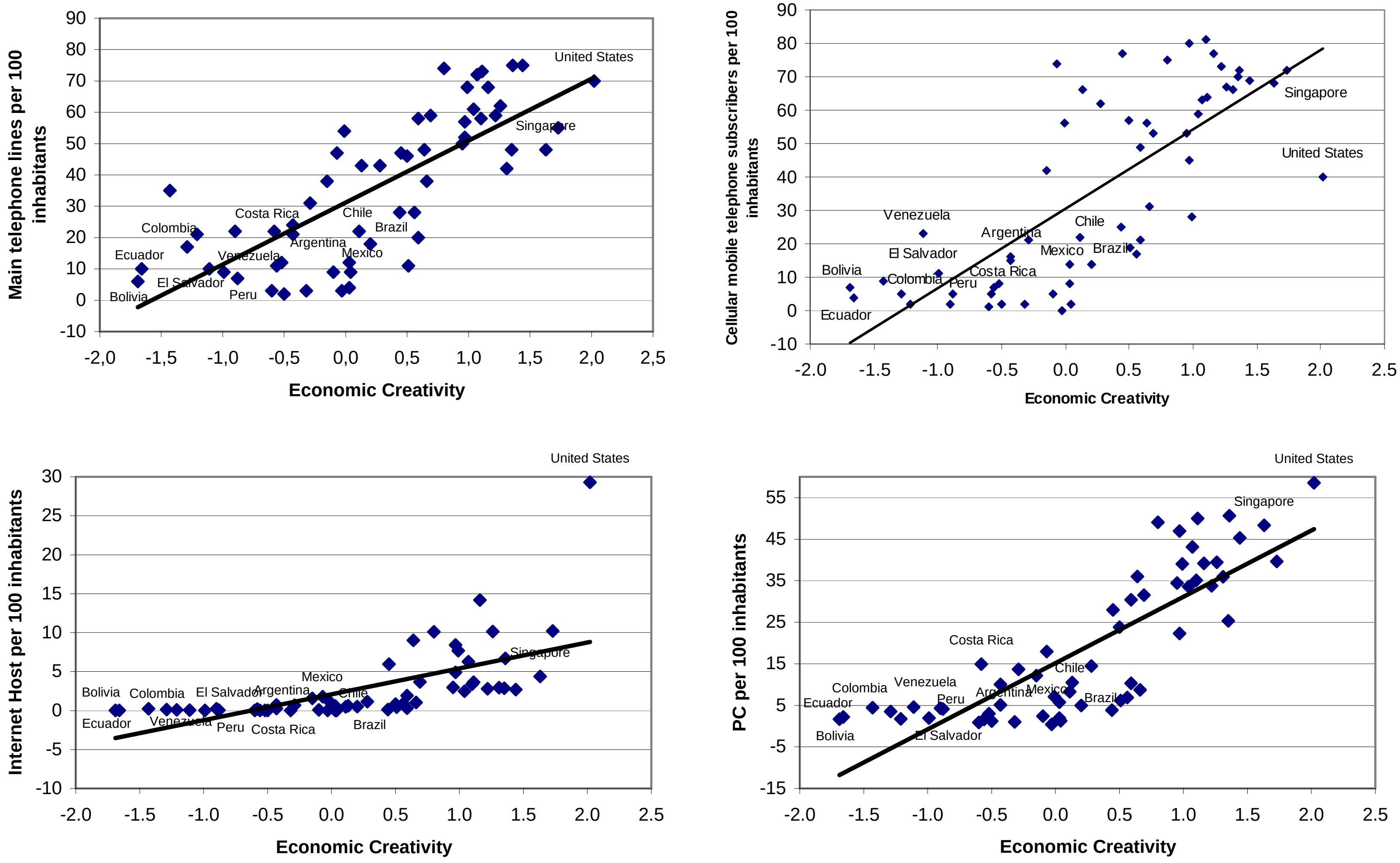
Although these global competitiveness report measures on innovation and creativity are extremely relevant, they are partly based on surveys which by being subjective, can be somewhat criticized for lack of comparability across countries and self reporting biases. Nevertheless, when using different innovation indicators as internet hosts, number of personal computers, telephones and other information and communication technologies (IT) it was found that they are highly correlated with this innovation and creativity index.

In fact, the correlation between information technologies and economic creativity is high, although it is higher for industrial economies than for developing nations. For the 49[5] countries included by Warner (2000) in his index, when analyzing the correlations between the Economic Creativity Index and density of fix phones, cellular phones, Internet hosts and personal computers, a significant correlation of 0.77, 0.76, 0.62 and 0.82 respectively was found. Even more, when concentrating in Latin American countries the correlations for fix phones, cellular phones and personal computers where 0.62, 0.54, 0.48 respectively and even higher, 0.84 for Internet hosts (see **Graph 9**).

[4] Specifically, in the start-up index Peru is located in position 46 of 49, practically with the lowest index.

[5] The countries included are: United States, Hong Kong, Iceland, Luxemburg, Finland, United Kingdom, Netherlands, Singapore, Sweden, Israel, Australia, Taiwan, Norway, Belgium, Denmark, Ireland, Canada, Switzerland, New Zealand, South Africa, Germany, Hungary, Turkey, Korea, Malaysia, Spain, Indonesia, Greece, Poland, Austria, Chile, Thailand, Egypt, Mauritius, France, Portugal, Jordan, Japan, India, Italy, Philippines, Slovak Republic, Brazil, Zimbabwe, Vietnam, Scheck Republic, China, Argentina, El Salvador, Costa Rica, Mexico, Russia, Ukraine, Colombia, Venezuela, Peru, Bolivia, Bulgaria and Ecuador.

Graph 9
Economic Creativity and IT Indicators

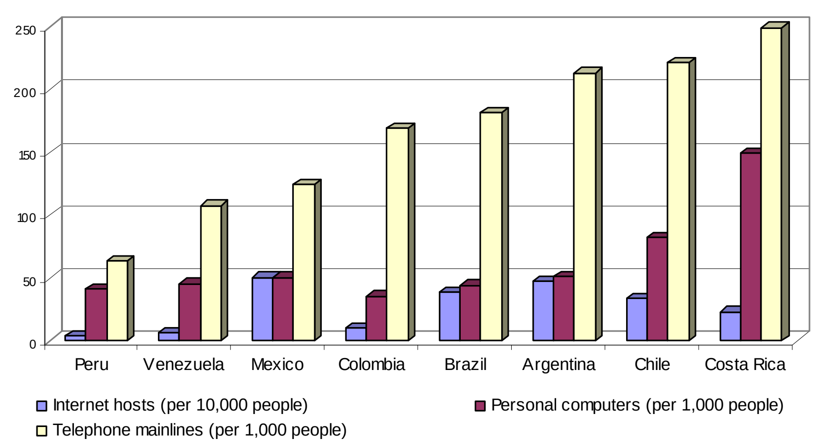


In general, the Internet is highly correlated with innovation, start-up of new business and even technological transfer. In other words, Internet is a useful proxy of economic creativity in the developing world and in Latin America, in particular. In this sense, when evaluating the impact of innovation over firm performance, Internet access will also be used as a proxy of innovation.

When analyzing in detail the availability of IT technologies in Latin America, it is clear again that Peru, similar to R&D expenditures, lags behind in terms of the availability of ITs expressed in the number of Internet hosts, personal computers, and telephones (see **Graph 10**). After the privatization in Peru, the number of telephones per hundred habitants increased from 2.7 to 6.6, and Internet hosts has increased from 1 per 1000 inhabitants in 1994 to 39 per 1000 inhabitants in 2000. In terms of the number of personal computers per 100 inhabitants, it has increased from 1.49 in 1995 to 4.09 in 2000. Even more, the number of personal computer per 100 white-collar workers has increased from 5.48 in 1995 to 14.19 in 2000. However, similar to other IT indicators, this represents one of the lowest scores in Latin American countries.

As the availability of ITs can act as a complementary input in scientific works, the less allocation of R&D fund coupled with the less availability of ICT infrastructure has kept Peru a less competitive country compared to the others in the region.

Graph 10
Availability of ITs in 2000: A Regional Comparison



Data Source: WDI 2002.

5. A Conceptual Approach to Study Innovatiness: The Technological Innovation System

5.1 Conceptual Framework

The previous section has shown the relationship between economic growth and innovativeness. It has also shown that in industrialized countries firms contribute to a large extent to R&D expenditures. However, firms alone are not able to take by themselves the complete process of knowledge generation that is necessary to innovate. It is necessary an interactive relationship among the different research institutions, universities and firms, in which each of these agents supply their knowledge and make explicit their needs so as to define the final outcome of innovation. This constant interaction allows the diffusion of scientific and technological knowledge thus benefiting less innovative firms.

Empirical studies have shown that these interactive relationships are present in industrialized countries and in those that have experienced high economic growth rates, giving rise to the concept of technological innovation systems (TIS). This concept refers to the different institutions, firms and government that conform the scientific and technological apparatus, and the way how these agents interact for the creation, diffusion and utilization of knowledge.

Patel y Pavitt (1994) define the TIS as the group of domestic institutions, their incentive structures and competences that determine the rate and direction of technological learning in a country. In that sense, they define four types of institutions: firms, universities and similar institutions that perform basic research, a mix of public and private institutions that provide education and technical training, and the government that finance and perform different activities to promote and regulate technical change.

For these authors, incentives include the market failures that prompt government to promote and finance basic research and that urge firms to train their employees even at the risk that they can leave the firm after the training. In the first case, governments will subsidize basic research because of the difference between social and private returns. In the second, firms' internal capabilities are difficult to replicate and provide a competitive advantage that more than compensates the cost of training.

There are also incentives associated to the temporal monopoly rents generated through technological innovation. Also, there are specific incentives such as the relevance of local demand (Porter, 1990; Fagerberg, 1992) that can become an important factor to build up competitive advantages.

The technological gaps among countries are the result of different research and development patterns and other related activities. These technological gaps have a microeconomic basis since firms have different technological capabilities (Teece y Pisano, 1994). In section 4, the data shows that Latin America ranks poorly in terms of technological creativity which means that firms are reluctant to adopt new technologies and perform very poorly in innovation.

The TIS concept has helped to find regularities and differences behind the different innovation rates and biases. Thus, it has been useful to understand the long term scope of the wealth of nations identifying the coherence between their economic structure and their institutions (Freeman, 2002). In that sense, there is a co-evolution between the level of economic development and the development of institutions (Freeman, 2002; Gu, 1999, Cooper, 1999).

Variations to the concept of TIS have been made to reach specific goals. Knowledge is not created, diffused and used in a uniform manner, on the contrary, some technologies develop and diffuse in a more dynamic way than others. The study of technological systems (Carlsson, 2002) is important to define industrial and technology policies that aim at promoting new technologies.

On the other hand, a sectoral innovation system (Malerba, 2002) emphasizes how different agents perform market and non-pecuniary transactions for the creation, production and use of different products. These products can be created in different economic sectors that evolve according their own technological regimes and opportunities and the relationships they maintain with other sectors. This approach allows to analyze specific technological change and, therefore, it is necessary to incorporate additional elements than those found in a TIS. Thus, besides the different institutions and their incentive systems, it is necessary to include products, basic technologies, inputs, demand elements and the different relations and complementarities among them all. Thus, this approach helps analyze the factors behind the evolution of industries or economic sectors and explain their different rates of technical change. It also allows to design tailor-made policies for the different economic sectors.

The dynamic feature of TIS as a catalyst of learning processes (Lundvall, 2002) highlights the need to design coordinated development strategies. In this approach, the relationship between supplier an clients is critical because their transactions transfer valuable information that allows for a continuous learning and the incorporation of new knowledge to the productive process.

5.2 The Technological Innovation System in Peru

The poor innovation performance of Peru shown in **Sections 3** and **4** is a direct result of the lack of understanding and interest of the role of S&T in economic development[6]. This is not a new situation, Peru has lagged the efforts made by other countries in the region to promote the scientific and technological institutional framework and to design promotion policies.

It is only in the late 1960s that the Consejo Nacional de Investigación (CONI) is funded. During all the 1970s, various technology-related institutions are created such as the Instituto de Investigación Tecnológica Industrial y de Normas Técnicas (ITINTEC), the Instituto Tecnológico Pesquero del Perú (ITP) and the Instituto Nacional de Investigación y Normalización de la Vivienda (ININVI). Later on, the CONI becomes the Consejo

[6] The Advising Committee for Technological Innovation at the Nacional Competitiveness Council has declared that the technological innovation does not have a high priority among the different agents of the Peruvian TIS. This committee states that the TIS is fragmented and does not show links that facilitate knowledge transfer. It also states that there is not a market for technological services, the innovation capabilities are scarce and there is limited funding for innovation. This committee has defined the following objectives: (a) to promote a culture that values innovation and quality improvement; (b) to increase the demand of firms for S&T; (c) to improve the generation, transfer, diffusion and exchange technology systems; (d) to generate innovation capabilities; and (e) to increase the private investment and expenditures in innovation (Consejo Nacional de la Competitividad, 2003).

Nacional de Ciencia y Tecnología (CONCYTEC) aimed at serving as "the link of the State with the scientific and technological community" (Flit and Barrio, 1994). However, likewise many countries in Latin America it was not possible to forge that link or to connect the scientific community with the productive sector. Nor it was even possible to set a research agenda that corresponded to vast sections of the population needs and generate the transmission of knowledge within the same scientific and technological community.

The idea of TIS has been recently adopted by the draft of the 2002 General Law of Promotion of Science and Technology for National Development. However, the legalist scope of this draft seems to believe that linkages among the different agents of the TIS can be created through a decree: "The National System of Science, Technology and Innovation (SINACYT) is created as an open, non exclusive, institutional space, whose components are all programs, projects and S&T activities developed by public, private, associative or individual institutions or entities" (CONCYTEC, 2002).

The latter means that CONCYTEC has an mistaken conception of a TIS. It perceives the TIS as a mega institution that has a central unit for management support where different actors such as research or innovation centers, firms, NGOs and funding agencies can take part, however, "this participation will be ruled by a regime which includes qualification and register norms" (CONCYTEC, 2002).

Despite the CONCYTEC and the State conception of a TIS, what is found in Peru is a series of institutions with scarce research and innovation capacities that have limited links among themselves or with other agents such as firms. There is also a complete lack of explicit policies to promote technological innovation or even that support the formation of highly trained human resources. However, there are some advances in the provision of technological services for firms, especially for small and medium ones, as well as the creation of some financial mechanisms for technical assistance.

For some authors like Sagasti (2003), there is no such a thing as a Peruvian TIS. However, there are institutions dedicated to S&T activities that may not be effective and respond to misleading incentives. In that sense, Mulling Consulting (2002) acknowledges the existence of a very fragmented TIS, whose parts that do not interact in a constructive way but instead compete among themselves.

In the following lines there is a description of the main components of the Peruvian TIS.

5.2.1 Firms

Two factors have influenced the current configuration of the Peruvian entrepreneurial sector. On the one hand, the 1980s economic crisis produced an informalisation process that hindered private investment and severely damaged manufacturing firms which respond by reducing the size of their productive units. **Table 2** shows that 96% of the Peruvian firms have 10 or less workers. These firms usually sell their products in the domestic black market[7], thus they cannot access to formal credit.

Table 2

Perú: Número de unidades empresariales por tamaño según sectores (1996)

Actividad económica	Micro empresa (1)	Pequeña (2)	Mediana (3)	Grande (4)	Total
Total	**507,335**	**17,496**	**2,625**	**291**	**527,747**
Agricultura	1,523	396	59	7	1,985
Pesca	6,258	348	55	3	6,664
Minería	5,000	570	70	27	5,667
Manufactura	65,604	4,680	698	109	71,091
Electricidad, Gas y Agua	2,470	168	20	8	2,666
Construcción	12,307	816	125	11	13,259
Comercio	313,826	7,386	1,136	95	322,443
Turismo, Hoteles y Restaurantes	46,967	1,205	30	1	48,203
Transporte y Comunicaciones	14,039	948	147	11	15,145
Intermediación Financiera	0	36	30	5	71
Otros	39,341	943	255	14	40,553

(1) Unidad empresarial con hasta 10 trabajadores.
(2) Unidad empresarial que tiene entre 11 y 50 trabajadores.
(3) Unidad empresarial que tiene entre 51 y 200 trabajadores.
(4) Unidad empresarial con más de 200 trabajadores.

Fuente: GRADE (2001).

Small size firms have scarce technological capabilities and seldom demand technological services. Robles et al (2001) reports that only 7 out of 10 microfirms in the industrial branches of Confections, Metalworking and Informatics Services know the existence of entrepreneurial development services[8], but only 5 out of 10 have used them. This study also shows that microfirms in the Informatics Services (i.e. internet coffee bars, computers ensamblaje? and software creation), a knowledge intensive branch, know extensively the existence of these entrepreneurial services (99%) and more than 80% have used them.

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[7] Robles et al (2001) estimates, based on a sample of microfirms in the branches of Confections, Metalworking and Informatics Services, that they only contribute with 0.44% of the taxes paid in those sectors.

[8] Entrepreneurial development services are offered by independent professionals in topics such as legal, taxing and accounting aspects, as well as services in the areas of management, marketing, commercialization and finances. Additionally, these services can be classified by the intervention mode: (a) direct intervention services (i.e. training and capacitation services, generation and transfer of technology, information, consulting and technical assistance, and commercial promotion and marketing); (b) intermediation services (i.e. entrepreneurial cooperation and integral assistance centers); and (c) context services (i.e. creation of infrastructure and regulation) (Robles et al, 2001).

The openness of markets during the 1990s hit on the state-owned firms. These firms that performed some research and development were privatized and acquired by foreign firms, which get their technological inputs abroad. On the other hand, the vast majority of medium firms have disappeared, thus losing an important segment of firms with some kind of technological capabilities.

In the remaining segment of large and medium firms, few of them conceive innovation as an activity different from investment which is associated to the expansion of the productive capacity. Beside those firms that sell mainly to foreign markets, few of them understand that innovating new products and processes is necessary to gain new markets. In that sense, few firms will be able to take advantage of the new trade agreements recently signed by Peru[9].

The new configuration of the Peruvian industrial sector makes difficult the relationship among firms and, therefore, the possibility of developing productive chains. Large firms operate with high technical standards close to the international technological frontier, while the small ones operate with obsolete technologies, lack management tools and quality standards. For example, the mining sector demand most of its inputs and services directly from foreign suppliers[10].

According to CONCYTEC (2001), from 8,976 surveyed firms only 9% invested in technology not embedded in capital. From these, 61% acquired technological services, 20% technological licenses, 10% trade marks and 5% metrology, normalization and quality services. Despite the low figures, they are an indicative of an incipient demand and willingness to pay for technological services.

5.2.2 Government

The importance of the government as a component of TIS rests in its capacity to formulate policies aimed at overcoming market failures that restricts technological innovation, to assign resources for implementing research and development programs in government institutions, to provide infrastructure, and to establish adequate regulation and normalization systems to rule the operation of firms.

a. Policies aimed at overcoming market failures

Edwards (2001) argues that the main factors that determine innovation and assimilation of technologies are education, good institutional environment, access to credit, adequate infrastructure, and to some extent openness.

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[9] Peru has signed the Andean Trade Preferences and Drug Eradication Agreement (ATPDEA) in September 2002. By this agreement, the US government grants trade preferences to Colombia, Bolivia and Peru for more than 5,600 products. In addition, Peru has been accepted as an associated member to MERCOSUR, the common market formed by Brazil, Argentina, Uruguay and Paraguay.

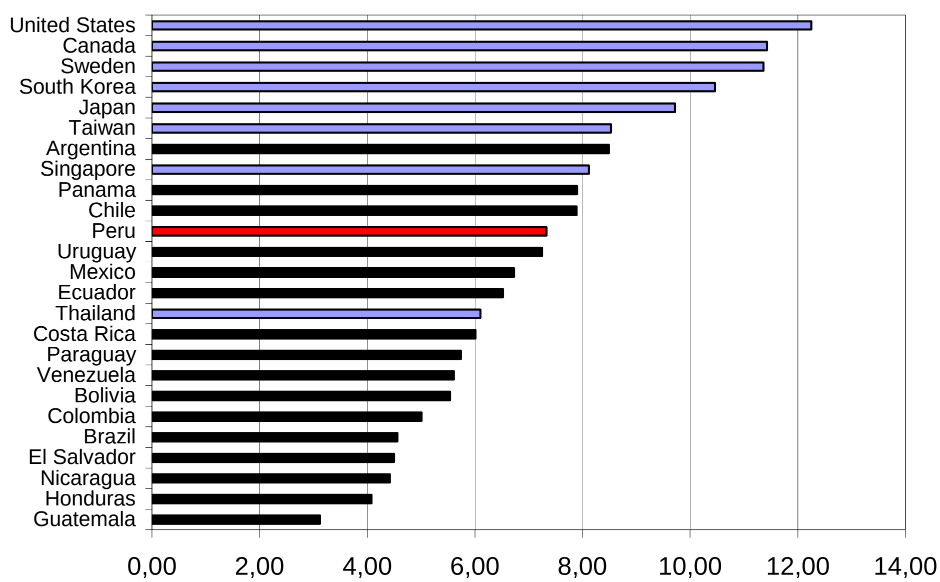
[10] The commercialization may be registered as a domestic transaction but the goods and services are not produced domestically.

Education: a Problem of Quality and Mismatch to Demand

The Peruvian government has not formulated a coherent scientific and technological policy. Besides the legal framework that supported the creation of different scientific and technological organizations, there has not been any intention to design policies to promote technological innovation in the productive sector. Even recently, the focus was on formulating a National Plan of Science and Technology and on generating research programs and projects that will be executed by public institutions. This scope disregarded implicitly the participation of the private sector. At the sectoral level, the few incentives for the promotion of technological activities were the incentives to import capital goods. The lack of policy instruments have to do with the lack of technology management capabilities in the public sector. The formulation of policies has been, and still is, in the hands of Peruvian scientists dedicated to basic research with little knowledge about the interactions needed to transfer the results of basic research to the productive sector.

The government has been not even able to formulate "horizontal" policies, such as education policy, that are known to be an important factor to increase productivity (Chong, 2001) and the capability of innovation. More educated workers are more able to devise more efficient ways to work. Skilled labor force play a crucial role in taking advantage of the potential offered by new innovations locally or externally developed.

Graph 11
Average Years of Education Among Total Population in 2000

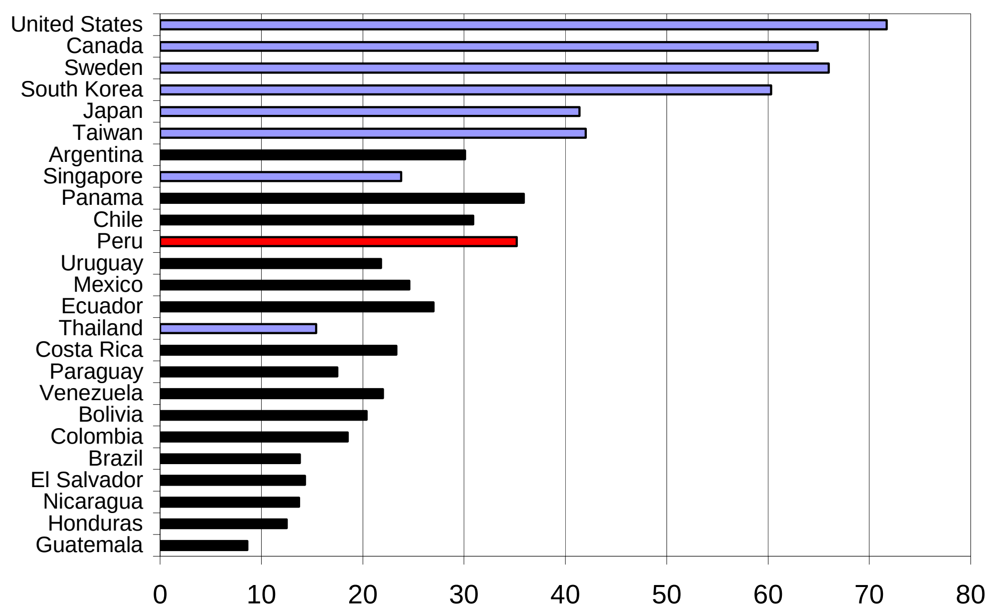


Source: Barro, Robert, J. and Jong-What Lee, International Data on Educational Attainment: Updates and Implications (CID Workin Paper No. 42), Harvard University

Using estimates from the Barro-Lee data set on Education, it has been shown that educational attainment in Latin America lags behind attainment in other regions. As mentioned by Duryea and Pages (2002a) average years of schooling attained by the population older than 25 in Latin America was approximately 6 years of schooling in 2000 while the averages were 11 years in the United States, Canada and Sweden. Even though, when analyzing the average years of education among total population, as it can be seen in **Graph 11**, Latin America is not as unskilled. Peru is ranked close to Taiwan and to Chile and Argentina with more than eight years of education in average, and the average for Latin America is 5.92 years.

Again using Barro-Lee figures, the availability of skilled workers is approximated using the share of population who has completed at least secondary schooling. Despite the percentage of skilled workers in South Korea, Taiwan, the United States, Canada, Japan and Sweden is at least twice as that of the Latin American countries, Peru, Argentina, Panama and Chile had rates over 30%, close to the ones of Taiwan and Japan (see **Graph 12**).

Graph 12
Percentage of Population who Completed Secondary Education

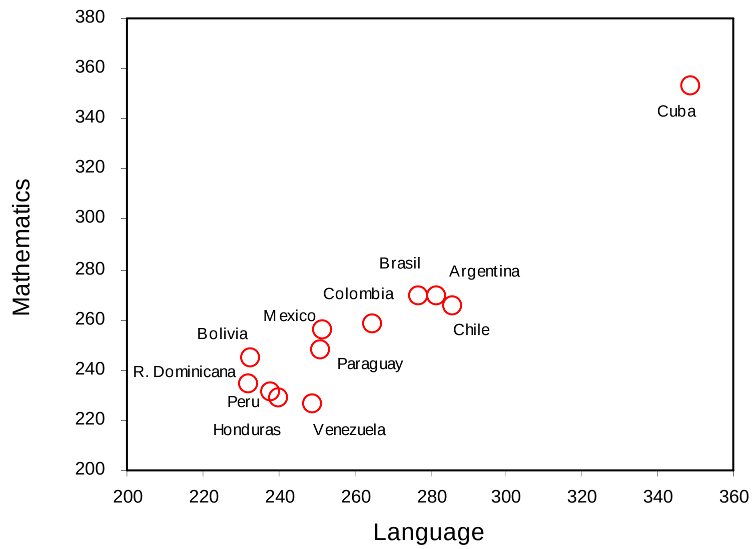


Source: Barro, Robert, J. and Jong-What Lee, International Data on Educational Attainment: Updates and Implications (CID Workin Paper No. 42), Harvard University

Figures show that Peru as well as other Latin American countries is over the average of the region in terms of education attainment. There is also a significant percentage of skilled labor, even close to what is found in Japan and Taiwan. Despite there has been a significant improvement in enrollment in the last years, the quality of education shows a completely different picture.

There are scarce measures of schooling quality available in Latin America, but all suggest that the quality of schooling in the region is very low. As mentioned by Duryea and Pages (2002a) only few countries participate regularly in internationally comparable achievement tests, making comparisons across countries and regions very difficult. However, in the few occasions where Latin American countries have participated, students perform below other countries, particularly relative to those in East Asia. Even more there is a wide inequality within the region. **Graph 13** shows the ranking of Peru and other Latin American countries in terms of the first regional comparable test in the subjects of Language and Mathematics for third and fourth level of primary education. The results indicate that Peru's scores are clearly within the worst amongst the countries included in the study. On the other hand Chile was amongst the best performers in the region (after Cuba and Argentina in Math Scores and after Cuba, Argentina and Brazil in Language)[11].

Graph 13
Measuring the Quality of Education (4th Grade)



Source: UMC, Ministerio de Educación del Perú, Bulletin No. 9

As a result, a large percentage of educated workers earn wages below poverty levels. Duryea and Pages (2002b) show that in Peru 46 percent of workers with some secondary education and 19 percent of workers with four years of university education earn very low wages. These percentages are similarly in Nicaragua and Bolivia. On the other hand, in the case of Chile these numbers are substantially smaller, 21 percent and 2 percent respectively, and similarly for the cases of Argentina and Costa Rica. This result also explains why, returns to primary and secondary education[12] are high in countries like Peru, given that they are measured in percentage rates – i.e. the final impact on absolute wages depends on the base to which that percentage applies, which in the case of Peru is very little.

[11] Although it is not clear what is causing such failures in education, Duryea and Pages (2002) point out three major reasons: reduced expenditure in education, low quality of teachers and poor educational systems which lack mechanisms of control and accountability at all levels.

[12] To measure returns to education a standard Mincer equation is estimated of the following form:
$\ln(y) = \alpha_0 + rS + \alpha_1 E_P + \alpha_2 E_0 + \alpha_3 E_P^2 + \alpha_4 E_0^2 + \alpha_5 X + \mu$, where S is the number of years of schooling, r is the returns to education, E_P *and* E_0 are potential and occupational experience respectively, and X are sociodemographic characteristics.

Institutional Environment

Although improving educational attainment in Peru and other countries of the region will help to boost innovation, which in turn will foster more productivity (Acemoglu; 2002), these workers won't be able to productively use their skills if the economic and institutional environment in which they work is not appropriate. These include a good bureaucracy, clear property rights, as well as institutions and resources that enforce them, control of corruption and a good rule of law.

Clearly, the lack of this adequate institutional environment is the case of Peru and many Latin American countries, in which a lot of red tape requirements are imposed. Although the global index of public institutions registers Peru in position 45, there are several indicators in which there is a significant delay, which affects negatively the competitiveness of the country. For example, Peru is ranked position 71 out of 75 countries in terms of the red tape required to open a firm. Even more, the indicator of trust in politicians ranks Peru in position 74, just over Zimbabwe (see **Table 3**).

Table 3

Competitivity in the Institutional Environment

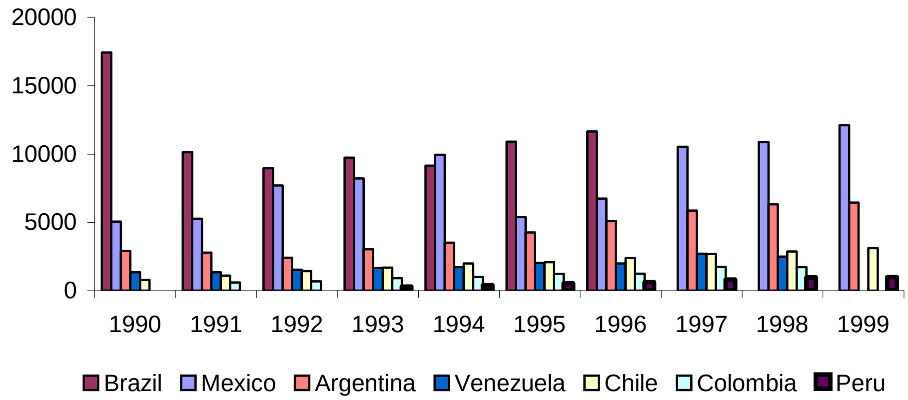
Institutional Capital	
Judiciary Independence	73
Corruption of Public Institutions	30
Trust on Politicians	74
Competence of Public Servants	60
Organized Crime	57
Property Rights Protection	56
Institutional Change Costs	68
Informal Sector	65
Governmental Capital	
Government Expenditures	18
Marginal Tax Rate to Entrepreneural Income	24
Not Reported Benefits and Salaries	42
Fiscal Evasion	53
Red Tape Requirements to Register a New Firm	71
Number of Days Needed to Open a New Firm	54

Source: Global Competitiveness Report 2001-2002

In terms of property rights protection Peru ranks in position 56, something which is essential to protect the significant costs of research and development required for new products or processes. If there are no clear property rights then the incentive to develop knowledge is weakened. In Latin America, mainly Brazil, Mexico and Argentina, have realised this situation and they have taken actions to make the protection of intellectual property rights increasingly important. As a result and as shown in **Graph 14** there is a significant increase in the number of applied patents for residents and non residents in these countries compared to other countries in the region.

Similarly to the above, labor relations and regulations affect productivity in multiple ways. Duryea and Pages (2000a), by defining a set of rules that govern employment, labor relations can be conductive to high motivation, high effort and high productivity, or instead, they can promote low moral and poor outcomes. The available evidence suggests that the quality of labor relations and regulations is poor in Latin America. Specifically in terms of labor regulations, Heckman and Pages (2001) show that mandated benefits and job security regulations have a substantial impact on employment and turnover rates in Latin America. They even show that job security provisions are an extremely inefficient and inequality-increasing mechanism to provide income security to workers[13]. Contradictorily, Latin American countries job security contributions constitute more than 85% of the total costs of labor regulations, being Peru one of the countries with the highest costs despite the reforms carried out during the nineties.

Graph 14
Patents Applications of Residents and Non Residents – 1990-1999



Source: Indicadores Ricyt 1990-1999

In summary, there is a clear need for institutional regime pertaining to information disclosure, transparency, accountability, the rule of law, as well as the structure and functioning of the government, including issues of governance and the reduction of corruption.

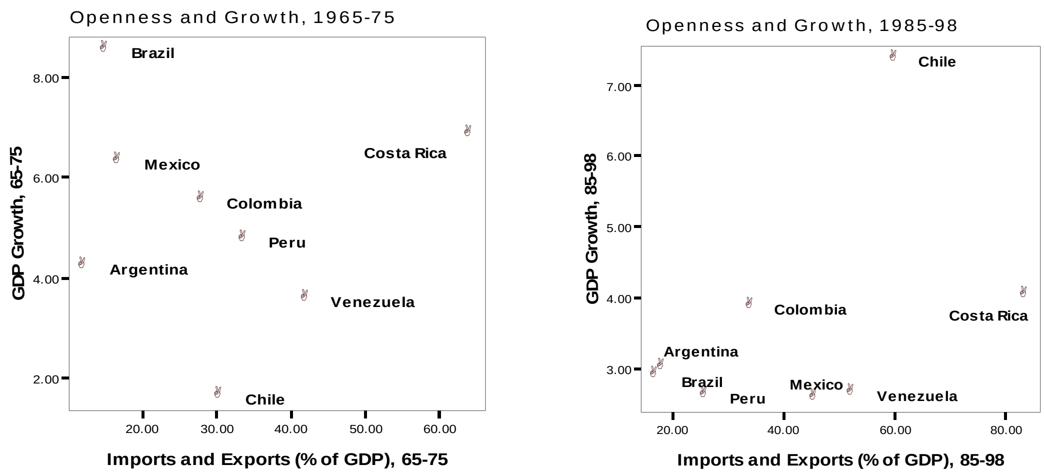
Openness

Finally, openness proves to be another potentially important factor in innovation and technological absorption as shown in the 2000 Global Competitiveness Report. Open economies can have access to latest machinery and equipment and therefore, to latest technologies as it happened in East Asia (Chong and Zanforlin, 2001). Although, when

[13] They are inefficient because as shown by Heckman and Pages (2000) they reduce the demand for labor; they are inequality-increasing because some workers benefit while many others are hurt. The impact on inequality is multifaceted. Job security increases inequality because it reduces the employment prospects of young and possibly female and unskilled workers. It also increases inequality because it segregates the labor market between workers with secure jobs and workers with very few prospects of becoming employed. Finally, job security provisions increase inequality, if it increases the size of the informal sector.

plotting GDP growth for 1965-75 and 1985-98, there is not a clear relationship with the exception of Chile (see **Graph 15**).

Graph 15



Even more, in a globalise economy openness is essential to be able to access to the latest technologies and to allow to the free flow of ideas need to develop a knowledge based economy.

b. Access to Credit and funding of S&T

One of the major bottlenecks for productivity and growth in Latin America is the scarcity of credit. This is not surprising, given that the supply of private credit as a proportion of GDP in the region is only a third compared with the developed countries or Southeast Asia (IDB; 2001). Although the inadequate depth of the financial sectors of many Latin American countries is due in part to macroeconomic circumstances, the institutional framework is equally or more important, and it can aggravate instability of a macro origin[14].

Unlike developed countries where financial markets are more developed, access to credit is easier and faster, and creative financial instruments exist[15], in Latin America financial development and access is quite limited and there is a huge need for financial institutions to be specialized in start-ups and venture capital[16]. In the index of access to external finance

[14] The functioning of credit markets requires an institutional framework that makes it possible to alleviate problems typical of financial contracts, such as asymmetry of information, adverse selection, moral hazard, contract enforcement and temporal inconsistency.

[15] In developed countries a new firm can obtain a venture capital firm's back for, say, eight years, and then go public through an initial public offering (IPO) even though no positive earnings are in prospect for many years until (and if) they products are successful.

[16] Barajas and Steiner (2001) did a more detailed look at the evolution of credit and bank behavior in our five countries (Argentina, Mexico, Peru, and Colombia), over a shorter sample, the last twenty years and they clearly showed as an stylised fact the restrictions to credit found in Latin America. They also show how in the 1990s there was a change of trend, spurred in part by financial liberalization measures undertaken at the beginning of the decade. Unfortunately, later in the decade such measures have slowdown.

through banks or the bond market developed by Warner (2000), Peru ranks 41 of 59 countries, while Chile and Brazil ranks 21 and 34 respectively.

With the greater reforms of the 1990s in countries like Peru, there was an increase in access to credit, although the most severe institutional deficiencies remained – the lack of protection for financial creditors and the various forms of interference by governments in financial markets, as well as uncertain legal frameworks. Even more, banks have significantly high operative costs in relation to their gross margins. In Peru for example they represent 80% while in Chile and Brazil 60.8% and 74.3% respectively.

With regards to the direct government function of funding for S&T, the performance seems to be very poor. According to the Ministry of Economics and Finance, the budget assigned to S&T institutions during 1994-1998 was in average 0.25% of GDP, without including the budget assigned to universities. If the latter is included, the budget reaches 0.80% of GDP, which is almost the level reached by the largest countries in Latin America, such as Argentina, Brazil and Mexico. However, these figures are clearly overestimated since these figures include administrative costs and reflect the appropriation given to these institutions but does not reflect actual execution of programs and projects. The adjusted figure provided by the Inter American Network for Science and Technology (RICyT) is just 0.08% of GDP, far lower for the average of a country with medium income like Peru.

Fortunately, in the last year there has been an effort to establish a Science and Competitiveness Fund (FONCYC), backed with a loan from the Inter American Development Bank. The FONCYC will channel about US$ 35 million to finance four lines: (a) innovation projects presented by firms; (b) S&T projects presented by universities and research institutions; (c) strengthening of S&T capacities; and (d) strengthening of the TIS. The fund is expected to be operative by mid 2004. Grants will be given via competition and incentives have been designed to encourage the presentation of projects that foster the linkages among firms, universities and other research institutions.

The FONCYC will cover in part the void of government funding for innovation in the private sector and will complement isolated initiatives funded by cooperation agencies such as INCAGRO, that funds agricultural research in firms.

c. Provision of Infrastructure

Peru as most Latin American countries not only has inadequate and insufficient infrastructure, but also it is concentrated in few metropolitan areas. As can be seen in **Table 4**, with the exception of Chile, Mexico, Brazil and Argentina, few paved roads, inefficient ports[17] and low penetration of telecommunications[18] characterize these countries.

[17] Despite notable progress over the past decade, Latin American ports are still among the most inefficient in the world (IDB 2001).
[18] Despite two thirds of the Latin American countries have privatised their telecommunications, and they are trying to bring competition to the sector the penetration in developed countries is still five times greater than in these countries, although this gap is being reduced more rapidly in Latin America than in the rest of the developing world.

Even more, utility prices, particularly electricity and the price of telephone service, remain high despite the intense restructuring and privatization during the 90's (see **Graph 16**). Latin America has been a leader in the restructuring of electricity sectors, but these reforms have not been consolidated throughout the region. In many countries, competition remains limited and prices high, and the regulatory systems had been criticized for their lack of transparency and their lack of the legal and institutional framework within which regulatory systems must function.

Table 4
Indicators of Infrastructure

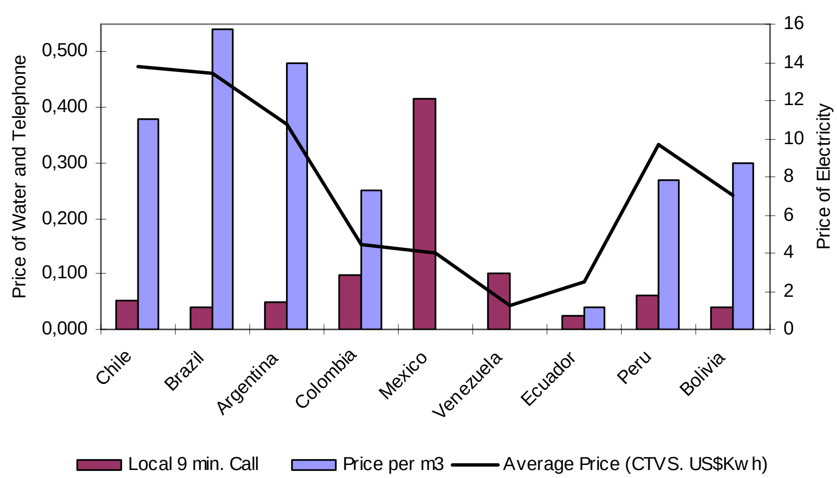
	Telecommunications			Water and Sanitation		Electricity		Roads	
Country	**Fix Lines per 100 habs.**[1]	**Cellular lines per 100 habs.**[1]	**Investment (million US$)**[2]	**% of population with access to potable water**[2]	**% of population with access to Sanitation**[2]	**Electricity loss (% of output)**[3]	**Consumption (KW per capita)**[3]	**Roads, total network (km)**[3]	**Roads, paved (% of total roads)**[3]
Chile	23,90	34,02	1101,0	94	97	5,48	2309	79353	18,9
Brazil	21,69	16,66	8852,5	87	77	17,29	1811	1726854	5,6
Argentina	21,63	18,61	1904,0	79	85	14,78	1938	215471	29,4
Colombia	17,05	7,38	1156,6	91	85	23,89	772	112988	14,4
Mexico	13,48	20,06	5082,2	86	73	14,36	1570	329532	32,8
Venezuela	11,20	26,35	293,5	84	74	23,35	2493	96155	33,6
Ecuador	10,37	6,67	44,5	71	59	22,79	620	43197	18,9
Peru	7,75	5,92	429,9	79	66	12,05	654	72900	12,8
Bolivia	6,04	8,74	109,6	77	76	17,85	390	53628	6,4

1/ Year 2001 2/ Year 2000 3/ Year 1999

Source: For telecommunications:ITU; for Water and Sanitation: World Bankand OPS-OMS Evaluation 2000; and for Roads:World Bank

In summary, there is still a lot of work to be done increasing competition and improving infrastructure, given that this is an essential pre condition for productivity growth.

Graph 16
Costs of Infrastructure



Note: In telephone is the traffic weighted average of regular and reduced rates of a local 9-minute call within the same exchange area. In Electricity is the residential average price between January 1994 and March 1998.
Source: Tarifica, World Bank and OPS-OMS evaluation 2000

d. Regulatory function

Finally, the regulatory function of the Peruvian government is very disperse. There is not a coherent national system of standards and norms. There is a lack of technical personnel to work in this area. As a result, the country has a poor performance in international meetings that discuss the use of standards as a way to regulate international trade. The country also has problems in applying international standards to domestic products thus becoming a constraint to penetrate international markets. On the other hand, the system of national laboratories is not accredited at an international level. This becomes a major weakness of technological infrastructure (Mulling Consulting, 2002).

5.2.3 Research and Technological Institutions

a. Traditional Research and Technological Institutions

The vast majority of the research and technological institutions are public entities, that were created during the 1970s and 1980s to provide technical support for targeted industrial branches. These institutions have been recently gathered in a collegiated body called the National Center for Research and Science, Technology and Innovation Services (see **Table 5**).

Table 5

Members of the National Center for Research and Science, Technology and Innovation Services
• Centro de Información e Interconexión Telemática (CENDECYT) • Instituto Nacional de Becas y Crédito Educativo (INABEC) • Instituto Nacional de Investigación y Capacitación de Telecomunicaciones (INICTEL) • Instituto Nacional de Investigaciones de la Amazonía Peruana (IIAP) • Servicio Nacional de Meteorología e Hidrografía (SENAMHI) • Instituto Nacional de Recursos Naturales (INRENA) • Instituto del Mar del Perú (IMARPE) • Instituto Tecnológico Pesquero (ITP) • Consejo Nacional de Camélidos Sudamericanos (CONACS) • Instituto Nacional de Investigación Agraria (INIA) • Instituto Geofísico del Perú (IGP) • Comisión Nacional de Investigación y Desarrollo Aeroespacial (CONIDA) • Instituto Geográfico Nacional (IGN) • Instituto Peruano de Energía Nuclear (IPEN) • Instituto Geológico Minero y Metalúrgico (INGEMMET)

Most of these institutions are funded by budget appropriations from the central government, which means that they count with limited financial resources to fund research and to maintain an adequate infrastructure. Just a few of these institutions have other sources of funding, such as INGEMMET whose budget is covered entirely by the 10% of the revenues coming from the mining rights. Another example is IMARPE in which 30% of the budget is covered by several payments such as fishing permits. Also, IIAP receives 3% of the oil canon, which represents 50% of its budget.

Research and technological institutions are not evaluated regularly to assess their contribution to the country. Just a few of them have internal systems to secure quality standards. A recent study indicates that the administrative costs represent a high share of their budget, reaching levels as high as 50% or more nor there is a set of performance indicators (Mullin Consulting, 2002). All this may indicate the need of a major restructuring of these institutions.

The same study tried to evaluate a sample of these institutions using as a criterion if they execute any of the four most common objectives that research and technology institutions must fulfill in developing countries: (a) management of natural resources and environment; (b) technical support for public utilities; (c) technical support for regulatory functions; and (d) promotion of technical change in the economy (Mullin Consulting, 2002). As can be seen in **Table 6**, most of the evaluated institutions have a weak role in the promotion of technical change, meaning basically transfer of technology, and some even have abandoned such a role. Two of the institutions have left behind their original missions or functions. Two of them, like the IPEN and INGEMMET, are far behind the technological frontier in their respective fields of knowledge and have abandoned or modified the role they had in their creation.

Table 6

	Management of natural resources and environment	Technical support for public utilities	Technical support for regulatory government functions	Promotion of technical change in the economy
IGP	Provides inputs for risk dissasters assessment	Not a function	Can provide support for the planning of land use	This is not one of the institute's aims
IIAP	Main role	Not a function	Not a function	Performs some activities with marginal farmers
INGEMMET	Main role	Not a function	Can provide support for the planning of land use	Not a funcion since 1993
INIA	Moderate role	Not a function	Not a function	Main role but the feedback is weak
INICTEL	Not a function	Its original role has disappeared. Now it is looking to help rural areas to fulfill its communication	Not a function in Peru but has assisted other countries in this goal	Weak performance in transfer of technology but a strong one in training

		needs		
IMARPE	Important role	Not a function	Important role	Weak performance in transfer of technology
INS	Not a function	Produces biological agents and vaccines for the Health System	Has an important regulatory role	Weak performance in transfer of technology
IPEN	Not a function	Its original role has disappeared. Now produces isotope for the Health System	Has a regulatory function	Weak performance in transfer of technology. Looking for a redefinition of mission
ITP	Not a function	Not a function	Recently adopted misión but without resources	Main role but weak performance in transfer of technology. More successful in training.

Source: Mulling Consulting (2002).

b. The system of Technological Innovation Centers (CITEs)

The system of Technological Innovation Centers (CITEs) has been created, under the responsibility of the Ministry of Production (former Ministry of Industry), as an instrument to increase the technological level and the innovation capabilities of firms. The aim is to increase firms competitiveness and productivity. However, these CITEs are targeting mostly small and medium firms and thus they do not help firms that have already compete in international markets to increase their competitiveness.

Its main goals are: (a) to create the idea of a Peruvian product for export and domestic consumption; (b) to create a favorable technological environment for investments and collaboration among firms; (c) to transfer technology for small and medium firms; (d) to improve the quality and differentiation of products, as well as to promote design and the use of computer assisted patterns; (e) to perform research and development to improve the productivity and increase the value of natural resources; (f) to train and upgrade human resources, as well as to form trainers; (g) to diffuse technological information about trends in markets and fashion; (h) to monitor and make technology prospection; and (i) to promote technical standards and norms in each industry branch (Carazo et al, 2000).

The CITEs are created according to criteria such as the generation of employment and incomes in the targeted branch, the degree of linkage generation and synergies, the existence of a cluster of small and medium firms that will aid in the diffusion of technology and justify any actions to support the branch, the branch's level of value added, regional competitiveness and national identity; the perspectives in their respective markets; the availability of technologies with easy assimilation; and the existence of a critical mass of firms.

Table 7

CITE	Branch	Cluster
CITEccal	Leather, shoes and related industries	Caquetá – Lima Trujillo (Minka and PASE) Arequipa – (Habitat) Huancayo (INIDER)
CITEmadera	Word and furniture	Villa El Salvador Pucallpa
CITEvid	Wine and grapes industry	Ica –Moquegua – Tacna Majes II – Cascas
CITEconfecciones Pirka	Textile – Cotton and mixed confections Alpaca and other animal fibers knittings	Lima
CITEconfecciones El Taller	Textile – Cotton and mixed confections Alpaca and other animal fibers knittings	Arequipa
CITEagroindustrial CEPRORUI-El Taller	Coast agroindustry	Arequipa - Tacna

Source: Carazo, Mercedes (¿?) "Centros De Innovación Tecnológica, un Desafio para la Microempresa", MITINCI, Lima.

Table 7 shows the CITEs that are currently at work and depend directly from the Ministry of Production. There are some other CITEs that are administered by non government organizations such as the CITEcerámica, aimed at supporting clay and ceramics firms in the area of Chulucanas in Piura; the CITEfrutas tropicales y plantas medicinales, that provides technical assistance for the processing of tropical fruits and medicinal plants; the CITEmecánica that supports small metal working factories in Lima; and CITEEmpaque, that provides technical assistance in packaging and packing materials in the free trade zones (CETICOS) in Tacna and Piura.

The role of CITEs in promoting technical change in small and medium firms has been very important. Although the coverage of the services they provide is small and circumscribed to specific locations, they are helping to introduce quality standards and to increase productivity levels in this segment of firms. However, to have a boost in the overall productivity level of the industrial branches in which they work, it is necessary to complement their work with other programs aimed at creating links with large firms.

5.2.4 Universities

Peru has an excessive number of universities: 27 state universities and 26 private ones. Besides those, there are 7 more state universities in process of creation and 17 private ones. This high number is a response to the high demand of tertiary education in the country. The great majority of the universities have as mission to form professionals, despite the low quality of the education they impart.

State universities are the ones that usually have performed some research but budget constraints in the Education budget has decreased the resources available for research and to maintain their scientific and technological infrastructure. In addition, a series of institutional difficulties such as red tape that impede professors to manage their own research budgets or the imposition of large amount of teaching hours are a great constraint for the formation, attraction and retention of researchers. On the other hand, aside for a few exceptions, universities have tended to perform basic research but the advances, if any, have not any impact in the productive sector due to a lack of technological demand from firms or government programs.

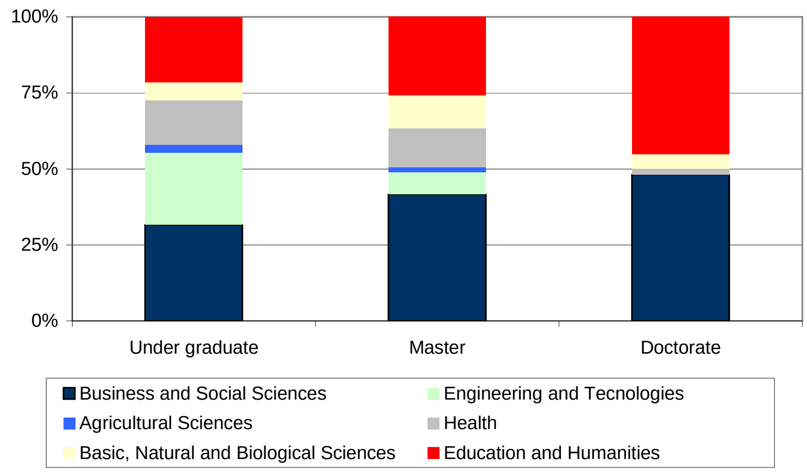
With regards to the educational role of universities, budget constraints have also hindered the quality of education and training. Salaries in the academia are extremely low so that most universities have lost their best professors. Although the problems of quality and the presence of significant "low wages" in Peru and similar countries of the region, the next question is if the production function of the universities and institutes of skilled workers is matching or not the demands of the productive sector. **Graph 17** shows how as more educated are the skilled workers the more they concentrate in education and humanities and social sciences and the less in engineering and technologies.

Even more, and for the case of Peru, a pseudo panel was developed to evaluate if there was a mismatch between the field of the skilled worker and the area where he/she ends working. **Table 8** shows the results for the averages of a pseudo panel for the years 1996-1998 for wage earners for Metropolitan Lima with higher education, both from universities and from technical institutes. The rows show their field of study and the columns the economic sector where they end working. More than 21 percent of workers trained in basic sciences end working in services and 25 percent of workers trained in Biological sciences end working in public administration. Even more, and contrary to what could be expected, productive sectors concentrate less that 18% of skilled workers and 16 percent of skilled workers in natural and basic sciences, technologies and engineering, and biological sciences. Nevertheless, 18 percent of workers trained in all fields end working in commerce and restaurants and 33% in services.

Finally, **Graph 18** shows the performance of the different economic sectors, the enrolment and the number of undergraduate studies in similar fields to the respective economic sector. Consistently to the previous findings in Peru, there is no clear correlation between the evolution of the economic sectors and the level of enrolment and less to the level of completed undergraduate students, which practically are inelastic to changes in growth of the economic sector. The exception is the case of Chile, a clear relationship can be observed with the different economic sectors, although similar figures for students which completed their undergraduate studies were not available.

Graph 17

Distribution of Skill Workers by Field



Source: National Higher Education Census, Asamblea Nacioanl de Rectores e INEI, 1996

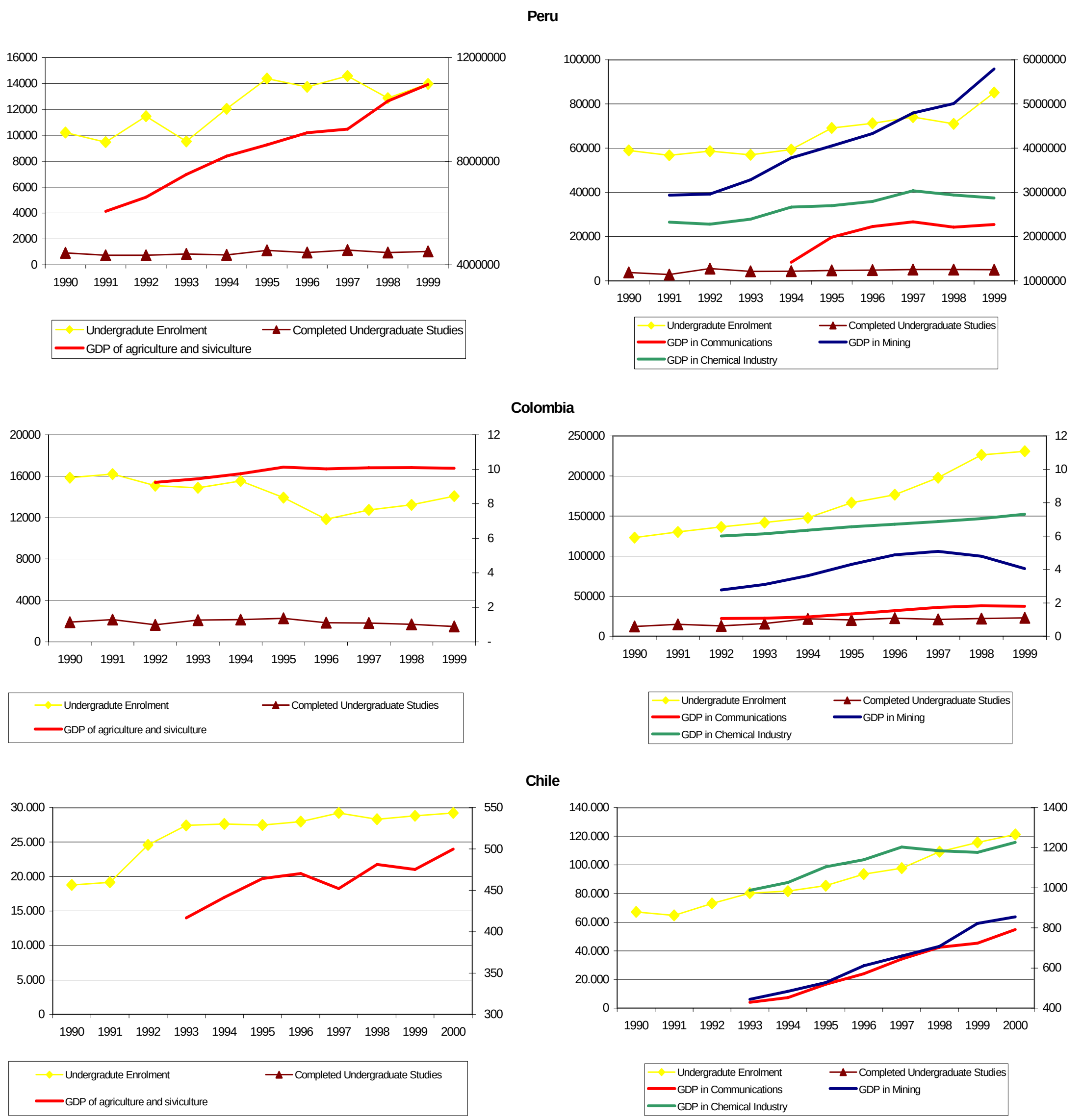
Table 8
Supply and Demand by Field of Skill Labor

Field Studied	Fishing and Agriculture	Minning	Consumption Goods Industry	Intermediate and Capital Goods Industry	Water, Electricity and Gas	Construction	Commerce, Restaurants and Hotels	Transport and Communications	Finance, Insurances, and Services to Firms	Public Administration and Defense	Other Services
Professionals											
Natural and Basic Sciences	0,0	1,4	14,0	7,5	5,6	4,1	29,1	3,8	12,2	1,6	20,9
Technologies and Engineer	0,4	2,5	13,2	16,0	2,7	6,6	13,2	11,0	10,5	11,0	12,8
Biological Sciencies	5,5	3,2	15,1	0,0	0,0	11,6	10,8	11,5	4,2	24,9	13,3
Health Sciencies	0,0	0,6	1,0	2,2	0,0	0,6	9,9	3,2	1,9	6,2	74,3
Education, Humanities and Administration	0,3	0,8	4,0	4,4	0,6	1,9	15,3	3,1	16,7	9,2	43,7
Social Sciencies	0,0	0,0	2,3	3,9	0,0	0,0	12,6	7,0	17,8	12,1	44,4
Other	1,0	0,0	2,1	1,1	0,0	0,0	4,0	9,2	5,5	73,2	3,8
Technical											
Natural and Basic Sciences	0,0	0,0	8,8	8,2	0,0	1,6	25,4	8,5	22,2	7,5	17,7
Technologies and Engineer	0,5	0,0	11,8	14,6	1,4	8,1	26,1	14,1	11,4	1,1	10,9
Biological Sciencies	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	100,0	0,0	0,0
Health Sciencies	0,6	0,0	10,6	3,0	1,8	0,0	15,5	3,0	1,4	8,0	56,2
Education, Humanities and Administration	0,5	1,9	10,4	9,2	0,0	2,6	32,8	8,0	17,7	7,6	9,4
Social Sciencies	0,0	0,0	6,1	5,1	0,6	1,2	29,3	2,9	19,7	11,0	24,3
Other	0,0	0,0	0,0	25,1	12,3	12,8	37,7	0,0	0,0	12,2	0,0
Total	0,4	0,8	6,8	6,6	0,9	2,6	18,3	5,8	14,1	10,8	33,0

Source: Seudo Panel Encuestas de Empleo 1996-1998. Lima

Graph 18

Evolution of GDP and Number of Skill Workers by Economic Sector



In the specific case of private universities, there is a great dispersion in quality, some of the universities are known for the excellent education they provide but the great majority offer a mediocre education. These universities do not perform scientific research, however, there are some remarkable exceptions such as the Universidad Cayetano Heredia that has a solid research program in medical and biological sciences.

Another feature of the Peruvian universities is the lack of supply of postgraduate courses. Due to the lack of research, there are very few universities that grant masters or PhD degrees. In its turn, this is a cause for the shortage of research professionals. The great majority of researchers in Peru have been trained in foreign universities[19].

5.2.5 Relationships among local actors

The weakness of the different TIS actors has contributed to a limited relationship among them. In the first place, there is an insufficient interaction between the government technology institutes and domestic firms. On the one hand, large and medium firms have a negative prejudgment about these institutions seeing them as entities that research on topics that do not help to solve the firms' problems and because their timeframe is different to that managed by firms. On the other, small firms do not demand technological services because of the lack of knowledge about their existence or, even worst, because of their belief that they do not have any technical problem.

In the second place, the relationship between universities and firms is also limited. Some universities provide services to firms, especially in the area of management. Recently some entrepreneurial support programs have been launched covering a large variety of thematic areas such as environment, information systems, biological sciences and industrial processes, among others. One seldom form of linkage is the elaboration of theses aimed at solving a form's concrete problem. Firms are reluctant to programs like these but they could become in a effective means to forge ties between these two actors.

In the third place, the relationship among firms themselves is almost absent. The technological heterogeneity among firms and the lack of technical standards makes very difficult that they work together via outsourcing or in association to satisfy large contracts. For the same reason, foreign firms cannot work with domestic ones because the former usually work with higher quality standards that are not shared by the latter, thus losing a great opportunity to generate spillovers in the economy. As shown in **Section 9**, cluster formation is limited because the locational and organizational factors are not present in the country.

Finally, but not least, firms do not have a defined demand for research and technological services, and as a result, the supply of these services is very limited.

In the last years, however, a series of organizations and programs aimed at provide technical support and advice have been created (see **Table 9**). Most of these have been created by initiative of the productive sectors, both private and public, and supported by international technical cooperation funds. A salient feature of these organizations and programs is that they are not linked to the established research and technological institutions.

[19] In fact, one of the funding lines available from the Science and Competitiveness Fund (FONCYC) will provide funding to state universities to set up postgraduate courses.

Table 9
Technical Support and Advice Programs for Firms

Program	Objectives and/or functions
Programa del Centro de Desarrollo Industrial de la Sociedad Nacional de Industrias	Technical assistance and advising in: organization of work, quality systems, ISO certification. Training, elaboration of industrial directories, databases.
Unidades Municipales de Promoción Empresarial (UMPES)	Local development consensus building, information and management of financial services, adjustments in management, regulation and local taxes.
Centro de Servicios y Transferencia Tecnológica de la Pontificia Universidad Católica del Perú	Consulting services and technical support in Sciences and Engineering, Education, Economics, Management, Administration, Humanities and Arts.
UNITEC - Universidad Nacional de Ingeniería	Technological supply in environment and urbanism, management, information systems, metal working, energy, industrial processes, electronics and telecommunications, building, mining and metallurgy, advanced technologies and training.
Proyecto FORTEPE (Ministerio de Educación y Unión Europea)	Horizontal Project for Training Trainers in Technological Education (PROTEC): Improve the quality of the technical training system and professional education.
BONOPYME	Financial support for small and medium firms to ask for technical assistance.

In addition, industrial training institutions such as TECSUP and SENATI offer technological support services in different areas. For example, TECSUP is offering mineralogical and hydrometallurgical testing, covering a demand not satisfied by INGEMMET.

5.2.6 Relationships between local and foreign actors

The links between local and foreign agents has become one of the main knowledge sources in developing countries. These links are generally of three types: the commercial ones established between local firms and their suppliers, the collaboration ones between local and foreign institutions, and those resulting from technical cooperation programs.

The first type of relationship is typical between foreign or subsidiary firms and their foreign suppliers. Many of these firms sell their products in external markets and use state-of-the-art technologies that are created in industrialized countries. The lack of domestic capabilities and the strict standards that regulate these firms' products make them depend on technological services supplied abroad. Firms from extractive industries such as mining and oil are good examples of this situation. Given that these relationships are forged through commercial transactions, spillovers are not generated and any diffusion of knowledge is made through equipment and technology suppliers[20].

[20] Pavitt (1984) proponed different patterns of technical change for different industries. There are industries in which innovations are generated mainly by capital goods and inputs suppliers and, therefore, the transfer of technology is made via the purchase of equipment. In other cases, reverse engineering and licensing are the main means for technology transfer and imitation in industries that rely on economies of scale, whose products have incorporated high technology or depend on specialized suppliers. It is important to mention that in any case, the transfer, diffusion or imitation of technology require investment aimed at elevating the capabilities of the recipient firms.

The second type of relationship is the one that occurs among universities and different types of research and development institutions. These relationships are forged by personal contacts of the researchers working in both the local and foreign institutions. Their benefits are the improvement in-the-job of the local researchers capabilities, via internships in foreign institutions and via scholarships to pursue graduate studies in the foreign institutions. The increase of capabilities effect is enhanced when the local researchers are also engaged in teaching. In addition, this kind of relationship makes local researchers to know the different international sources of funding for S&T activities. However, this type of relationship can generate the subordination of the local research agendas to those defined in industrialized countries. The effect of this subordination is not only reflected in researching topics that do not contribute to the recipients' country problems but can generate frustration in the local researchers because once the cooperation is over they are over qualified and without opportunities to apply the knowledge they have acquired (Kuramoto y Sagasti, 2002).

The third type of relationship is geared to technical cooperation programs. These programs are aimed at transferring technical expertise to developing countries. However, they face a major restriction since donors are accountable to their constituencies at home. As a result, donors "feel more comfortable (…) if they can point to visible activities which encourages a bias towards self-contained and pre-ordered package (…) clos(ing) off options for creative learning or incremental discovery" (Fukuda-Parr et al, 2002). In addition, recipient governments may be reluctant to reject billions of dollars even when they may not agree with the donors priorities, as well as they may lack the capabilities to define their own ones.

The common feature in these three types of cooperation is that local agents have to invest in elevating their scientific and technological capabilities to take advantage of the transmitted knowledge. It is also necessary that local agents pursue a more active role in the definition of their needs and negotiate the conditions of these relationships. This is the only way to take advantage of these types of cooperation and convert them in useful tools to increase the country's capabilities.

6. A Micro View: R&D and Firm Performance in Peru

Starting with the work of economists such as Zvi Griliches (1980,88,90,94), and Edwin Mansfield (1983 and 1998) there have been numerous studies demonstrating the positive impact of R&D on productivity growth in the US (see for example: Romer (1986), Lucas (1988), Aghion and Howitt (1992), and Grossman and Helpman (1992) growth models). Other economic growth models have taken the specific form of external learning by doing, as in Lucas (1988, 1993), Stokey (1988), and Young (1991, 1993). Especially relevant is Lucas' (1993) conclusion that learning by doing is a prime candidate to explain the incredible growth observed, for example, in South Korea over the last three decades.

This section of the paper tries follow this research but looking into the micro foundation behind the impact on growth by analyzing the impact of R&D expenditure on the performance of the firms. To be able to carry this we use a yet not explored firm database developed in August of 2000 by the Peruvian Consejo Nacional de Tecnologia (CONCYTEC). This survey, representative country wide, by economic sector[21] and by size (small, medium and large enterprises), collects information on science and technology indicators for 8,976 firms. This unique dataset is of extreme value to understand the innovation process on the side of the firms and its interrelation with universities, research institutes, and public institutions within the existing institutional framework.

This dataset allow us to determine from the side of the firms whether the investment in R&D and access to innovations are desirable in terms of their performance. In particular and following Boubakri and Cosset (1998), the study will try to determine whether the firms increase their performance measured for example by:

i. Their operating efficiency
ii. Their output
iii. Employment

Finally, we also are able to explore if the source of the expenditures on R&D (own, private firms, government, public and private universities, foreign firms, etc) implies or not a difference in their impact on the performance of firms.

Based on these performance measures, the empirical approach consisted of two stages. In the first stage, a simple statistical analysis was executed to study changes in firms' performance as a result of access to new technologies or expenditure in R&D. In the second approach, a regression analysis was performed controlling most of the differences between firms and variables, other than R&D or innovativeness indicators that could explain the performance of the firm. The regression analysis also allows studying the impact of the intensity of investment and its respective impact over their performance rather than use the access to it.

6.1. Statistical Analysis

The statistical analysis, following Boubakri and Cosset (1998), analyze several science and technology indicators at the levels of the firms and compute the means of performance variables for the companies that invest in R&D to compare them with companies that don't invest in R&D.

Once the means are calculated then using differences the sample counterpart of the investment in R&D effect on the performance variables will be:

$$\Delta\overline{P} = [\overline{P}^{investinR\&D} - P^{notinvestinR\&D}] \tag{1}$$

and then we can use the two-tailed Wilcoxon signed-rank test to test for significant changes in the variables, as well as a proportion test to determine whether the proportion (p) of firms experiencing a change in a given direction is greater than what would be expected by

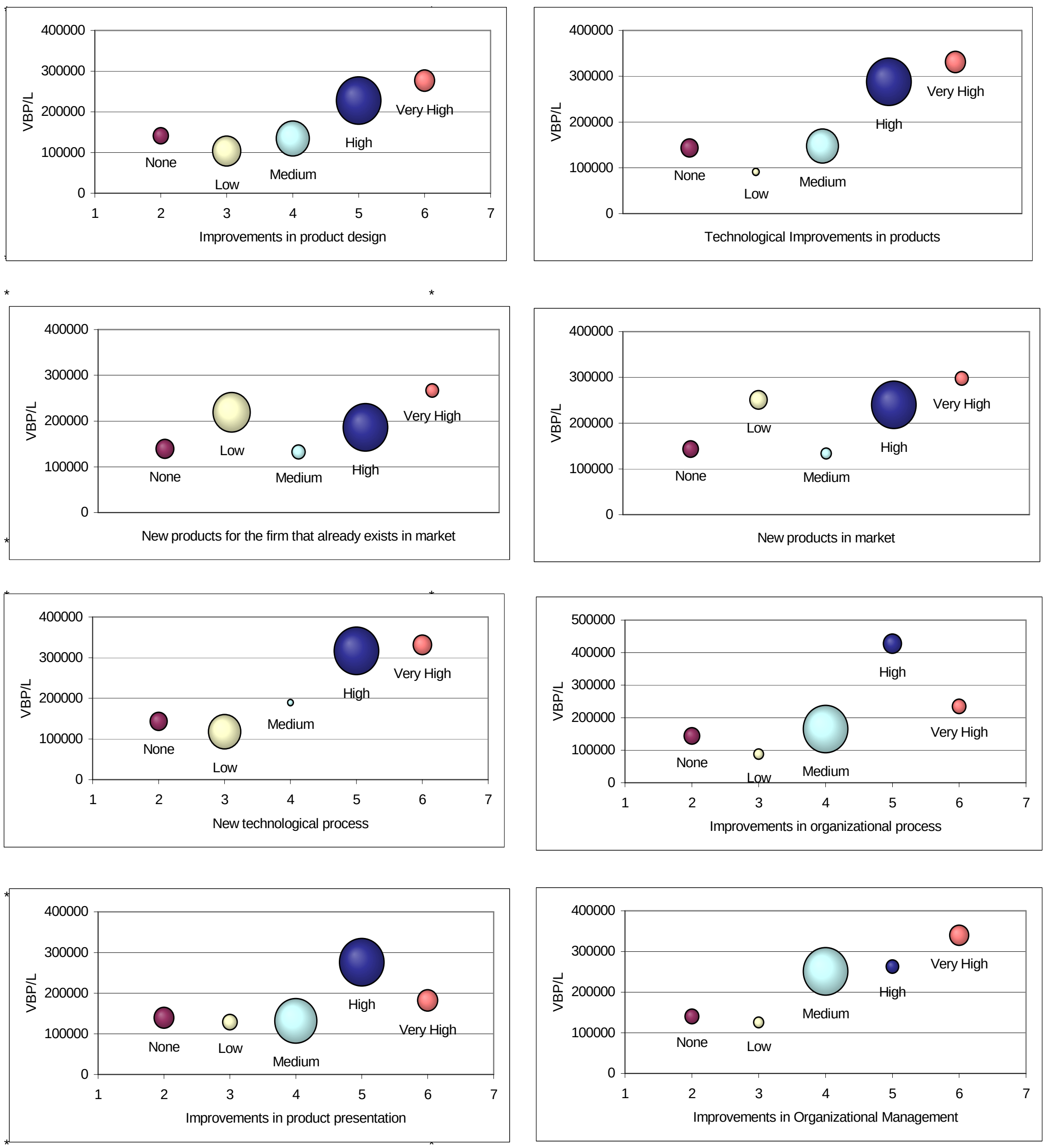
[21] The sectors included are: Commerce, Services, Fishing, Manufacturing, Hydrocarbons, Electricity, Transport, Communications, Construction and Agro industry.

chance, typically testing where $p=0.5$. In addition we will also calculate these differences in means for each of the different sectors and for the different sources of R&D.

If we consider the simplest possible model to capture the effect over performance with no regressors, it can easily be derived such that performance depends on the dummy of doing or not R&D,

$$P_{i,t} = \alpha + \gamma R\&D_i + u_i \qquad \mathrm{E}(u_i / R\&D_i) = 0 \tag{2}$$

Graph 19
Performance of the Firm and Different Indicators of Innovation

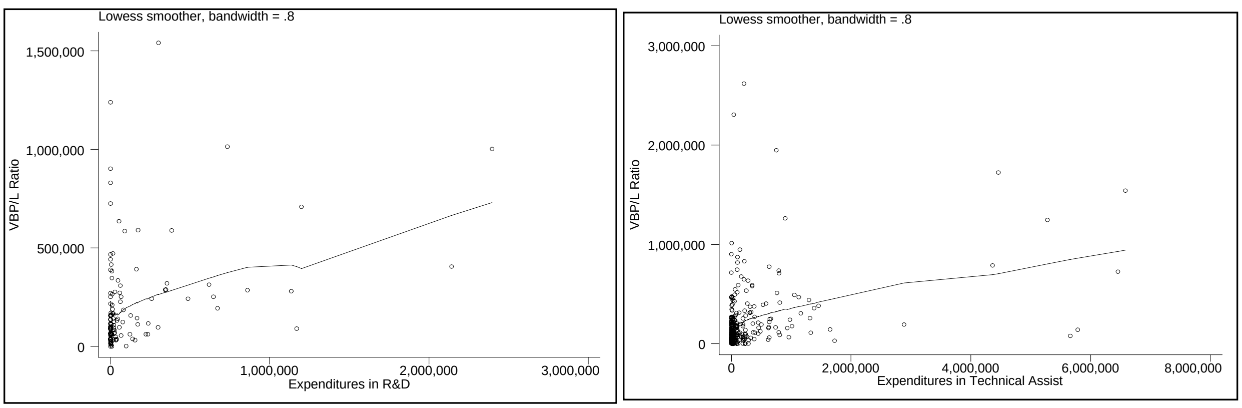


Note: The size of the circle represents the amount of R&D Expenditure

Graph 19 plots the relationship between firm performance measured in terms of output per worker and different indicators of R&D. In each graph, the vertical axis measures firms performance using production efficiency as an indicator, the y-axis measures the intensity of innovation which goes from 1 to 7, being seven the highest level of innovation. Finally, the size of the circle measures the amount of R&D expenditures invested by the firm.

For technology improvements in products and improvement in product design there is a clear positive relationship. For all other indicators the relationship is not clear, this could be because of the small amount of R&D in Peru and specifically in firms. Even though, and consistent with the positive correlation of the size of the circles (amount of expenditure in R&D) and the performance indicators, when we look only into expenditures in R&D (see **Graph 20**) a positive relationship is found.

Graph 20
Expenditures in Research and Development and Technical Assistance and Output per Worker



Source: Encuesta Económica Anual (1998). Plots are Smoothed Kernel Densities

Finally, a difference in means of performance variables (product efficiency, sales efficiency, exports/production, ROS and ROA) is carried out comparing firms that report expenditures in R&D against companies, which do not report expending in R&D.

Table 10 shows the main results for firms with and without expenditures in R&D within the manufacturing sectors for which there was information on at least a firm using some of their resources in R&D. Additionally, and consistent to what was identified in section 4.1, we also introduce firms with computers and with access to Internet as proxies of innovation. Similarly, the performance indicators were compared, within the sectors in which there is at least one firm with any of those IT indicators, between firms with and without access to both IT indicators.

The first column of **Table 10** indicates the number of firms that reported some expenditure in R&D, the second column indicates the number of firms that did not report R&D expenditures and the next five columns shows the difference in means for each of the performance indicators as well as the statistical significance of the difference.

As can be seen in the table, although the small amount spent on R&D, some sectors show a significant and positive difference with respect to firms that didn't expend on R&D. This result is even stronger for the cases of IT technologies were the link on productivity and R&D is also significant for the sectors where there is some investment in innovation. The latter is consistent to what was identified in section 4.1 showing the importance of the correlation between IT technologies and the rate of innovation. For example, under elaboration of food beverages, the difference in sale efficiency and production efficiency between firms with and without any of the three innovative indicators used is significant. This means that firms that incur in research and development expenditures increase their factor productivity.

Table 10

First Differences Between Innovative and Non-Innovative Firms

	T-Test for Difference in Means between firms with R&D and firms without R&D						
Description	**Number of Firms With R&D**	**Number of Firms Without R&D**	**Sales Efficiency**	**Production Efficiency**	**Exports/ Production**	**ROA**	**ROS**
ELABORATION OF FOOD AND BEVERAGES	31	316	35.49 **	34.99 **	58.33	317.20 *	113.37 ****
TEXTILES	7	160	6.01	6.01	6.29 *	160.67	19.25
GARMENTS	6	105	7.97	15.67	5.10	21.18	107.66 **
LEATHER PRODUCTS	3	79	28.12 *	28.26 *	6.18	35.05	22.16
PRODUCTION OF PAPER AND PAPER SUB PRODU	2	44	43.01 ***	17.47 ***	1.22	1.39	1.99 *
PRINTING AND GRAPHIC REPRODUCTION	3	124	2.64	2.72	106.00 *	11.10	5.22
SUBSTANCES AND CHEMICAL PRODUCTS	25	150	123.02	109.88	30.84	147.67	104.77 *
PLASTIC PRODUCTION	7	102	8.95	8.92	6.14	17.52	13.81
NON METALIC MINERAL PRODUCTS	5	78	6.21	5.42	4.15	76.00	62.39 **
PRODUCTION OF COMMON METALS	5	30	4.02	4.01	4.87	32.08	29.27
METAL BASED PRODUCTS EXCLUSING MACHINEF	12	127	13.33	13.81	46.73	76.93	132.40
PRODUCTION OF MACHINERY AND EQUIPMENT	4	65	66.31	66.36	3.07	64.38 *	66.99
MACHINERY AND ELECTRIC EQUIPMENT	4	47	3.10	3.10	3.01	46.53 **	3.74
PRODUCTION OF VEHICLES	2	27	1.02	1.06	1.24	12.32	1.29
PRODUCTION OF FURNITURE	3	91	39.62 **	39.83 **	1.02	4.16	2.30

	T-Test for Difference in Means between firms with Computes and firms without Computers						
Description	**Number of Firms With R&D**	**Number of Firms Without R&D**	**Sales Efficiency**	**Production Efficiency**	**Exports/ Production**	**ROA**	**ROS**
ELABORATION OF FOOD AND BEVERAGES	167	124	287.65 ****	287.75 ****	123.70	124.00	287.59 **
TEXTILES	96	47	139.03 *	126.57	99.89 **	44.94	53.43 **
GARMENTS	44	35	43.99	43.91	61.37 **	41.83	73.99
LEATHER PRODUCTS	42	27	50.51	49.71	65.82	28.61 *	31.70 *
PRODUCTION OF PAPER AND PAPER SUB PRODU	31	9	9.13	9.12	29.00	32.44	15.02
PRINTING AND GRAPHIC REPRODUCTION	75	18	47.91 ***	47.13 ***	50.89	53.07 **	18.41 **
SUBSTANCES AND CHEMICAL PRODUCTS	122	32	32.01	32.04	57.78 **	41.55	35.75
PLASTIC PRODUCTION	89	20	19.97	19.90	87.00 ****	104.42	21.09
NON METALIC MINERAL PRODUCTS	49	21	67.93 **	67.45 **	48.00 ****	19.29	20.91
PRODUCTION OF COMMON METALS	21	7	20.01	20.01	20.00 ***	6.01	23.33
METAL BASED PRODUCTS EXCLUSING MACHINEF	83	26	41.58	38.33	89.27 **	25.31	25.06
PRODUCTION OF MACHINERY AND EQUIPMENT	46	22	45.01	45.01	47.00 *	21.11	21.14
MACHINERY AND ELECTRIC EQUIPMENT	38	9	44.55 ****	44.51 ****	32.00 **	10.00	11.29
PRODUCTION OF VEHICLES	14	11	22.66	22.32	13.00	16.59	21.32
PRODUCTION OF FURNITURE	44	20	44.45 *	44.65 *	48.67	19.28	20.27

	T-Test for Difference in Means between firms with Internet and firms without Internet						
Description	**Number of Firms With R&D**	**Number of Firms Without R&D**	**Sales Efficiency**	**Production Efficiency**	**Exports/ Production**	**ROA**	**ROS**
ELABORATION OF FOOD AND BEVERAGES	103	139	157.33 ****	158.19 ****	145.09	160.69 ***	230.32 ***
TEXTILES	64	60	79.83	69.74	93.55 ****	58.27	91.80 ****
GARMENTS	22	45	21.13	21.12	22.67 ***	49.14	64.19 ****
LEATHER PRODUCTS	25	31	25.55	25.37	24.00	32.31	52.34
PRODUCTION OF PAPER AND PAPER SUB PRODU	23	15	22.23	22.19	21.00	22.07	35.25
PRINTING AND GRAPHIC REPRODUCTION	40	43	62.59 **	65.74 **	34.14	59.34	79.70
SUBSTANCES AND CHEMICAL PRODUCTS	86	53	91.33 ***	93.84 ***	125.98 ****	83.25	77.81
PLASTIC PRODUCTION	64	38	93.71 ****	90.73 ****	66.20 ***	74.50	55.08
NON METALIC MINERAL PRODUCTS	36	28	46.26 **	44.58 **	51.50 ***	25.61	29.00
PRODUCTION OF COMMON METALS	19	7	18.01	18.01	18.00 ***	7.01	23.39
METAL BASED PRODUCTS EXCLUSING MACHINEF	59	38	94.80 ****	94.11 ****	55.30 ***	38.71	37.25
PRODUCTION OF MACHINERY AND EQUIPMENT	29	32	28.01	28.01	48.99	31.64	31.80
MACHINERY AND ELECTRIC EQUIPMENT	30	13	30.30 *	28.35	34.37	32.42 **	15.75 **
PRODUCTION OF VEHICLES	10	9	11.04 *	10.99 *	12.56	12.37	9.35
PRODUCTION OF FURNITURE	26	31	37.44	37.91	42.55	32.49	35.03

Note: **** Significance at 0.001 level, *** significance at 0.01, ** significance at 0.05 and * significance at 0.1

Sales efficiency is total sales divided by total workers; production efficiency is the gross value of production (market value of total sales and inventories) over total workers; Exports/production is the value of export over gross value of production; ROA is the rate of return over assets and ROS is the rate of return over sales.

6.2. Econometric Analysis

Our regression analysis will basically consist in trying to model our performance measures (P) as a function of the following variables:

$$P_{i,t} = f(X_{i,}, D_{R\&D}, S_j) \qquad (3)$$

Where $P_{i,t}$ is any of the performance measures previously detailed for firm *i*, X_i are firm characteristics, $D_{R\&D}$ is the amount of expenditure in R&D reported by the firm, and Sj are variables at the level of the sector of the firm. Equation (3) will be estimated using a simple OLS panel data of firms and controlling by four digits SIC code economic sector fix effects. An additional advantage of the regression analysis is that it will also allow us to not only measure the impact of access to R&D but also the impact of the intensity of use by including, for example, a variable on the amount of expenditure in R&D.

Table 11 shows the results of the OLS regression over three performances variables. Essentially the explanatory variables are the main factors of production, i.e. capital, labor and materials. Additionally, controls for the age of the firm to control for the experience in the sector of the firm and access to telephone are included. All variables with the exception of the dummy variable for access to telephone are in logarithm.

When analyzing the impact over output it is shown that there is a positive correlation between output and all the factors of production. Labor, capital and materials all have a positive and very significant coefficient. Age on the other hand is not significant although the coefficient is positive. Moreover, the sum of the coefficients of the three factor of production is just over one, something that validates the assumption of a constant elasticity of substitution specification.

When analyzing the impact of research and development expenditures, as expected, the more the firms expend in R&D the more they will produce. Although, the coefficient is 0.0095, which means that the elasticity of R&D expenditure to output is significantly less than 1, i.e. increases in R&D expenditures won't result in significant increases in production. Similar results are obtained when the dependent variable is sales for export. Again the coefficient of R&D expenditures, although positive and significant at the 0.001 levels, is small. On the other hand, when analyzing the determinants of the amount of R&D expenditures it is found that size of the firm matters most. In average the size of the firms that expend in R&D is 177 employees while the average size of the firms with no expenditure in R&D is 23 employees.

In the last column of **Table 11,** results with respect operative profits are shown. As expected again R&D expenditures are significant but now the coefficient is 0.15. This result could imply that expenditure in R&D rather than increasing production is allowing firms to improve they productivity and efficiency and therefore increase their profit. Similar results are obtained if we include other performance measures as dependent variable.

Table 11
Effects of Research and Development Expenditures on Firm Performance

	Ln(Output)		ln(sales for export)		ln(operative profits)	
ln(capital)	0.10273	***	0.26493	***	-0.00913	
	(.0057)		(.0362)		(.0444)	
ln (employment)	0.26901	***	0.50848	***	1.25742	***
	(.0116)		(.0738)		(.0905)	
ln (materials)	0.73257	***	0.20534	***	0.85098	***
	(.0071)		(.0435)		(.0534)	
ln (Expenditure in R&D)	0.00950	***	0.09628	***	0.15352	***
	(.0033)		(.021)		(.0258)	
age	0.00106		-0.00553		-0.00785	
	(.0014)		(.0088)		(.0108)	
age square	0.00003		0.00009		0.00006	
	(.0000204)		(.0001)		(.0002)	
Has Telephone	0.04765	**	-0.57502	***	0.64548	***
	(.0212)		(.1337)		(.1639)	
Constant	1.80352	***	-7.54871	***	-7.29939	***
	(.1624)		(1.0505)		(1.2878)	
N	3731		3897		3897	
R square	0.9607		0.3832		0.5421	
Adjusted R-square	0.9594		0.3635		0.5274	
F-Test Fix effects	729.4	***	19.39	***	36.94	***

Note: This is an OLS regressions of a panel of firms for 1998 from the Encuesta Economica Annual of Peru. The regression includes fix effects for four digit SIC code economic activity level.

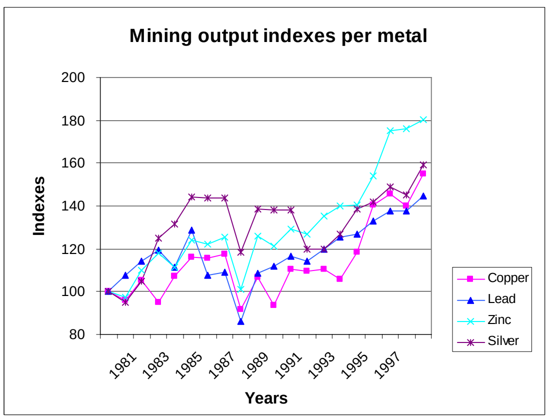
In the next section our methodological analysis will try to incorporate two case studies: one in the mining industry and the other in agriculture. The case studies clearly complement the cross-section study by providing insights on the process of innovation and adoption, the institutional, legal and regulatory framework, and give us more clear ideas of the bottlenecks and barriers that firms have to be able to have the appropriate incentives to invest more actively in R&D and therefore to innovate more. The advantage of these two sectors is that in both of them we can identify different sources of R&D, different strategies and institutional frameworks.

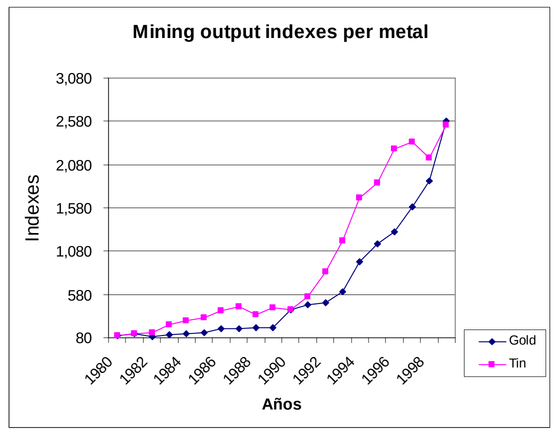
7. Case Study: Technological innovation in copper hydrometallurgy

7.1 Justification

Mining is one of the most dynamic industries in the Peruvian economy. As **Graph 21** shows, mining output has increased in the last 20 years. In the period 1980-1999, copper output has increased by 55%, lead by 45%, zinc by 80%, silver by 60% and gold by 1,479%. These increases in output are the result of a boom in mining investment that meant the modernization of the industry and the adoption of state-of-the-art mining technologies that boosted productivity and output.

Graph 21





Among those technologies, hydrometallurgy was one of the most important since it has made possible to exploit massive gold disseminated deposits that have resulted in a fourteen-fold increase in gold output and in the inclusion of Peru as one of the 8 largest gold producers in the world.

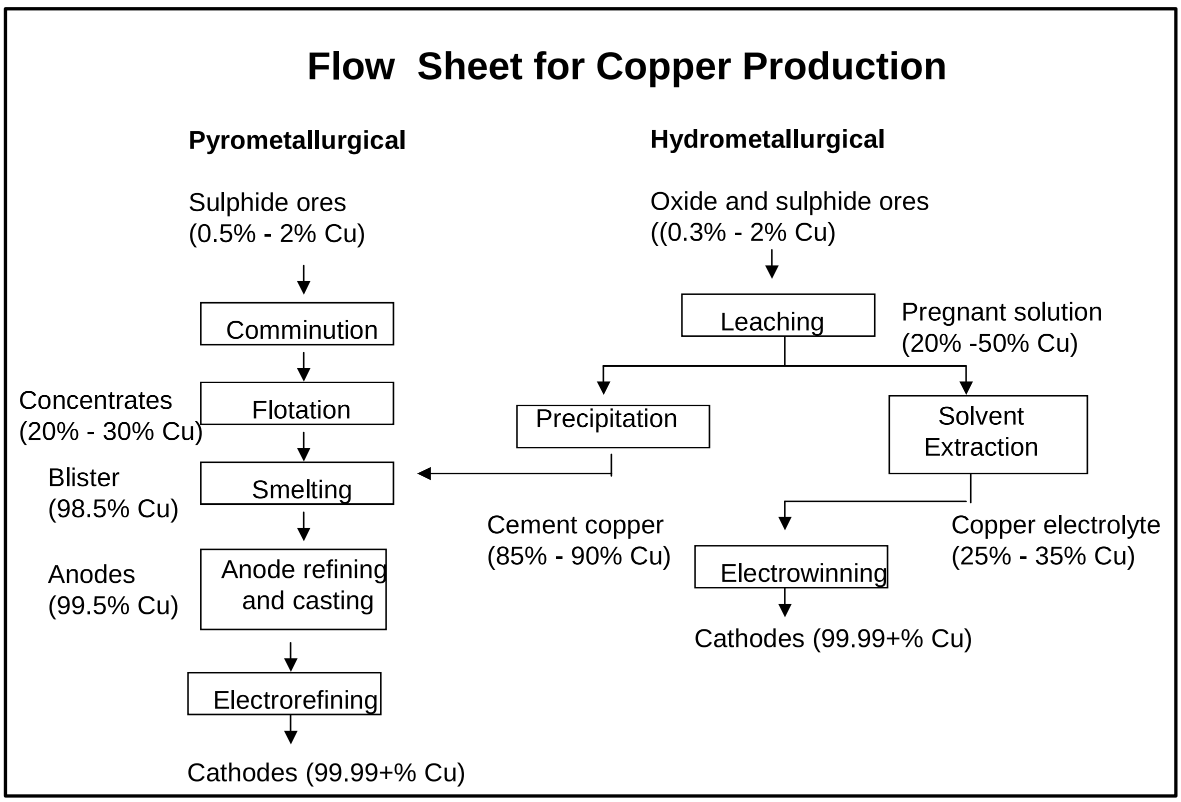
However, the development of hydrometallurgy is tightly linked to the copper industry and Peru was one of the first countries to adopt it and to contribute to its development. The initial success story is the focus of the case study that will be presented in the next sections.

7.2 Background

The commercial application of the hydrometallurgy technology to produce copper is one of the major metallurgic innovations during the last half of the twentieth century. Conventional mineral processing or pyrometallurgy involve several stages since the identification of mineral resources till the production of refined copper. These stages, which also involve specific sub-stages or unit operations, are: (a) prospecting and exploration of attractive deposits; (b) mining or extraction of the valuable mineral; (c) beneficiation, which involves the transformation of mineral into a commercial product called concentrate; (d) smelting that transforms concentrates into a higher content product called blister copper; and (e) refining, that purifies blister copper into 99.99% or more copper cathodes (see **Figure 1**).

Hydrometallurgy, developed mostly during the seventies, made it possible to skip several unit operations within the beneficiation, and all the smelting and refining stages. By this new technology, mainly copper oxide ores, are sprayed with an acid solution that percolates through the grinded material and liberates copper into the solution (leaching stage). This pregnant solution is then pumped to tanks and mixed with organic reagents that extract copper from the leachate (solvent extraction - SX stage). The addition of sulphuric acid strips copper into an electrolytic solution. The rich electrolyte is sent to the electrowinning circuit that through electric current generates ion transfer, having as result that copper settles in cathodes (electrowinning - EW stage) (see **Figure 1**).

Figure 1



The simplification of the conventional mining process had great impacts in the operation costs. Thus, hydrometallurgy was seen as a disruptive technology able to change the way copper and other metals were produced. First, it allowed to treat marginal deposits with low content copper ores. Second, it facilitated the production of refined copper without the high investment costs required to set up smelting and refining facilities. Third, operations deploying this new technology did not relied on economies of scale to be profitable. Fourth, it facilitated vertical integration in an industry in which relied on this strategy to reduce the cyclical volatility that affected mineral markets (Kuramoto, 2003).

Developing countries saw hydrometallurgy as the opportunity to catch up since they were dependent on mineral revenues and faced entry barriers in the mining business given the huge investments required and the reliance on imported technology (Warhurst, 1985). In fact, the technology was not fully developed and it required a lot of experimentation to deploy it in a mineral deposit. Specifically, the technical parameters of leaching were not fully optimised. Furthermore, a promising line of research, bioleaching, was being initiated since there was evidence that bacteria helped leaching of sulphur ores[22].

In the context of nationalised mining industries that were eager to find a solid competitive advantage different from higher grades, the Andean Pact launched two technological projects, "Acid or bacterial heap and dump leaching for marginal copper ores" and "Copper recovery from ion exchange in copper sulphate solutions", aimed at developing hydrometallurgy (PADT-Cu) in Peru and Bolivia in the late seventies.

The specific objectives of these projects were to develop appropriate technology to exploit domestic mineral resources with biological sources available in the region; to develop semi-industrial facilities to support the diffusion of this technology; to implement bacterial leaching operations using complex mineral dumps and/or abandoned sulphur copper deposits; and to promote the increase of copper production via this new technology (Macha and Sotillo, 1975).

To conduct the activities of these projects, CENTROMIN[23] set up a laboratory in La Oroya and pilot dumps were built in Toromocho (Morococha). In addition, MINERO Peru and INCITEMI[24] set up research centres in Arequipa and Lima. Also, a pilot solvent extraction and electrowinning (SX-EW) plant was built in Cerro Verde (Arequipa), which later became the fourth commercial plant in the world that deployed this new technology[25].

7.3 Sectoral innovation system during the 1970s and 1980s

The Andean Pact projects initiated a major research effort in Peru. Peru, and also Bolivia, had a large mining tradition and a series of institutions have been created along the years to support this activity. Thus, there was a technological infrastructure that could enhance the efforts of the recently launched hydrometallurgic projects.

7.3.1 Firms

[22] Sulphur ores are the most abundant copper ores in the world.

[23] CENTROMIN PERU was the state-owned mining firm that operated the previously owned facilities of Cerro de Pasco Corp.

[24] MINERO PERU was the state-owned mining firm aimed at developing new mineral deposits, such as Cerro Verde, where part of the research activity was conducted. INCITEMI was the National Mining Research Institute, it later became the INGEMMET (Instituto Nacional de Geología, Minería y Metalurgia).

[25] The first comercial SX-EW plant in the world was Blue Bird constructed in the United States in 1968. It was followed by Bagdad (1970), also in the United States; Nchanga (1973) in Zambia; and Cerro Verde (1974) in Arequipa, Peru.

During the early seventies, the Peruvian government nationalized the large foreign firms. Two major enterprises were expropriated: Cerro de Pasco Corporation, a mining and metallurgical complex located in the central Sierra, and Marcona Mining Corporation, an iron mine located in the southern department of Ica. These two enterprises became the state-owned firms, CENTROMIN PERU and HIERRO PERU.

In addition, another state-owned firm, MINERO PERU, was created to develop new mineral deposits. In fact, MINERO PERU developed the Cerro Verde mine in Arequipa and the Tintaya mine in Cusco.

It is important to mention that only one large foreign firm remained as such. Southern Peru Copper Corporation, the largest copper operation in Peru, was able to accelerate the development of a new mine. Unlike Cerro de Pasco and Marcona, Southern Peru showed that a foreign firm could contribute to the government's goal of turning mining into the driving sector of the Peruvian economy.

Without a few exceptions, the government did not nationalize small and medium firms. Most of them were owned by long established Peruvian mining groups.

The newly nationalized mining firms experienced an intense learning process since Peruvian engineers had to take in charge the operation of the facilities. This process was very welcomed because with the foreign administration they were relegated to a subordinate position. The largest learning opportunities appeared in Cerro Verde and Tintaya since the engineers had the opportunity to participate in the launching and the operation of new large copper mines.

The Cerro Verde project became the milestone in the Peruvian mining. The Cerro Verde deposit had considerable copper oxide reserves that were feasible to be exploited by the new hydrometallurgic technology. This technology had only been previously deployed in the Blue Bird (1968) and Bagdad (1970) operations in the United States, and in Nchanga (1973) in Zambia.

All the experimentation and studies done for the development of Cerro Verde were performed mostly by Peruvian engineers. The Andean Pact projects were instrumental for this. They provided with the necessary data to optimize both the leaching and solvent extraction stages in Cerro Verde. These projects allowed a tight collaboration among the different state-owned firms and an efficient use of their testing facilities and laboratories.

The small and medium mining firms were less active in research or in innovation.

7.3.2 Government

During the seventies, the government relied very much in central economic planning. The National Planning Institute was very active defining the priorities for the country. Despite the rigid framework, the government was able to set national priorities to spur economic development.

Mining had always been an important sector for Peru, but the government believed that it responded mainly to corporate interests and, therefore, its contribution to development was meager. Thus, the new state-owned firms set the priorities of developing large deposits to increase mineral production, especially in copper, and to develop deposits far from the coastal region to promote decentralization, such as Tintaya.

The government set the goal of adding value to mineral production. Thus, it promoted the construction of two refineries: the Ilo refinery to treat the copper concentrates produced at Southern Peru and the Cajamarquilla refinery to treat zinc concentrates produced by firms located in the Sierra Central. The decision to deploy hydrometallurgy in Cerro Verde was also geared to this goal.

Finally, the government also set the policy of commercializing all the mineral products. The objective was to increase mining's retained value. This led to a state-owned mineral commercializing firm called Minero Peru Comercial (MINPECO).

7.3.3 Research and technological institutions

Mining is an industry that relies heavily in experimentation. Each deposit has its unique characteristics and even when the mining and metallurgical technology is pretty standard, laboratory and pilot plant tests have to be performed to optimize each process. For this reason, various mining related institutions have been created since the last half of the XIX century.

Most of these institutions were professional associations aimed at gathering engineers and at contributing to the exchange of knowledge. Later, as Peru became interesting as a mining country, it was necessary to increase the geological information. As a result, in 1940, the Peruvian Geological Institute was created and 20 years later the Geological Survey Commission was set up.

It is in 1973 that the Scientific and Technological Mining Institute was created. This is the first attempt to diversify the focus from the geological research to other areas of mineral-related knowledge, such as metallurgy. This institute was merged in 1978 with the Institute of Geology and Mining to create the National Institute of Geology, Mining and Metallurgy (INGEMMET). Like many other technological research institutes, INGEMMET had limited links with firms and the results of their research was not successfully transfer to firms.

At the end, INGEMMET focus most of its research to complete the Peruvian geological map.

7.3.4 Universities

In the seventies, the most important universities providing Geology, Mining and/or Metallurgical Engineering were the Universidad Nacional de Ingeniería (UNI) and Universidad San Marcos. Other universities, especially those located in mining areas, created mining-related faculties given the strategic importance that the government provided to this sector[26].

Universities were mainly focused at forming professionals but they had a limited role in generating mining knowledge. They had little interaction with firms.

7.3.5 Relationships among domestic agents

There was a limited relationship among the different actors conforming this sectoral innovation system. Although it must be noted that the Andean Pact project contributed to the joint work of professionals from different divisions at CENTROMIN and MINERO PERU. In fact, Warhurst (1985) reported that the Peruvian team, as opposed to the Bolivian one, was able to create a collaborative environment and a good transmission of knowledge.

Outside the boundaries of the Andean Pact project, knowledge was mainly transmitted through informal means. The engineers working in the project shared their experiences with other engineers working at mining firms and presented their advances in conferences such as the Mining Convention. However, formal knowledge transfer mechanisms were not designed. In fact, the advances made in bacterial leaching at Toromocho and Cerro Verde were not transferred to other research institutes or universities to continue with further research. Once the Andean Pact project ended, the main depositaries of the knowledge generated were the people themselves.

7.3.6 Relationships between domestic and foreign agents

In the first place, the Andean Pact project allowed interactions between the Bolivian and Peruvian teams. Technical visits to experimentation sites and workshops were considered as activities of this project. This created personal links that were maintained along time.

In the second place, this project allowed interaction with research groups from universities and laboratories in advanced countries. It also provided Peruvian engineers the opportunity to pursue advanced training in foreign laboratories and universities.

7.4 Legislative change and its effect on the sectoral innovation system

The effects of the reforms launched in the 1990s had an important effect in the mining innovation system described in the previous section. The liberalization of markets and the incentives provided to the mining sector impulse investments. For the period 1990-2007, it is expected that the investment in the sector will reach US$ 2 billion (Sánchez, 1998).

These new investments spurred the setting up of new mining operations using state-of-the-art and environmental-friendly technologies, as well as the modernization of the existing

[26] In fact, during the 1970s the government launched media spots urging young people to study mining engineering.

mining operations. The sector as a whole was benefited by an important transfer of technology via the imports of capital goods and equipment.

Several operations using hydrometallurgical technologies were set up to exploit copper and gold. First, the Yanacocha gold project was launched in 1994[27]. Yanacocha became the first large scale gold operation in Peru deploying cyanide leaching and Merrill Crowe method for gold recovery. Second, in 1995, Southern Peru Copper Corporation developed a leaching, solvent extraction and electrowinning (LIX-SX-EW) operation in its Toquepala deposit with a capacity of 40,000 MT of copper cathodes. The plant was set up in the Toquepala deposit and was fed by the dumps accumulated since the beginning of the operation in the 1960s. Third, the increase of capacity of the LIX-SX-EW operation, from 30,000 MT to 50,000 MT of copper cathodes at Cerro Verde. This operation was privatized and acquired by Cyprus Amax in 1993[28]. Fourth, the launching of the Pierina gold operation in Ancash. This operation, that uses a technology similar to that deployed in Yanacocha, belongs to Barrick and has the one of the lowest operating costs in the world.

More recently, Southern Peru has developed a new LIX-SX-EW plant in Cuajone with a capacity of 22,000 MT of copper cathodes. BHP Tintaya has developed a LIX-SX-EW plant to treat copper oxide ores available in its deposit. Several other smaller operations deploying various hydrometallurgical methods have been developed.

The effects of the increase mining investment in the sectoral innovation system has not been favorable. Most of the mining investment has been performed by foreign firms which developed large deposits under EPCM (engineering, procurement and construction management) contracts. As a result, these projects have generated a limited demand for domestic goods and services. This situation has affected Peruvian manufacturing firms but also research institutions and universities since services such as lab tests and environmental impact assessments are mostly performed abroad (Kuramoto, 2001).

In the Peruvian mining sector, firms are not small but tend to be large or medium, both in terms of sales and employment. These firms do little research and development, since the mining sector sells homogeneous products for external markets. Some research is done locally but tends to be focused on the optimization of their operation processes. Research that could have a major scope of impact is done by foreign firms at other locations, whether in their home country or other locations with better scientific and technological infrastructure.

Economic reforms have had an adverse effect on research institutions and universities. Their precarious situation during the 1980s, when budgets were decreased drastically, did not improve after the reforms. The prevalent idea in the government was that foreign direct investment and imports will became the main sources of technology transfer so it was not

[27] Yanacocha is owned by the US firm Newmont (51%) and the Peruvian firm Minas Buenaventura (49%). This operation is located in the Northern Sierra, in the department of Cajamarca, one of the poorest in Peru. By the end of 1998, proven and probable reserves were 20.1 million ounces. Yanacocha has become the largest gold operation in Latin America with an annual production of xx million oz. per year.

[28] In 1999, in one of the most important mergers occurred in the copper industry, Phelps Dodge acquired Cyprus Amax and thus, Cerro Verde is now property of the former.

necessary to strengthen the research institutions. In fact, the mission of INGEMMET was narrowed to the culmination of the geological map and any other research was removed from the agenda. The infrastructure of this institute is largely unutilized.

The previous does not mean that some research is taking place. An industrial training institute began to provide mineral lab tests analysis for small firms, given the high costs that credited and recognized labs, such as SGS, charge. However, the demand is very little and this institute has decided to transfer the knowledge they accumulated in hydrometallurgical methods to the formation of human resources.

The situation is similar in the universities. Their budgets have shrunk, they are focused to their educational tasks and little research is done. A recent survey has identified that only four universities with geology, mining and metallurgical engineering faculties are apt to perform research (Arteaga, 2003).

With respect to the relationships among the different actors that form the mining innovation system, they are mostly informal and based on personal relationships. People that worked together in different mining projects tend to keep their contacts and discuss operational problems and ways about how to solve them. The role of consultants and suppliers is also important since they serve as a source of knowledge transfer. They offer state-of-the-art solutions and even the latter provide in-house training courses for the mining firms that are their clients.

Mineral conventions are a more formal way to transfer knowledge. These meetings provide the opportunity to gather professionals working in different mining projects. They usually present papers related to operational problems or applied research performed in-house. These conventions also serve as a networking mechanism, given the assistance of mining professionals, entrepreneurs, suppliers, technical and financial consultants and other people related to the mining business.

With respect to the links established by domestic and foreign actors, they are mainly fostered and maintained at a personal level. Mining professionals keep their links with their professors at the universities where they studied their graduate courses and/or their colleagues from the companies they worked.

7.5 Roles of public and private sectors

From the descriptions of the mining innovation system, it can be argued that firms, whether state-owned or private, were, and probably still are, the most active actors in pursuing technological innovation in this sector.

During the implementation of the Andean Pact project, state-owned firms participation was crucial for they provided human capital and their facilities to carry out the activities. The focus on problem-solving and the consideration of economic viability was crucial for the advances earned by this project. In the specific case of Cerro Verde, learning was not only circumscribed to technical aspects of hydrometallurgy but to the acquisition of capabilities related to the preparation of the feasibility study and the negotiations with representatives of financial and banking institutions as well as suppliers. In fact, it was possible that certain black boxes were opened. For example, given the shortage of budgets[29] and the high costs of the anodes and used for the electrowinning plant, it was possible to set up an anode plant with Japanese aid.

The links with research institutions, like INGEMMET, and universities was not very tight. There was the idea that the former institutions should focus on scientific rather than applied research. Besides the time frames for each type of actor were different. While state-owned firms wanted to accelerate the pace of the project, research institutions and universities did not care about time and the most important thing was to perform a good research.

As a result of this lack of linkages, the capabilities acquired by the mining professionals that participated in the Andean Pact project generated limited spillovers. As opposed, in Chile the spread of this technology, also spurred by new projects launched by the state-owned firm CODELCO, was aided by the codification of knowledge via universities. In fact, during the 1980s, one of the most important researcher in this field, Esteban Domic[30], set up courses of hydrometallurgy in the Universidad de Chile where he taught and was supervisor of several thesis on the topic.

This lack of codification was responsible for the feeble diffusion of this technology and the lack of availability of specialized human capital. In fact, after the 1990s economic reforms, private firms that incorporated hydrometallurgical methods in their operations did not look for the professionals that worked on the Andean Pact project[31].

It is important to mention that the LIX-SX-EW technology is currently standardized and there are suppliers for every stage of this process, so firms did not have to devote large amounts of time and effort to use this technology. It is only required to hire external engineering consultants to define the technical parameters of the project (size, requirement of equipment, etc.). This does not mean that some internal experimentation has to be performed, especially at the leaching stage because every deposit has its own characteristics. However, the learning process generated inside firms is limited because the technology has become dominated by the suppliers, especially engineering firms.

Even Cerro Verde, which was acquired by Cyprus Amax, had a set back since directives from Cyprus took over the operation. Fortunately, most of the technical staff remained in their jobs, such as mine and plant superintendents, but auxiliary facilities like the anodes plant were closed. The aim of efficiency became imperative and Cerro Verde had to stick to its core competence: the production of copper cathodes.

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[29] Peruvian mining state-owned firms, like Cerro Verde, did not have control on its revenues, they were collected by the central government. The budget of Cerro Verde was prepared and justified and the government the could approve the appropriation designated for the firm.

[30] Esteban Domic was directive of Sociedad Minera Pudahuel, a company that devoted great efforts to optimize bacterial leaching. This company holds a patent on bacterial leaching.

[31] For example, when Southern Peru representatives were asked if they had used information about the Andean Pact project, they said they did not know about the existence of such project.

One important feature of the spread of the LIX-SX-EW technology during the 1990s is that firms have been consulting each other on an informal basis. For example, Southern Peru has consulted Cerro Verde and some Chilean mining firms about bacterial leaching. Also, technical staff assuming directive positions in other mining firms had a previous experience in hydrometallurgy in Cerro Verde or Southern Peru.

There is also some evidence of applied research inside firms. In the last International Copper 2003 Conference, Cerro Verde and Tintaya presented the results of their research aimed at improving their operational efficiency. In spite that the papers will be published in the conference proceedings publication, the diffusion inside the country and to other actors of the Peruvian mining innovation system will be very limited.

8. Case Study: Technological innovation to control the fruit fly in the mango agriculture

8.1 Justification

During the last 40 years, Peruvian agriculture has suffered major changes that impeded a continuous productivity growth in the sector. The Agrarian Reform launched in 1969 have as main focus the change in the property regime of land. As a result, it increased State intervention in agriculture and caused the withdraw of agriculture entrepreneurs and technicians. The 1980s brought about an unstable macroeconomic environment and a very severe El Niño phenomenon that was perverse to this sector and helped in its continuous deterioration.

In the last decade, major economic reforms were launched that affected agriculture. Within the agricultural sector major changes were: (a) the elimination of price controls, both refuge and guaranty prices; (b) the liquidation of the Agrarian Bank and the elimination of the preferential interest rates for agriculture; (c) the elimination of state-owned firms for agricultural commercialization; and (d) the elimination of non-tariff mechanisms and imports quotas (Ministerio de Agricultura, 2002).

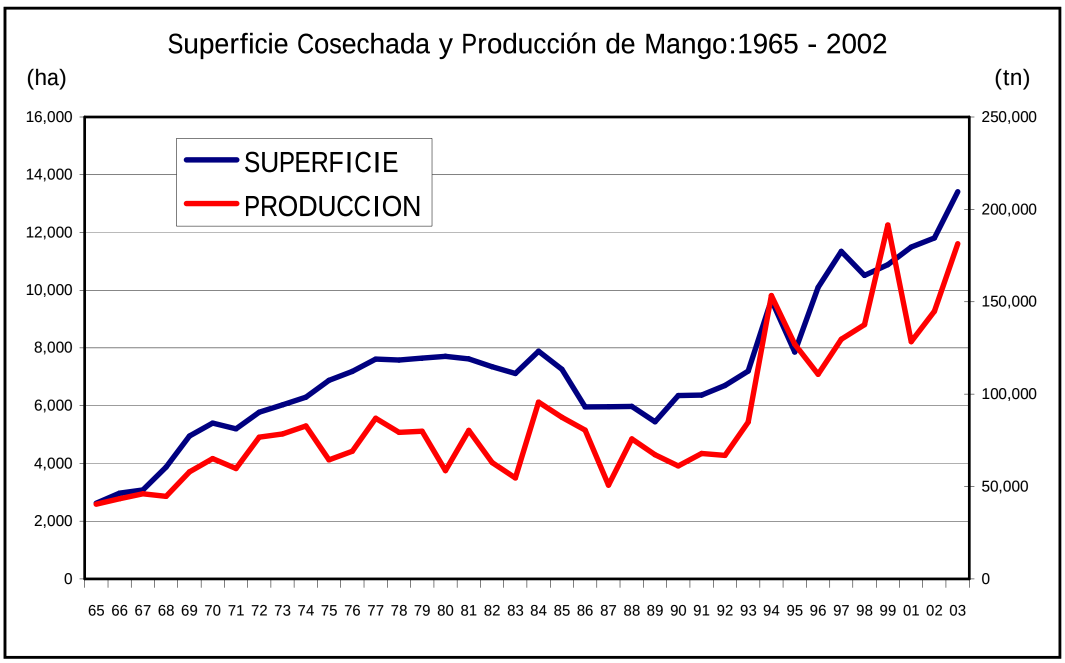
Despite the previous measures hit severely the agricultural production units, output began to grow. Export-oriented agriculture became the fastest growing segment. During the last 11 years, the sales of agricultural products to external markets have increased 120% and for 2001 their value reached 9.3% of total Peruvian exports. The products responsible for this increase are the so-called non-traditional agricultural exports, such as mango, asparagus, avocado, paprika, marigold meal and grapes, among others.

Peru is consolidating as a mango exporter. In the period 1990-2002, accumulated exports reached 202 thousands of metric tonnes, which represented US$ 191 million and represented 74% of the total exports of fresh fruits. In the same period, the harvested area raised from 6,352 to 13,404 hectares (see **Graph 22**), mainly in 10 departments: Piura[32] (5,908 has.), Lambayeque (924 has.), Ucayali (720 has.), Ica (660 has.), Lima (643 has), Cajamarca (590 has), Ancash (390 has), La Libertad (240 has), Junín (169 has) and San Martín (146 has).

Although figures look impressive, there are important constraints that need to be overcome in order to fulfil Peru's potential as a major mango exporter. One of such constraints refers to the harmful effect of the fruit fly. This plague not only affects mango but some other 200 vegetable and fruit species. It affects crop's productivity and it is estimated that generates losses of about US$ 90 million per year and a decrease in production of about one third of all the horticultural production. In addition, countries that import fruits, such as the United States, Japan and European countries, have very strict sanitation rules and procedures to avoid the entry of infected fruit.

The next sections will develop the innovation efforts made to control the fruit fly in Peru and how different agents have collaborated in these efforts.

Graph 22



Fuente: DGIA-MINAG

32 Piura concentrates around 68% of total mango supply. Most of the harvested area is located in the San Lorenzo valley. This area had recently a major dispute with a mining firm that wanted to develop the Tambogrande gold deposit and required the farmers to be resettled in other areas. Though different actions that included a plebiscite, the farmers faced the mining firm. At the end, the public rejection and the failure of the mining firm to meet certain financial requirements impeded the development of the mining project.

8.2 Background

8.2.1 On the mango crop

Mango is a tree that can reach between 10 and 40 meters high. The fruit is rounded with a hard seed. Its pulp can be firm or juicy, with or without fibre. It can weight between 100 grams and 1 kilogram. The fruit is sweet and has high contents of calcium, magnesium, potassium and phosphor, vitamin A and several aminoacids.

Mangos are original from South Eastern Asia, mainly India, and were introduced in America by the Portuguese in Brazil and by the Spanish in Mexico. It arrived to Peru in the XVIII century and it developed into the creole or regional species. The current export-oriented species (Kent, Edwards, Tommy Atkins and Keitt) were brought from the Florida State to the Experimental Station of La Molina in 1960 (IICA, 1999). Because of the weather in Lima, mango plants did not develop fully. Five years later, that the plants were sent to Piura as part of an integral plan to promote mango agriculture. The tropical weather in this department suited perfectly the needs of mango plants. The crop began spreading all over this region and an export-oriented agriculture develop.

The main factors that contributed to this spread were: (a) adequate soil and weather, with no rain, that allows a very sweet fruit, better colour and less turpentine in the skin; (b) mango harvest in Piura occurs counter-season, so prices are relatively high in international markets; (c) good access to the Paita export port; (d) the mango is a fruit with a growing demand in the northern hemisphere compare to other tropical fruits such as bananas or pineapples (IICA, 1999).

8.2.2 On the fruit fly

The fruit fly is a dipterous insect that gathers more than 1,000 species. From these, around 25 species are pernicious to agriculture. The two more dangerous species are the *Ceratitis Capitata* and the *Anastrephia Fraterculus,* both found in the coastal valleys in Peru. These flies attack fruits and vegetables. The female flies deposit their eggs in the fruit, where the latter develop as larvae and ruins the crop.

The *Ceratitis Capitata* was first found in Bermudas Islands in 1856 and in Australia in 1897. It spread to places such as Brazil, Italia, Argentina, New Zealand, the United States, Costa Rica, Peru and some other countries in Latin America. In 1956, it is first detected in Peru. It seems that was introduced in citric fruits coming from Brazil.

By 1995, it was reported that the fruit fly was found in 82 out of 219 countries. Some countries previously infested such as the United States, Mexico and Chile were able to eradicate this plague. Different methods of control and eradication were implemented since the detection of the fruit fly. **Table 12** shows the prevalence of the different efforts to control the fruit fly and the periods in which they were implemented. In the period 1900-1950, efforts were focused on attaining biological control of the plague. This involved the breeding of wasps to hurt the fruit fly larvae. Almost at the same time, between 1909 to 1931, low toxicity insecticides were used. The tree trunk was fumigated and the larvae was attracted with a lure rich in proteins. Semiochemics were used to increase the effectiveness of lures. Also in the 1960s, the technology of breeding sterile fruit fly began to spread. In this period, efforts were devoted to develop pilot projects to use sterile flies to reduce drastically the birth rate of the fruit fly. Between the 1960s and 1980s, new synthetic organic insecticides were launched and began to be used to fight the fruit fly. Finally, in the 1980s, once the sterile fruit fly technology show good results, large laboratories where the sterile flies were bred began to be built to produce massive amounts of flies.

Table 12
International fruit fly control methods

Method of control	Periods
▪ Biological control	1900 - 1950
▪ Chemical control with lure and inorganic insecticides	1909 - 1931
▪ Sterile insect technique (SIT) pilot projects	1960 - 1970
▪ Chemical control with lure and synthetic organic insecticides	1960 - 1980
▪ Semiochemics	1960 to date
▪ Large scale SIT projects	1980 - 1990

Domestic efforts to control and research about this plague were initiated in 1965. These efforts included traditional biological control, the use of organic insecticides and the use of sterile insects. In 1972, a lab for mass breeding sterile fruit flies (between 100 and 250 million flies weekly) was constructed in La Molina. At the same time, the Tacna valley in the Southern coast of Peru was selected to initiate a demonstrative control project. The Tacna valley was selected because it was geographically isolated from the rest of the other coastal valleys, thus the chances of defeating the plague were greater than in other locations. Partial results were achieved but the efforts continue to eradicate the fruit fly in that valley. It is important to mention that there is an agreement between Chile, a country free of fruit fly, and Peru to continue with this control and eradication project in this next to the border valley.

8.2.3 The fruit fly and mango exports

The success in the mango adoption in Piura set the bases for the establishment of an export-oriented agriculture. Mango became the fifth more exported agricultural product in Peru. As mentioned in an earlier section, the quality of the Peruvian fruit and its counter-season harvest provided competitive advantages to Peruvian exporters.

Mangos are one of the hosting plants for fruit flies. According to a 2003 survey made by SENASA (National Service of Agrarian Sanitation), mango is the fifth most infested crop with fruit fly in Piura but it is the first among the exporting crops. Given the sanitation measures in the United States, the main Peruvian mango importer, several measures have been adopted to eliminate the chances that infested mangos enter the United States border.

Before the 1990s, mangos were fumigated with methyl bromide. The 1991 Montreal Protocol defined this chemical as one that contributed to deplete the ozone layer. A phase-out program was defined and in the time-frame of 6 years (from 1999 to 2005), its used should be eradicated in developed countries.

Thus, the US Department of Agriculture developed different alternatives to substitute the use of this chemical. For the treatment of imported fruit a sanitation protocol was developed, using heat treatments. The hot water treatment is a process in which mangos are introduced in no more than 4 inches depth, at a temperature of 47°C for 75 to 90 minutes. This immersion eliminates the chances of fruit fly contamination at the egg and larvae stage, as well as eliminates other infections such as the anthracnosis fungal infection[33].

This treatment was introduced in Piura in 1988. Since then the Animal, Plant and Health Inspection Service from the US Department of Agriculture oversees the whole treatment and the expenses are covered by the Peruvian exporters. In addition, the treatment is only provided to fruit coming from certified farms by SENASA.

Another available heat treatment is the water steam treatment. This treatment was also developed and first applied in the United States in 1929. The fruit is exposed to water steam at temperatures of around 46°C for 8 hours. The disadvantages of this treatment is that requires an expensive infrastructure and not all fruits resist the heat for that long. This treatment is required by Japanese authorities.

Another, not so spread treatment is the ionizing radiation. The radiation kills pathogenic microbes and insects in their egg and larvae phase. It also delays the ripening of some fruits and vegetables. The Food and Drug Administration approves ionizing radiation for fresh fruit as long as it does not exceed 100 Gy (Tijero, 1992).

8.3 Sectoral innovation system

Although the agricultural innovation system is much larger[34], this section will only develop the innovation system that is related to the mango production chain and the efforts to control the fruit fly.

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[33] The anthracnosis fungi attack mango trees during the florescence stage till the fruit is partially developed. The tree loses its leaves and the fruits become soft and rotten. The unripe infested fruits present brown spots that grow after the harvest, thus the damage is only evident by the time the fruit is already embarked.

[34] For a complete definition of the agricultural innovation system, see (INIA, 2003).

The mango production chain is conformed by a large number of farmers, a reduced number of mango exporters, an even more reduced number of mango processors, and a series of institutions aimed at support the mango agricultural and exporting activities. Most of the interactions in the mango production chain are found in the agricultural stage since mango is exported as fruit rather than processed. **Figure 2** provides an overview of the main interactions among the different institutions, private and public, and associations, which include firms. A thorough description of these institutions and associations will be developed in the next sections.

8.3.1 Firms

As mention earlier, there is a great number of farmers that cultivates mango. Most of them are located in Piura, which concentrates most than half of all the hectares cultivated. Farmers are grouped in 5 major associations: PROMANGO, ADEPROMANGO, Asociación de Productores de Mango del Valle del Alto Piura, Asociación de Productores de Arroz - Centro del Valle de San Lorenzo and APPEAP. **Table 13** shows the main characteristics of these associations. It can be appreciated that PROMANGO is the association that gathers farmers with the largest properties and concentrates the largest part of the mango shipments. This association is not part of APEM, the association of mango exporters, but has a solid position in the industry. In fact, they preside agro-industrial CITE, a technological innovation centre in Piura. PROMANGO is looking for funding to increase the Piura's mango production chain.

There is another important association of medium farmers, ADEPROMANGO, that works directly with exporter firms, which facilitate them with working capital and technical assistance. This a regional association and thus has a strong link with the regional government. The Asociación de Productores de Mango del Valle del Alto Piura is also a regional association, which gathers smaller farmers. This association is receiving technical assistance from PSI/PERAT, a special program for irrigation and technical assistance. There are another two associations that gather farmers in San Lorenzo, a well known valley that produces not only mangos but limes and rice; and an association of farmers dedicated to cultivate ecological mangos. Finally, there is a vast amount of farmers, more than 4,000, that are independent and do not belong to any association. The production of these farmers is used to complement exporting shipments, but they sell mostly in the domestic market.

Figure 2
Interactions among the actors of the mango production chain

Nº	Agentes	Cámara C. Piura	Munic. Salitral	Gob. Regional	CIPCA	IDEAS	RR.EE	ADEPRO-MANGO	PROM-PEX	PRO-MANGO	APEM	UNI. Piura	UNI. Agra.	PRO-DUCE	PERAT	MINAG	INCA-GRO	SENASA	INIA
1	INIA									2	2	2	1				2**	3*	
2	SENASA								1			1							
3	INCAGRO																		
4	MINAG																		
5	PERAT																		
6	PRODUCE																		
7	U.Agraria																		
8	U.Piura																		
9	APEM	1																	
10	PROMANGO																		
11	PROMPEX																		
12	ADEPROMANGO																		
13	RR.EE.																		
14	IDEAS																		
15	CIPCA																		
16	G.Regional																		
17	Munic. Salitral																		
18	Cámara C. Piura																		

Notes:

(1) Agreements
(2) Projects
(3) Actions
(4) Others

*** High interaction
** Medium interaction
* Low interaction

Table 13
Mango farmer associations

Organization	No. Of members	Cultivated area (Has.)	Exported TM	Observations	Agreements and interaction
PROMANGO (Asociación de Productores de mango)	26	1,500 has. and 50 has. of organic mango	10,000	Are not part of APEM. Has its own greenhouses. Presides the agroindustrial CITE.	Has presented a project on the competitiveness of the Piura's mango production chain to INCAGRO
ADEPROMANGO (Asociación de productores de mango de Piura)	176	2,000		Exporter firms charge them 3% rebate for losses and 6 jabas per ha. for technical assistance.	Exporter firms finance the crops against the harvest. They are working with the Regional government a project for processing low grade mangos
Asociación de productores de mango del valle del Alto Piura	63	200	8 containers	They are asking for the electrification of wells.	They receive crop management assistance from PERAT/PSI and the municipality of Chulucanas
Asociación de productores de arroz. Centro del Valle de Lorenzo	150	400			
APPEAP (Asociación de productores Ecológicos del Alto Piura)	200				Has a certification from Biolatina
Non-organized producers [35]	4,485				

On the other hand, the most important association of mango exporters is APEM, Asociación Peruana de Exportadores de Mango. This association gathers 80% of all mango exporters. Among their members are the three largest mango exporters that concentrates more than half of all mango exports. The most important exporters are: Bounty Fresh Peru (21.5%), Sunshine Export (17.4%) and Agrowest (13.7%).

At the end of the production chain, there are a series of service providers such as surveillance firms that certify production according to different protocols such as ISO, HACCP and others; customs agents and logistic firms. The Chamber of Commerce of Piura also provides an origin certificate necessary to access tariff preferences in the US and Europe. It also provides legal, foreign trade, accounting and tax advising.

Although this study is focusing in fresh mango exports, there are agents that process mango and sell to external markets mango pulp and juice, mango slices and conserves.

[35] Most of the non-organized producers have also lemon plantations. Mangos are harvested only once a year while lemons can be harvest all year long, thus providing farmers with a continuous positive income (IICA 1999).

8.3.2 Government

The 1990 economic reforms hit severely agriculture, thus reducing the budgets for the government institutions and programs. The Ministry of Agriculture is the main authority in charge of defining the policies to promote and develop this sector. As such, the Planning Office is the entity aimed at surveying and evaluating the agricultural foreign trade, participating in international agreements and evaluating the main government agricultural projects. General Direction of Agriculture Promotion from the Ministry of Agriculture is the entity aimed at strengthening the farmers' organizations.

SENASA, the National Service for Agricultural Sanitation, is the only government institution that works actively in the control and eradication of the fruit fly. It runs a laboratory that produces 100 to 250 million sterile fruit flies. It also monitors the presence of this plague in the 30 most important valleys in Piura, Lambayeque, Lima, Ica, Arequipa, Moquegua and Tacna, covering around 75,000 has. SENASA has also constructed an irradiation center to treat fresh fruits for export.

The Special Program for Irrigation and Technical Assistance (PSI/PERAT) helps farmers to reach reasonable profit margins. To attain this objective, the program is working in 2003 with 300 demonstrative farms and 150 learning circles to motivate farmers to incorporate technological innovations, such as technically sound irrigation.

INCAGRO is a special project aimed at funding technological innovation projects in agriculture. It promotes the participation of public and private actors as a way to create interactions in the agricultural sector. At present, it is funding a project to provide technical and commercialization assistance to farmers in order to increase the supply of ecological fruits. For the next year, INCAGRO will be financing PROMANGO in a project to increase the productivity of the mango production chain.

Other government offices dealing with mango production are the Ministry of Foreign Commerce and the Ministry of Production. The former, through its exports promotion office, PROMPEX, promote the mango supply in external markets through roadshows, a clearinghouse of demand and supply, initiatives to promote quality upgrading, among others. PROMPEX has promoted the creation of the two most important organizations of the mango production chain: APEM and ADEPROMANGO.

The Ministry of Production promotes the processing of mango through the technological innovation centres (CITEs). It has created the Agroindustrial CITE with the participation of 6 other institutions: the University of Piura, the University of Lambayeque, PROMANGO, ALGARROBO, CIPCA and the Chamber of Commerce of Piura. This CITE will support the research and provide technical assistance in products like mango and algarrobina. This CITE will also aimed at promoting interactions among the government, academia and the private sector.

Finally, local governments also play a role in the mango industry. The Regional Government of Piura has a division that promotes investments, projects and exports. It has organized the International Mango Festival as a way to promote this production chain. It is helping to articulate mango farmers through a packing facility and it is trying to look for funding for the next agricultural season. The Municipality of Salitral is supporting the initiatives of some NGOs to promote ecological agriculture. It counts with an agribusiness commission and is part of the Agricultural Provincial Commission.

8.3.3 Research and technological institutions

The most important agricultural research institution is INIA, Instituto Nacional de Investigaciones Agrarias, that aims at generating and transferring technologies. During the last decades, the whole agricultural innovation system has been seriously damaged, thus the new INIA's administration is trying to reconstruct this system and to establish the linkages among the different actors in the agricultural sector. One of its main objectives for the mango industry is: (a) to improve the quality and increase the variety of exporting mangos; (b) to transfer agronomic best practices in nutrition, irrigation, pruning and sanitary control; (c) to diminish the seasonal productivity problem; and (d) to control the growth and vegetative development of new varieties of mango. INIA runs the Experimental Station of Hualtaco in Piura, that is the largest mango germoplasm bank in the country.

8.3.4 Universities

The Universidad Agraria de La Molina is the main agricultural university in Peru. It has a major research program in fruits, in which the aim is to increase productivity and to establish development nuclei for the main species and varieties of fruits. The focus is mainly to study and support fruits with high potential of commercialization. In that sense, mango is not one of the targeted fruits of this program.

The Universidad de Piura has an Agricultural; Agribusiness Engineering and Food Sciences departments. The university is currently working in the control and analysis of physical, biological and physiological damage.

8.3.5 Relationships among domestic agents

Despite the diverse institutions and actors working in the mango production chain, there is little interaction among them. Because of its export-oriented nature, the main objectives of the different actors are to increase the exporting supply and to maintain adequate levels of quality. Although it is understood that to increase productivity is necessary to improve technology and practices in every chain link, current efforts are focused on the harvesting, post-harvest handling and packing. Thus, there is tight link between the exporters and farmers. Some of the former provide technical assistance and working capital to the farmers to cover the expenses of the agricultural campaign.

Initiatives to improve the agricultural practices are provided by some government institutions such as INIA, SENASA or the special irrigation program. There is also some localised initiatives run by NGOs that are supporting mango exporters. For example, IDEAS is providing technical assistance in Salitral to promote the mango ecological agricultural. This NGO has an agreement with a large exporting firm to purchase the ecological mangos. This firm buys normal mangos at US$ 81 per ton, while pays US$ 100 for the ecological ones.

The Agroindustrial CITE is another initiative to promote linkages among different actors. This institution has recently been created so their actions are by now limited.

At the experimentation level, one important interaction is the one between SENASA and the IPEN, the National Institute for Nuclear Energy. The latter institute is helping SENASA with the implementation of a radiation facility. This facility will represent an alternative treatment for the fruit fly.

8.3.6 Relationships between domestic and foreign agents

There have been several interaction spaces between foreign and domestic institutions and agents. In the first place, the first Technical Agriculture School was created in 1901 with the help of a Belgian mission coming from the Faculté Universitaire des Sciencies Agronomiques de Gembloux (Bélgica). The university maintains several agreements with different universities from Europe and the United States.

With regards to mango, the first varieties are brought in the late 1950s through an agreement with the Ministry of Agriculture and the Florida Experimental Station. Although there was a extended phase of experimentation in the facilities of La Molina and other experimental stations, especially in Piura, some farmers have imported seeds from other countries such as Puerto Rico and Venezuela. This reflects the difficulties of government institutions to reach the production sector.

A current are of close interaction is that of sanitation. As the United States is the main exporting destiny and mangos require heat treatment to be admitted in that country, the APHIS-USDA supervises this process in conjunction with SENASA that provides a certification. In addition, the certification can only be issued if the mango comes from farms certified by SENASA.

With regards to other initiatives to control and eradicate the fruit fly, there is some interaction between Peruvian authorities in the southern border and Chilean institutions. Chile, a major agricultural country, is free of the fruit fly and is interested that Peru eradicates this plague so that chances of an infestation become almost nil.

8.4 Roles of the public and private sectors

The previous sections show that the public and private sectors have very specific roles in the mango production chain. Long term issues that have to do with the collection of mango germosplasm, the training of farmers in managing their farms and the transfer of agricultural best practices are, not surprisingly, in the hands of public or not-for-profit institutions. These activities do not generate rents to the providers of these services, therefore private actors will not feel attracted to participate in these activities, even when the benefits are higher productivity levels.

On the other hand, the post-harvest activities and packing are in the complete interest of exporters. They are likely to provide technical assistance in these activities to the farmers that supply them and which whom they establish long term relationships. At this stage, exporters have the pressure of meeting the terms agreed in the contracts with their foreign clients. If they fail to do so, they will lose the contract and that will have consequences for the future.

Given that this kind of exports is profitable and do not require any sophisticated procedure, exporters are not interested in advancing in the production chain looking for value adding. Only some of the major exporters are exporting some basic processed mango products like juices or pulp. Major investments will have to be done in order to increase this production and compete with the established exporters like India and Mexico.

9. How can we Improve Innovativeness?

Sections 3 and **4** showed that overall levels of R&D spending remain extremely low in Peru and even throughout most of Latin America and developing world. Especially in Peru, the total expenditure in Science and Technology less than 1% of the GDP (0.89%), only 0.08% is invested in R&D, and only 1.8% of the firms declare doing some R&D compared to rates of R&D expenditure of more than 2% of GDP in developed countries. There is a clear need for Peru and other Latin American countries to increase both the absolute levels of R&D funding but also the effectiveness of current R&D investments given that knowledge and technical progress are main forces behind productivity growth.

Sections 7 and **8** showed that at an institutional level, the Technological Innovation Systems at the copper mining and mango agriculture industries suffer from a lack of inter-relationships among the different actors. Despite the advances that have occurred in both industries in the development of hydrometallurgy and the control of the fruit fly, the lack of inter-relationships impedes an adequate creation, transfer-adoption and diffusion of knowledge within those two industries. The two previous sections also suggest the kind of specialization of Peruvian industries: mainly primary production. Even when this kind of production is not synonym of negligible value added or technological sophistication, it is clear that these industries are not among the most dynamic.

However, Peru's factors endowment, rich in natural resources but poor in human and financial capital, requires a technological strategy that, on the one hand, upgrades primary production and spurs technological learning that could be later transfer to industries more knowledge and technology intensive; and on the other, encourages the development of the latter industries.

The creation, transfer-adoption and diffusion of knowledge are key determinants of productivity growth. In any kind of industry, productivity is thought to be necessary for enduring permanent increases in economic growth and associated increases in employment and earnings. Both, the stock of knowledge and the flow are important for productivity increases. Education and training are ways for diffusing existing stock of knowledge and inducing a proper environment for knowledge creation. Creation of knowledge in an economy comes mostly from R&D and through learning-from doing production. The creation of knowledge by itself does not only need to increase productivity, it also needs to be disseminated and used.

In this section practices in different developed, developing and Latin American countries are analyzed to provide concrete recommendations for policymaking and knowledge use, as well as shed light of the importance for the private sector to increase the resources it devotes to R&D. The section will look in detail to possible strategies that can be use to increase the effectiveness of R&D research. Experiences on the building of innovation clusters, creating linkages with universities, innovation funds, and the development of specialized research centers will be analyzed under the light of developed, developing and Latin American countries experiences identifying goals, problems and accomplishments as a way to identify possible best practices that can be replicated.

Despite the focus of the next section on creating high technology regions because that is the focus of most of the available literature, it is clear that knowledge is valuable regardless of the sector in which it is applied, the following general recommendations will also be relevant for the industries that were used like case studies.

9.1 Creating Technology Regions: Innovation Clusters

The current situation in Latin America raises many concerns about its future development prospects. As had been seen in previous sections the development of high skilled human capital, access to information resources and continuous innovation and the diffusion of new technologies are essential to sustain international competitiveness in a new globalize economy.

As mentioned by Quandt (1998) the prominence of high-technology industries in many new industrial regions in developed countries has produced a large number of studies on the factors that favor the creation of such complexes. Silicon Valley, Route 128 and the Research Triangle Park (Rogers and Larsen, 1984; and Voyer, 1997a) are always being used as examples of successful strategies to develop centers of innovation and business incubators. In this sense U.S., Japan, and many developed countries had been studying how to link the community college or local university better to firms to be able to reproduce these science cities.

The experience of industrialized countries and the limited evidence yet available from the developing world show that much work is still needed to shed light on the constrains and opportunities that industrializing countries face in trying to develop high-technology clusters. Although the basic conditions needed are summarized in **Figure 2**.

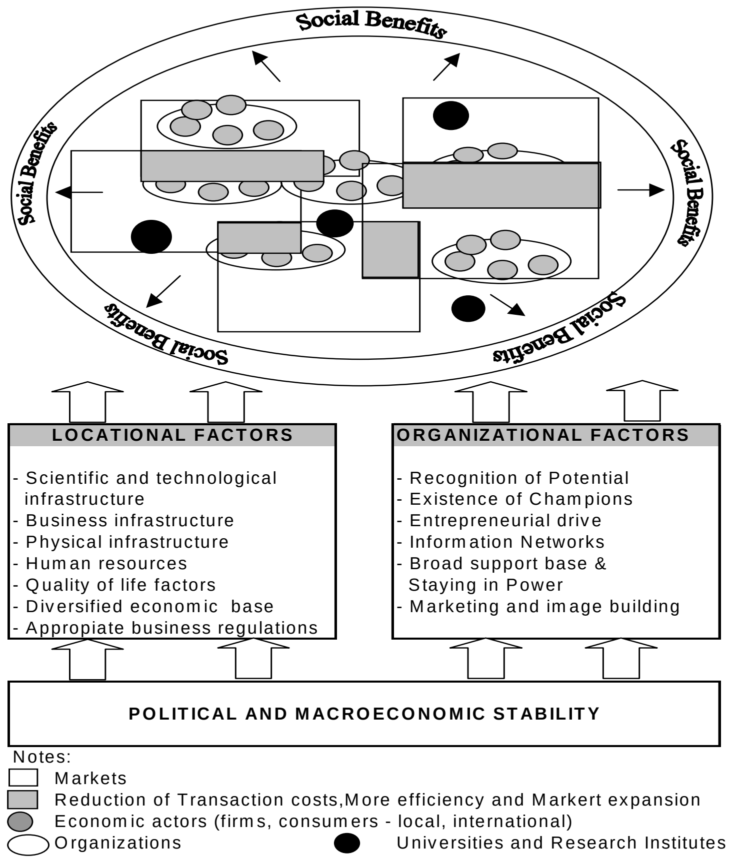
Essentially in **Figure 2**, it is shown, that in addition to political and macro economic stability there are two types of factors that are required for the development of this innovation clusters: locational factors and organizational factors. Locational factors refer mainly to all infrastructure conditions required, i.e. scientific and technological infrastructure (universities and private research labs, libraries, technological incubators, innovation centers and science parks), business infrastructure (venture capital is commonly regarded as a decisive factor or other types of funding), physical infrastructure (adequate transportation, telecommunications, water and power), human resources (critical mass of high skilled labor as well as ongoing education and training programs), a diversified economic base (extensive supplier and distribution networks and specialized services), appropriate business regulations (adequate and flexible labor legislation, appropriate tax levels[36], etc) and adequate quality life factors basically for entrepreneurs and the upper segments of technical and scientific workers.

It is clear that in Peru locational factors are very limited. Both case studies, showed that the technological infrastructure is poor. Universities are under-equipped thus constraining their role in the generation and as depositaries of new knowledge, and do not maintain close relationship with firms, the main responsible of innovations. There is no venture capital available in any of the two sector analyzed. In the case of copper mining, firms basically rely on credit provided by the specialized financial markets and in its business partners such as metals customers. In the case of mango agriculture, farmers rely on the advances of working capital provided by the exporters. Human resources and specialized service providers, especially in the mango agriculture, are missing.

Organizational factors basically refer to less tangible governance or organizational elements, which are also important and which had also explained the success of many of the already existing clusters. The first, and one of the most important in terms of policy making, is the recognition of potential of knowledge-based industries by regional or local leaders. A close look to all previous experiences of clusters development reveals that either individuals or governments (local or national) had intervened in the development of the clusters, either through direct policies or by linking institutions (see **Table 14**). For example, in Silicon Valley, initially with the direct links between Stanford University and startup firms and later with the creation of the "Joint Venture Silicon Valley" as an initiative to overcame the growing gap between industry, government and local communities. In Austin, Texas, where the business, academic and government communities came together to promote high technology development, which resulted, for example in attracting Smatech, and in many other cases as shown in Table 6[37].

[36] The treatment of R&D by the tax system varies extensively between countries and over time. Because R&D is expensed it is tax privileged compared to fix investment and there is a wide discussion on the literature on its impacts (for a literature review see Hall and Reenen 2000).
[37] In development countries, as India this is also the case. For example in Banglore India, growth of the cluster is stimulated by government incentives such as duty free imports and five-year tax holidays.

Figure 2
Necessary Elements for Developing High-Technology Regions



The case studies reveal a lack of clear policies to support the advances on any of the two sectors studied. The agricultural authorities have failed in providing policies that spur sustained growth and innovation. Reduction in research budgets and, most important, in agricultural extension has been decisive for the meager innovation in the sector. Mining policy has only been focused on spurring mining investment, but there has been a complete lack of attention to encourage mining research or, at least, the spread of the non-proprietary knowledge generated in firms.

A second organizational factor, which also needs special mention, refers to the temporal dimension, i.e. the need for broad support base and staying in power. The evidence had shown that it takes long time to grow a cluster of critical mass. Silicon Valley for example can be tracked back to 1912, other clusters like Boston's Route 128 and Ottawa, basically started by wartime research, and many others during the postwar period. In average it can take more than 30 years to build a viable cluster[38]. This means that a sustained effort is

[38] For example, the Ottawa cluster, which goes back to the 1950's only reached "critical mass" in the 1990s (Voyer 1997a).

needed to develop clusters and therefore policy makers must set up mechanisms that will transcend the normal 4-5 year political timeframe.

Although none of the Peruvian cases can be considered as a cluster, they can be considered as agglomerations. In the mining case, the country has more than a century of experience. Time in which the technological capabilities required to perform research and development in hydrometallurgy have been developed. Unfortunately, changes in policy and environment discouraged the continuation of these efforts. However, private efforts continue but there is the lack of state policy to help spread and codified all the knowledge acquired in this field. In the mango agriculture, the lack of adequate policies and resources have limited public and private research efforts. Firms and institutions like SENASA became mere users of imported technology.

A third organizational factor which Voyer (1997a and 1997b) calls “the existence of champions”, i.e. influential individual that can drive the development of high-technology clusters, is of significant importance. These “champions”, refer to scientists as Frederick Terman[39], Professor of Electrical Engineering at Standord University and William Shockley[40], the co-inventor of the transistor at Bell Labs, were essential in the development of the Silicon Valley[41]. Although, champions can also be institutions or people with institutional responsibilities, as the case of Gerry Turcotte, the President of the Ottawa-Carleton Research Institute (OCRI) essential for the development of the Ottawa cluster, or even more, Chambers of Commerce which have a particular influential role in Europe, or the Science and Technology Ministries with great influence in Brasil or the Costa Rica Investment Development Board (CINDE).

Currently, Peru lacks such champions. It was only in the 1980s, that MINERO PERU and specifically Cerro Verde became crucial to the study and development of copper hydrometallurgy. However, lack of a broader support and participation of knowledge generation institutions limited the advances of Cerro Verde’s efforts and its wider diffusion.

[39] In 1938, Terman gave a loan of $538 to his two bright students, William Hewlett and David Packard to develop Hewlett’s variable-frequency oscillator. Terman was also instrumental in the establishment of the Stanford Research Park in 1951 to stimulate university-industry linkages.

[40] Shockley was able to attract brilliant engineers and physicists to his company. Eight of these employees left to launch Fairchild Semiconductor and this company was the spawning ground for other spin-offs.

[41] Similarly, Georges Kozmetsky was instrumental in the development of Austin, Texas, Georges Freche’s vision drove the high technology development of Montpellier, while Néel, Merlin, and Dubedout played the same role in the development of Grenoble (Voyer 1997a).

Table 14
Do Clusters Develop Just Through "laissez-faire"?

Industrial Cluster	Location	Intervention	Catalyst Institution
Lombardy	Italy	Accounts for 32%of governments R&D. Even more to ensure that SMEs in the region gain access to the latest technology, the regional government has entered into a 50/50 partnership with a number of industrial associacions to establish a innovation centre, CESTEC.	
Baden-Wuerttemberg	Germany	The Government has the highest concentration of research institutes in Europe and accounts for 30% of Germany's R&D capability. There are nine universities, 23 polytechnics, 11 Max Plank Institutes and 14 Fraunhofer Institutes and research centres.	Steinbeis Foundation for Economic Promotion,and is privately funded
Rhone Alpes	France	CNRS was attracted as well as the nuclear research centre, CENG. The financing for a firm's buildings are guaranteed by the municipal government. The regional government spends about 50% of its budget (aproximately FF 4 Billion) on education, training and research.	Chambers of Commerce play a crucial role in promotion.
Catalonia	Spain	Development of the Valles Technological Park (PTV), the National Microelectronics Centre and the University of Barcelona.	
Silicon Valley	USA	Growth of firms stimulated by the dramatic expansion of military and aerospace demand for electronic devices in the late 50's and 60's.	Joint Venture: Silicon Valley catalys non profit organization created to overcome the growing gap between industry, government and the local communities.
Boston Route 128	USA	Growth of firms stimulated by the dramatic expansion of military and aerospace demand for electronic devices in the late 50's and 60's.	American Research and Development, the U.S. first modern venture capital fund.
Austin, Texas	USA	Local government supply needed infrastructure, the state government maintain a solid commitment to fund R&D, faculty salaries, student support, and related educaytional development activities. Also there was important defense related activities.	Sinergy between firms, universities and government is developed by the presence of a number of institutions that create them. For example, Austing Technology Incubatir, Texas Capital Network Inc, The Know-How Network, etc.
Montreal	Canada	Generous incentives from the province of Quebec. For example a $ 300 million venture capital fund, Innovatech, to help high technology start-ups	Innovatech fund to help alliances between firms and universities

Finally, there are other essential factors as entrepreneurial drive, both in individuals and in supporting organizations, and marketing and image building, which are also of importance for the development of these clusters. If they are not present many supporting institutions can focus on bringing sound business practices to the entrepreneur and in marketing the advantages of the cluster, the important issue is to recognize the need of these factors too[42].

[42] Where entrepreneurship is lacking as in the Japanese Technopolis Program or in Atlantic Canada for example, there was a failure despite the fact that the technical underpinnings are in place.

In general, Latin American countries lack of most of these locational and organizational factors. Just because clusters are usually understood as mere concentrations of productive units that take advantage of agglomeration economies, firms in these concentrations do not feel urged to invest in innovation and the "cluster" usually stagnates. Furthermore, governments tried to promote these concentrations without much success because they are lacking the understanding of the importance of locational and organizational factors and even of innovation itself[43]. As a result, efforts in primary sectors, as well as the development of science parks and technological incubators in Latin America are still very limited. Although, and as an example that they can be done, in South America Brazil stands out as the country where the most significant efforts have occurred as can be seen in **Table 15**. In addition, some high-tech incubators are also under development in countries such as Argentina, Chile and Venezuela. Even more, most of this clusters still lack some of the basic conditions outlined in Figure 1.

One of the major characteristics of the Brazilian clusters is the significant participation of the government in developing them but especially that policy makers have realized of the importance of encouraging close public/private partnerships as a way to develop successful linkages between firms, universities and the government. For example, in Curitiba, the capital city of the southern Brazilian state of Paraná, and the latest industrial cluster developed in Brazil, to encourage close public/private relationships two agencies where established. Unicamp, the Ministry of Commerce and Industry and private firms, created in 1976 Codetec to conduct R&D, undertake technology transfer and foster start-ups. As a result several small spin-offs were created specially in the area of fine chemicals.

[43] For an overview of clusters in development countries, see Schmitz (1999) and Nadvi (1999).

Table 14: Innovation Clusters										
Country	**Project**	**Year**	**U**	**F**	**G**	**Brief Description**	**Objectives**	**Some "success" indicators**	**Government Role**	**Environment Advantages**
Brazil	Curitiba	1996	x	x	x	• Technological park oriented to the software production for the industry of informatics.	• Generate a software industry oriented to international markets. • Create a technological park (software park) in the Industrial Center of Curitiba. • Offer maturity possibilities for projects through technological incubators. • Become the first headquarter of the National Software Program for Exportação, Softex-2000.	• Second larger software producer in Brasil. • 3500 enterprises of different size dedicated to the technologies of information. • More than 40 thousand jobs generated in the region.	• Initiative of the Municipal Administration of Curitiba. • The State Government supports through the project financing. • High level of planning strategies (urban, environment and university).	• Evidence of industrial development in the seventies. • Tax exonerations in the zone. • High level of interaction between the private and public sectors. Most of them linked to International Institutions leaders in science and Technology. • Tight links between local universities and enterprises (mutual support).
Brazil	Campinas	1980 (circa)	x	x	x	• Technological cluster oriented to the generation and development of technological capacities exploting the concentration of universities (public and private) in a geographical area oriented to investigation, investigation centers and industries with high levels of investment. • Its principal objective is the investigation in information and telecommunication technology.	• Develop local technological capacities in certain strategic industries.	• Transnational high-tech enterprises installed in the zone (IBM, HP, Texas Instruments, General Electric, Alcatel, Algan, Lucent, Motorolla, Nortel), as well as small local enterprises highly specialized. • Since 1995, it has received investments in telecommunications, information technologies and microelectronics for more than a thousand million dollars.	• Improve the link amongst investigation centers, universities and enterprises through related institutions (agencies): in one it intervenes through the Ministry of Commerce and in other through the Municipal Government.	• Located in a zone of high industrial development since the seventies. • Universities with postgraduate teaching and oriented towards investigation. • Existence of investigation centers. Two are outstanding: one oriented towards telecommunications and other towards the computing technologies.
Brazil	Porto Alegre Technopole	1995	X	X	X	• Technological multinuclear cluster: software, electronics and life sciences (healthcare, medical technology, biotechnology, pharmaceutical industry and medical devices). • Response to a national plan for the development of regional spaces. • Multi-institutional project which responds to the interests of the actors involved.	• Generate technological innovation in specific areas due to the interaction amongst different actors relating firms with universities and involving the municipal government.	• Consolidation of technology enterprises born in incubators. • Consolidation of investigation centers (public and private). • Development of new areas which responded to spontaneous associations between firms and universities.	• Active leadership of the municipal government. • Active participation of local public universities in technological aspects.	• Exploitation of the infrastructure facilities for S&T, (fiber optic networks, technological parks). • Located in the city with the best standards of living in the country and with a consolidated urban development.

In 1975, Ciatec was established as a committee for high-technology development that involved the city government, Unicamp and private firms and later become municipally controlled. Ciatec has established an incubator that supports some 20-technology firms and houses a center to support software developers. Ciatec is also involved in a program to facilitate technology transfer between research institutions and firms.

This strong correlation between the regional specialization in high-technology industries and especially their interaction with top-level universities and other organizations that support high-technology industrialization, such as R&D centers, research institutions and industrial associations are the essential reason for the success of this cluster. Even more, in the case of the Campinas cluster, local groups also find out the importance of these linkages and are now renewing their efforts to strengthen local institutions for the coordination and encouragement of university-industry cooperation.

In this sense creating and increasing linkages with universities are essential, not only in the development of clusters but in general in increasing spillovers from research done at universities and research centers. Although, many academics, such as David Blumenthal (1992), James B. Rule (1998), and Paul A. David, David C. Mowery, and W. Edward Steinmueller (1992), have deep reservations about the involvement of universities and professors in the commercialization of science, seeing science and commercialization as antithetical. In part this reflects the belief that commerce will essentially distort the essential values and culture of the university which itself is bad, but there is also a positive argument that if academics choose research topics based even in part on expected commercial value rather than potential scientific payoff, then necessarily the advance of science is retarded. This effect is compounded, it is argued, because all scientists will keep commercially valuable information secret or patented rather than contributed freely to the common pool of scientific knowledge for use.

This argument neglects the facts that commercially valuable science will be more highly compensated, attracting more students to enter the field who would otherwise be lost to science as well as encouraging more work by those in the field. Also that commercially valuable applications will attract new sources of research funding, and that scientists competing for academic recognition in fact tend to keep discoveries secret until they have exploited them in their own research so that patenting requirements may in fact speed disclosure (Eisenberg, 1987).

9.2 Creating and Increasing Linkages with Universities

As previously mentioned one of the hottest topics in economics is the role of technology explaining economic growth, and differences in productivity and economic growth across countries. In particular, the generation of new science in the not-for profits sectors, as universities and research institutes, and its transfer to the commercial sector appear to play central roles, usually examined in terms of knowledge spillovers[44]. Although, these "geographically localized knowledge spillovers" have proved unable to explain what it is about research universities that are crucial for their local economic impact and, therefore, are unconvincing both to policy makers and the public.

Knowledge spillovers have generally been measured across all sciences and industries, or have been studied in only one or a small number of geographic areas for which data has been collected. Even more there has been little work done on trying to examine knowledge production in sufficient detail to address questions of differentiated human capital of particular scientists and how different institutional structures and their implicit incentives affect the generation and diffusion of both basic and commercially valuable knowledge and its transfer to industry[45].

Recent evidence on the process of learning, specifically through the working relationships of scientists from universities and firms, has only recently been examined for one technology that spans a number of industries, biotechnology (Zucker, Darby and Armstrong 1994 and 2001; see also Zucker, Darby and Brewer 1998). The first two of these papers provide evidence that "spillovers" appear to explain the transfer process only when the variables that measure working relations between university and firm scientists are absent, thus providing empirical evidence that a market relationship between university scientists and firms explains the observed technology transfer, what is called in this section as *"linkages with Universities"*. Even more they show the significant impact over the performance of firms by the presence of links to scientists. Torero (1998) validates this result too in the semiconductor industry.

Another issue, which is central in creating the linkages between universities and firms, is the institutional framework. Institutional theory argues that certain types of organizations with a fairly standardized set of rules and interactions will have legitimacy and widespread usage in a society at a point in time. For example, in the U.S. nearly all research universities grant individual professors the right to consult for or even be principals in outside firms, while in Japan, the national research university faculty are prohibited from engaging in such activities and are supposed to transfer technology to the industry as part of their government paid duties; other nations have a variety of rules on faculty outside activities.

It is important in this sense for Latin American countries in not to fall on mistakes of experiences like the one of Japan and in avoid shaping their institutional practices by

[44] Paul Romer (1986, 1990) has been a particularly effective advocate of the importance of spillovers for growth and international trade. Zvi Grilliches (1992) did a masterly survey of that body of work and its potential importance in understanding continued technical progress.

[45] Adam Jaffe (1989) and Adam Jaffe, Manuel Trajtenberg and Rebecca Henderson (1993) have exploited patent data to show that there is a very significant, geographically limited connection between university and other research and the application of that research to patentable innovations45. Edwin Mansfield (1994) confirmed the significance of corporate/local-university linkages in a survey of 70 corporations in various high technology industries. Pisano (1989) has done innovative work exploring the varieties of more formal collaboration, including university-firm collaborations. Lerner (1993, 1994) has been exploring the nature of the venture capital industry involvement.

histories and public ideas of fairness more than by rational design of a work-rule/compensation package that optimizes technological transfer. The details of institutional incentives seem to have a significant effect on how each society utilizes its endowments of intellectual human capital. Thus, national institutional structures affect behavior through their implicit incentive systems.

In Latin America there seem to be some successful experiences on creating links between universities and firms. Three examples of them are summarized in **Table 16**; two are in Chile and one in Costa Rica.

Since 1990s the mining industry has been central to Chileans economy growth, representing around 47% of all their exports. Specifically copper has been one of the major mining resources of Chile of around 8.5 percent per year. It was in 1856 that Universidad the Chile started an academic department on mining engineering with financial support from the enterprises on the sector but with no expertise in the copper industry. Although it took forty years (Meller 2001) from 1925-1965 for Chile to start realizing of the importance of developing domestic capacity to analyze the role of copper and to educate Chilean professionals and technicians in the management of the copper industry, Chile's experience of cooperation between mining firms and universities is important. One of the first steps is the creation in 1970 of the Centro de Investigacion Minera y Metalurgica (CIMM) a private research center specialized in basic and applied research in mining and metallurgy with funding from private firms and the government and which had clear links with Codelco (see Appendix A).

Even more, since the mid 90s an strategic alliance has been developed between the Department of Mining Engineering of the Chilean University and the enterprises of the mining sector. This new strategy give as a result a significant increase in the enrollments in mining fields, specialized programs funded by firms and the formation of high quality professional miners. In addition there had been several permanent academic seminars[46] and the creation of a Mining Consultant Council University- Industry, which serves as a catalyst for increasing the links with universities. As it was mentioned in a previous section, the leading position that Chile has achieved in copper hydrometallurgy, as opposed to Peru, was possible because of the capacity of universities to act as knowledge creation and diffusion agents of this new technology.

Another successful example is the Academy of Aeronautic Sciences funded in 1999. This academy works as a project that links the firm leader in the commercial aviation sector (Lanchile) with the academic sector (Universidad Técnica Federico Santa María). It performs its operations in Santiago city and its main objective is the formation of professionals and technicians in related activities such as pilots, maintenance technicians

[46] Nowadays, the program counts with the following industrial sponsored meetings: Codelco of Evaluation of Mining Technology and Location, Enami of Pirometallurgy; Phelps Dodge of Minerals Processing; with the sponsor of the Chilean branches of Phelps Dodge of Mining Candelaria and Mining Ojos del Salado; El Abra (Sociedad Contractual Minera El Abra) of Hydro-Electrometallurgy and Collahuasi (Compañía Minera Doña Inés de Collahuasi) of Geomechanics y Geotechnics. Also, the mine Homestake Chile is supporting with education and research activities in other areas.

and engineers. Recently, it has implemented a master program in Aeronautic Engineering Sciences, it is directed to the familiarization of last generation technologies and industrial management. Several contacts with similar institutions have been established in order to benefit from agreements and training programs.

Finally, the case of INTEL in Costa Rica is an important experience. Since 1996 INTEL decided to locate a plant in Costa Rica given the active policy of the government in responding to Intel's concerns in areas like education, electricity and taxes. Specifically in education, the government made big efforts to keep aligned with the high-tech sector demand; through the public sector: Instituto Nacional del Aprendizaje (INA) and through the private sector: Instituto Tecnológico de Costa Rica (ITCR) which did an alliance with INTEL. The ITCR set up an incubator under the management of the Escuela de Administración y Negocios and the Ministerio de Ciencia y Tecnología. This high-tech orientation has enabled Costa Rica not only to get the INTEL plant but also to experiment a big growth in the software industry and in the exports of IT services. More than one hundred software development companies currently operate in Costa Rica. They employ more than 1,000 professionals and export to countries in Latin America, the Caribbean, North America, South East Asia, Europe and even Africa.

An important factor that also needs to be taken in account, similar to the role of catalyst institutions in the most famous innovation clusters detailed in Table 6, as a successful institutional arrangement is the role-played by the Costa Rica Investment Development Board (CINDE). It is a private, apolitical, non-profit organization founded in 1982. CINDE has as its main mission to promote investment in the country in specific sectors and works to foster Costa Rica's development, by serving as a catalyst and facilitator for the investment process in the country[47]. From its non-political, non-sectorial interest position, CINDE has excellent relations with both the public and the private sectors and its efficiency and success was shown in the key role it played in attracting the attention of INTEL to Costa Rica.

Even more, CINDE strategically reorganized itself and now concentrates in promoting Costa Rica as a competitive investment site in three sectors that benefit from significant strengths and advantages that the country has to offer (i.e. skilled-labor intensive industries): Medical Devices, Electronics, and Services. A fourth sector, Special Projects, includes projects in areas such as textiles, tourism, and others. As a result, Costa Rica now fosters not only INTEL but also companies as Sawtek, Remec, Babyliss/Conair. Skyes, Western Union, Procter & Gamble, Roche, Baxter, Aboot Laboratories, Carter's, Sara Lee, Warnaco, VF Corporation.

[47] CINDE's offices in New York and California proactively look for expanding companies and provide tailor-made services to investors. An additional team in Costa Rica advises on how to do business in the country, creates customized itineraries according to the investor's needs, and provides support during and after the establishment of operations. CINDE develops a long-term relationship with the investor established in the country and is committed to providing continued assistance to the investor as may be required.

Table 16: Creating Linkages with Universities										
Country	**Project**	**Year**	**U**	**F**	**G**	**Brief Description**	**Objectives**	**Some "success" indicators**	**Government Role**	**Environment Advantages**
Chile	Academy in Aeronautic Sciences	1999	X	X		• Educative institution founded by the private sector (Lanchile) specialized in the professional and technical formation in the commercial airline sector.	• Formation of human resources specialized in the sector. • Orientation towards undergraduate programs. • Postgraduate (master) recently implemented.	• Up to year 2002 it maintains in operation. • There is no evidence of the success reached.	• Association strictly amongst private agents.	• None.
Chile	Department of Mining University of Chile	1856 (foundation) 1990 Decade (link U-E)	x	x		• Academic department of the Chilean University in charge of the academic formation of mining engineers with financial support from the enterprises of the sector (public and private).	• Formation of high quality professional miners to the enterprises of the mining sector. • Offer specializations and postgraduate programs in mining.	• Revert the fall in enrollments in these areas (1990: 110; 1996: 46; 1998: 80). • 6 specialized programs financed by the enterprises. • First Postgraduate International Program in Mineral Economics (2001)	• None but it is a public university.	• Reception of funds for the implementation of specialized programs.
Costa Rica	Alliance Intel – Instituto Tecnológico de Costa Rica (ITCR)	1996	x	x	x	• University-Enterprise link scheme, including entrepreneur meetings through investigation and development centers, productive programs and academic departments (formation and training).	• Offer training programs for technical personnel oriented to cover the occupational enterprise needs. • Develop training programs and assessment according to the enterprise needs.	• Significant increase in the number of training programs offered (between 1995 and 1998 the enrolment was duplicated, assessment services triplicated and the training programs increased in 50%).	• Active participation through the Science and Technology Ministry in the promotion and linkage between universities and enterprises.	• Governmental decision of capturing investment of high-tech enterprises. • Specific infrastructure to attract high-tech industries.

The presence of this type of catalyst institutions can reduce enormously the transaction costs necessary to attract FDI but also to increase the linkages between firms and Universities[48].

Is essential to mention that CINDE's role won't be possible without the important role of the government through the active participation of the Science and Technology Ministry in the promotion of linkages between universities and firms and the clear incentives to promote FDI present in the country[49].

Research institutions, whether within of independent of universities also play a role in transferring technology to existing firms and to generate spin-offs. In the case of Peru one of the main reasons why two of its major research centers in Agriculture, one state funded INIA (Instituto Nacional de Investigacion Agropecuaria) and the International Center of Potatoes (CIP), funded with international funds, had not been successful is because of the lack of links with the productive sectors. The main critique to both of these centers is the lack of use of their innovations, although all the success they had have in basic and applied research (see Appendix A)[50]. As shown before, even when INIA has a research agenda for fruits, it does not cover the study of mango, even when its exports amount for 75% of total fruit exports and when problems such as the fruit fly plague are a major problem for mango farmers and exporters.

A different picture can be seen in the INIA of Chile where since 1975 the government pushed INIA toward self-financing, and as a result by 1985 the institution was earning 40% of its income from sales, a clear result of how the application of their research improved. The human capital and experience officially located in INIA, but put to use by private enterprises, were important elements in the initial identification and evaluation of varieties and technologies accessible from abroad and the current success of the Chilean agriculture.

Another experience more related to the needs of SMEs, which is still in its beginning, is the CITEs in Peru. Between 1999 and 2005, four Centers of Technological Innovation (CITE) will be established in the main SME productive sectors (shoes, wood furniture, garment industry and production wine and Pisco), as part of the agreement between the Ministerio de Industria y Comercio and the Agencia Española de Cooperación (AECI). The four

[48] Specifically in the case of INTEL one of the concessions given by the government included the addition on the curricula of the Instituto Tecnologico de Costa Rica (ITCR) training programs for technical personnel oriented to cover the occupation enterprise needs as for example a one-year "Associate Degree" program focused on semiconductor manufacturing.

[49] The main incentives for FDI present in Costa Rica can be summarized in: (a) no limitations on foreign ownership of property and for conducting business; (b) the Constitution grants foreigners and nationals equal rights and obligations; (c) no restrictions on capital or fund repatriation and transfers; (c) intellectual property laws in accordance with WTO standards; and (d) Agreements with several countries for Investment promotion and protection

[50] Although, an exception, is the recently re-activation of INICTEL (Instituto Nacional de Investigación y Capacitación en Telecomunicaciones) which currently is strongly committed to have close links with the major firms in the sector and is adjusting its training programs in accordance to agreements with telecommunication enterprises.

CITEs', public and private, will have as a main objective to promote industrial development and technological innovation linking government, small enterprises and universities. CITEs' must provide technological services to the firms to help to promote their creativity strength. For example, The CITE of Leather, Footwear and Related Industries (CITEccal) involves the following institutions: MITINCI, Promoción de las Exportaciones, Ministerio de Educación, Asociación de Pequeños y Medianos Fabricantes de Calzado, Managerial Unions of Footwear and Leather, Suppliers, Universities and the Spanish Government through the INESCOP (Instituto Tecnológico del Calzado y Conexos), which is one of the main technology European centers in the sub sector with headquarters in Valencia-Spain. Therefore, all necessary actors participate as part of it. The main question is how this CITE's could be self-sustainable over the time specially once the funds of the Spanish Cooperation are finished in 2005.

Given the importance of funding and linking it to increase in linkages between academe and commerce, in the next section experiences of competitive funds are analysed. The main idea is how using initial funding of the government you can complement it with private funding and at the same time make firms, universities and research institutes to get together to be able to access to this funds.

9.3 Innovation Funds funded by the Government as an Alternative to Promote Innovation and Increase Linkages with Universities and Firms

Investment capital is key to the growth of firms and hence to the success of any innovation policy and clusters development. In all successful experiences analysed there was a range of financial instruments ranging from venture capital firms, funds, to banks and to government programs. High technology investments are risky by definition, and therefore venture capital comes to play an important role in the start-up phase, since banks and governments are conservative by nature.

United States has the most well developed venture capital community and much of it developed along Route 128 and Silicon Valley. Canada's venture capital community is less well developed but is catching up, and is ahead of that in Europe and Asia where regional governments play an important role. For example, in the Montpellier area, the regional government joined with banks and some individuals to set up Mistral Investments, In Baden-Wuerttemberg, the Steinbeis Foundation, a Lander supported non-profit organization has funds to invest in ventures. In Lombardy, ventures are funded by CESTEC, a partnership between the regional government and industry.

However, in poor countries, and therefore poor governments like the case of Peru and many Latin American counties the mix of financing instruments is crucial given the scarcity of funds. In this sense there are several new financing alternatives that are already being used in countries like Chile that could be use as a best practice to be applied in countries like Peru. These new alternatives combine both co-financing as well as the creation of links between firms, universities and research institutes to promote innovation.

Table 17: Innovation Funds Funded by the Government										
Country	**Project**	**Year**	**U**	**F**	**G**	**Brief Description**	**Objectives**	**Some "success" indicators**	**Government Role**	**Environment Advantages**
Chile	FONDEF	1991		x	x	• State Fund based in a system of experts in evaluation to support innovative processes: new products, technology and technological infrastructure transfer to priority areas.	• Support the technology transfer towards private firms. • Promote the link investigation centers-enterprises in the transfer process.	• Support to the areas considered as important in terms of development. • More than 350 approved projects since the beginning of operations. • US$ 282 millions in financial resources.	• Develops the principal role as a fund manager. • Fund Management through CONICYT.	• BID support in the creation of the fund.
Chile	National Fund in Technological Development (FONTEC)	1991		x	x	• State-managed fund orientated towards productive private enterprises. • Focus in manufacture and agriculture sectors centered in technological transfers. • The state provides part of the funds.	• Promote the technology transfer towards the firms through a permanent fund.	• Fast approval procedures (40-45 days) • In 10 years, it has financed more than 1700 projects providing approximately US$100 millions.	• The state is the sole fund supplier and it also evaluates the projects.	•

Table 17 shows two of the currently most successful funds in Chile, FONDEF and FONTEC. FONDEF is an open competition fund set up in 1991 by the Chilean Government under the administration of CONICYT[51] and with a Bank Loan from the Inter American Development Bank. Its main objectives are to strengthen the provision and transference of high quality scientific services that have a significant impact on productive activity, for special economic areas of high priority and/or national interest: agro-industry, forestry, informatics, manufacturing, mining and fisheries (including aquaculture). Recently, some new areas have been incorporated: water and energy management, health and education (with emphasis in higher education).

One essential characteristic of FONDEF is that the projects they finance seek to improve the relationship between firms (which contribute with 20% of the project budget) and research oriented institutions. Most of the projects are oriented towards innovative processes: new products and services and other technological innovation; technology transfer projects and technological infrastructure projects in priority areas. This allows not only increase the linkage between firms, universities and research institutes, but at the same time allow for public and private partnerships in obtaining the necessary resources to carry out the research. As a result and within five years following the introduction of FONDEF, private spending nearly doubled from the one in 1990 (13% of total spending on research in the farm sector) to about 20% of total farm sector research expenditures.

In 1991 CORFO the official agency dedicated to the sponsorship of the industrial activities in Chile establish a fund named Fondo Nacional de Desarrollo Tecnológico (FONTEC) to support private companies that provide either goods or services, from any sector. The fund finances project in technological innovation, technology transfer, and technological capacity building and infrastructure. In practice, the largest number of grants is awarded in the area of manufacturing, being agriculture the next favored sector (up to year 2000, 41% and 21% of the projects were granted to these sectors respectively). The state will provide up to a maximum of 50% funding for any project, although the firm or consortium needs to obtain security for the liability, should the project fail to meet mutually agreed targets (in fact, an average of 39% of the funds were granted by the state). Similarly to FONDEF this fund promotes both co-financing and also private, university and research centers linkages.

The development of these types of competitive funds, in which not only the government participates but specially the private sector is of great importance because it not only assures they will be self-sustained over time but also they are a way by which firms, universities and research institutes can increase their interaction.

It is important to mention that Peru is recently applying to an Inter American Development Bank (IADB) Science and Technology loan. This loan that is available for all Latin American countries and that was crucial to develop the innovation funding programs in Chile[52]. This loan will help Peru to develop FONCYC, the Science and Competitiveness Fund, which will fund innovation projects from firms, universities and other institutions, as

51 Consejo Nacional de Ciencia y Tecnología.

52 Peru has been one of the few countries in Latin America that have not apply for this loan. Brazil, Chile, Mexico and Venezuela have applied successfully several times for this loan.

well as support the formation of human capital and the strengthening of the National Innovation System. Applications for funding will be evaluated on a merit basis and a set of criteria that include cooperation and the creation of linkages among different actors, that contribute to create a competitive advantage in firms and that match the selected economic areas chosen for the fund, among others[53].

10. Conclusions

The experience of industrialized countries, and even the limited evidence for some developing countries show the importance of innovation as the shift to a knowledge-based economy accelerates and the globalisation process intensifies with the lowering of various trade barriers and though international agreements.

This paper tried several questions with respect to the situation of innovation and previous R&D strategies and how they could be applied in countries like Peru. Its clear from the macro overview carried that Peru and most of Latin American countries, with the exception of Chile, Brazil and Mexico, are latecomers in recognizing the importance of innovation and R&D expending significantly less in these activities than high-income countries.

In this sense investment policies that encourage externality-generating activities (improvements in education) or introduce increasing returns (improvements in physical infrastructure) can be good for growth. Also important are complementary policies that facilitate the spread of knowledge and that permit free entry and exit of firms – and free mobility of people, capital and technology (World Bank Report 1995 p.35).

Latin American countries are characterized for several scarcities. Scarcity of capital in general and especially for technology based start-ups, such as venture and seed capital, this has limited their possibilities for growth and diversification. Scarcity of ample knowledge base, such as a concentration of dynamic industries, high-level research programs and a substantial critical mass of high quality scientists, engineers and technical workers. Universities and research institutes, with rare exceptions, are isolated of industries and had not developed any linkages to them loosing the possibility of generating positive externalities and neglecting the fact that commercially valuable science will be more highly compensated, attracting more students to enter the field who would otherwise be lost to science as well as encouraging more work by those in the field.

Even more, basic research, education, training and physical infrastructure in those countries are not only inadequately as previously shown, but also concentrated in a few metropolitan regions, mostly the capitals of the countries. The geographical concentration of technology sources and skilled labor combined with generally poor transport and communication links imply few localities are viable options for technology based industrial development.

[53] For more information about FONCYC, go to its web page at URL: http://www.concytec.gob.pe/ProgramaCyT/FONCYC/

In addition, there are other obstacles in these countries, costly labor regulations, high taxation, and general lack of effective intellectual property rights, which constraints innovative activity and reduces the success prospects of start-ups, and there are very poor development of information networks, although the increasingly cheaper access to ICT is improving this.

All these scarcities and obstacles have influenced in the way the Technological Innovation System work. The Peruvian TIS, similar to others in developing countries, is fragmented, presents little interactions among its different agents, and respond to competing and contradictory incentives which reflects the lack of coherence in the government's policies. Moreover, there is no clear understanding of the TIS concept by policy makers who believe this system can be created by law.

The paper has also shed some light on the performance of a particular sectoral innovation system regarding the adoption and diffusion of a particular technology. Two findings are worth highlighting. First, the lack of interaction between knowledge generating institutions, such as universities and government research institutes, and firms is pervasively limited. Second, the role of firms, whether state-owned or private ones, has been crucial for the improvement and adoption of the technology. Both findings persist the changes in economic and institutional conditions, such as the ones experienced after the 1990 economic reforms.

In addition to political and macroeconomic stability, which are necessary conditions for growth and development to occur, this paper identified basically three major factors that can summarize what countries in Latin America can do to be able to increase their innovation capacity.

The first factor is the clear need to develop linkages between firms and academia. Linkages with universities and research institutes play a pivotal role in the development of innovation and innovation clusters by (a) achieving scientific pre-eminence; (2) creating, developing, and maintaining new technologies for emerging and traditional industries; (3) educating and training the required workforce and professions for economic development through technology; (4) attracting large technology companies; (5) promoting the development of home-grown technologies and (6) contributing to improved quality of life and culture. Importance of appropriate institutional frameworks is crucial for setting the right incentives to encourage university scientists to collaborate through adequate property rights in business ventures.

In this sense, high quality universities and research institutions are a necessary condition. For example, in the case of Intel in Costa Rica, its introduction was determined precisely by the relatively high quality of local labour force. In additionally, Costa Rica is also responding to the increase demand of skill labour at different levels by improving the overall quality of universities and high schools.

Simultaneously, the presence of catalyst agencies to promote these linkages is of crucial importance. The lack of these institutions, and therefore the lack of more linkages explain the failures of most of the clusters. For example, in the case of the industrial cluster in

Paris, while it grew, the links between large and small firms and between research institutes and industry remained weak and this is one of the major reasons of the limitation of their innovative performance despite the efforts of the government (Castells and Hall, 1994). On the other hand, as in the case of Silicon Valley, and many other clusters in developed countries, and even in Costa Rica, and Chile these types of institutions were of significant importance in their success and are a policy instrument that governments can use.

The second factor identified in the importance of the development of clusters, not as a substitute but as a complement to the previous factor. Proximity is important in the relationship between industry and local research institutions because the ties wear off with distance. As showed in the study of Acs and Anselin (1997), spillovers of the university research on innovation extended over a range of 120 kilometers from the innovating area. So it is not surprising to see clusters develop in areas where major research is carried out as the case of MIT with Route 128 and Stanford with Silicon Valley, or even the PUC in Curitiba which has began an strategy to transform itself into a research based university instead of a teaching enterprise to increase its linkages to firms. Although, previous experiences had shown that the idea that clusters will develop through “laissez-faire” is unrealistic. A close look to most successful clusters in developed and developing countries reveals that either individuals or government or regional authorities have had intervene in shaping the development of clusters.

Consistent with one of the major restrictions in poor countries, the third factor is how to develop funds for R&D. The experience of the funds from Chile and how they combine private and public partnerships so that resources not only come from the public sector but also from the private sector are of crucial importance and are strategies that should be replicated across the region. They not only give access to funding and increase linkages between firms, research institutes and universities, but at the same time the are competitive and sustainable in the future as the private sector participation increases over time. Fortunately, the creation of the Fondo de Ciencia y Competitividad (FONCYC) will partially fill the void of financial funds for innovation.

In addition to the scarcity of financial capital, most firms in countries like Peru are SMEs and therefore they will face the usual problems of lack of capital and marketing expertise. In this sense experiences as the one of Banglore in India, where the government, financial institutions and industry are working together to address these issues by setting up venture capital funds, establishing marketing channels to target countries and developing infrastructure needed for an IT cluster is essential.

Alternatively, as in the case of Malaysia, attracting foreign direct investment (FDI) could be the cornerstone of tan economic development strategy, but at the same time it is important to have an umbrella strategy to create links of the FDI with domestic investment to move towards a higher value added local production and technology development functions. As mentioned by Michael Porter (1990) “ A development strategy based solely on multinational firms may doom a nation to remaining a factor-driven economy. If reliance on foreign multinationals is too complete, the nation will not be the home base for any industry… Foreign multinationals should be only one component of a developing nation’s economic strategy and an evolving one”.

Finally, is important to mention the importance of time. A real challenge for Peruvian policy makers and politicians who only think on a very short term scope and when trying to plan on a long term basis do not understand that work has to begin now in order to have results in a decade or more. It is essential for policy makers to keep in mind that the development of innovation policies and knowledge based clusters required in average thirty years; therefore they need to set in place mechanisms that transcend the normal time frame of a politician. The few clusters in Brazil and in other developing countries are still relatively young. They are experiencing some of the early developmental problems seen in other parts of the world in the early stages of cluster development (limited entrepreneurship, lack of venture capital, limited information networks). The important issue is to keep in mind clusters take time to develop but at the end their success could be of great importance for the development of the country.

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Appendix A: Research Centres that foster Technological Transferences

Country	Project	Year	U	F	G	Brief Description	Objectives	Some "success" indicators	Government Role	Environment Advantages
Chile	Centro de Investigación Minera y Metalúrgica (CIMM)	1970		x	X	• Private centers specialized in basic research and in applied research to the mining and metallurgy sectors created by private enterprises and state transferences.	• Develop and promote research products oriented to the Chilean mining industry. • Recently, they have oriented part of their efforts to the promotion on research on environmental impact of the copper industry.	• It operated like the model of a research center. • More than 1000 researchers were formed. • After loosing the state financing, CODELCO`s research area was significantly reduced • Actually, its research is oriented to the environmental impact of the mining operations, specially copper. Their findings are used for the development of regulatory policies.	• The Chilean State supported until 1988. Actually, it works with private and public funds.	• Agreements with CODELCO permitted the access to research funds and the meeting of specialized scientists. • Actually, it concentrates in offering its research results, in order to be used in the elaboration of public policies related to the management and environmental regulation.
Peru	Instituto Nacional de Investigación y Capacitación en Telecomunicaciones (INICTEL)	1971		X	X	• Public research and training center in the telecommunication area.	• Develop applied research. • Realize studies and quality projects. • Offer training through update, specialization or postgraduate studies. • Recently, start a project of enterprise incubators.	• Training programs based in agreements with telecommunication enterprises. • Specific agreements with firms on conferences in topics of telecommunications.	• Depends on the Transport and Communication Ministry but it has autonomy.	• Increase linkages with firms due to the entrance of new firms in the telecommunication area.

Appendix A: Research Centres that foster Technological Transferences (Continuation)

Country	Project	Year	U	F	G	Brief Description	Objectives	Some "success" indicators	Government Role	Environment Advantages
Peru	Instituto Nacioal Investigación Agraria (INIA)	n.a.			X	• Public investigation center oriented to research and technology diffusion in the agricultural sector.	• Generate and transfer technologies. • Develop research in specific areas: maintenance of genetic resources, improving and management of different crops. • Manage genetic resources associated to vegetal and animal species of the country. • Offer services (analysis, training, studies and assessments). • Offer basic agricultural products: seeds, reproductive plants.	• 11 Intensive and permanent programs. • Until year 2000, 55 research projects were operative. • Between 1995 and 1999, more than US$24 millions were derived to the rural sector as capital expenditure. • For the same period more than 7 thousand experiments were realized. • Scarce evidence of interaction with private firms or universities. • Scarce evidence of a favorable impact or improvements in the crops processes.	• Dependent entity in administrative terms of the Agricultural Ministry.	• None.
Peru	CIP	1971				• International Private Research Center dedicated to the scientific investigation on tubers (potatoes and sweet potatoes).	• Carry out scientific research on the crop and genetic management of tubers like potatoes and sweet potatoes, principally. • Manage the transport and manipulation of the genetic material of research products. • Applied knowledge transfer through the training of selected agents.	• When it was founded, it received a donation of US$65 thousand dollars. Its budget from donations in the year 2000 was US$21 million dollars. • Development and introduction to the market of new potatoes varieties. • Recovery of native potatoes species in danger of extinction. • Development of a training system, individualized or in groups, with alternatives of distance teaching (with materials and using TIC).	• None, due to the fact that it is a private center. • Since 1999, the Peruvian government recognizes its status as an international center.	• Receives financing from international governments, international institutions and private foundations. • Strategic alliances with international research centers.